Instruction

MI 019-173
May 2007

83S-A Sanitary Vortex Flowmeter

Installation, Troubleshooting, and Maintenance

Invensys®

FOXBORO®

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1. Introduction

Overview

The 83S-A Sanitary Vortex Flowmeter (Figure 1) measures fluid flow rates using the principle of vortex shedding. The flowmeter produces a 4 to 20 mA analog or pulse signal proportional to the volumetric flow rate.

Fluid flowing through the flowmeter body passes a specially shaped vortex shedder that causes vortices to form and shed alternately from the sides of the shedder at a rate proportional to the flow rate of the fluid. These shedding vortices create an alternating differential pressure that is sensed by a sensor located in the shedder. A pulsed voltage is generated by the sensor with a frequency that is synchronous with the vortex shedding frequency. This voltage is then conditioned by an electronic module and processed by the microcontroller to produce a digital signal, an analog (4 to 20 mA dc) signal, and a scaled pulse signal.

The flowtube body is connected to the electronics housing by a 4.5 m (15 ft) flexible cable. The electronics housing is mounted to a bracket, which must be mounted to a “vibration-free” wall or pipe.

Reference Documents

In addition to this instruction, there is other user documentation supporting the 83S-A Sanitary Vortex Flowmeter. These documents are shown in Table 1.

Table 1. Reference Documents

Document Number	Document Description
Dimensional Print	
DP 019-154	83S-A, Sanitary Vortex Flowmeter
Parts List	
PL 008-713	83S-A, Sanitary Vortex Flowmeter

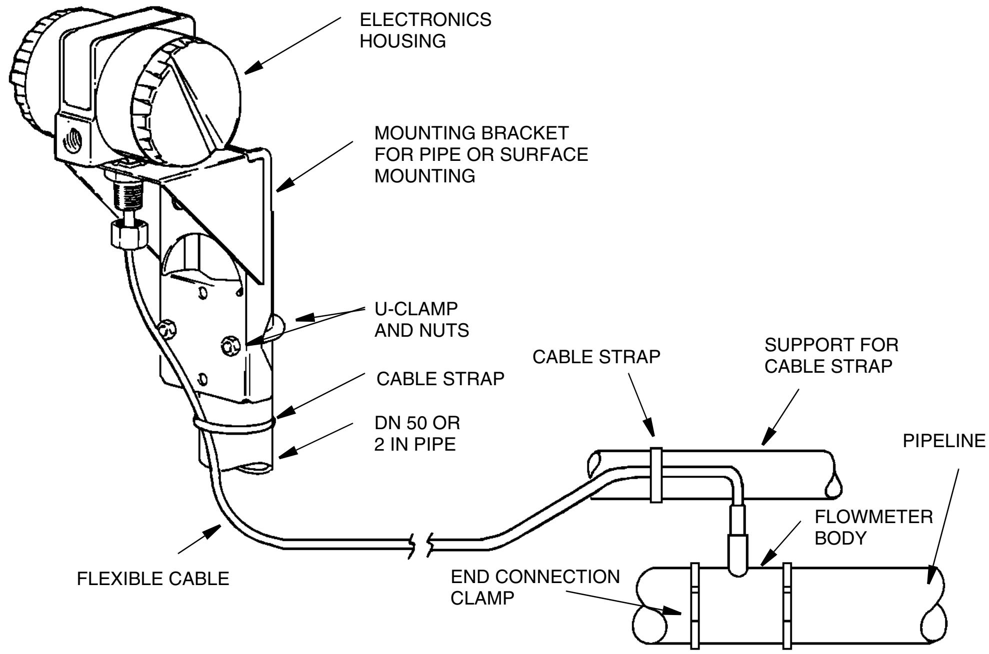

Figure 1. 83S–A Sanitary Vortex Flowmeter

Standard Specifications

Table 2. Standard Specifications

Item	Specification
Process Temperature Limits	–18 and +200°C (0 and 400°F)
Ambient Temperature Limits	–40 and +85°C (–40 and +185°F)
Power Supply Requirements Analog Mode Supply Voltage Limits Supply Current Pulse Mode Supply Voltage Limits Supply Current	 10.5 and 50.0 V dc 22 mA dc 10.5 and 50.0 V dc 15 mA dc.
Product Safety Specification	Refer to instrument data plate for type of certification and observe applicable wiring requirements. Electrical certifications and conditions of certification are listed in Table 3.
Flow Rate Requirements	Refer to FlowExpertPro™ sizing program.

Table 2. Standard Specifications (Continued)

Item	Specification
Static Pressure Limits	Full vacuum to pressure rating of mating connections, as follows: With Flanged Connection All sizes: 1035 kPa (150 psi) For all Other Connections 50 mm (2 in) size: 1725 kPa (250 psi) 80 mm (3 in) size: 1035 kPa (150 psi)
Flowmeter Output:	
Analog	4 to 20 mA dc into a maximum of 1925 Ω depending on power supply (refer to graph in Figure 14).
Pulse	Square wave voltage equals supply voltage minus two volts. Maximum current is 10 mA (sink or source). Shielded, twisted cable is recommended.

Electrical Safety Specifications

— NOTE

The 83S-A Flowmeters have been designed to meet the electrical safety descriptions listed in Table 3. For detailed information on status of testing laboratory approvals/certifications, contact Invensys Foxboro.

Table 3. Electrical Safety Specifications

Agency Certification, Types of Protection and Area Classification	Application Conditions	Electrical Safety Design Code
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.	Temperature Class T3C at 85°C and T4A at 40°C. Connect per TI 005-105.	
CSA Suitable for Class I, Division 2, Groups A, B, C, D; Class II, Division 2, Groups F, G; Class III, Division 2.	Maximum ambient = 85°C.	A
FM intrinsically safe for Class I, Division 1, Group A, B, C, D, Class II, Division 1, Groups E, F, and G, Class III, Division 1.	Temperature Class T3C at 85°C and T4A at 40°C. Connect per TI 005-101.	
FM Nonincendive Class I, Division 2, Groups A, B, C, D, Class II, Division 2, Groups F, G, Class III, Division 2.	Ta = 85°C.	

2. Installation

Fundamental Installation Requirements

Foxboro vortex flowmeters shall be installed to meet all applicable local installation regulations, such as hazardous location requirements, electrical wiring codes, and mechanical piping codes. Persons involved in the installation should be trained in these code requirements to ensure that the installation takes maximum advantage of the safety features designed into the flowmeters.

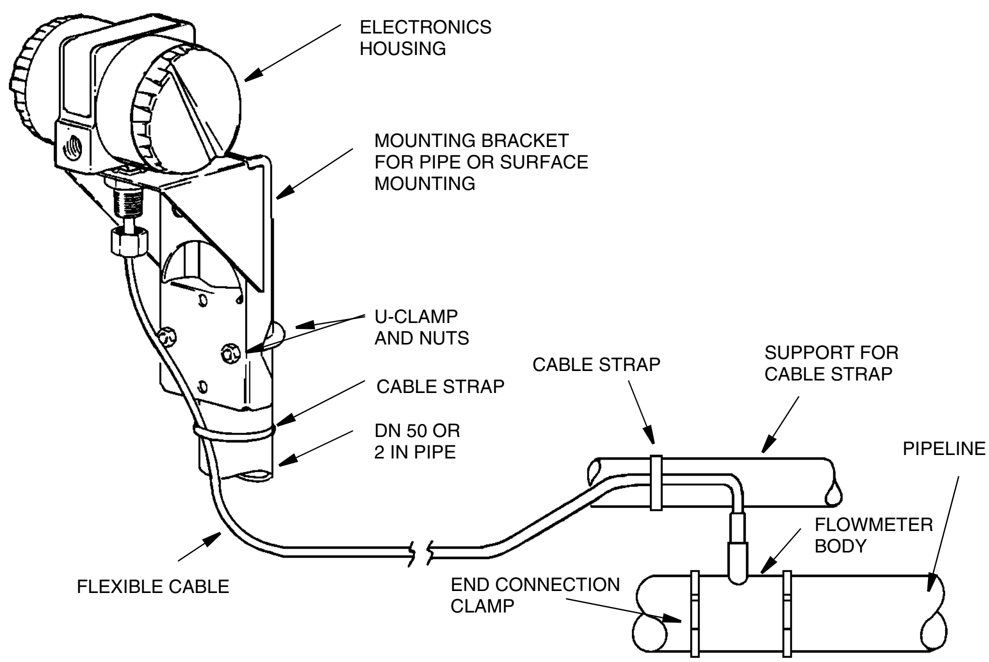

Figure 2. 83S Sanitary Vortex Flowmeter

Unpacking

The 83S Series Vortex Flowmeter is built to be durable, but it is part of a calibrated precision system and should be handled as such.

Use care when unpacking. The flowmeter is a two-piece unit. The flowmeter is shipped with the flowtube body connected to the electronics housing by a flexible cable. Do **not** cut or disconnect the cable.

Packing material should be disposed of in accordance with local regulations. All packing material is nonhazardous and is generally acceptable to landfills.

Flowmeter Identification

To determine the model configuration of your flowmeter, refer to Figure 3. For interpretation of the Model Code, refer to PL 008-713.

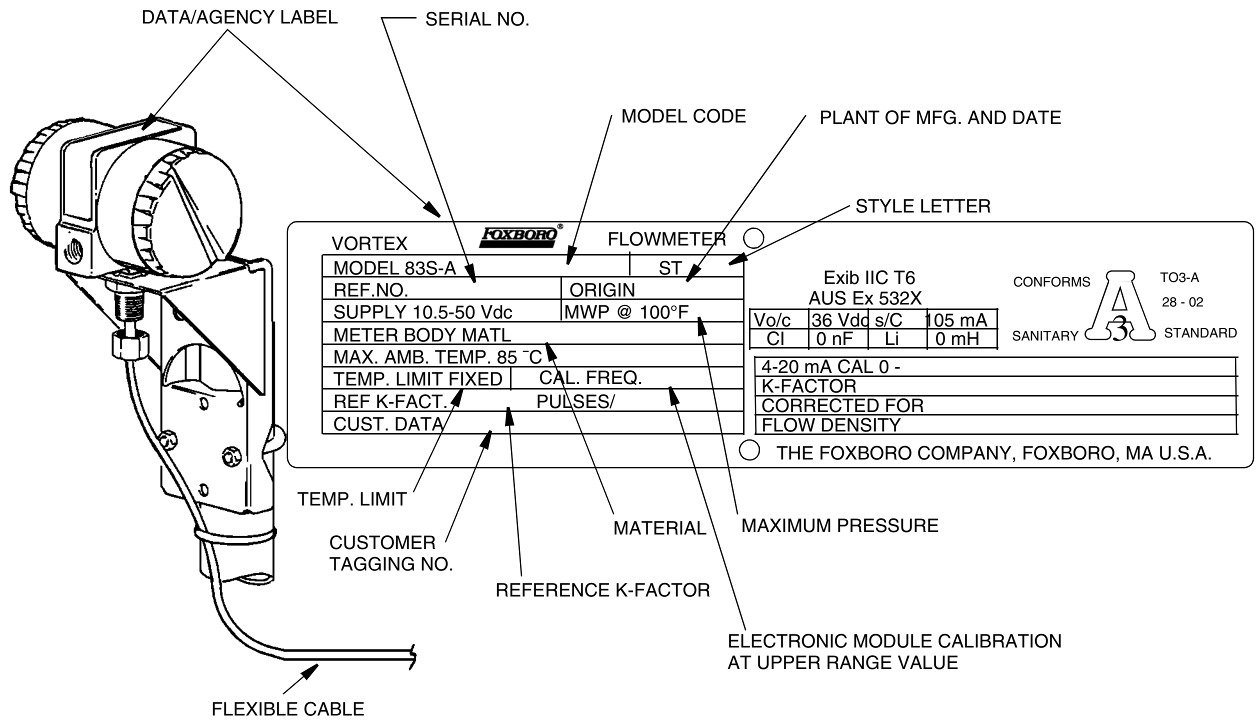

Figure 3. Flowmeter Identification

Mechanical Installation

Dimensions

For overall dimensions of the flowmeter and end connections, see DP 019-154.

Piping Considerations

⚠ CAUTION

1. Prior to installation, spring back the piping on either end of the flowmeter to allow as much space as is required to install the flowmeter without damaging the flowtube ends.
2. Mating end connection parts (clamps, connections, and gaskets) are required and are supplied by user. Select a gasket or seal material which is suitable for the process liquid.
3. Support the cable that connects the flowmeter body to the electrical housing. The support must be approximately 30 cm (12 in) from the flowmeter body.
4. Temperature limit of cable is 105°C (220°F). Do not support cable on surface exceeding this temperature. See Figure 4.

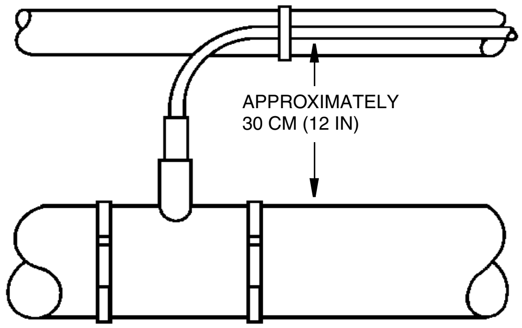

Figure 4. Flowmeter Body Cable Support

Effects of Piping on Flowmeter Performance

The vortex shedder axis can be oriented to reduce, or in some cases eliminate, vibration influence. Positioning the flowmeter body so that vibrations are parallel to the sensor diaphragms minimizes the effect of vibrations.

The flowmeter body should be mounted in a straight, unobstructed pipe to ensure that it performs to its fullest capabilities. The recommended minimum amount of minimum pipe upstream is shown in Table 4. For additional information, refer to “Determining the Corrected K-Factor” on page 35. There should be a minimum of eight diameters of straight pipe downstream. See Figure 5.

It is recommended that control valves, when required, be mounted downstream from the flowmeter body to ensure that back pressure is sufficient to maintain a full pipe, and to prevent pressure loss sufficient to cause flashing or cavitation. Ensure that gaskets do not protrude into pipe line.

! CAUTION

The piping that attaches to the flowmeter body end connections must be rigidly supported. This minimizes the effects of piping vibration on flowmeter performance.

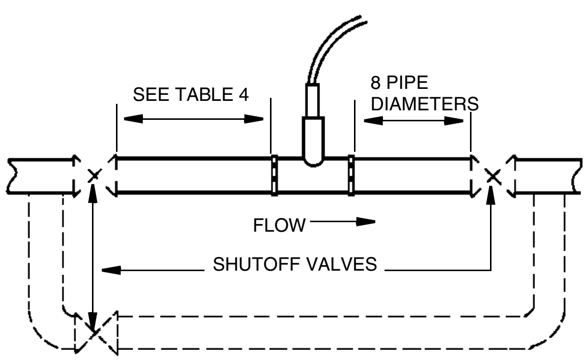

Figure 5. Bypass Piping

— NOTE

1. The flowmeter should not be located near pump discharge line or suction lines. Pumps often produce oscillatory flow which may affect vortex shedding or produce pipe vibration.
2. Flowmeters mounted near the discharge of liquid positive displacement pumps may experience severe flow fluctuations and cause damage to the sensor.
3. Good piping practice is to assume that for four pipe diameters upstream and two pipe diameters downstream, the internal surface of the pipe shall be free from mill scale, pits, holes, reaming scores, rifling, bumps, or other irregularities.

Table 4. Typical Piping Configurations

Upstream Configuration	Recommended Upstream Pipe Diameters[a]
90° Elbow	30
Two elbows in different planes with closest elbow in same plane as shedder element[b].	45
Two elbows in different planes with closest elbow perpendicular to plane of shedder[b].	35
1.5:1 reduction in piping diameter.	35
Butterfly valve (wide open)	30

(a) For other piping information, see Appendix A.

(b) Shedder is located in bore of flowmeter.

Bypass Piping

It is sometimes desirable to provide bypass piping if the flow cannot be interrupted for servicing the flowmeter. See Figure 5.

— ! WARNING

If a bypass is used, it must also incorporate some means to relieve the pressure from the main line before the vortex flange bolts or clamps are loosened.

Installing the Flowmeter Body

The 83S Sanitary Vortex Flowmeter has six different end connection possibilities. The end connections that you have were determined through the selections made in the original specification of your flowmeter configuration.

All end connections are welded to the flowtube body.

The mating end connections, gaskets, and clamps are supplied by the user.

3A I-Line Fitting (Code "C")

The 3A I-Line fitting mates with Cherry Burrell 15 WI or equivalent. See Figure 6.

1. Insert seals into flowtube ends.
2. Insert mating pipe end and tighten clamp securely.

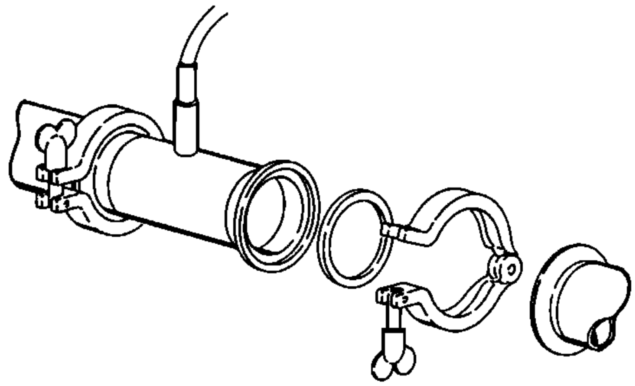

Figure 6. 3A I-Line Fitting

ANSI Class 150 RF Flange (Code "F")

The ANSI Class 150 RF flange is a crevice-free design for general sanitary service. See Figure 7.

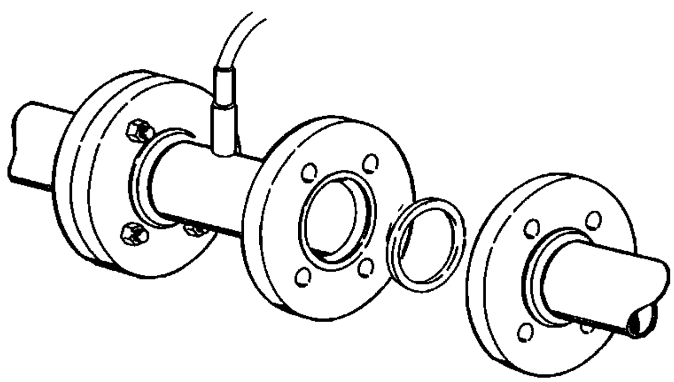

Figure 7. ANSI Class 150 RF Flange

1. Gaskets are normally required and are supplied by the user. Select a gasket material that is suitable for the process fluid.
2. Insert gaskets between body of flowmeter and adjacent flanges. Position gaskets so that ID of each gasket is centered on ID of flowmeter and adjacent piping.

! CAUTION

1. Verify that the ID of the gaskets is larger than that of the flowmeter bore and pipe and that they do not protrude into the flowtube entrance or exit. Protrusion into the flowstream has an adverse affect on performance.
2. Gaskets do not prevent flanges from being wetted by process fluids.

— NOTE
If welding of flanges to the process piping is required, protect the inside diameter of the flowmeter from weld splatter. Failure to do this may adversely affect flowmeter accuracy.

3. Visually inspect for concentricity of mating flanges.
4. Tighten bolts in accordance with conventional flange bolt tightening practice (i.e., incremental and alternate tightening of bolts).

SI Coupling (Code "M")

Code "M" is an SI (DIN 11851) coupling with an external thread. See Figure 8.

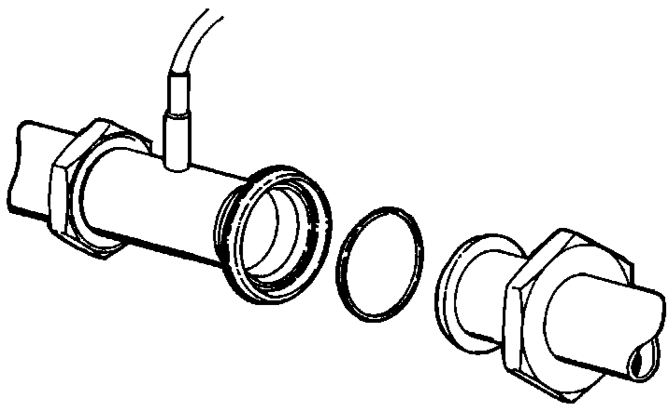

Figure 8. SI Coupling

1. Insert seals into grooves in flowtube ends.
2. Tighten nuts securely.

RJT Coupling (Code "R")

Code "R" is an RJT coupling (ring-type joint coupling) per BS 1864 with an external thread. See Figure 9.

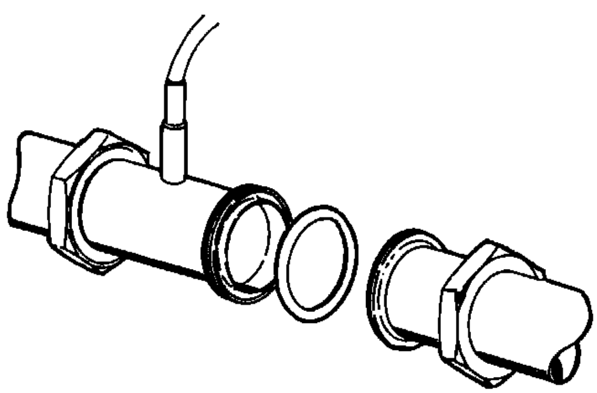

Figure 9. RJT Coupling

1. Insert seals into cavity in flowtube ends.
2. Tighten nuts securely.

3A Tri-Clamp (Code "T")

Code "T" is a 3A Tri-Clamp Type Quick-Disconnect Ferrule. It mates with Tri-Clover 14 WMP or equivalent. See Figure 10.

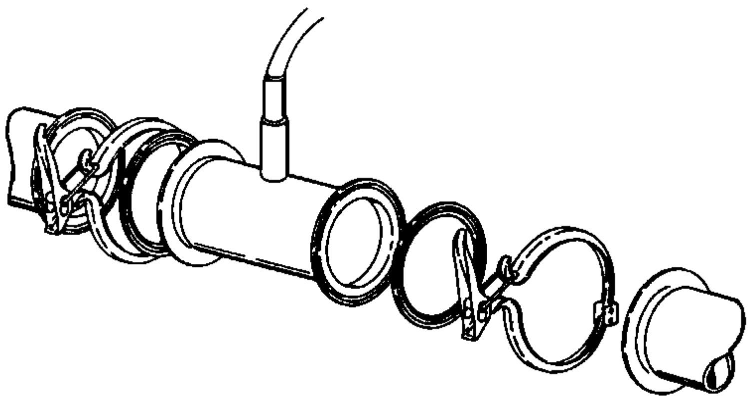

Figure 10. 3A Tri-Clamp

1. Insert seal into flowtube ends.
2. Full face contact should be made between the ends prior to installing and tightening the clamps.

ISS Coupling (Code "U")

Code "U" is an ISS (ISO 2853) coupling with an external thread. See Figure 11.

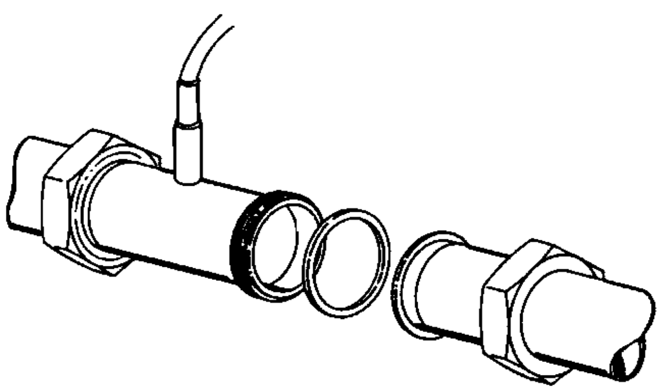

Figure 11. ISS Coupling

1. Insert seals onto flowtube ends.
2. Tighten nuts securely.

Mounting the Electronic Housing

The electrical housing can be either pipe or wall mounted. Do **not** mount the electronic housing on process piping. Excess vibration may damage the electronic module and electronic module housing. Support the cable that connects the flowmeter body to the electronic housing. The supports must be approximately 30 cm (12 in) from the flowtube body and the electronic housing. A loose cable may cause wear at the cable connections (see Figure 12).

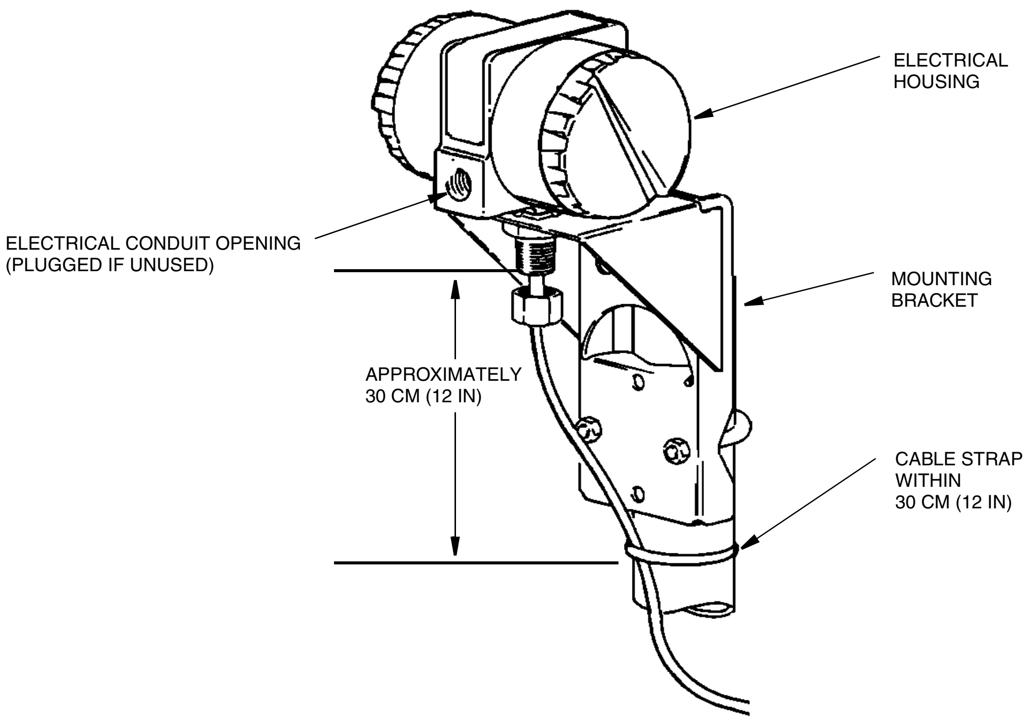

Figure 12. Pipe-Mounted Electrical Housing

⚠ CAUTION

Temperature limit of cable is 105°C (220°F). Do not support cable on any surface that exceeds this temperature.

Field Termination Wiring

NOTE

The wiring installation shall be in accordance with the local and national regulations applicable to the specific site and classification of the area.

The electronics housing has an electronic module compartment and a field terminal compartment. It also provides 1/2 NPT conduit openings for access from either side of the flowmeter and for ease in wiring to the field terminals. See Figure 13.

— **NOTE**

One conduit opening contains a threaded plug. Do not discard this plug.

Remove the field terminal compartment cover (shown in Figure 13) to make electrical connections. Keep the electronic module compartment cover closed to ensure protection for the electronic module and to prevent moisture and atmospheric contaminants from entering the compartment.

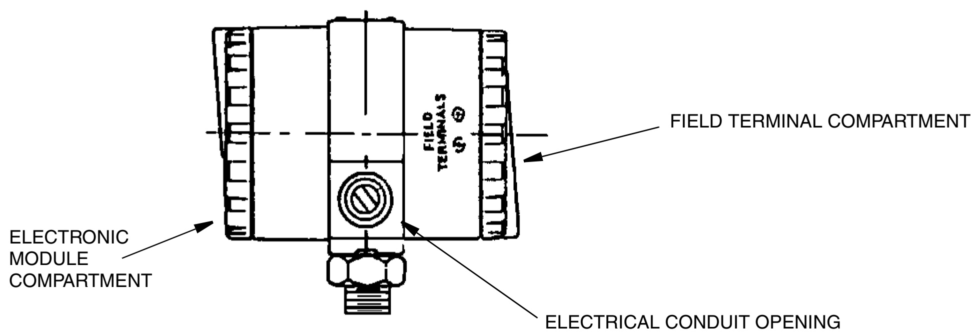

Figure 13. Electronics Housing

4 to 20 mA Output Mode

- Two-wire twisted cable (twisted pair of 24 AWG minimum) is recommended.
- For a given supply voltage, the flowmeter must operate within the shaded area shown in Figure 14.

— **NOTE**

Voltage at the flowmeter must be between 10.5 and 50 V dc. Power supply ripple must not allow the instantaneous voltage to drop below 10.5 V dc.

- Grounding of the negative lead of the flowmeter loop at the user power supply ground is recommended. See Figure 15.
- In high noise (RFI, cable crosstalk, etc.) installations, for best results it is recommended that shielded twisted pair be used. The shield should be terminated at power supply ground.

— **NOTE**

When using the flowmeter in the analog (4 to 20 mA dc) output mode, do **not** connect the pulse output line. Connecting a load to the pulse output line affects the accuracy of the 4 to 20 mA dc measurement (0.5% maximum).
If it is desired to connect a load to the pulse output line while in the analog output mode, accuracy can be restored by recalibrating the electronic module with the load connected.

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1. Make connections to the field terminal block as shown in Figure 16.
2. Replace cover. Tighten cover securely to engage O-ring. This prevents moisture or other contaminants from entering the compartment.

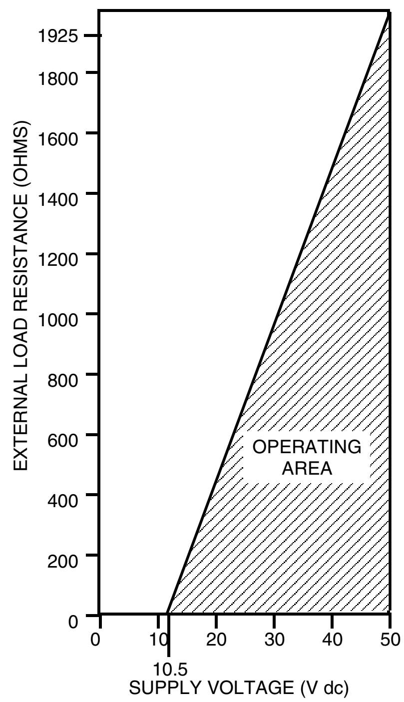

Figure 14. Load Requirements - Analog Output

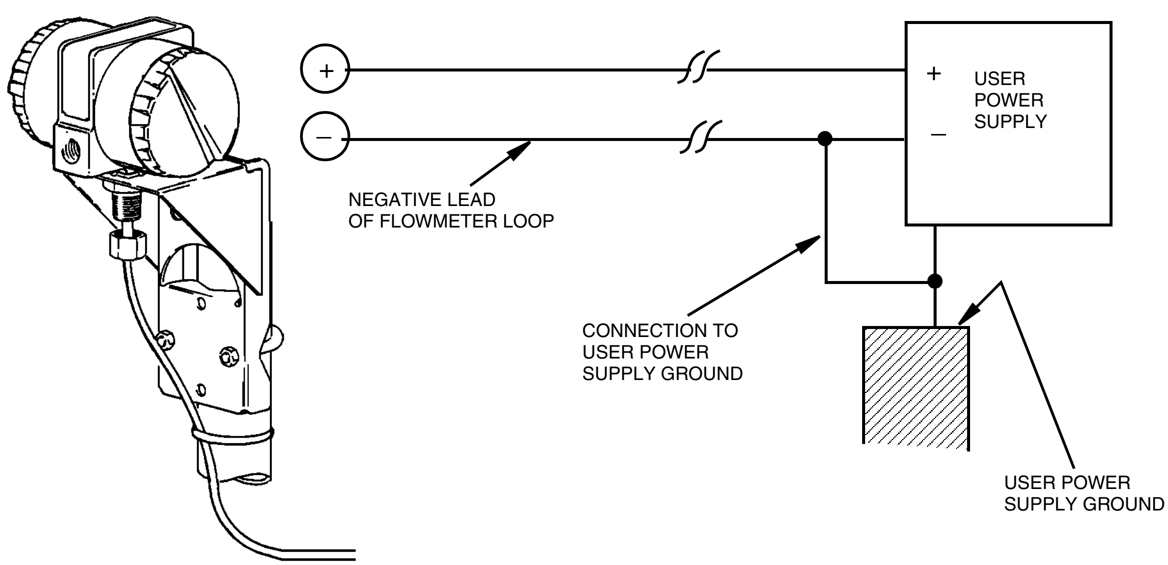

Figure 15. Grounding the Flowmeter Loop

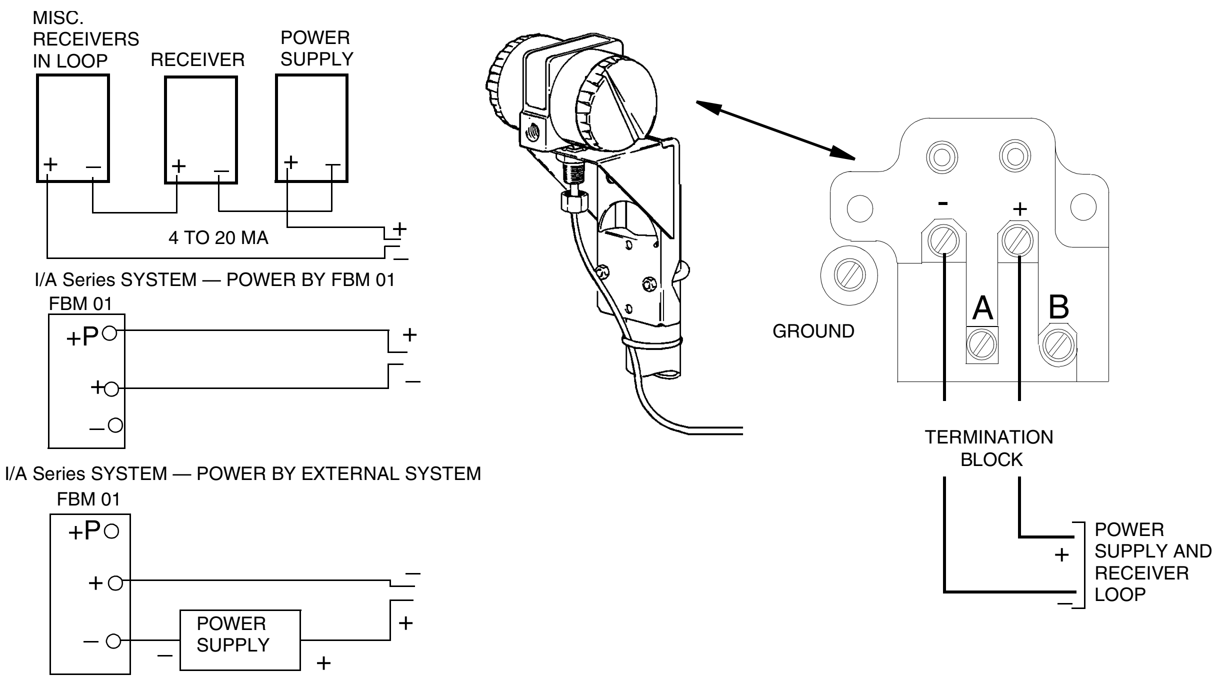

Figure 16. 4 to 20 mA Output Mode Electrical Connections - Loop Wiring

Pulse Output Mode

- Three-wire shielded cable (24 AWG minimum) should be used. The signal has fast edges which could cross-couple to other conductors if not shielded.
- See "Standard Specifications" on page 2 for Pulse Output specifications.
- Grounding the negative lead of the flowmeter loop at the user power supply ground is recommended. See Figure 15.
- The shield should be terminated at the user power supply ground connection.

1. Make connections to the field terminal block as shown in Figures 17 through 23.
2. Replace cover. Tighten cover securely to engage O-ring. This prevents moisture or other contaminants from entering the compartment.

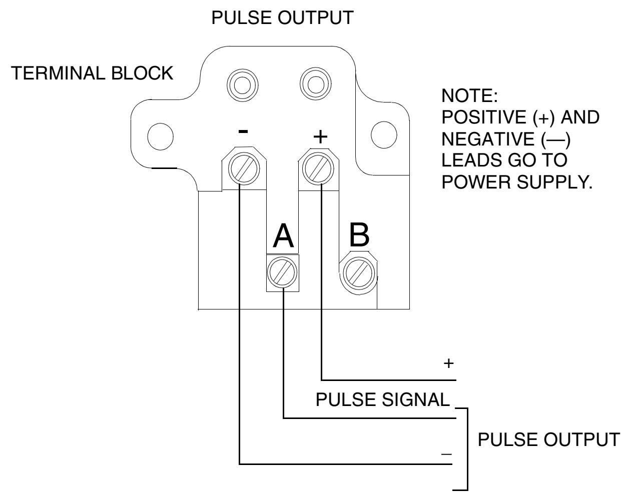

Figure 17. Pulse Output Wiring - General

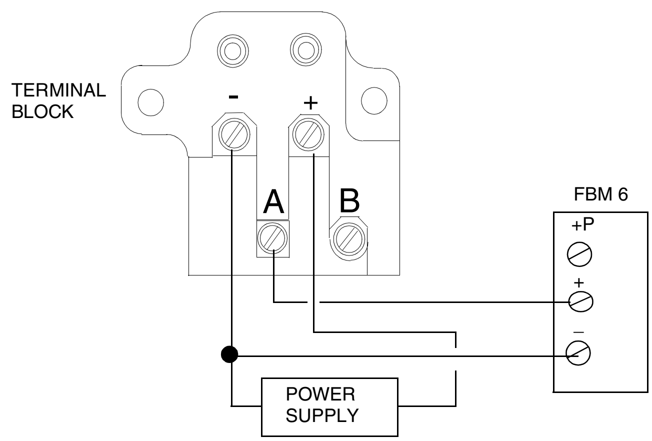

Figure 18. Pulse Output with I/A Series System Flowmeter Powered by External Power Supply

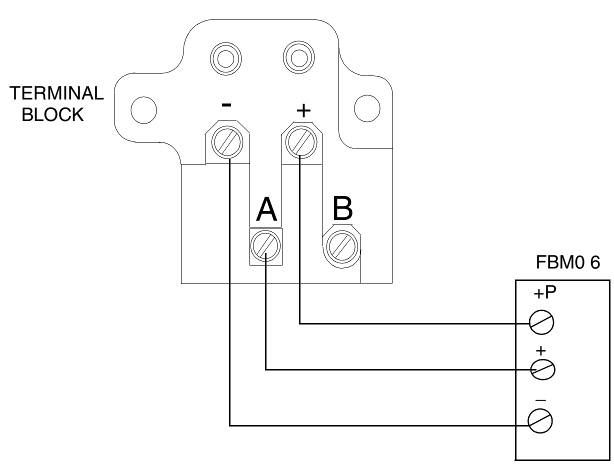

Figure 19. Pulse Output with I/A Series System Flowmeter Powered by FBM06

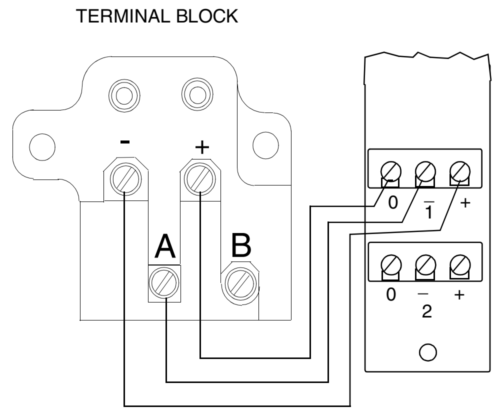

Figure 20. Pulse Output with 2AI-F2V or 2AI-F2F (SPEC 200)

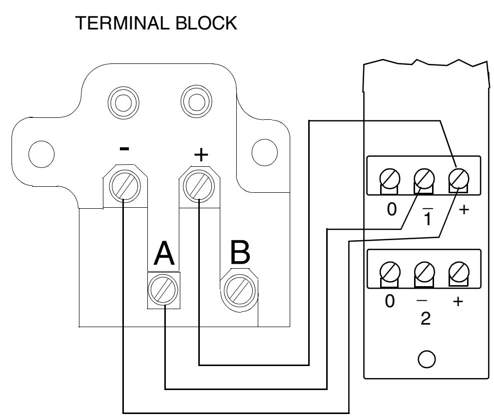

Figure 21. Pulse Output with 3A2-F2D or 3A2-Q2D (SPEC 200)

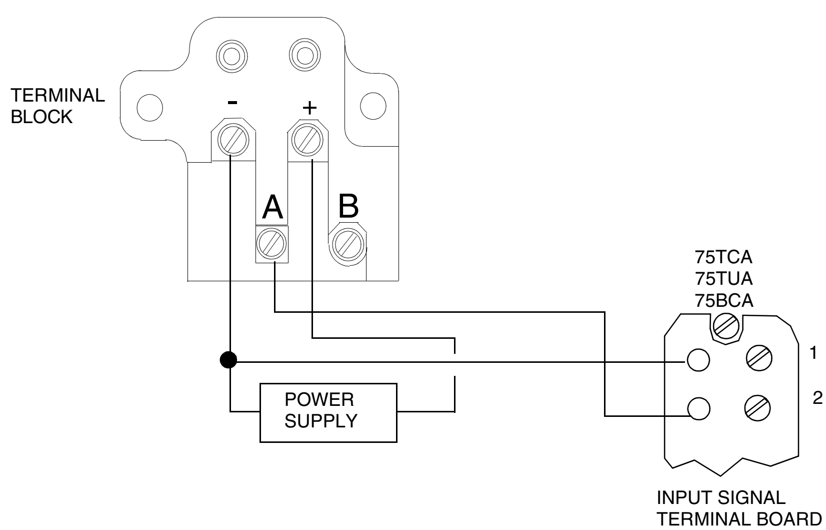

Figure 22. Pulse Output with 75TCA, 75TUA, and 75BCA Totalizers and Batcher (Flowmeter Powered by External Power Supply)

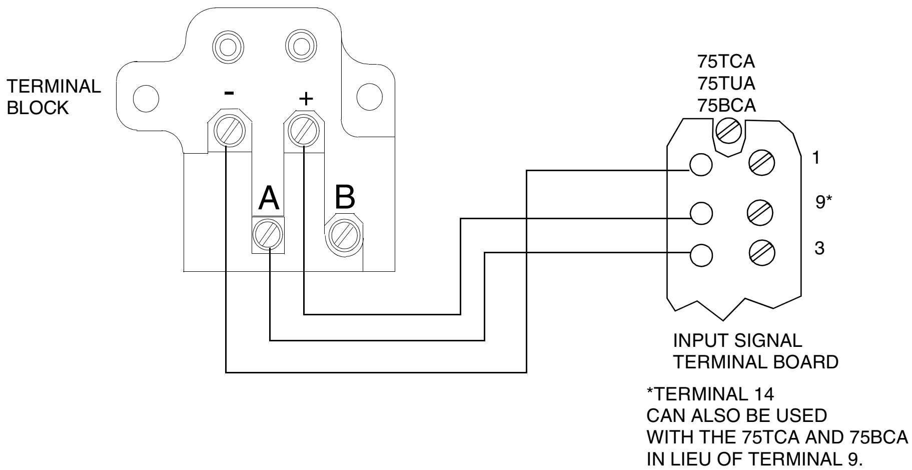

Figure 23. Pulse Output with 75TCA, 75TUA, and 75BCA Totalizers and Batcher (Flowmeter Powered by Totalizer or Batcher)

Flowmeter Grounding

The electronics housing and the flowmeter body must be connected to local ac ground. The ground screw located in the Field Terminal compartment. See Figure 16.

Electronic Module Switch Settings

All electronic module switch settings are set at the factory based on the customer-specified flow range. Figure 24 illustrates the electronic module assembly's label board and identifies switch functionality.

Output Mode Selection

The output mode selection is made by the setting of Switch **J** as shown in Table 5.

Table 5. Output Mode Selection

Switch J Position	Output Mode
Off On	4 to 20 mA dc Pulse

Electronic Module Filtering

The electronic module noise filter is set at the factory based on the customer-specified flow range. The electronic module filter consists of both high and low frequency noise filters. Each filter can be independently set, allowing the filtering to be tailored to each application. Table 4 and Table 5 show the possible switch settings. “Electronic Module 4 to 20mA Calibration” on page 29 contains information for determining the frequency range for a specific application.

Table 6. High Frequency Noise Filter Switches

Step	Upper Range Frequency (in Hz)	Switch Positions		
		A	B	C
1	2300 to 3300	off	off	off
2	1500 to 2300	off	on	off
3	700 to 1500	off	on	off
4	350 to 700	off	on	on
5	160 to 350	on	off	off
6	80 to 160	on	off	on
7	< 80	on	on	off

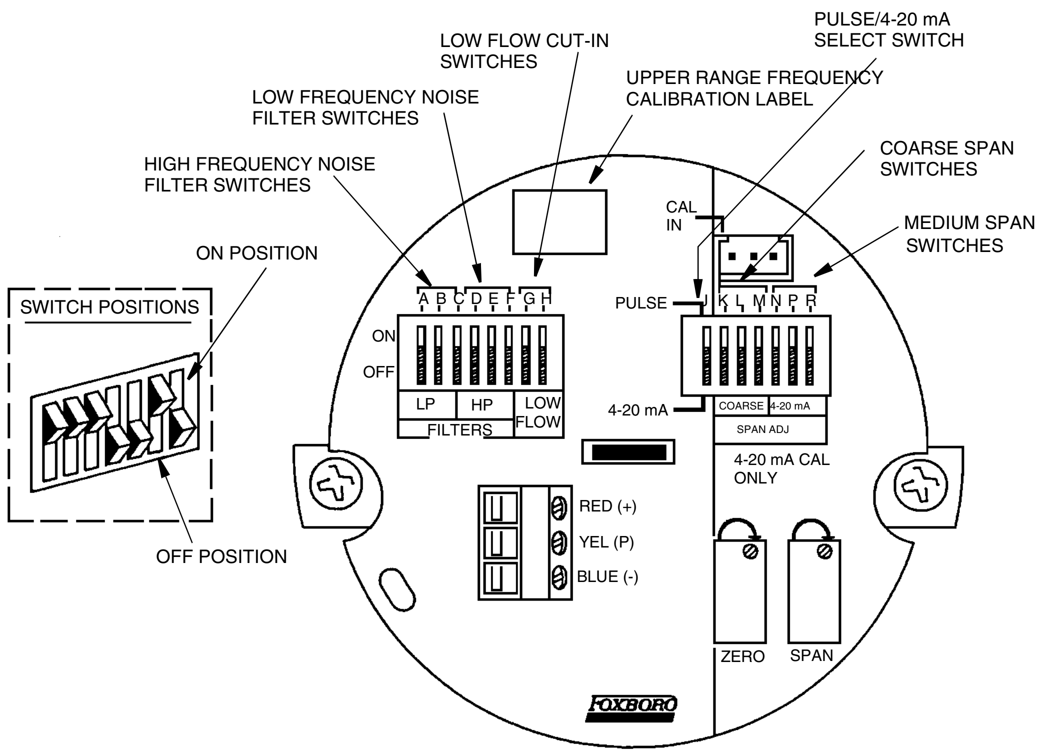

Figure 24. Electronic Module Switch Locations

Table 7. Low Frequency Noise Filter Switches

Step	Frequency (in Hz)	Switch Positions		
		D	E	F
1	< 5	off	off	off
2	5 to 10	off	off	on
3	10 to 30	off	on	off

Table 7. Low Frequency Noise Filter Switches

Step	Frequency (in Hz)	Switch Positions		
		D	E	F
4	30 to 64	off	on	on
5	64 to 150	on	off	off
6	> 150	on	off	on

Low Flow Cut-in

The low flow cut-in selection determines the minimum flow rate that the electronic module can measure and return a non-zero indication of flow. Occasionally, erratic output conditions can occur at low flows. This is due to system noise such as pulsing pumps, surging flows, or vibrating pipes. To eliminate these false signals, the low flow cut-in can be raised. Raising the low flow cut-in by one step increases the low flow cut-in by a factor of two.

All flowmeters are set at the factory to the "LO" low flow cut-in position, which is the default setting. This setting can be increased to achieve greater noise immunity as described above. Or, it can be decreased for lower flow rate measurement capability as shown in Table 8.

Table 8. Low Flow Cut-In Switches

Low Flow Cut-In	Switch Position	
	G	H
Min	off	off
Low	off	on
Med	on	off
High	on	on

Calibration Switches

Switches **K**, **L**, **M**, **N**, **P**, **R**, and both potentiometers are used only for calibrating the 4 to 20 mA dc output. All flowmeters intended to be employed in the analog output mode are factory calibrated to the user-specified Upper Range Value (URV) flow rate. These flowmeters should not have to be changed unless the desired URV has changed. The calibration frequency corresponding to the URV is located on the adhesive label on the front side of the electronic module as shown in Figure 24. See "Electronic Module 4 to 20mA Calibration" on page 29.

— NOTE

Setting switch **J** to the pulse output mode disables the calibration switches. Calibration for URV is unnecessary in the pulse output mode.

3. Troubleshooting

General Troubleshooting

To maximize the usefulness of this chapter, read this General Troubleshooting section first. Then, follow the applicable procedural steps in the order in which they're presented.

Flowmeter Has No Output with Fluid Flow in the Pipe

Refer to “No Output Troubleshooting” on page 22.

Flowmeter Output Indicates Flow When There is No Flow

In some installations, the flowmeter can indicate flow when the line is shut down. This could be the effect of a leaking valve, sloshing fluid, or noise sources such as pump-induced pipe vibration. To eliminate these false signals, try the following:

1. Raise the low flow cut-in one step. See “Electronic Module 4 to 20mA Calibration” on page 29. Check output.
2. Increase the Low frequency noise filter by one step. Check output.
3. Decrease high frequency noise filter by one step. Check output.
4. Repeat Steps 1 through 3 until output is suppressed.

Flowmeter Output Indicates Higher Flow Rate with Decreasing Flow

1. Increase high frequency noise filter by one step. Check output.
2. Increase low flow cut-in by one step. Check output.
3. Increase low frequency noise filter by one step. Check output.
4. Repeat Steps 1 through 3 until output is suppressed. But, do not increase high frequency noise filter by more than two steps from its original position.

Unstable Output under Low Flow Conditions

Most often a noisy (greater than 5% of reading) output is due to incorrect piping or inadequate damping of pipe vibration from pumps or other noise sources. See “Piping Considerations” on page 6.

This situation can generally be improved by adjusting the low flow cut-in and the low and high frequency noise filters. See “Low Flow Cut-in” on page 20.

No Output Troubleshooting

1. Verify that power is actually supplied to the flowmeter. If flowmeter has loaded the power supply and produced a low voltage, or caused a fuse to blow, proceed with Step 1a. If the voltage is low but a fuse has not blown, proceed to Step 2.
   a. Remove electronic module compartment cover. Disconnect red, yellow, and blue leads from electronic module. If voltage returns to normal power supply output, then electronic module has failed and should be replaced.
   b. If loading still persists, remove electronic module from housing. Examine power leads for shorts (red, yellow, blue ribbon cable). If ribbon cable has not been damaged, then housing/terminal block assembly has failed. Return flowmeter to Invensys Foxboro for service.
2. Remove field terminal cover and output indicator (if option is present).
3. Measure voltage across terminal block (+/–terminals). Voltage should be between 10.5 and 50 V dc. If voltage is zero, check for a blown fuse as discussed in Step 1 above. If voltage is not zero but outside the specified range, see “Standard Specifications” on page 2. If voltage is within the specified range, proceed with Step 4.
4. Remove the Electronic Module compartment cover.
5. Measure the voltage across electronic module assembly's terminal block (at the positive and negative terminals). If voltage is zero, then terminal block or housing has failed. Return flowmeter to Invensys Foxboro for service. If voltage is within the specified range, proceed with Step 6.
6. Measure loop current via test jacks located on the field terminal block. The test jacks are used to measure the voltage drop across a 25 Ω current interpreting resistor. This determines that the flowmeter, rather than the receiving device, is not responding.
7. Increase fluid flow rate to ensure that lack of flowmeter response is not due to its operation below the low flow cut-in. Use test jacks to monitor loop current.
8. For flowmeters configured for 4 to 20 mA output, perform flowmeter calibration test procedure. This establishes whether the electronic module is functioning properly. If flowmeter does not respond during this test, the electronic module has failed and should be replaced. Refer to “Electronic Module Replacement” on page 28 for details. If electronic module passes calibration test procedure, skip to Step 9 below.
9. For flowmeters configured for pulse output mode, follow the calibration procedure with the following exceptions. Using the calibration input on the front of the electronic module (identified as **CAL IN**), simply inject a frequency within the expected flowrate range of the flowmeter. If pulse output does not respond, then the electronic module assembly has failed and should be replaced. If electronic module responds appropriately, proceed with the procedure described in “Sensor Test Procedure” on page 23.

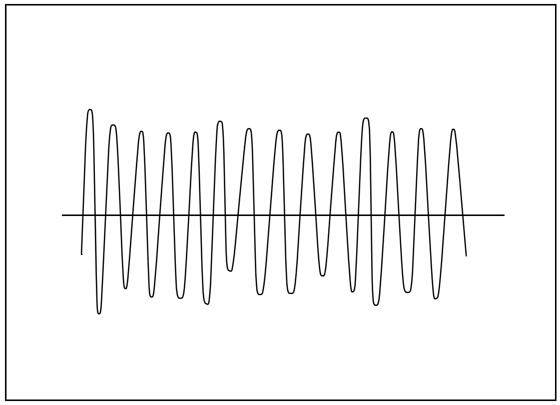

Figure 25. Normal Vortex Frequency Waveform

Sensor Test Procedure

1. Remove Electronic Module from housing using the handle located in the center of the Electronic Module label board.
2. Disconnect yellow and brown sensor leads from back of Electronic Module.
3. Connect sensor leads to an oscilloscope.
4. With fluid flow in the pipe, observe signal waveform on oscilloscope. Waveform should be similar to that shown in Figure 25.
   a. If waveform is similar to Figure 25, the sensor is good. If there is no output from the electronic module, the electronic module input stage has failed. The electronic module should be replaced.
   b. If there is no sensor output signal, the sensor has failed. The entire meter should be returned to Invensys Foxboro.

4. Maintenance

Introduction

The operation of the 83S-A Sanitary Vortex Flowmeter consists of three basic functions: generation and shedding of vortices in the fluid stream, sensing of vortices, and amplification and conditioning of the signal from the vortex sensor. Should a malfunction of the flowmeter be suspected, the cause can normally be isolated to one of these three functions.

Personnel involved in maintenance of vortex meters should be trained and qualified in the use of the equipment required and in the removal and replacement of the meter in the piping. They should also be qualified for the routine maintenance of the meter components.

Vortex Generation and Shedding

The process of vortex generation and shedding can be degraded or destroyed by disturbances in the upstream flow, the nature of the flowing fluid, or by damage to the vortex shedding element (rare). Such flow disturbances may be created by gaskets protruding into the flowing stream, by some form of partial blockage in the upstream piping, by the piping configuration, or by the existence of two-phase flow. Should the vortex shedding element become heavily caked, coated, or physically damaged to such an extent that its basic shape or dimensions are changed, the vortex shedding process may be impaired. Also, the length of straight, unobstructed run of upstream piping is important (refer to “Piping Considerations” on page 6).

Vortex Sensor

The vortex sensor is mounted in the vortex shedding element. It consists of a piezoelectric crystal which is sealed inside a liquid-filled capsule by two diaphragms. The vortex shedding process creates an alternating differential pressure on the capsule diaphragms which is transmitted through the fill liquid to the piezoelectric crystal.

The differential pressure or mechanical force acting on the crystal causes it to develop a pulsed voltage with a frequency equal to the vortex shedding frequency. Damage to sealing diaphragms or other physical damage could cause the sensor to operate improperly.

Amplification and Conditioning

The vortex sensor signal is amplified and conditioned in the output module (electronic module), which is located in the electronic module compartment of the electrical housing. The function of the electronic module, in addition to amplification and conditioning, is scaling of the raw sensor output for transmission as a 4 to 20 mA signal. A simplified block diagram of the flowmeter is shown in Figure 26.

As shown, the electronic module accepts the raw sensor output directly from the vortex sensor. The electronic module receives the vortex signal and then performs its conditioning, scaling, and amplification functions.

The electronic module also has several user selectable inputs located on an accessible label board on the front side of the Electronic Module. These inputs provide for output mode selection, noise filtering adjustment, and electronic module calibration. The label board of the electronic module is shown in Figure 27.

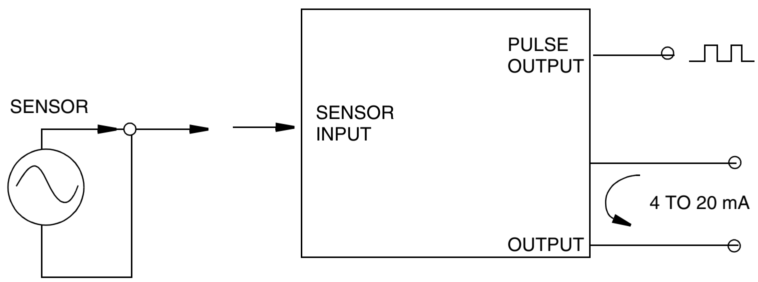

Figure 26. Flowmeter Block Diagram

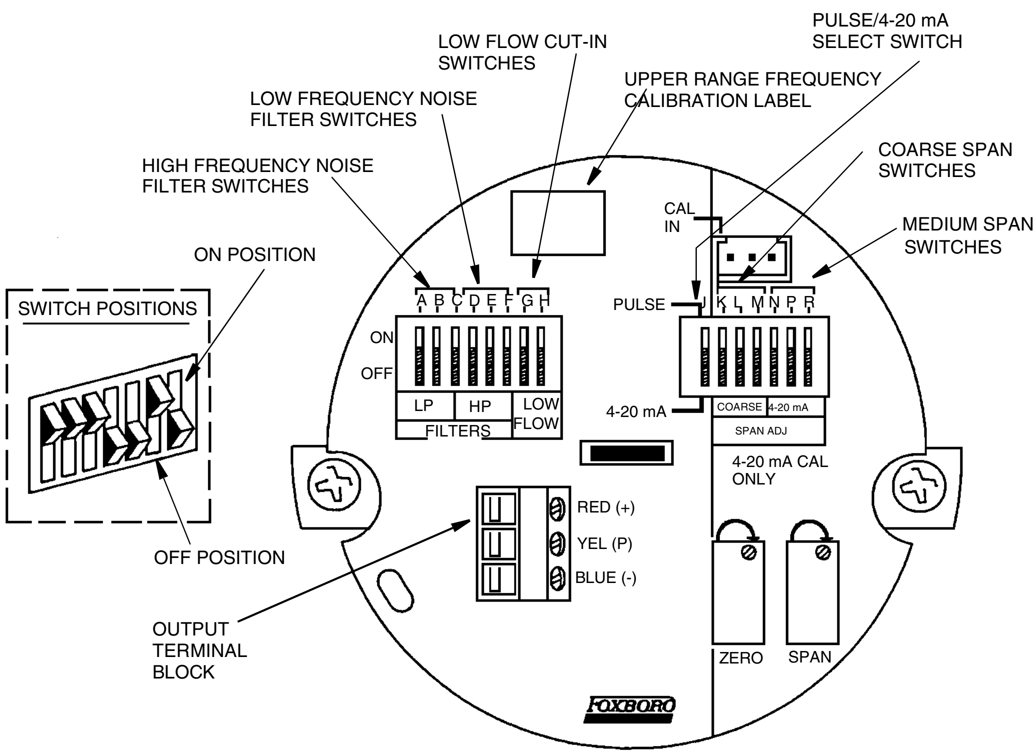

Figure 27. Electronic Module Label Board

Electronic Module

The Electronic Module is made up of two printed wiring assemblies (PWAs), a plastic enclosure with a label, and two captive screws. The Electronic Module is housed in the flowmeter housing opposite the side labeled **FIELD TERMINALS**. The electronic module has two terminal blocks. See Table 9 on page 27 for a summary of the terminal block connections.

Table 9. Electronic Module Terminal Block Connections

Location of Connector	Letter Code	Color	Description
Front	R	Red	Loop+
	Y	Yellow	Scaled Pulse Out +
	B	Blue	Loop –, Scaled Pulse Out –
Back	B	Brown	Sensor + or Preamp Out +
	R	Red	Preamp Power +
	O	Orange	Preamp Power –
	Y	Yellow	Sensor – or Preamp –

Electronic Module Removal

1. Remove power from the flowmeter.
2. Remove Electronic Module compartment threaded cover.
3. Disconnect the three signal leads (red-yellow-blue) at front of the Electronic Module.
4. Unscrew the two captive screws, one on each side of the Electronic Module.
5. Pull electronic module (using handle in center of Electronic Module label board) far enough out of the housing to be able to disconnect the brown and yellow sensor leads from the terminal block on the back of the electronic module. Refer to Figure 28.
6. Pull the signal leads (red-yellow-blue cable) out of the holes in the PWAs and plastic enclosure and remove electronic module from housing.

— NOTE

Do not cut the plastic tie wraps.

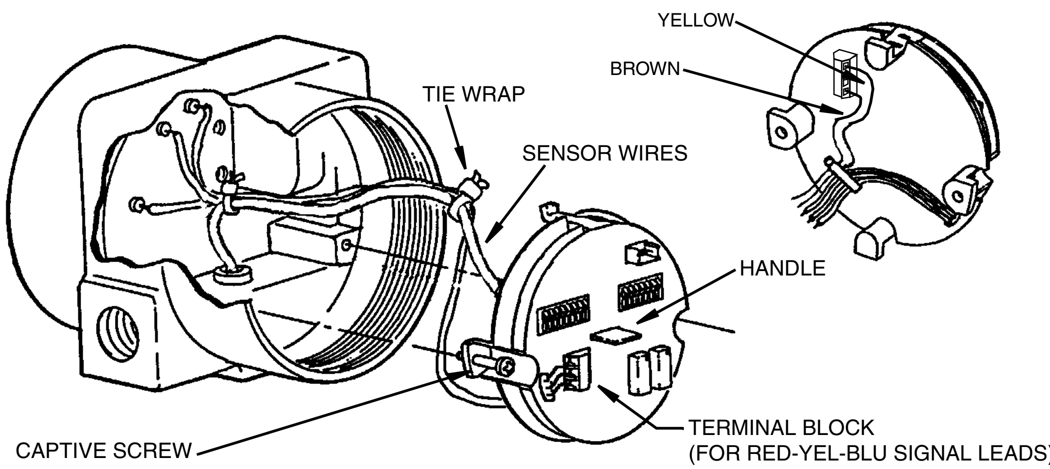

Figure 28. Electronic Module Removal

Electronic Module Replacement

CAUTION

Ensure that power is not applied to the flowmeter before proceeding.

1. Remove the Electronic Module following the procedure above.

NOTE

The replacement Electronic Module is shipped in a protective anti-static plastic bag along with a small adhesive label. Do not remove it from this bag until it is ready to be installed in a flowmeter. This minimizes the possibility of damage due to accidental electrostatic discharge. Use of an electrostatic mat prevents electrostatic discharge.

2. Remove the new Electronic Module from its protective bag.

NOTE

The signal and sensor leads should already be tied together in the housing.

3. Calibrate the Electronic Module according to the instructions in the following section, “Electronic Module 4 to 20mA Calibration”.
4. Refer to Figure 28. Connect the brown and yellow sensor leads to the color coded terminal block on back of the Electronic Module.
5. Feed signal leads (red-yellow-blue cable) through holes in the PWAs and connect them to the terminal block on front of the Electronic Module following color code on the label.
6. After the sensor and signal leads are connected, locate Electronic Module in the housing over the two mounting holes.
7. While taking care not to pinch the sensor and signal leads between the Electronic Module and housing, tighten the captive mounting screws.
8. Replace the housing covers.

Electronic Module 4 to 20mA Calibration

A vortex flowmeter may require calibration for the following reasons:

- ♦ A new meter was ordered without specifying the desired range.
- ♦ An existing installation requires a range change because of a change in process operating conditions.
- ♦ A replacement Electronic Module is being installed.

— **NOTE**
The Electronic Module does not require calibration if the unit is being operated in the pulse mode; that is, 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 vary 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, thus avoiding the tasks of removing the module from its housing and disconnecting the sensor leads.

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, 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

If a replacement module is being installed, the upper range frequency can be read from the label on the front of the module being replaced (see Figure 27 on page 26). In this case, skip to Step III below. If a range change to an existing installation is required due to a change in operating conditions, or if a new meter was ordered without specifying the desired range (in this case the label reads 25 Hz), begin with Step I.

I. Determining the Corrected K-Factor

The first step in calibrating an 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.

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

To calibrate an Electronic Module it is necessary to determine the vortex frequency corresponding to the desired upper range flow value. If a replacement module is being installed, this frequency can be read from the label on the front of the module being replaced (see Figure 27). In this case, skip to Step III. If a range change to an existing installation is required because of a change in operating conditions, or if a new meter was ordered without specifying the desired range (in this case the label reads 25 Hz), the upper range frequency can be calculated by one of the following procedures:

1. *FlowExpertPro* – This meter selection/sizing software program, available from Invensys Foxboro, displays a *nominal* upper range frequency, based on a built-in *nominal* K-factor and corrected for process temperature (see second 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. *FlowExpertPro* incorporates this correction internally, based on the flowing process temperature that was entered 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 10). 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)

   If 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)

   If 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 to 20mA.

5. **Span Switches** (K-M, N, P, and R)

   The span switches must be set to encompass the upper range frequency determined in Step II. This ensures that the span potentiometer can be used in the final step to calibrate the module. If a replacement module is being installed, set the span switches to duplicate the settings of the module being replaced. Otherwise, use the following procedure:

   a. Set the coarse span switches (K, L, and M) per the intervals defined in Table 11 on page 33.

      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 12 on page 33.

      Example:

      The frequency, 312 Hz, represents a value that is 56% of the value between 200 and 400.
      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 29 on page 34. 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 29).

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

If the calibration cable is not available, remove the module from the housing as described in “Electronic Module Removal” on page 27. Disconnect the sensor leads (Brown and Yellow wires) from the 4-connector terminal block on the back of the module and connect the wires from the sine wave generator (1 Volt peak-to-peak, centered on zero) to the B(+) and Y(-) terminals.

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 “Electronic Module Replacement” on page 28.
6. Write the calibrated upper range frequency on an adhesive label and stick it to the front face of the module.

— NOTE
A blank label comes with a replacement module kit.

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 set to their proper positions. If a replacement module has been installed, reset switches D, E, F, G, and H to their original positions, as recorded earlier. In all other cases, and for a replacement module if any uncertainty exists, establish and set the appropriate switch settings (D through H) according to the instructions in the Installation section (see “Electronic Module Switch Settings” on page 18).

Table 10. High Frequency Noise Filter Switches

Step	Upper Range Frequency (in Hz)	Switch Positions		
		A	B	C
1	2300 to 3300	off	off	off
2	1500 to 2300	off	on	off
3	700 to 1500	off	on	off
4	350 to 700	off	on	on
5	160 to 350	on	off	off
6	80 to 160	on	off	on
7	< 80	on	on	off

Table 11. 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 12. 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

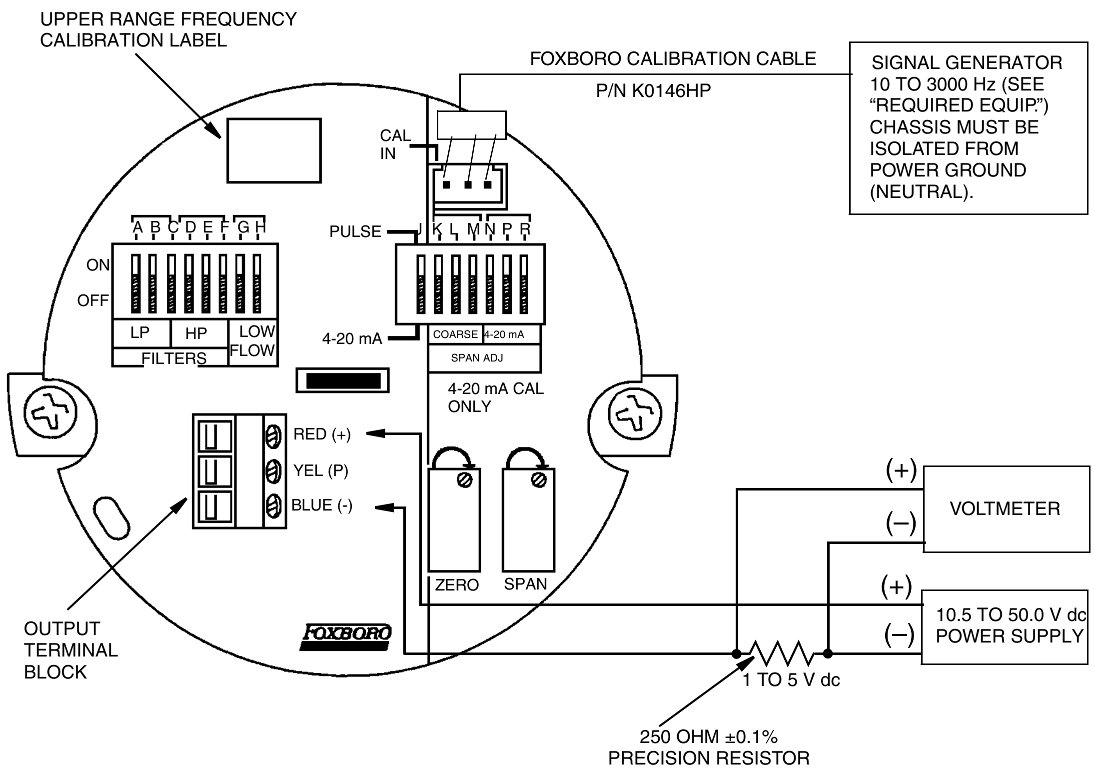

Figure 29. Analog Electronic Module Calibration Hook-Up

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 takes account of 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 changes in dimensions arising from thermal expansion. The correction factor for this effect (TFC) is:

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

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

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

Mating Pipe Correction Factor (MCF)

Table 13 shows the K-factor offset caused by the use of Schedule 10 or Schedule 40 pipe instead of the Schedule 5 pipe used at the factory to determine the Reference K-Factor. For example, the K-factor of an 3-inch flowmeter installed in Schedule 10 pipe has an offset of +0.5%. Therefore, the K-factor value specified on the flowmeter data plate needs to 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 13. K-Factor Mating Pipe Offset

Flowmeter Size				
mm	**in**	**Schedule 5**	**Schedule 10**	**Schedule 40**
50	2	ref	+1%	+2%
80	3	ref	+0.5%	+1%

Upstream Piping Disturbance Correction Factor (UCF)

The flowmeter should be installed in straight unobstructed pipe to ensure that it performs to its full capabilities. The information in Figures 30 through 34 shows the offset that can be expected by introducing various upstream disturbances.

Referring to Figure 30, for example, if a liquid installation requires one 90°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 30 as follows:

Draw a vertical line at 20 pipe diameters in Figure 30. 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 needs to 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

— NOTE

1. The graphs shown in Figures 30 through 34 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 30 through 34 apply specifically to wafer type vortex flowmeters. For sanitary meters, add 1/2 Pipe Diameter to the measured distance between flanges.

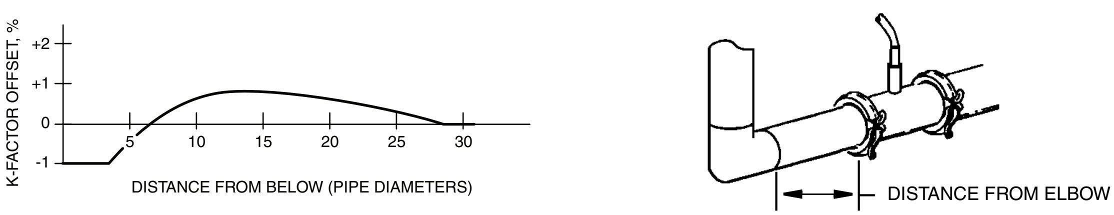

Figure 30. K-Factor Offset Distance from Elbow - Single Elbow with Shedder Parallel to Elbow Plane

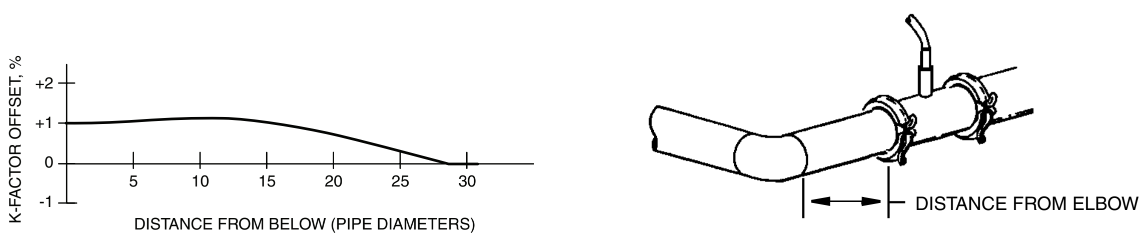

Figure 31. K-Factor Offset vs. Distance from Elbow - Single Elbow with Shedder Perpendicular to Elbow Plane

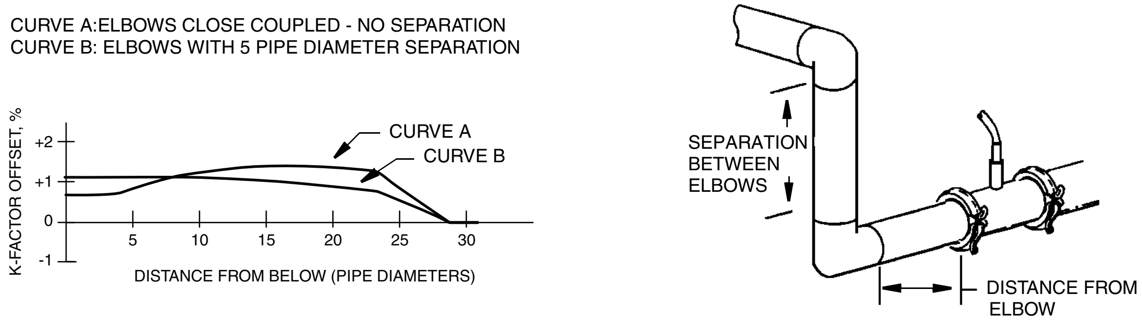

Figure 32. K-Factor Offset vs. Distance from Elbow - Two Elbows with Shedder Parallel to Plane of Closest Elbow

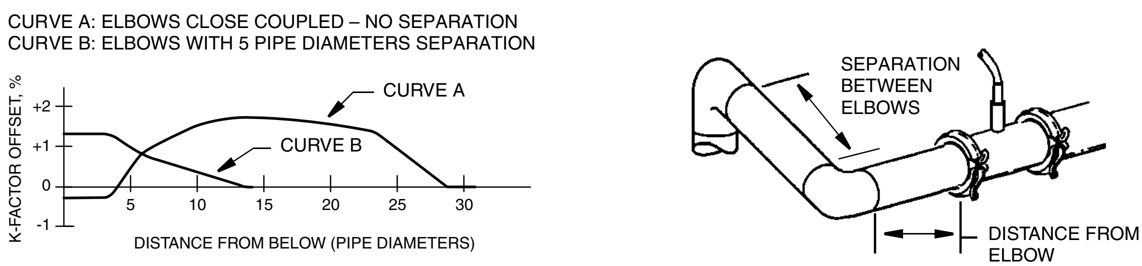

Figure 33. K-Factor Offset vs. Distance from Elbow - Two Elbows with Shedder Perpendicular to Plane of Closest Elbow

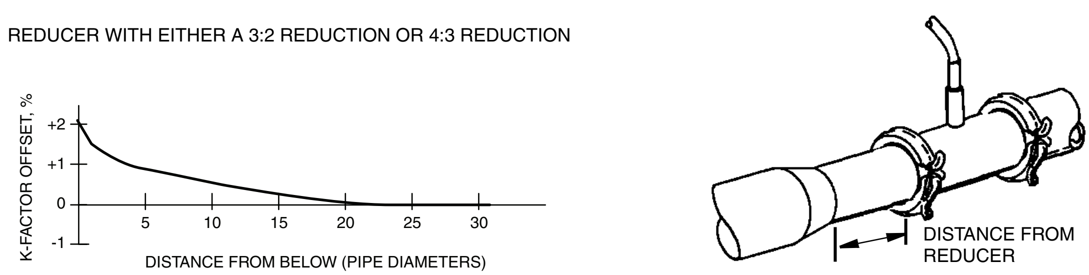

Figure 34. K-Factor Offset vs. Distance from Reducer

Total Bias Correction Factor (BCF)

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

$$BCF = TCF \cdot MCF \cdot UCF$$

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:

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

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 flowmeter to calibrate the 4 to 20mA output, so that 20mA corresponds to the URV. The URF may be calculated with the aid of *FlowExpertPro*, a meter sizing/selection software program available from Invensys Foxboro (see “Electronic Module 4 to 20mA Calibration” on page 29), 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 Condition

(1)

$$URF = CKF \cdot CF \cdot \frac{URV}{Time}$$

Volume Flow at Base Conditions

(2)

$$URF = CKF \cdot CF \cdot \frac{URV}{Time} \cdot \frac{\rho_b}{\rho_f}$$

Mass Flow

(3)

$$URF = CKF \cdot CF \cdot \frac{URV}{Time} \cdot \frac{1}{\rho_f}$$

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 14).

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 14. 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)

$$\rho = \frac{3.48 \cdot G \cdot P_{abs}}{Z \cdot T_{abs}}$$

When using U.S. Customary units,

(5)

$$\rho = \frac{2.70 \cdot G \cdot P_{abs}}{Z \cdot T_{abs}}$$

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) sanitary 316 SS flowmeter
- Reference K-Factor = 79.3 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 40 piping

The Corrected K-Factor is, from Appendix A,

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

TCF = $1 - 3 \times 9.59 \times 10^{-6} \times (90-70) = 0.999$
MCF = $1 + (+.10)/100 = 1.010$
UCF = 1.0
CKF = $0.999 \times 1.010 \times 1.0 \times 79.3 = 80.0$ pulses/ft^3

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

(1)
$$URF = CKF \cdot CF \cdot \frac{URV}{Time}$$

Also, since the flowrate is in USgpm, CF = 0.13368 (from Table 14) and Time = 60 (# of seconds per minute).

Hence,

$$URF = 80.0 \times 0.13368 \times \frac{300}{60} = 53.5\ Hz$$

Steam Example (Saturated)

Given:

- 50 mm (2 in) sanitary 316 SS flowmeter
- Reference K-Factor = 281.4 pulses/ft^3 (from the data plate)
- Upper Range Value = 2500 lb/hr
- Flowing Temperature = 300°F
- Flowing Pressure = 67 psia
- Close coupled double elbow with shedder parallel to plane of closest elbow, 10 pipe diameters upstream of meter
- Schedule 10 piping

The Corrected K-Factor is, from Appendix A

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

$TCF = 1 - 3 \times 9.59 \times 10^{-6} \times (300-70) = 0.993$
$MCF = 1 + (+1.0)/100 = 1.010$
$UCF = 1 + (+1.0)/100 = 1.010$
$CKF = 0.993 \times 1.010 \times 1.010 \times 281.4 = 285.0$ pulses/ft^3

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

(3)
$$URF = CKF \cdot CF \cdot \frac{URV}{Time} \cdot \frac{1}{\rho_f}$$

Also, since the URV/ρ_f is in ft^3/hr, CF = 1.0 (from Table 14) and Time = 3600 (# of seconds per hour).

From Steam Tables, $\rho_f = 0.1546$ lbs/ft^3.

Hence,

$$URF = 285.0 \times 1.0 \times \frac{2500}{3600} \times \frac{1}{0.1546} = 1280 \text{ Hz}$$

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