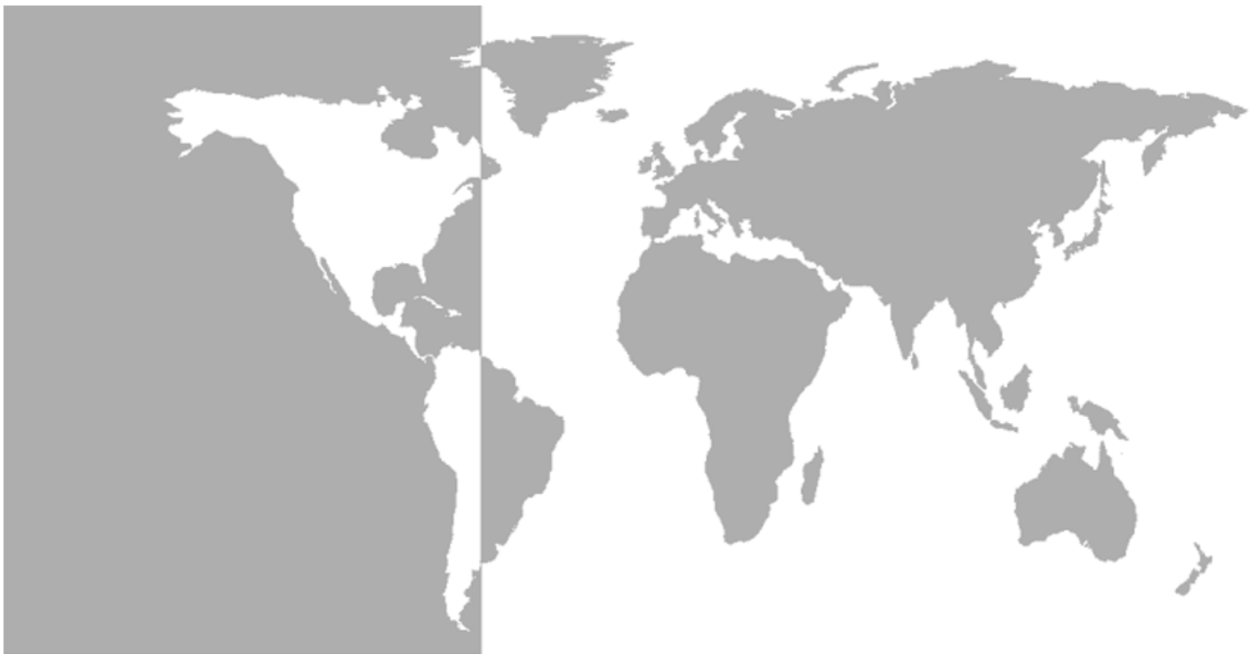
GE
Sensing



PanaFlow™ MV

Vortex Mass Flowmeter

User's Manual

GE
Sensing

Panaflow™ MV

Vortex Mass Flowmeter

User's Manual

910-280A

June 2007

Warranty

Each instrument manufactured by GE Sensing, Inc. is warranted to be free from defects in material and workmanship. Liability under this warranty is limited to restoring the instrument to normal operation or replacing the instrument, at the sole discretion of GE. Fuses and batteries are specifically excluded from any liability. This warranty is effective from the date of delivery to the original purchaser. If GE determines that the equipment was defective, the warranty period is:

- one year for general electronic failures of the instrument
- one year for mechanical failures of the sensor

If GE determines that the equipment was damaged by misuse, improper installation, the use of unauthorized replacement parts, or operating conditions outside the guidelines specified by GE, the repairs are not covered under this warranty.

The warranties set forth herein are exclusive and are in lieu of all other warranties whether statutory, express or implied (including warranties of merchantability and fitness for a particular purpose, and warranties arising from course of dealing or usage or trade).

Return Policy

If a GE Sensing, Inc. instrument malfunctions within the warranty period, the following procedure must be completed:

1. Notify GE, giving full details of the problem, and provide the model number and serial number of the instrument. If the nature of the problem indicates the need for factory service, GE will issue a RETURN AUTHORIZATION number (RA), and shipping instructions for the return of the instrument to a service center will be provided.
2. If GE instructs you to send your instrument to a service center, it must be shipped prepaid to the authorized repair station indicated in the shipping instructions.
3. Upon receipt, GE will evaluate the instrument to determine the cause of the malfunction.

Then, one of the following courses of action will then be taken:

- If the damage is covered under the terms of the warranty, the instrument will be repaired at no cost to the owner and returned.
- If GE determines that the damage is not covered under the terms of the warranty, or if the warranty has expired, an estimate for the cost of the repairs at standard rates will be provided. Upon receipt of the owner's approval to proceed, the instrument will be repaired and returned.

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Appendix E: MODBUS Communications

Chapter 1

Introduction

Overview

The GE Sensing Series MV80 In-Line and the Series MV82 Insertion PanaFlow MV Flowmeters provide a reliable solution for process flow measurement. From a single entry point in the pipeline, PanaFlow MV meters offer precise measurements of five parameters including mass flow, volumetric flow, temperature, pressure and fluid density. The unique PanaFlow MV design reduces fugitive emissions, wiring, startup time and workforce requirements.

PanaFlow MV digital electronics allows reconfiguration for most gases, liquids and steam with generous rangeability. The meter outputs a pulse signal for remote totalization and up to three 4-20 mA analog signals for monitoring your choice of the five process variables. The local keypad/display provides instantaneous flow rate, total flow, temperature, pressure and density in engineering units.

Operating the PanaFlow MV

The Series MV80 and MV82 PanaFlow MV Meters' simple installation combines with an easy-to-use interface that provides quick setup, long term reliability and accurate mass flow measurement over a wide range of flows, pressures and temperatures.

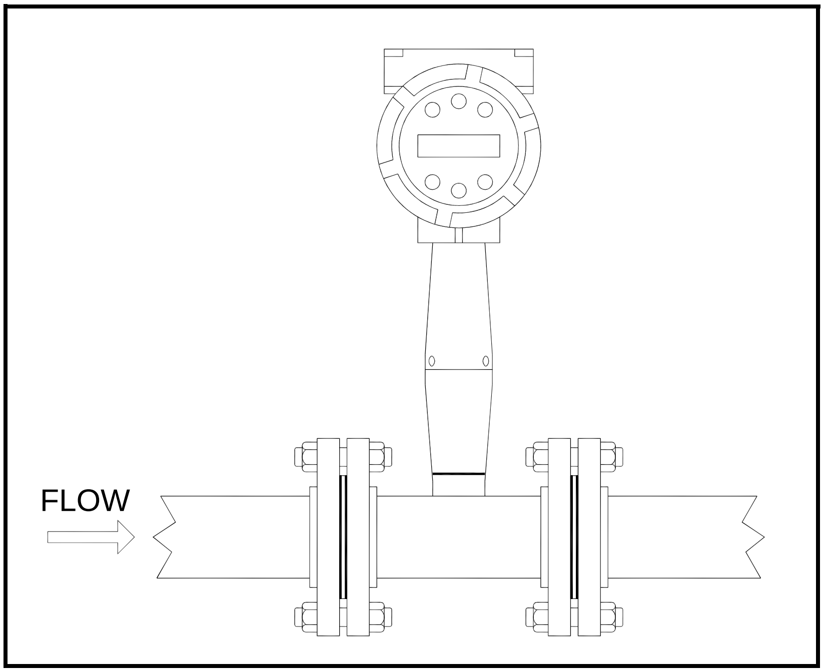


Figure 1-1: In-Line Vortex Multi-Parameter Mass Flowmeter

The Series MV80 and MV82 Multi-Parameter PanaFlow MV Vortex Mass Flowmeters use a unique sensor head to monitor mass flow rate by directly measuring three variables–fluid velocity, temperature and pressure. The built-in flow computer calculates the mass flow rate and volumetric flow rate based on these three direct measurements. The velocity, temperature and pressure sensing head is built into the PanaFlow MV meter's flow body.

Operating the PanaFlow MV (cont.)

To measure fluid velocity, the flowmeter incorporates a bluff body (shedder bar) in the flow stream and measures the frequency of vortices created by the shedder bar. Temperature is measured using a platinum resistance temperature detector (PRTD). Pressure measurement is achieved using a solid-state pressure transducer. All three elements are combined into an integrated sensor head assembly located downstream of the shedder bar within the flow body.

Velocity Measurement

The PanaFlow MV vortex velocity sensor is a patented mechanical design that minimizes the effects of pipeline vibration and pump noise, both of which are common error sources in flow measurement with vortex flowmeters. The velocity measurement is based on the well-known Von Karman vortex shedding phenomenon. Vortices are shed from a shedder bar, and the vortex velocity sensor located downstream of the shedder bar senses the passage of these vortices. This method of velocity measurement has many advantages including inherent linearity, high turndown, reliability and simplicity.

Vortex Shedding Frequency

Von Karman vortices form downstream of a shedder bar into two distinct wakes. The vortices of one wake rotate clockwise while those of the other wake rotate counterclockwise. Vortices generate one at a time, alternating from the left side to the right side of the shedder bar. Vortices interact with their surrounding space by over-powering every other nearby swirl on the verge of development. Close to the shedder bar, the distance (or wave length) between vortices is always constant and measurable. Therefore, the volume encompassed by each vortex remains constant, as shown below. By sensing the number of vortices passing by the velocity sensor, the PanaFlow MV Flowmeter computes the total fluid volume.

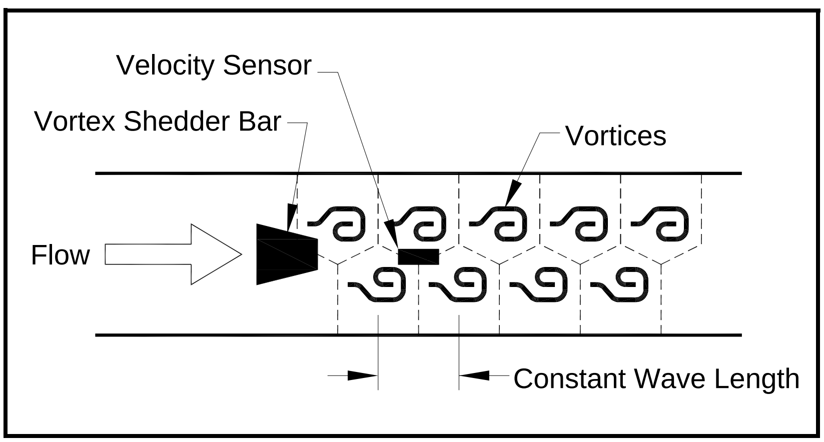


Figure 1-2: Measurement Principle of Vortex Flowmeters

Vortex Frequency Sensing

The velocity sensor incorporates a piezoelectric element that senses the vortex frequency. This element detects the alternating lift forces produced by the Von Karman vortices flowing downstream of the vortex shedder bar. The alternating electric charge generated by the piezoelectric element is processed by the transmitter's electronic circuit to obtain the vortex shedding frequency. The piezoelectric element is highly sensitive and operates over a wide range of flows, pressures and temperatures.

Flow Velocity Range

To ensure trouble-free operation, vortex flowmeters must be correctly sized so that the flow velocity range through the meter lies within the measurable velocity range (with acceptable pressure drop) and the linear range.

The measurable range is defined by the minimum and maximum velocity using the following table.

Table 1-1: Measurable Ranges

	Gas	Liquid	
Vmin Vmax	$\sqrt{\frac{25 ft/s}{\rho}}$ 300 ft/s	1 ft/s 30 ft/s	English ρ (lb/ft^3)
Vmin Vmax	$\sqrt{\frac{37 m/s}{\rho}}$ 91 m/s	0.3 m/s 9.1 m/s	Metric ρ (kg/m^3)

The pressure drop for series MV82 insertion meters is negligible. The pressure drop for series MV80 in-line meters is defined as:

$\Delta P = .00024 \rho V^2$ English units (ΔP in psi, ρ in lb/ft^3, V in ft/sec)

$\Delta P = .000011 \rho V^2$ Metric units (ΔP in bar, ρ in kg/m^3, V in m/sec)

The linear range is defined by the Reynolds number. The Reynolds number is the ratio of the inertial forces to the viscous forces in a flowing fluid and is defined as:

$$Re = \frac{\rho V D}{\mu}$$

Where:
Re = Reynolds Number
ρ = mass density of the fluid being measured
V = velocity of the fluid being measured
D = internal diameter of the flow channel
μ = viscosity of the fluid being measured

Flow Velocity Range (cont.)

The Strouhal number is the other dimensionless number that quantifies the vortex phenomenon. The Strouhal number is defined as:

$$St = \frac{fd}{V}$$

Where:
St = Strouhal Number
f = frequency of vortex shedding
d = shedder bar width
V = fluid velocity

As shown in Figure 1-3 below, PanaFlow MV meters exhibit a constant Strouhal number across a large range of Reynolds numbers, indicating a consistent linear output over a wide range of flows and fluid types. Below this linear range, the intelligent electronics in PanaFlow MV automatically corrects for the variation in the Strouhal number with the Reynolds number. The meter's smart electronics corrects for this non-linearity via its simultaneous measurements of the process fluid temperature and pressure. This data is then used to calculate the Reynolds number in real time. PanaFlow MV meters automatically correct down to a Reynolds number of 5,000.

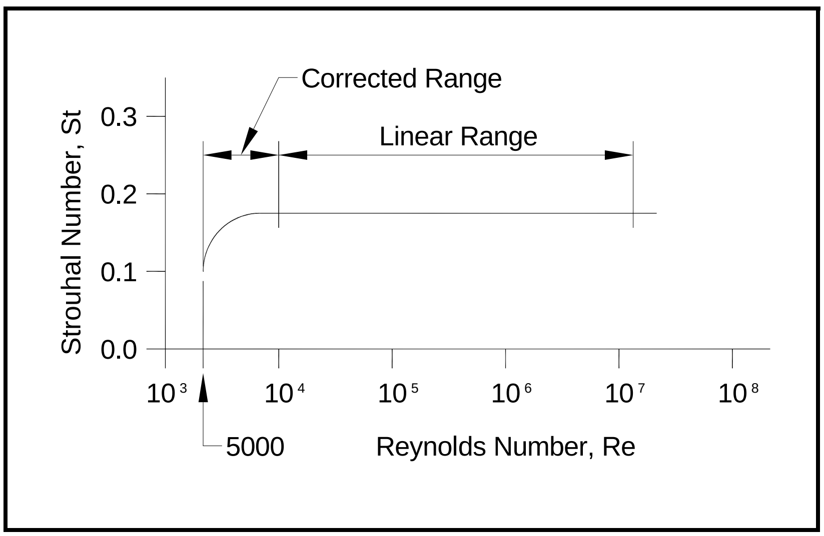


Figure 1-3: Reynolds Number Range for the PanaFlow MV

Temperature Measurement

PanaFlow MV Flowmeters use a 1000 ohm platinum resistance temperature detector (PRTD) to measure fluid temperature.

Pressure Measurement

PanaFlow MV Flowmeters incorporate a solid-state pressure transducer isolated by a 316 stainless steel diaphragm. The transducer itself is micromachined silicon, fabricated using integrated circuit processing technology. A nine-point pressure/temperature calibration is performed on every sensor. Digital compensation allows these transducers to operate within a 0.3% of full scale accuracy band within the entire ambient temperature range of –4°F to 140°F. Thermal isolation of the pressure transducer ensures the same accuracy across the allowable process fluid temperature range of –40°F to 750°F.

Flowmeter Configurations

PanaFlow MV Mass Flowmeters are available in two configurations:

- Series MV80 in-line flowmeter (replaces a section of the pipeline)
- Series MV82 insertion flowmeter (requires a “cold” tap or a “hot” tap into an existing pipeline)

The in-line and insertion configurations are similar in that they use identical electronics and have similar sensor heads. Besides installation differences, the main difference between an in-line flowmeter and an insertion flowmeter is their method of measurement.

For an in-line vortex flowmeter, the shedder bar is located across the entire diameter of the flow body. Thus, the entire pipeline flow is included in the vortex formation and measurement. The sensing head, which directly measures velocity, temperature and pressure is located just downstream of the shedder bar.

Insertion vortex flowmeters have a shedder bar located across the diameter of a short tube. The velocity, temperature and pressure sensor are located within this tube just downstream of a built-in shedder bar. This entire assembly is called the insertion sensing head. It fits through any entry port with a 1.875 inch minimum internal diameter.

The sensing head of an insertion vortex flowmeter directly monitors the velocity at a point in the cross-sectional area of a pipe, duct, or stack (referred to as “channels”). The velocity at a point in the pipe varies as a function of the Reynolds number. The insertion vortex flowmeter computes the Reynolds number and then computes the total flow rate in the channel. The output signal of insertion meters is the total flow rate in the channel. The accuracy of the total flow rate computation depends on adherence to the piping installation requirements given in Chapter 2. If adherence to those guidelines cannot be met, contact the factory for specific installation advice.

Flowmeter Electronics

PanaFlow MV Flowmeter electronics are available mounted directly to the flow body, or remotely mounted. The electronics housing may be used indoors or outdoors, including wet environments. Power requirements are 100 milliamps at 18-36 VDC. An optional AC powered unit is available. Three analog output signals are available for your choice of three of the five process variables: mass flow rate, volumetric flow rate, temperature, pressure or fluid density.

PanaFlow MV Flowmeters include a local 2 x 16 character LCD display housed within the enclosure. Local operation and reconfiguration is accomplished using six pushbuttons operated using finger touch. For hazardous locations, the six buttons can be operated with the electronics enclosure sealed using a hand-held magnet, thereby not compromising the integrity of the hazardous location certification.

The electronics include nonvolatile memory that stores all configuration information. The nonvolatile memory allows the flowmeter to function immediately upon power up, or after an interruption in power.

Chapter 2

Installation

Overview

The PanaFlow MV Flowmeter installations are simple and straightforward. Both the Series MV80 In-Line and Series MV82 Insertion type flowmeter installations are covered in this chapter. After reviewing the installation requirements given below, see page 2-3 for Series MV80 Installation instructions. See page 2-8 for Series MV82 Installation instructions. Wiring instructions begin on page 2-23.

Flowmeter Installation Requirements

Caution!
Consult the flowmeter nameplate for specific flowmeter approvals before any hazardous location installation.

Before installing the flowmeter, verify that the installation site allows for these considerations:

1. Line pressure and temperature will not exceed the flowmeter rating.
2. The location meets the required minimum number of pipe diameters upstream and downstream of the sensor head as illustrated in Figure 2-1 on page 2-2.
3. There is safe and convenient access with adequate overhead clearance for maintenance purposes.
4. The cable entry into the instrument meets the specific standard required for hazardous area installations.
5. For remote installations, the supplied cable length is sufficient to connect the flowmeter sensor to the remote electronics.

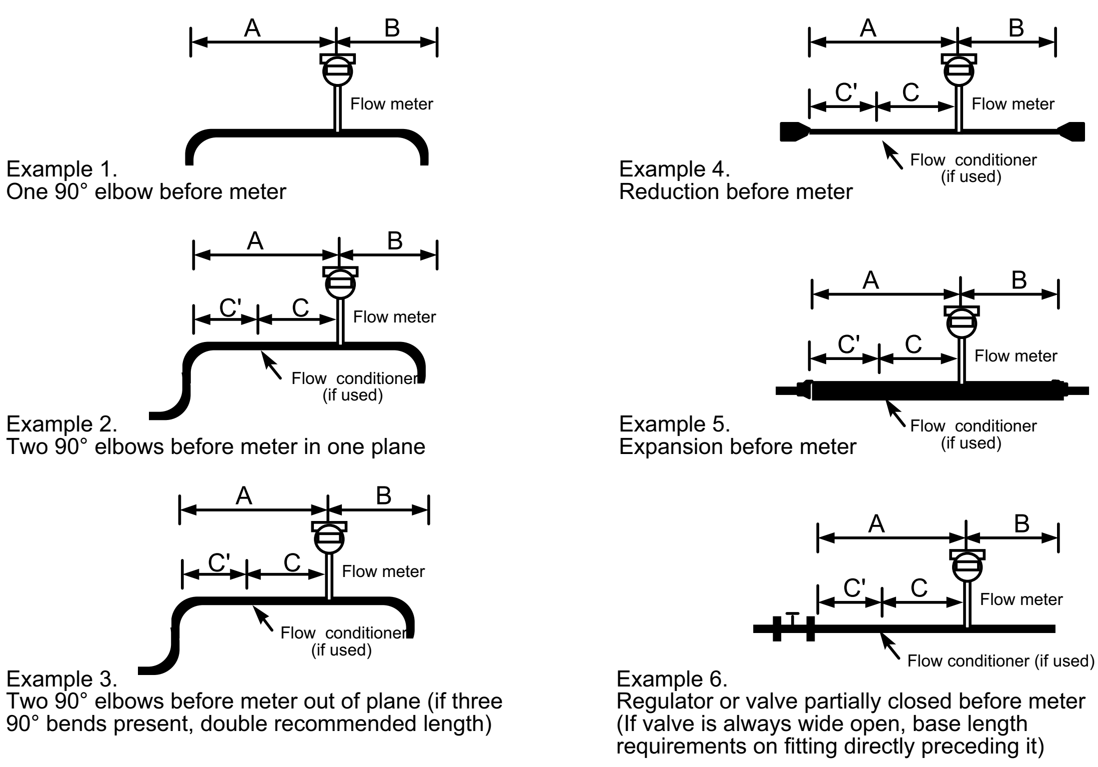
Also, before installation, check the flow system for anomalies such as:

- leaks
- valves or restrictions in the flow path that could create disturbances in the flow profile that might cause unexpected flow rate indications

Unobstructed Flow Requirements

Select an installation site that will minimize possible distortion in the flow profile. Valves, elbows, control valves and other piping components may cause flow disturbances. Check your specific piping condition against the examples shown below. In order to achieve accurate and repeatable performance, install the flowmeter using the recommended number of straight run pipe diameters upstream and downstream of the sensor.

Note: *For liquid applications in vertical pipes, avoid installing with flow in the downward direction because the pipe may not be full at all points. Choose to install the meter with flow in the upward direction if possible.*



	Minimum Required Upstream Diameters				Minimum Required Downstream Diameters	
	No Flow Conditioner	With Flow Conditioner			No Flow Conditioner	With Flow Conditioner
Example	A	A	C	C´	B	B
1	10 D	N/A	N/A	N/A	5 D	5 D
2	15 D	10 D	5 D	5 D	5 D	5 D
3	25 D	10 D	5 D	5 D	10 D	5 D
4	10 D	10 D	5 D	5 D	5 D	5 D
5	20 D	10 D	5 D	5 D	5 D	5 D
6	25 D	10 D	5 D	5 D	10 D	5 D
D = Internal diameter of channel. N/A = Not applicable						

Figure 2-1: Recommended Pipe Length Requirements for Installation - Series MV80 & MV82

Series MV80 In-Line Flowmeter Installation

Install the Series MV80 In-Line Flowmeter between two conventional pipe flanges as shown in Figure 2-3 on page 2-4 and Figure 2-4 on page 2-6. Table 2-1 below provides the recommended minimum stud bolt lengths for wafer-style meter body size and different flange ratings.

The meter inside diameter is equal to the same size nominal pipe ID in schedule 80. For example, a 2” meter has an ID of 1.939” (2” schedule 80). **Do not install the meter in a pipe with an inside diameter smaller than the inside diameter of the meter**. For schedule 160 and higher pipe, a special meter is required. Consult the factory before purchasing the meter.

Series MV80 Meters require customer-supplied gaskets. When selecting gasket material make sure that it is compatible with the process fluid and pressure ratings of the specific installation. Verify that the inside diameter of the gasket is larger than the inside diameter of the flowmeter and adjacent piping. If the gasket material extends into the flow stream, it will disturb the flow and cause inaccurate measurements.

Table 2-1: Flange Bolt Specifications

Stud Bolt Lengths for Each Flange Rating (inches)			
Line Size	**Class 150**	**Class 300**	**Class 600**
1 inch	6.00	7.00	7.50
1.5 inch	6.25	8.50	9.00
2 inch	8.50	8.75	9.50
3 inch	9.00	10.00	10.50
4 inch	9.50	10.75	12.25

The required bolt load for sealing the gasket joint is affected by several application-dependent factors, therefore the required torque for each application may be different. Refer to the ASME Pressure Vessel Code guidelines for bolt tightening standards.

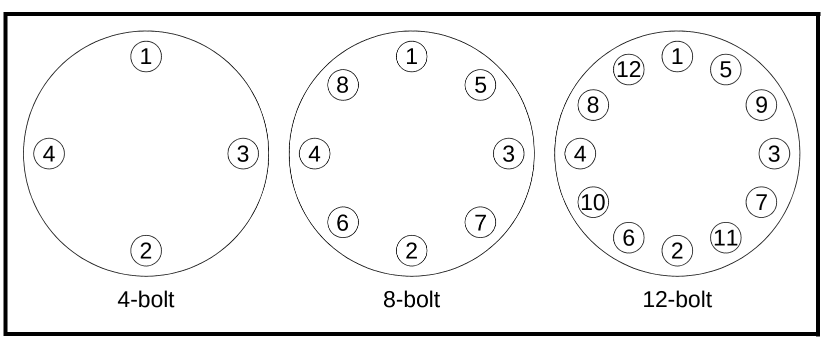


Figure 2-2: Flange Bolt Torquing Sequence

Wafer-Style Flowmeter

Install the wafer-style meter between two conventional pipe flanges of the same nominal size as the flowmeter. If the process fluid is a liquid, make sure the meter is located where the pipe is always full. This may require locating the meter at a low point in the piping system.

Note: *Vortex flowmeters are not suitable for two-phase flows (i.e., liquid and gas mixtures).*

For horizontal pipelines having a process temperature above 300° F, mount the meter at a 45 or 90-degree angle to avoid overheating the electronics enclosure. To adjust the viewing angle of the enclosure or display/keypad, see *Display/Keypad Adjustment* on page 2-22.

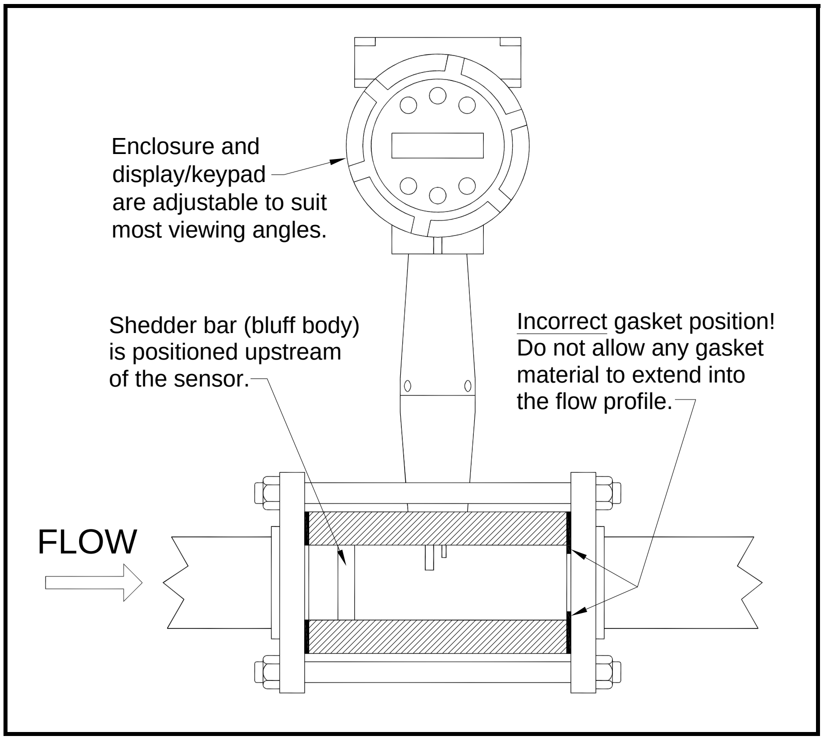


Figure 2-3: Wafer-Style Flowmeter Installation

Caution!
When using toxic or corrosive gases, purge the line with inert gas for a minimum of four hours at full gas flow before installing the flowmeter.

When installing the meter make sure the section marked "inlet" is positioned upstream of the outlet, facing the flow. This ensures that the sensor head is positioned downstream of the vortex shedder bar and is correctly aligned to the flow. Installing the meter opposite this direction will result in completely inaccurate flow measurement.

Wafer-Style Flowmeter (cont.)

To install the meter:

1. Turn off the flow of process gas, liquid or steam. Verify that the line is not pressurized. Confirm that the installation site meets the required minimum upstream and downstream pipe diameters.
2. Insert the studs for the bottom side of the meter body between the pipe flanges. Place the wafer-style meter body between the flanges with the end stamped “inlet” facing flow. Center the meter body inside the diameter with respect to the inside diameter of the adjoining piping.
3. Position the gasket material between the mating surfaces. Make sure both gaskets are smooth and even with no gasket material extending into the flow profile. Obstructions in the pipeline will disturb the flow and cause inaccurate measurements
4. Place the remaining studs between the pipe flanges. Tighten the nuts in the sequence shown in Figure 2-2 on page 2-3. Check for leaks after tightening the flange bolts.

Flange-Style Flowmeter

Install the flange-style meter between two conventional pipe flanges of the same nominal size as the flowmeter. If the process fluid is a liquid, make sure the meter is located where the pipe is always full. This may require locating the meter at a low point in the piping system.

Note: *Vortex flowmeters are not suitable for two-phase flows (i.e., liquid and gas mixtures).*

For horizontal pipelines having a process temperature above 300° F, mount the meter at a 45° or 90° angle to avoid overheating the electronics enclosure. To adjust the viewing angle of the enclosure or display/keypad, see *Display/Keypad Adjustment* on page 2-22.

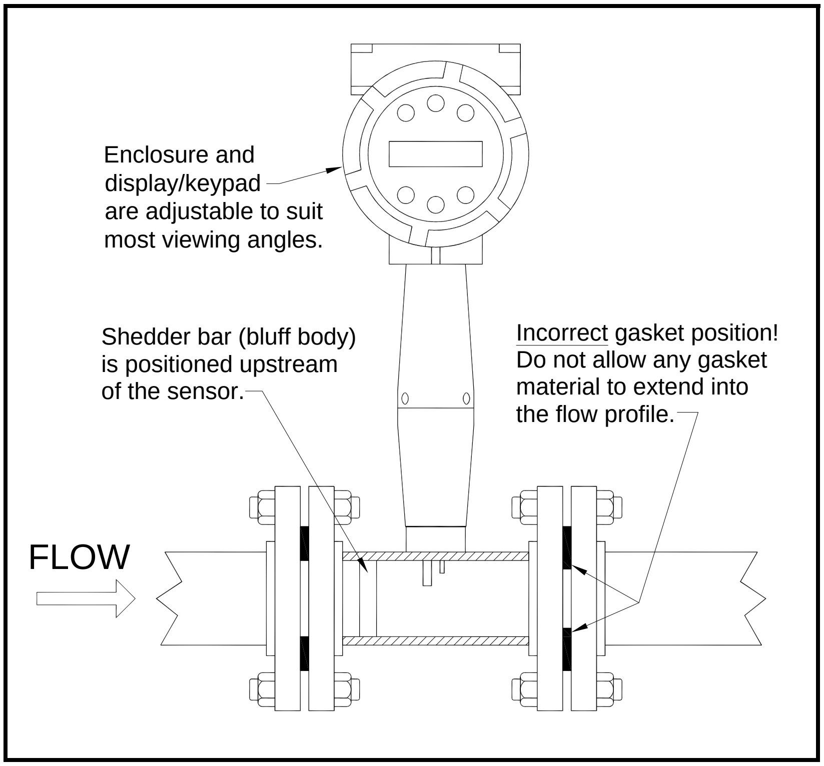


Figure 2-4: Flange-Style Flowmeter Installation

Caution!
When using toxic or corrosive gases, purge the line with inert gas for a minimum of four hours at full gas flow before installing the flowmeter.

When installing the meter make sure the flange marked “inlet” is positioned upstream of the outlet flange, facing the flow. This ensures that the sensor head is positioned downstream of the vortex shedder bar and is correctly aligned to the flow. Installing the meter opposite this direction will result in completely inaccurate flow measurement.

Flange-Style Flowmeter (cont.)

To install the meter:

1. Turn off the flow of process gas, liquid or steam. Verify that the line is not pressurized. Confirm that the installation site meets the required minimum upstream and downstream pipe diameters.
2. Seat the meter level and square on the mating connections with the flange marked “inlet” facing the flow. Position a gasket in place for each side. Make sure both gaskets are smooth and even with no gasket material extending into the flow profile. Obstructions in the pipeline will disturb the flow and cause inaccurate measurements.
3. Install bolts in both process connections. Tighten the nuts in the sequence shown in Figure 2-2 on page 2-3. Check for leaks after tightening the flange bolts.

Series MV82 Insertion Flowmeter Installation

Prepare the pipeline for installation using either a cold tap or hot tap method described on the following pages. Refer to a standard code for all pipe tapping operations. The following tapping instructions are general in nature and intended for guideline purposes only. Before installing the meter, review the mounting position and isolation value requirements given below.

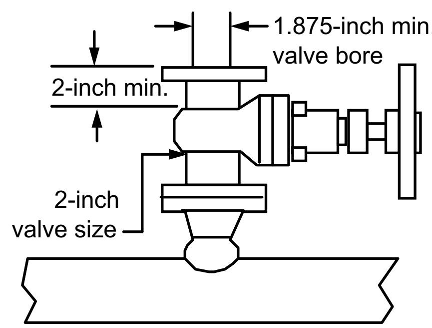
Mounting Position

Allow clearance between the electronics enclosure top and any other obstruction when the meter is fully retracted.

Isolation Valve Selection

An isolation valve is available as an option with Series MV82 meters. If you supply the isolation valve, it must meet the following requirements:

1. A minimum valve bore diameter of 1.875 inches is required, and the valve's body size should be two inches. Normally, gate valves are used.
2. Verify that the valve's body and flange rating are within the flowmeter's maximum operating pressure and temperature.



Isolation Valve Requirements

3. Choose an isolation valve with at least two inches existing between the flange face and the gate portion of the valve. This ensures that the flowmeter's sensor head will not interfere with the operation of the isolation valve.

Cold Tap Guidelines

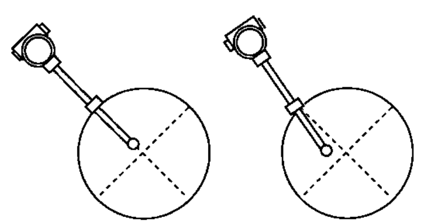
Refer to a standard code for all pipe tapping operations.

Caution!
When using toxic or corrosive gases, purge the line with inert gas for a minimum of four hours at full gas flow before installing the flowmeter.

!WARNING!
All flowmeter connections, isolation valves and fittings for cold tapping must have the same as or higher pressure rating than the main pipeline.

The following tapping instructions are general in nature and intended for guideline purposes only.

1. Turn off the flow of process gas, liquid or steam. Verify that the line is not pressurized.
2. Confirm that the installation site meets the minimum upstream and downstream pipe diameter requirements (see Figure 2-1 on page 2-2).
3. Use a cutting torch or sharp cutting tool to tap into the pipe. The pipe opening must be at least 1.875 inches in diameter. (Do not attempt to insert the sensor probe through a smaller hole.)
4. Remove all burrs from the tap. Rough edges may cause flow profile distortions that could affect flowmeter accuracy. Also, obstructions could damage the sensor assembly when inserting into the pipe.
5. After cutting, measure the thickness of the cut-out and record this number for calculating the insertion depth.
6. Weld the flowmeter pipe connection on the pipe. Make sure this connection is perpendicular to the pipe centerline within ± 5°.



7. Install the isolation valve (if used).
8. When welding is complete and all fittings are installed, close the isolation valve or cap the line. Run a static pressure check on the welds. If pressure loss or leaks are detected, repair the joint and retest.
9. Connect the meter to the pipe process connection.
10. Calculate the sensor probe insertion depth as described on the following pages. Insert the sensor probe into the pipe.

Hot Tap Guidelines

Refer to a standard code for all pipe tapping operations.

!WARNING!
Hot tapping must be performed by a trained professional. U.S. regulations often require a hot tap permit. The manufacturer of the hot tap equipment and/or the contractor performing the hot tap is responsible for providing proof of such a permit.

!WARNING!
All flowmeter connections, isolation valves and fittings for hot tapping must have the same as or higher pressure rating than the main pipeline.

The following tapping instructions are general in nature and intended for guideline purposes only.

1. Confirm that the installation site meets the minimum upstream and downstream pipe diameter requirements.
2. Weld a two inch mounting adapter on the pipe. Make sure the mounting adapter is within ± 5° perpendicular to the pipe centerline (see previous page). The pipe opening must be at least 1.875 inches in diameter.
3. Connect a two inch process connection on the mounting adapter.
4. Connect an isolation valve on the process connection. The valve's full open bore must be at least 1.875 inches in diameter.
5. Hot tap the pipe.
6. Close the isolation valve. Run a static pressure check on the welds. If pressure loss or leaks are detected, repair the joint and re-test.
7. Connect the flowmeter to the isolation valve.
8. Calculate the sensor probe insertion depth as described on the following pages. Insert the sensor probe assembly into the pipe.

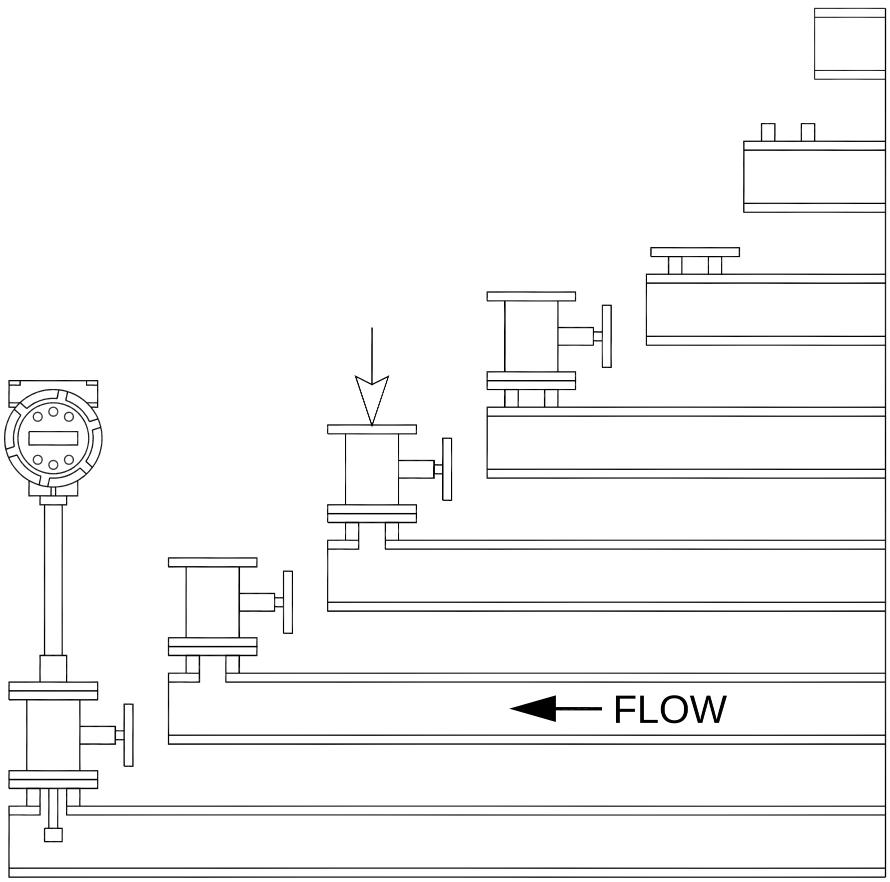


Figure 2-5: Hot Tap Sequence

Flowmeter Insertion

The sensor head must be properly positioned in the pipe. For this reason, it is important that insertion length calculations are carefully followed. A sensor probe inserted at the wrong depth in the pipe will result in inaccurate readings.

Insertion flowmeters are applicable to pipes 2 inch and larger. For pipe sizes ten inches and smaller, the centerline of the meter's sensing head is located at the pipe's centerline. For pipe sizes larger than ten inches, the centerline of the sensing head is located in the pipe's cross section five inches from the inner wall of the pipe; i.e., its "wetted" depth from the wall to the centerline of the sensing head is five inches.

Insertion flowmeters are available in three probe lengths:

- *Standard Probe* configuration is used with most flowmeter process connections. The length, S, of the stem is 29.47 inches.
- *Compact Probe* configuration is used with compression fitting process connections. The length, S, of the stem is 13.1 inches.
- *12-Inch Extended Probe* configuration is used with exceptionally lengthy flowmeter process connections. The length, S, of the stem is 41.47 inches.

Use the Correct Insertion Formula

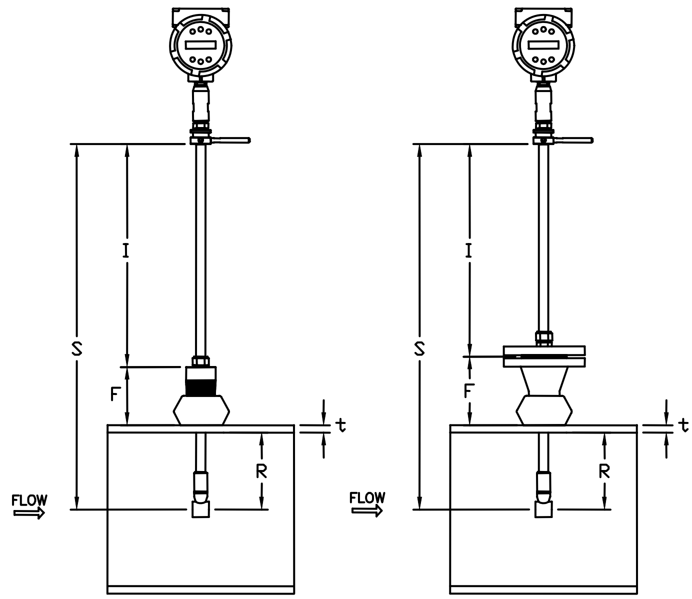
Depending on the flowmeter's process connection, use the applicable insertion length formula and installation procedure as follows:

- For flowmeters with a compression type connection (NPT or flanged), follow the instructions beginning on page 2-13.
- For flowmeters with a packing gland type connection (NPT or flanged) configured *with* an insertion tool, follow the instructions beginning on page 2-16.
- For flowmeters with a packing gland type connection (NPT or flanged) *without* an insertion tool, follow the instructions beginning on page 2-20.

!WARNING!
An insertion tool must be used for any installation where a flowmeter is inserted under pressure greater than 50 psig.

Installation with a Compression Connection*

Use the following formula to determine insertion length for flowmeters (NPT and flanged) with a compression process connection. The installation procedure is given on page 2-15.



Insertion Length Formula

I = S – F – R – t

Where:

I = Insertion length.
S = Stem length – the distance from the center of the sensor head to the base of the enclosure adapter (S = 29.47 inches for standard probes; S = 13.1 inches for compact; S = 41.47 inches for 12-inch extended).
F = Distance from the raised face of the flange or top of NPT stem housing to the outside of the pipe wall.
R = Pipe inside diameter ÷ 2 for pipes ten inches and smaller.
R = Five inches for pipe diameters larger than ten inches.
t = Thickness of the pipe wall. (Measure the disk cut-out from the tapping procedure or check a piping handbook for thickness.)

Figure 2-6: Insertion Calculation (Compression Type)

Example:
To install a Series MV82 meter with a standard probe (S = 29.47 in.) into a 14 inch schedule 40 pipe, the following measurements are taken:

F = 3 inches; R = 5 inches; t = 0.438 inches

The insertion length for this example is 21.03 inches. Insert the stem through the fitting until an insertion length of 21.03 inches is measured with a ruler.

*All dimensions are in inches.

Installation with a Compression Connection (cont.)

Caution!
The sensor alignment pointer must point downstream, in the direction of the flow.

!WARNING!
To avoid serious injury, DO NOT loosen the compression fitting under pressure.

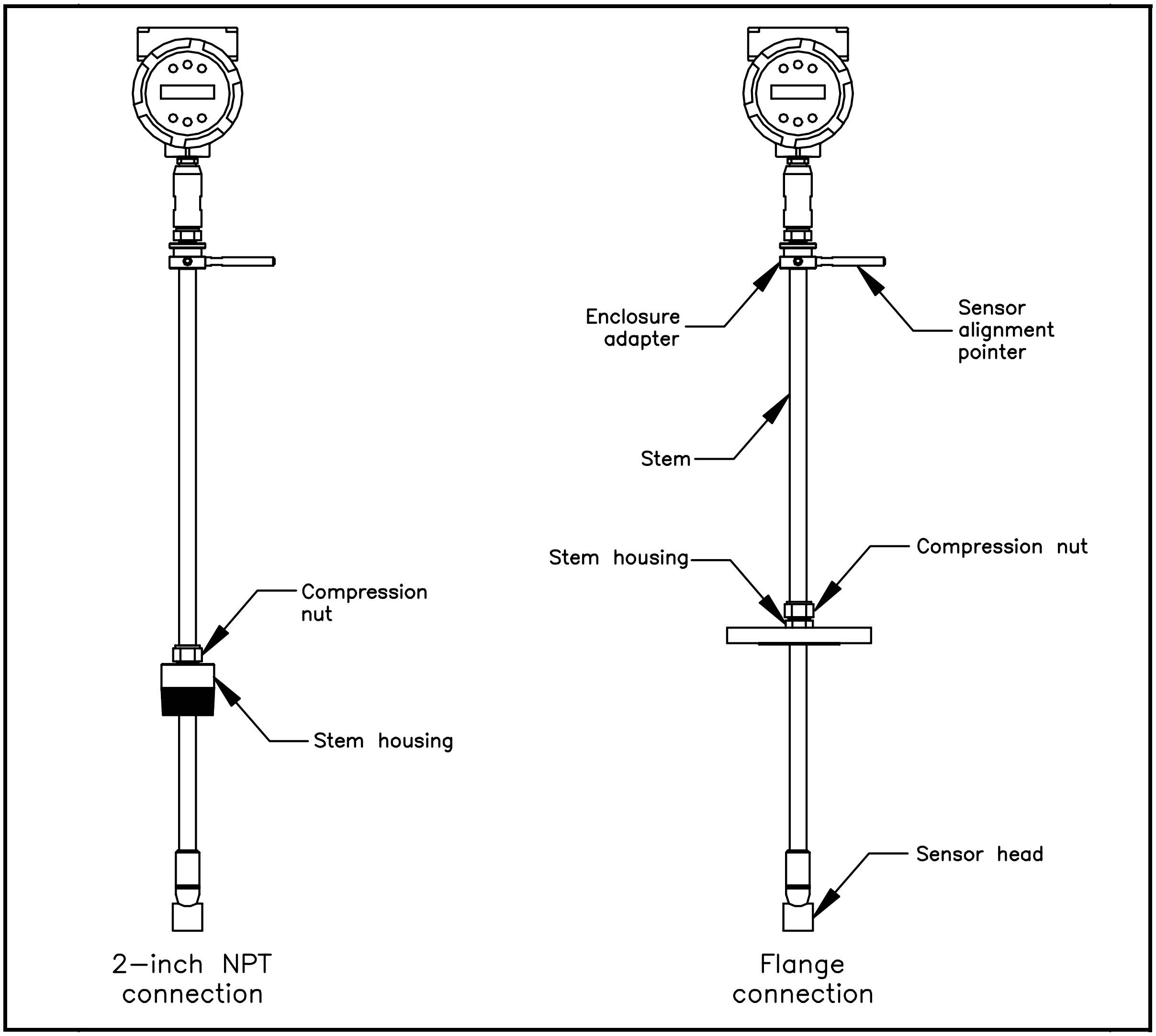


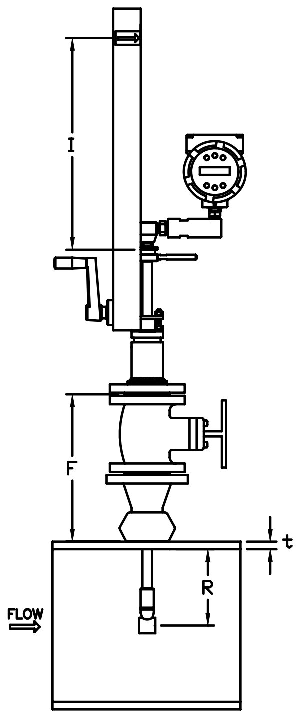
Figure 2-7: Flowmeter with a Compression Type Fitting

Installation with a Compression Connection (cont.)

1. Calculate the required sensor probe insertion length.
2. Fully retract the stem until the sensor head is touching the bottom of the stem housing. Slightly tighten the compression nut to prevent slippage.
3. Bolt or screw the flowmeter assembly into the process connection.
4. Use PTFE tape or pipe sealant to improve the seal and prevent seizing on NPT styles.
5. Hold the meter securely while loosening the compression fitting. Insert the sensor into the pipe until the calculated insertion length, I, is measured between the base of the enclosure adapter and the top of the stem housing, or to the raised face of the flanged version. Do not force the stem into the pipe.
6. Align the sensor head using the sensor alignment pointer. Adjust the alignment pointer parallel to the pipe and pointing downstream.
7. Tighten the compression fitting to lock the stem in position. **When the compression fitting is tightened, the position is permanent**.

Installation with a Packing Gland Connection*

Use the formula below to determine the insertion depth for flowmeters (NPT and flanged) equipped with an insertion tool. To install, see page 2-17 for instructions for meters with a permanent insertion tool. For meters with a removable insertion tool, see page 2-18.



Insertion Length Formula

I = F + R + t – 1.35

Where:

I = Insertion length.

F = Distance from the raised face of the flange or top of the process connection for NPT style meters to the top outside of the process pipe.

R = Pipe inside diameter ÷ 2 for pipes ten inches & smaller.

R = Five inches for pipe diameters larger than ten inches.

t = Thickness of the pipe wall. (Measure the disk cut-out from the tapping procedure or check a piping handbook for thickness.)

Figure 2-8: Insertion Calculation (Meters with Insertion Tool)

Example 1: Flange Style Meters:
To install a Series MV82 Flowmeter into a 14 inch schedule 40 pipe, the following measurements are taken:

F = 12 inches; R = 5 inches; t = 0.438 inches
The example insertion length is 16.09 inches.

Example 2: NPT Style Meters:
The length of thread engagement on the NPT style meters is also subtracted in the equation. The length of the threaded portion of the NPT meter is 1.18 inches. Measure the thread portion still showing after the installation and subtract that amount from 1.18 inches. This gives you the thread engagement length. If this cannot be measured use .55 inch for this amount.

F = 12 inches; R = 5 inches; t = 0.438 inches
The example insertion length is 15.54 inches.

*All dimensions are in inches.

Insertion Procedure for Flowmeters with Permanent Insertion Tool

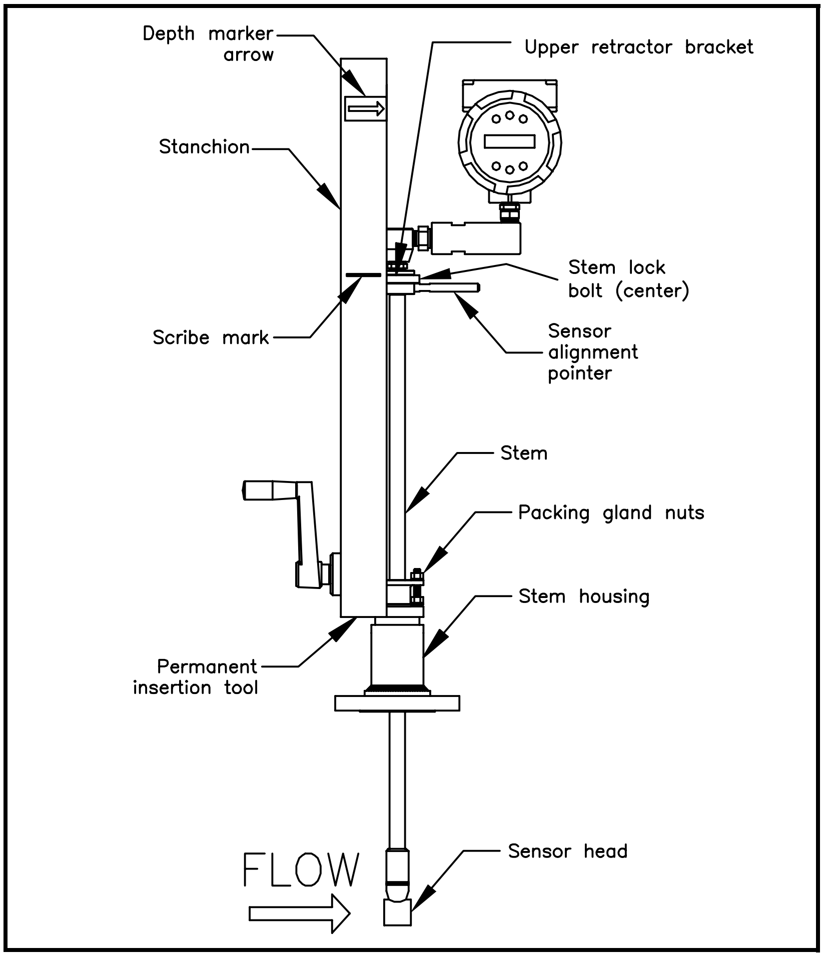


Figure 2-9: Flowmeter with Permanent Insertion Tool

Caution!
The sensor alignment pointer must point downstream, in the direction of the flow.

---

1. Calculate the required sensor probe insertion length (see previous page). Measure from the depth marker arrow down the stanchion and scribe a mark at the calculated insertion depth.
2. Fully retract the flowmeter until the sensor head is touching the bottom of the stem housing. Attach the meter assembly to the two inch full-port isolation valve, if used. Use PTFE tape or pipe sealant to improve seal and prevent seizing on NPT style.
3. Loosen the two packing gland nuts on the stem housing of the meter. Loosen the stem lock bolt adjacent to the sensor alignment pointer. Align the sensor head using the sensor alignment pointer. Adjust the alignment pointer parallel to the pipe and pointing downstream. Tighten the stem lock bolt to secure the sensor position.

Insertion Procedure for Flowmeters with Permanent Insertion Tool (cont.)

4. Slowly open the isolation valve to the full open position. If necessary, slightly tighten the two packing gland nuts to reduce the leakage around the stem.

5. Turn the insertion tool handle clockwise to insert the sensor head into the pipe. Continue until the top of the upper retractor bracket aligns with the insertion length position scribed on the stanchion. Do not force the stem into the pipe.

6. Tighten the packing gland nuts to stop leakage around the stem. Do not torque over 20 ft-lb.

Note: *If line pressure is above 500 psig, it could require up to 25 ft lb of torque to insert the flowmeter. Do not confuse this with possible interference in the pipe.*

Insertion Procedure for Flowmeters with Removable Insertion Tool

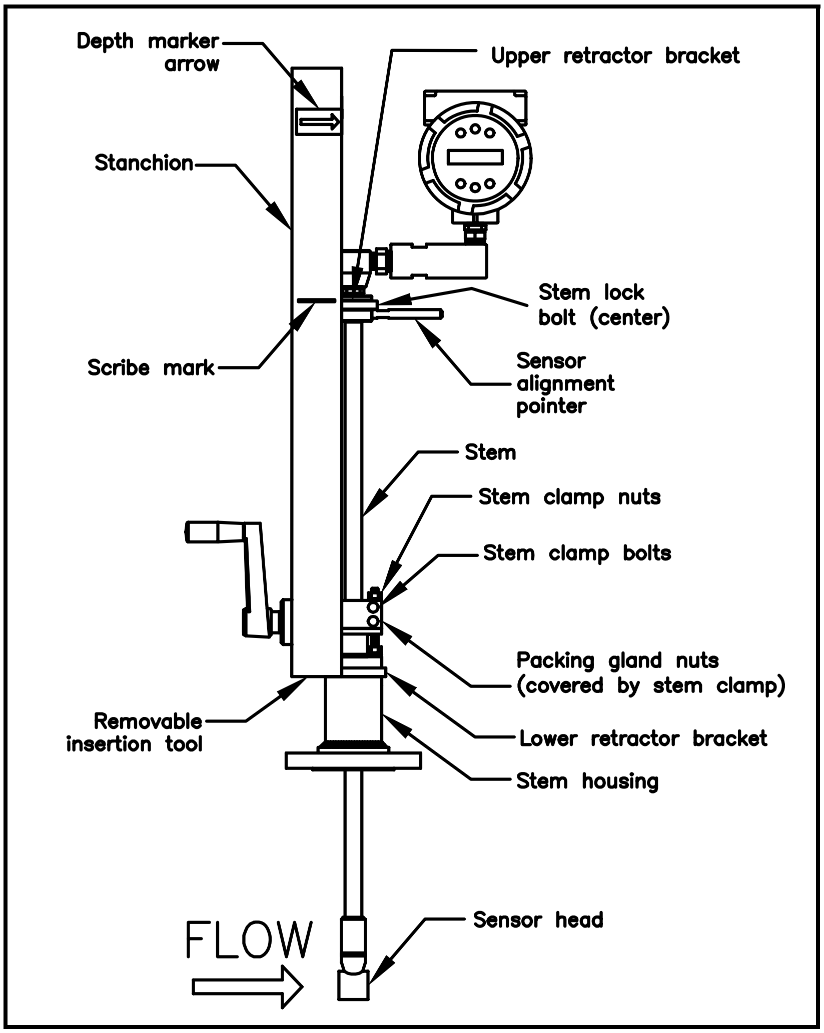


Figure 2-10: Flowmeter with Removable Insertion Tool

Insertion Procedure for Flowmeters with Removable Insertion Tool (cont.)

Caution!
The sensor alignment pointer must point downstream, in the direction of the flow.

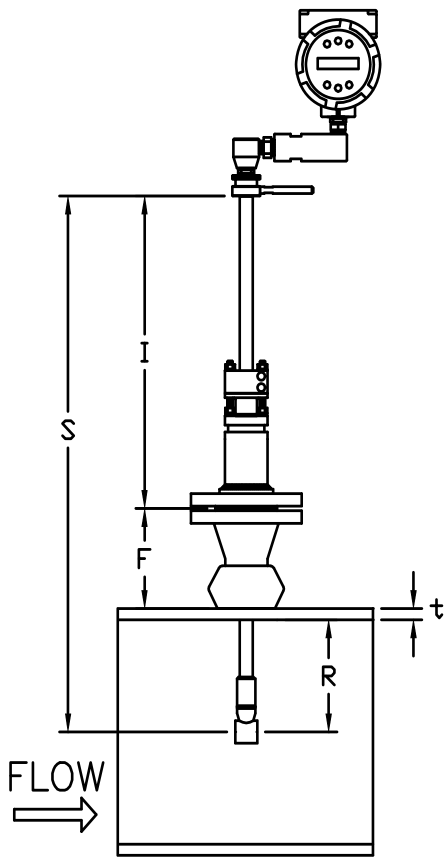
1. Calculate the required sensor probe insertion length. Measure from the depth marker arrow down the stanchion and scribe a mark at the calculated insertion depth.
2. Fully retract the flowmeter until the sensor head is touching the bottom of the stem housing. Attach the meter assembly to the two inch full-port isolation valve, if used. Use PTFE tape or pipe sealant to improve seal and prevent seizing on NPT style.
3. Remove the two top stem clamp nuts and loosen two stem clamp bolts. Slide the stem clamp away to expose the packing gland nuts.
4. Loosen the two packing gland nuts. Loosen the stem lock bolt adjacent to the sensor alignment pointer. Align the sensor head using the sensor alignment pointer. Adjust the alignment pointer parallel to the pipe and pointing downstream. Tighten the stem lock bolt to secure the sensor position.
5. Slowly open the isolation valve to the full open position. If necessary, slightly tighten the two packing gland nuts to reduce the leakage around the stem.
6. Turn the insertion tool handle clockwise to insert the stem into the pipe. Continue until the top of the upper retractor bracket lines up with the insertion length mark scribed on the stanchion. Do not force the stem into the pipe.

Note: *If line pressure is above 500 psig, it could require up to 25 ft lb of torque to insert the flowmeter. Do not confuse this with possible interference in the pipe.*

7. Tighten the packing gland nuts to stop leakage around the stem. Do not torque over 20 ft lbs.
8. Slide the stem clamp back into position. Torque stem clamp bolts to 15 ft lbs. Replace the stem clamp nuts and torque to 10-15 ft lbs.
9. To separate the insertion tool from the flowmeter, remove four socket head cap bolts securing the upper and lower retractor brackets. Remove the insertion tool.

Installation with a Packing Gland Connection and No Insertion Tool*

Use the following formula to determine insertion depth for meters with a packing gland connection (NPT and flanged) without an insertion tool.



Insertion Length Formula

$$I = S - F - R - t$$

Where:

I = Insertion length.

S = Stem length – the distance from the center of the sensor head to the base of the enclosure adapter (S = 29.47 inches for standard probes; S = 41.47 inches for 12 inch extended probes).

F = Distance from the raised face of the flange or top of NPT stem housing to the outside of the pipe wall.

R = Pipe inside diameter ÷ 2 for pipes ten inches & smaller.

R = Five inches for pipe diameters larger than ten inches.

t = Thickness of the pipe wall. (Measure the disk cut-out from the tapping procedure or check a piping handbook for thickness.)

Figure 2-11: Insertion Calculation (Meters without Insertion Tool)

Example:

To install a Series MV82 Flowmeter with a standard probe (S = 29.47) into a 14 inch schedule 40 pipe, the following measurements are taken:

F = 3 inches; R = 5 inches; t = 0.438 inches

The example insertion length is 21.03 inches.

*All dimensions are in inches.

Insertion Procedure with No Insertion Tool (Packing Gland Connection)

!WARNING!
The line pressure must be less than 50 psig for installation.

Caution!
The sensor alignment pointer must point downstream, in the direction of the flow.

1. Calculate the required sensor probe insertion length.
2. Fully retract the stem until the sensor head is touching the bottom of the stem housing. Remove the two top stem clamp nuts and loosen two stem clamp bolts. Slide the stem clamp away to expose the packing gland nuts. Loosen the two packing gland nuts.
3. Align the sensor head using the sensor alignment pointer. Adjust the alignment pointer parallel to the pipe and pointing downstream.
4. Insert the sensor head into the pipe until insertion length, I, is achieved. Do not force the stem into the pipe.
5. Tighten the packing gland nuts to stop leakage around the stem. Do not torque over 20 ft lbs.
6. Slide the stem clamp back into position. Torque stem clamp bolts to 15 ft lbs. Replace the stem clamp nuts and torque to 10-15 ft lbs.

Adjusting Meter Orientation

Depending on installation requirements, you may need to adjust the meter orientation. There are two adjustments available. The first rotates the position of the LCD display/keypad and is available on both in-line and insertion meters. The second is to rotate the enclosure position. This adjustment is allowed only on Series MV80 In-Line meters.

Display/Keypad Adjustment (All Meters)

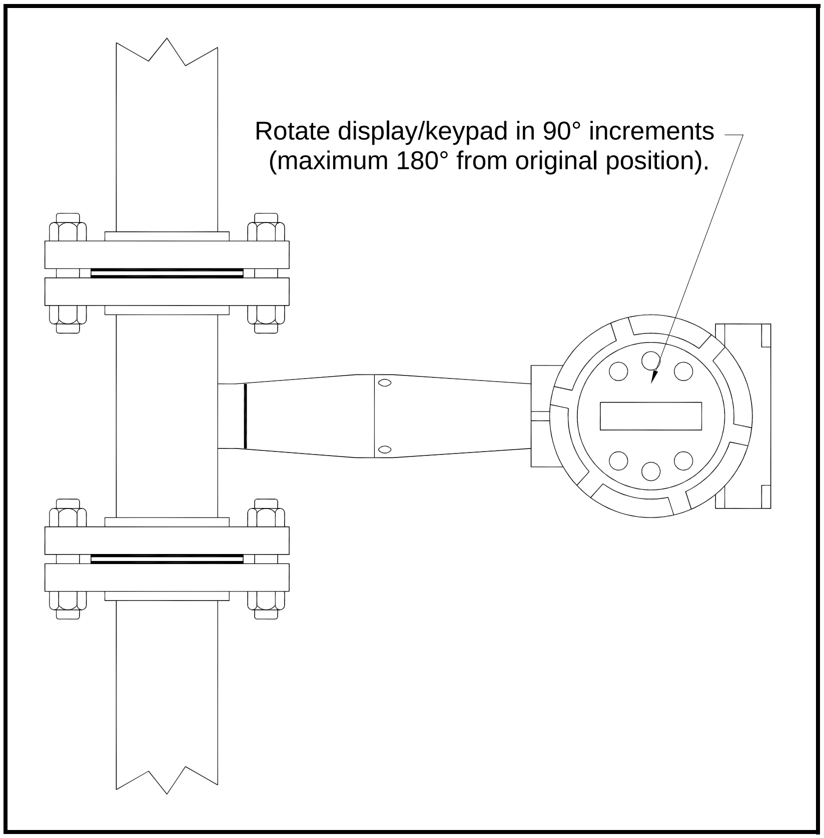


Figure 2-12: Display/Keypad Viewing Adjustment

The electronics boards are electrostatically sensitive. Wear a grounding wrist strap and make sure to observe proper handling precautions required for static-sensitive components. To adjust the display:

1. Disconnect power to the flowmeter.
2. Loosen the small set screw which secures the electronics enclosure. Unscrew and remove the cover.
3. Loosen the 4 captive screws.
4. Carefully pull the display/microprocessor board away from the meter standoffs. Make sure not to damage the connected ribbon cable.
5. Rotate the display/microprocessor board to the desired position. Maximum turn, two positions left or two positions right (180°).
6. Align the board with the captive screws. Check that the ribbon cable is folded neatly behind the board with no twists or crimps.
7. Tighten the screws. Replace the cover and set screw. Restore power to the meter.

Enclosure Adjustment (Series MV80 Only)

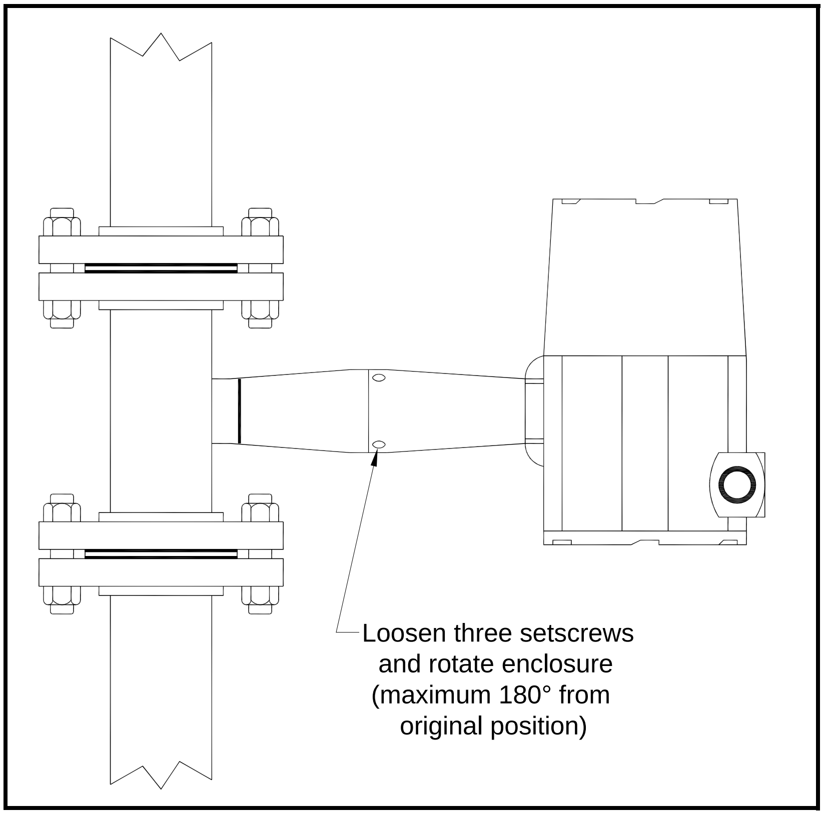


Figure 2-13: Enclosure Viewing Adjustment

To avoid damage to the sensor wires, do not rotate the enclosure beyond 180° from the original position. To adjust the enclosure:

1. Remove power to the flowmeter.
2. Loosen the three set screws shown above. Rotate the display to the desired position (maximum 180°).
3. Tighten the three set screws. Restore power to the meter.

Wiring Connections

!WARNING!
To avoid potential electric shock, follow National Electric Code safety practices or your local code when wiring this unit to a power source and to peripheral devices. Failure to do so could result in injury or death. All AC power connections must be in accordance with published CE directives. All wiring procedures must be performed with the power off.

Caution!
The AC wire insulation temperature rating must meet or exceed 85°C (185°F).

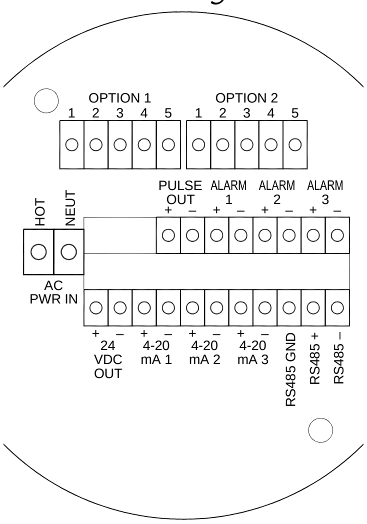
Wiring Connections (cont.)

The NEMA 4X enclosure contains an integral wiring compartment with one dual strip terminal block (located in the smaller end of the enclosure). Two 3/4-inch female NPT conduit entries are available for separate power and signal wiring. For all hazardous area installations, make sure to use an agency-approved fitting at each conduit entry. If conduit seals are used, they must be installed within 18 inches (457 mm) of the enclosure.

Input Power Connections

To access the wiring terminal blocks, locate and loosen the small set screw which locks the small enclosure cover in place. Unscrew the cover to expose the terminal block.

AC Power Wiring



The AC power wire size must be 20 to 10 AWG with the wire stripped 1/2 inch (14 mm). The wire insulation temperature must meet or exceed 85°C (185°F). Connect 100 to MV80 VAC (25 watts maximum) to the Hot and Neutral terminals on the terminal block. Connect the ground wire to the safety ground lug. Torque all connections to 4.43 to 5.31 in lbs (0.5 to 0.6 Nm). Use a separate conduit entry for signal lines to reduce the possibility of AC noise interference.

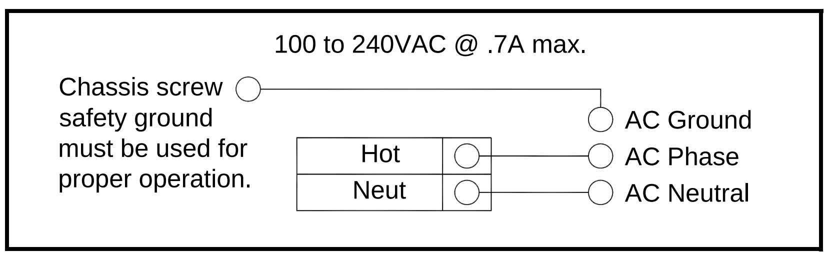
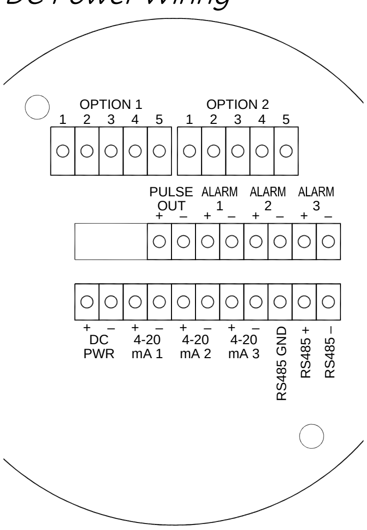


Figure 2-14: AC Power Connections

DC Power Wiring



The DC power wire size must be 20 to 10 AWG with the wire stripped 1/2" (14 mm). Connect 18 to 36 VDC (100 mA maximum current draw) to the +Pwr and –Pwr terminals on the terminal block. Torque all connections to 4.43 to 5.31 in lbs (0.5 to 0.6 Nm).

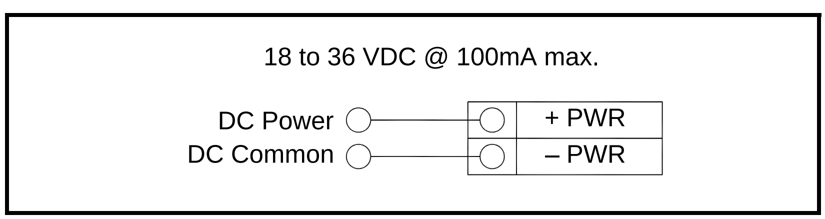


Figure 2-15: DC Power Connections

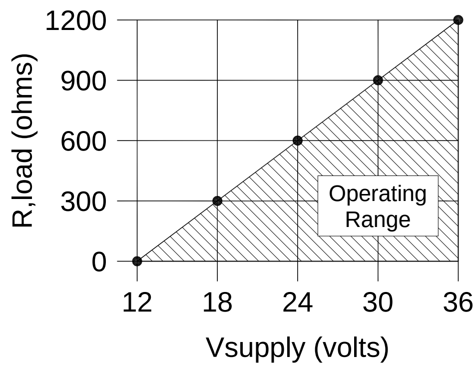
4-20mA Output Connections

The standard PanaFlow MV Flowmeter has a single 4-20 mA loop. Two additional loops are available on the optional communication board. The 4-20 mA loop current is controlled by the meter electronics. The electronics must be wired in series with the sense resistor or current meter. The current control electronics require 12 volts at the input terminals to operate correctly.

The maximum loop resistance (load) for the current loop output is dependent upon the supply voltage and is given in Figure 2-16. The 4-20 mA loop is optically isolated from the flowmeter electronics.

R_{load} is the total resistance in the loop, including the wiring resistance ($R_{load} = R_{wire} + R_{sense}$). To calculate R_{max}, the maximum R_{load} for the loop, use the maximum loop current, 20 mA. The voltage drop in the loop due to resistance is 20 mA times R_{load} and this drop is subtracted from the input voltage. Thus:

The maximum resistance $R_{load} = R_{max} = 50 \times (V_{supply} - 12V)$.



Vsupply (volts)	Rmax (ohms)
12	0
18	300
24	600
30	900
36	1200

Figure 2-16: Load Resistance Versus Input Voltage

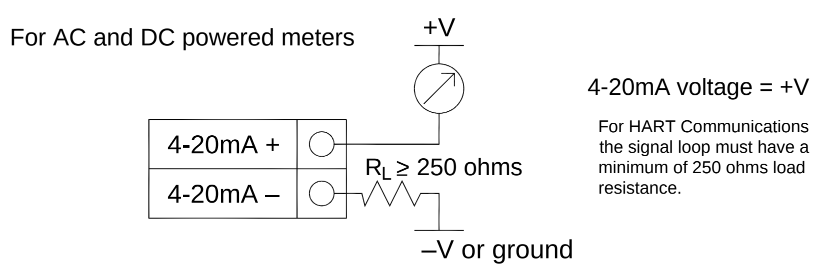


Figure 2-17: Isolated 4-20mA Output with External Power Supply

4-20mA Output Connections (cont.)

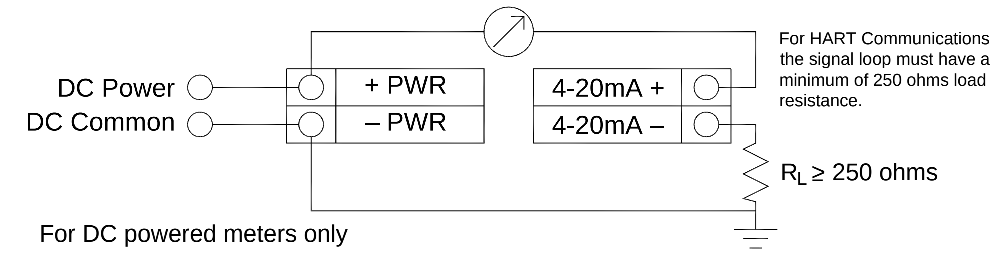


Figure 2-18: Non-Isolated 4-20mA Output using Meter Input Power Supply

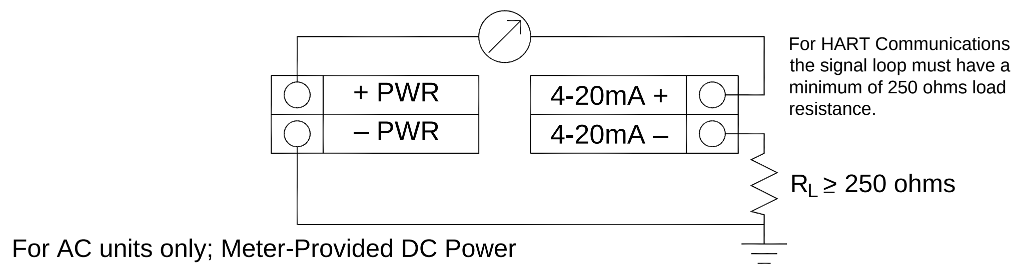


Figure 2-19: Isolated 4-20mA Output using Meter Provided Power Supply

Pulse Output Connections

The pulse output is used for a remote counter. When the preset volume or mass (defined in the totalizer settings, see page 3-7) has passed the meter, the output provides a 50 millisecond square pulse.

The pulse output optical relay is a normally-open single-pole relay. The relay has a nominal 200 volt/160 ohm rating. This means that it has a nominal on-resistance of 160 ohms, and the largest voltage that it can withstand across the output terminals is 200 volts. However, there are current and power specifications that must be observed. The relay can conduct a current up to 40 mA and can dissipate up to 320 mW. The relay output is isolated from the meter electronics and power supply.

There are three connection options for the pulse output–the first with a separate power supply (see Figure 2-20 below) and the second using the flowmeter power supply (see Figure 2-21 below). Use the first option with a separate power supply (5 to 36 VDC) if a specific voltage is needed for the pulse output. Use the second configuration if the voltage at the flowmeter power supply is an acceptable driver voltage for the load connected. (Take into account that the current used by the pulse load comes from the meter's power supply.) In either case, the voltage of the pulse output is the same as the voltage supplied to the circuit.

Pulse Output Connections (cont.)

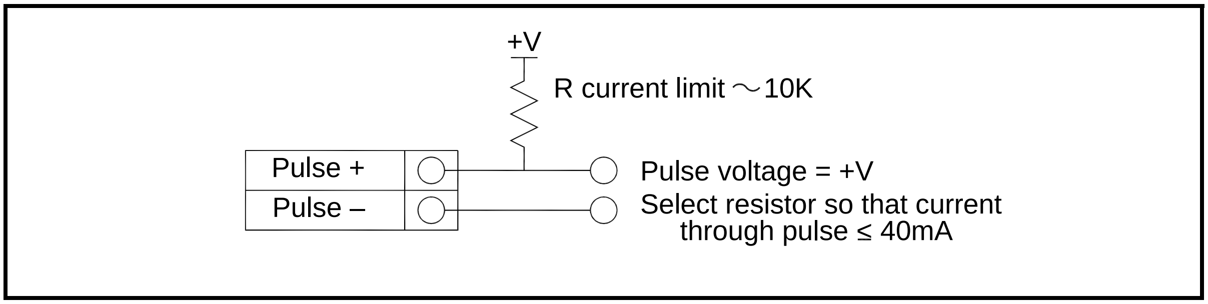


Figure 2-20: Isolated Pulse Output with External Power Supply

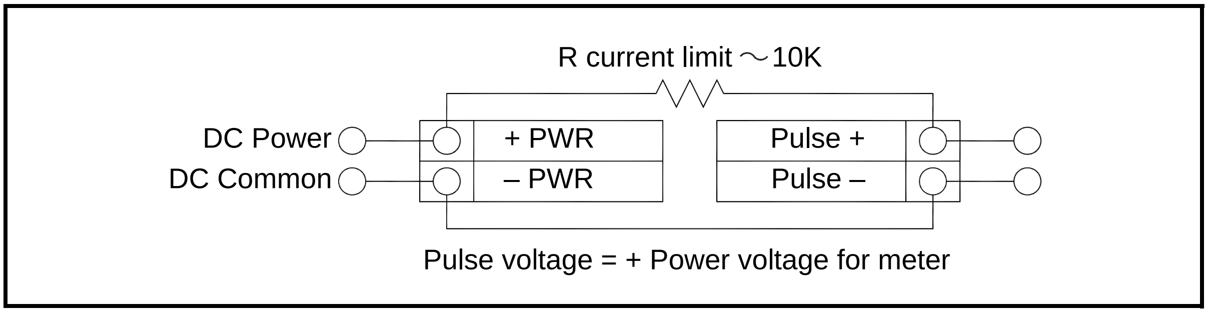


Figure 2-21: Non-Isolated Pulse Output Using Input Power Supply

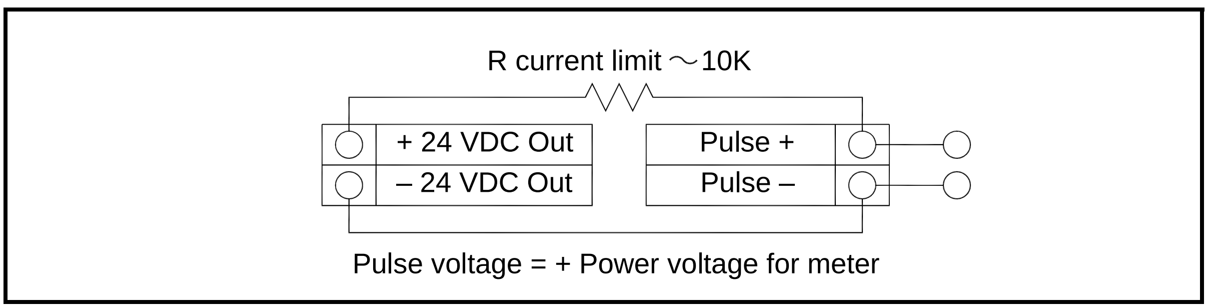


Figure 2-22: Isolated Pulse Output Using Meter Provided Power Supply

Alarm Output Connections

One alarm output (Alarm 1) is included on the standard Innova-Mass Flowmeter. Two or more alarms (Alarm 2 and Alarm 3) are included on the optional communication board. The alarm output optical relays are normally-open single-pole relays. The relays have a nominal 200 volt/160 ohm rating. This means that each relay has a nominal on-resistance of 160 ohms and the largest voltage that it can withstand across the output terminals is 200 volts. However, there are current and power specifications that must be observed. The relay can conduct a current up to 40 mA and can dissipate up to 320 mW. The relay output is isolated from the meter electronics and power supply. When the alarm relay is closed, the current draw will be constant. Make sure to size R_{load} appropriately.

Alarm Output Connections (cont.)

There are three connection options for the alarm output–the first with a separate power supply (Figure 2-23) and the second using the flowmeter power supply (Figure 2-24). Use the first option with a separate power supply (5 to 36 VDC) if a specific voltage is needed for the alarm output. Use the second configuration if the voltage at the flowmeter power supply is an acceptable driver voltage for the load connected. (Take into account that the current used by the alarm load comes from the meter's power supply.) In either case, the voltage of the alarm output is the same as the voltage supplied to the circuit.

The alarm output is used for transmitting high or low process conditions as defined in the alarm settings (see page 3-7).

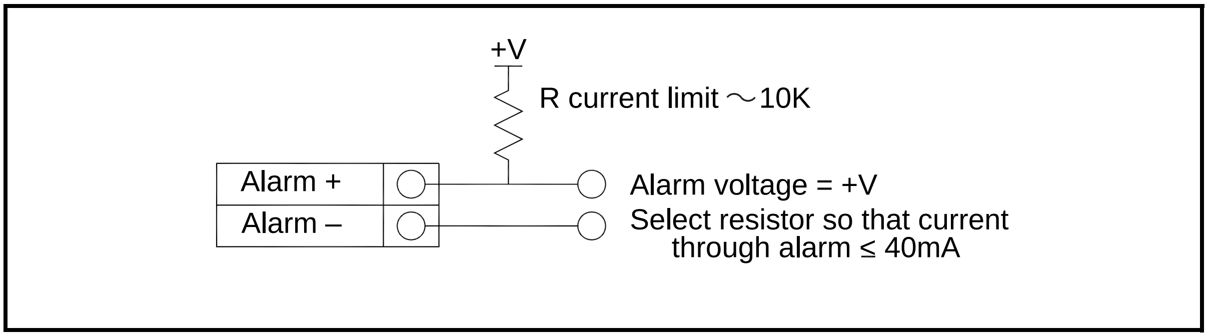


Figure 2-23: Isolated Alarm Output with External Power Supply

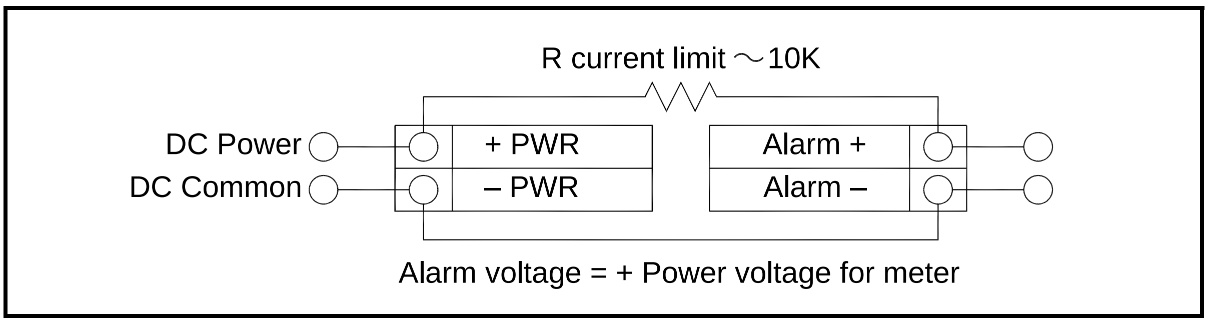


Figure 2-24: Non-Isolated Alarm Output Using Internal Power Supply

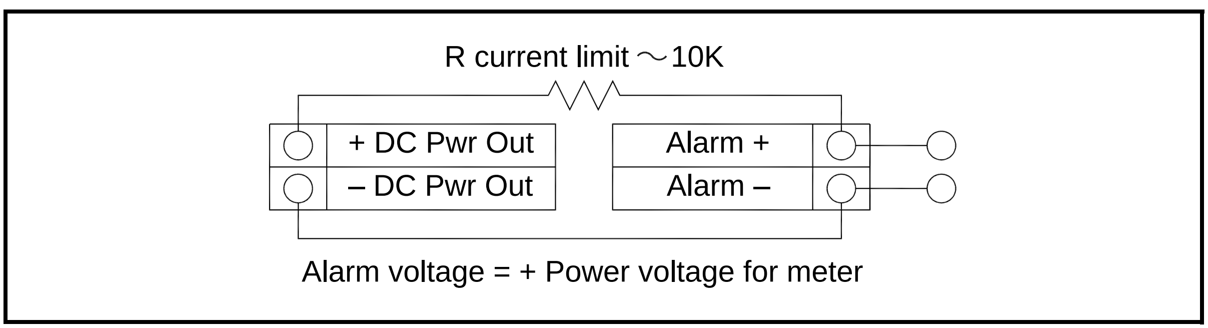


Figure 2-25: Isolated Alarm Output Using Meter Provided Power Supply

Remote Electronics Wiring

The remote electronics enclosure should be mounted in a convenient, easy to reach location. For hazardous location installations, make sure to observe agency requirements for installation. Allow some slack in the interface cable between the junction box and the remote electronics enclosure. To prevent damage to the wiring connections, do not put stress on the terminations at any time.

The meter is shipped with temporary strain relief glands at each end of the cable. Disconnect the cable from the meter's terminal block inside the junction box–not at the remote electronics enclosure. Remove both glands and install appropriate conduit entry glands and conduit. When installation is complete, re-connect each labeled wire to the corresponding terminal position on the junction box terminal block. Make sure to connect each wire pair's shield.

Note: *Incorrect connection will cause the meter to malfunction.*

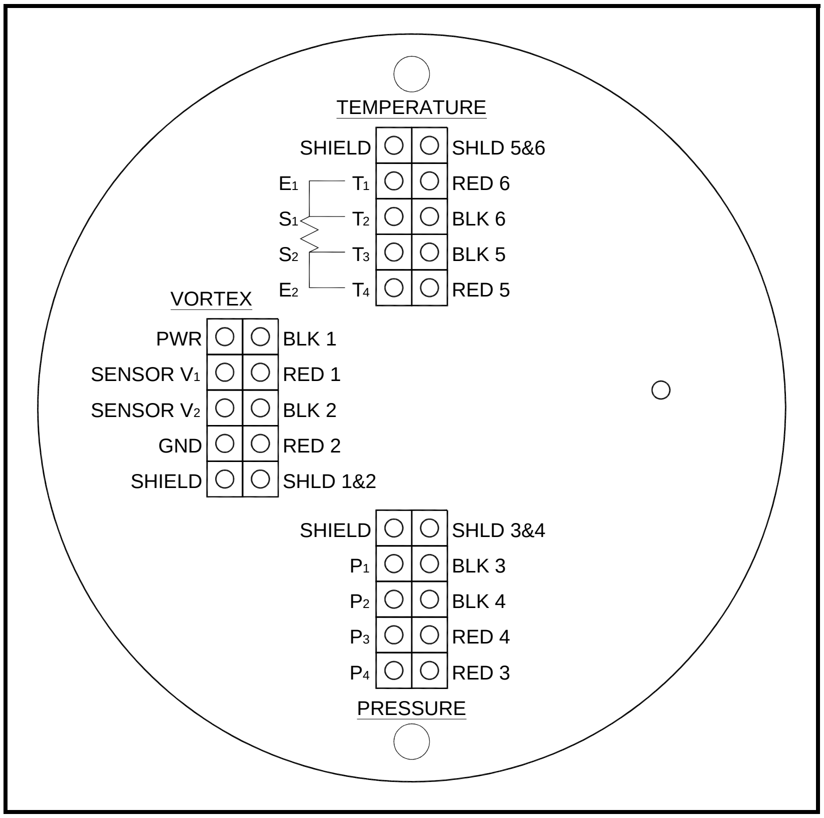


Figure 2-26: Junction Box Sensor Connections

Note: *The numeric code in the junction box label matches the wire labels.*

Optional Input Electronics Wiring

The meter has two optional input wiring terminal strips. These can be used to input a Remote or Second RTD input in the case of an Energy Monitoring meter, for the input of a Remote Pressure Transducer, to pass a Contact Closure or for a Remote Density measurement to name a few. In any case, the wiring diagram will be included with the meter if any of the options are specified. Otherwise, the optional terminal blocks will be left blank and non functional.

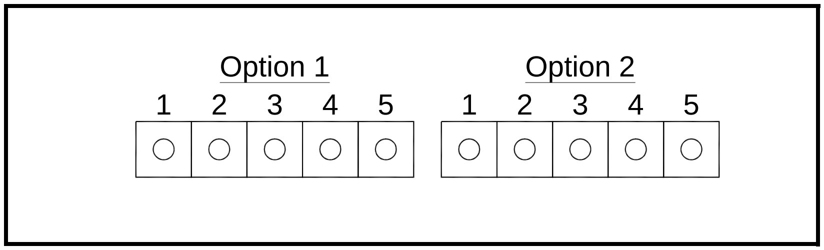


Figure 2-27: Optional Input Wiring Terminal Strips

Optional Energy EMS Input Electronics Wiring

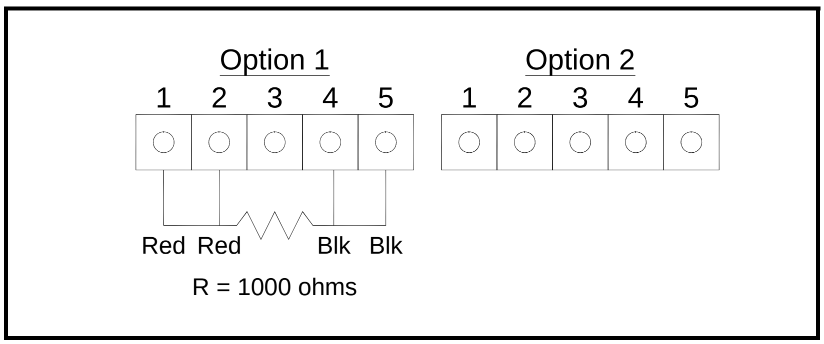


Figure 2-28: Optional Energy EMS Input Wiring Terminal Strips

The recommended customer supplied second RTD is a Class A 1000 ohm 4-wire platinum RTD. If a second RTD is not being used, then the factory supplied 1000 ohm resistor needs to be installed in its place.

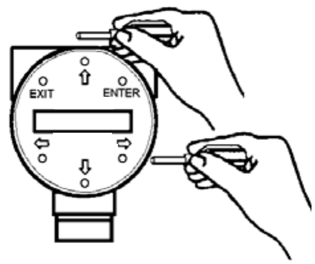
Chapter 3

Operation

Introduction

After installing the PanaFlow MV Flowmeter, you are ready to begin operation. The sections in this chapter explain the display/keypad commands, meter start-up and programming. The meter is ready to operate at start up without any special programming. To enter parameters and system settings unique to your operation, see the following pages for instructions on using the setup menus.

Display/Keypad



The flowmeter's digital electronics enable you to set, adjust and monitor system parameters and performance. A full range of commands are available through the display/keypad. The LCD display gives 2 x 16 characters for flow monitoring and programming. The six push-buttons can be operated with the enclosure cover removed. Or, the explosion-proof cover can remain in place and the keypad operated with a hand-held magnet positioned at the side of the enclosure as shown in the illustration at the left.

From the Run Mode, the ENTER key enables access to the Setup Menus (through a password screen). Within the Setup Menus, pressing ENTER activates the current field. To set new parameters, press the ENTER key until an underline cursor appears. Use the ↑ ↓ ← → keys to select new parameters. Press ENTER to continue. (If change is not allowed, ENTER has no effect.) All outputs are disabled when using the Setup Menus.

The EXIT key is active within the Setup Menus. When using a Setup Menu, EXIT returns you to the Run Mode. If you are changing a parameter and make a mistake, EXIT allows you to start over.

The ↑ ↓ ← → keys advance through each screen of the current menu. When changing a system parameter, all ↑ ↓ ← → keys are available to enter new parameters.

Figure 3-1: Flowmeter Display/Keypad

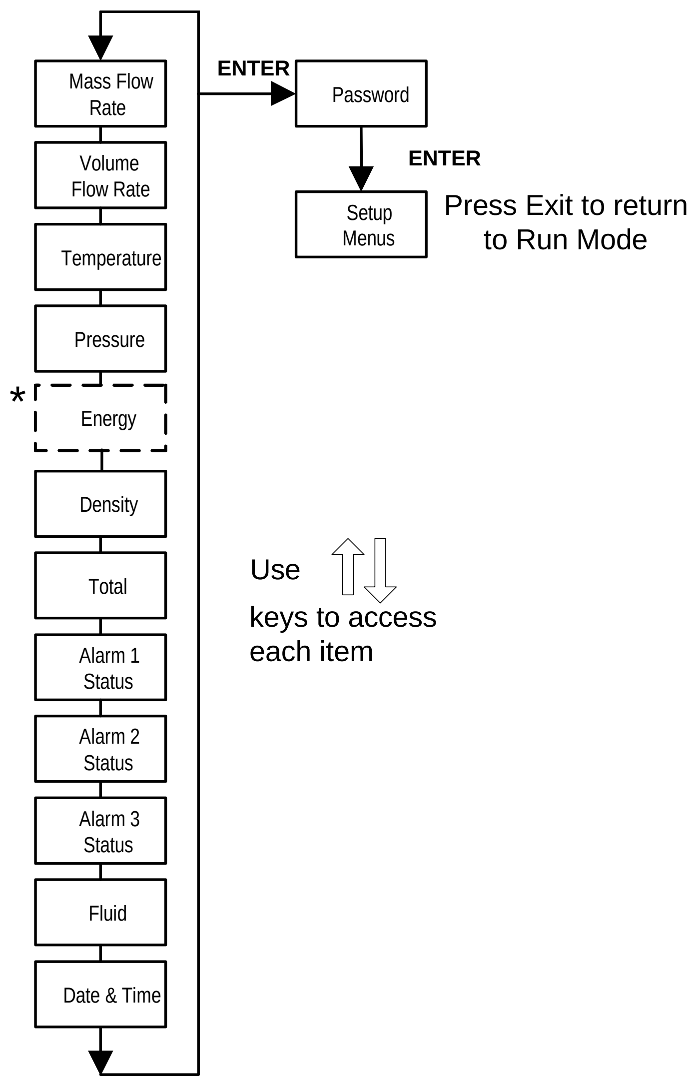
Startup

To begin flowmeter operation:

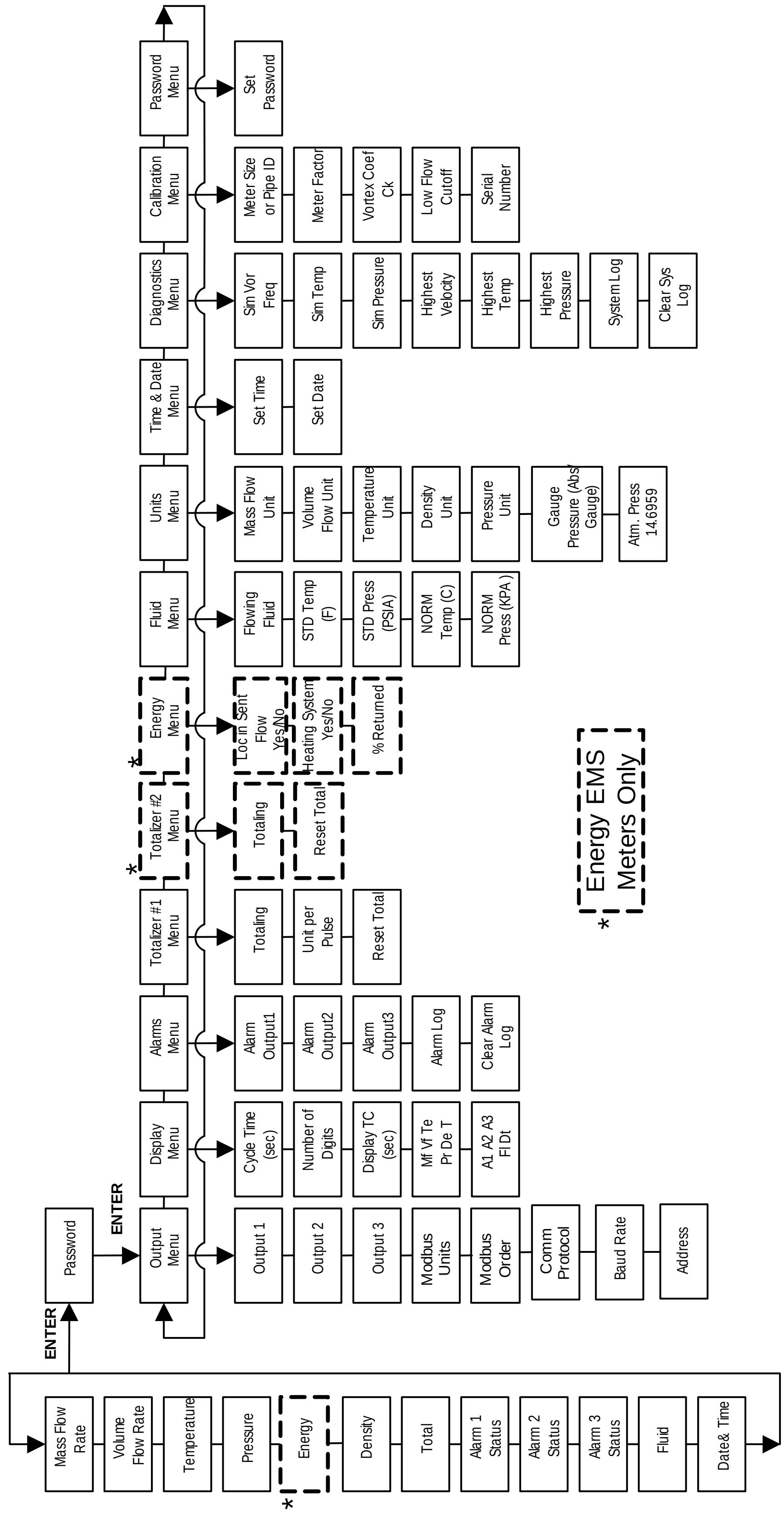
1. Verify the flowmeter is installed and wired as described in Chapter 2.
2. Apply power to the meter. At start up, the unit runs a series of selftests that check the RAM, ROM, EPROM and all flow sensing components. After completing the self-test sequence, the Run Mode screens appear (see figure below).

Note: *Starting the flowmeter or pressing EXIT will always display the Run Mode screens.*

3. The Run Mode displays flow information as determined by system settings. Press the ↑ ↓ arrow keys to view the Run Mode screens.
4. Press the ENTER key from any Run Mode screen to access the Setup Menus. Use the Setup Menus to configure the meter's multiparameter features to fit your application.



Setup Menus


Mass Flow Rate
Volume Flow Rate
Temperature
Pressure
Energy
Density
Total
Alarm 1 Status
Alarm 2 Status
Alarm 3 Status
Fluid
Date& Time
ENTER
Password
ENTER
Output Menu
Output 1
Output 2
Output 3
Modbus Units
Modbus Order
Comm Protocol
Baud Rate
Address
Display Menu
Cycle Time (sec)
Number of Digits
Display TC (sec)
Mf Vf Te Pr De T
A1 A2 A3 Fl Dt
Alarms Menu
Alarm Output1
Alarm Output2
Alarm Output3
Alarm Log
Clear Alarm Log
Totalizer #1 Menu
Totaling
Unit per Pulse
Reset Total
Totalizer #2 Menu
Totaling
Reset Total
Energy Menu
Loc in Sent Flow Yes/No
Heating System Yes/No
% Returned
Fluid Menu
Flowing Fluid
STD Temp (F)
STD Press (PSIA)
NORM Temp (C)
NORM Press (KPA)
Units Menu
Mass Flow Unit
Volume Flow Unit
Temperature Unit
Density Unit
Pressure Unit
Gauge Pressure (Abs/ Gauge)
Atm. Press 14.6959
Time & Date Menu
Set Time
Set Date
Diagnostics Menu
Sim Vor Freq
Sim Temp
Sim Pressure
Highest Velocity
Highest Temp
Highest Pressure
System Log
Clear Sys Log
Calibration Menu
Meter Size or Pipe ID
Meter Factor
Vortex Coef Ck
Low Flow Cutoff
Serial Number
Password Menu
Set Password
* Energy EMS Meters Only

Programming the Flowmeter

1. Enter the Setup Menu by pressing the ENTER key until prompted for a password. (All outputs are disabled while using the Setup Menus.)
2. Use the ↑ ↓ ← → keys to select the password characters (1234 is the factory-set password). When the password is correctly displayed, press ENTER to continue.
3. Use the Setup Menus described on the following pages to customize the multiparameter features of your PanaFlow MV Flowmeter. (The entire lower display line is available for entering parameters.)
4. To activate a parameter, press ENTER. Use the ↑ ↓ ← → keys to make selections. Press ENTER to continue. Press EXIT to save or discard changes and return to Run Mode.
5. **Program the UNITS menu first, because later menus will be based on the units selected**.

Example for Setting an Output

The following shows how to set Output 1 to measure mass flow with 4 mA = 0 lb/hr and 20 mA = 100 lb/hr with a time constant of 5 seconds. (All outputs are disabled while using the Setup Menus.)

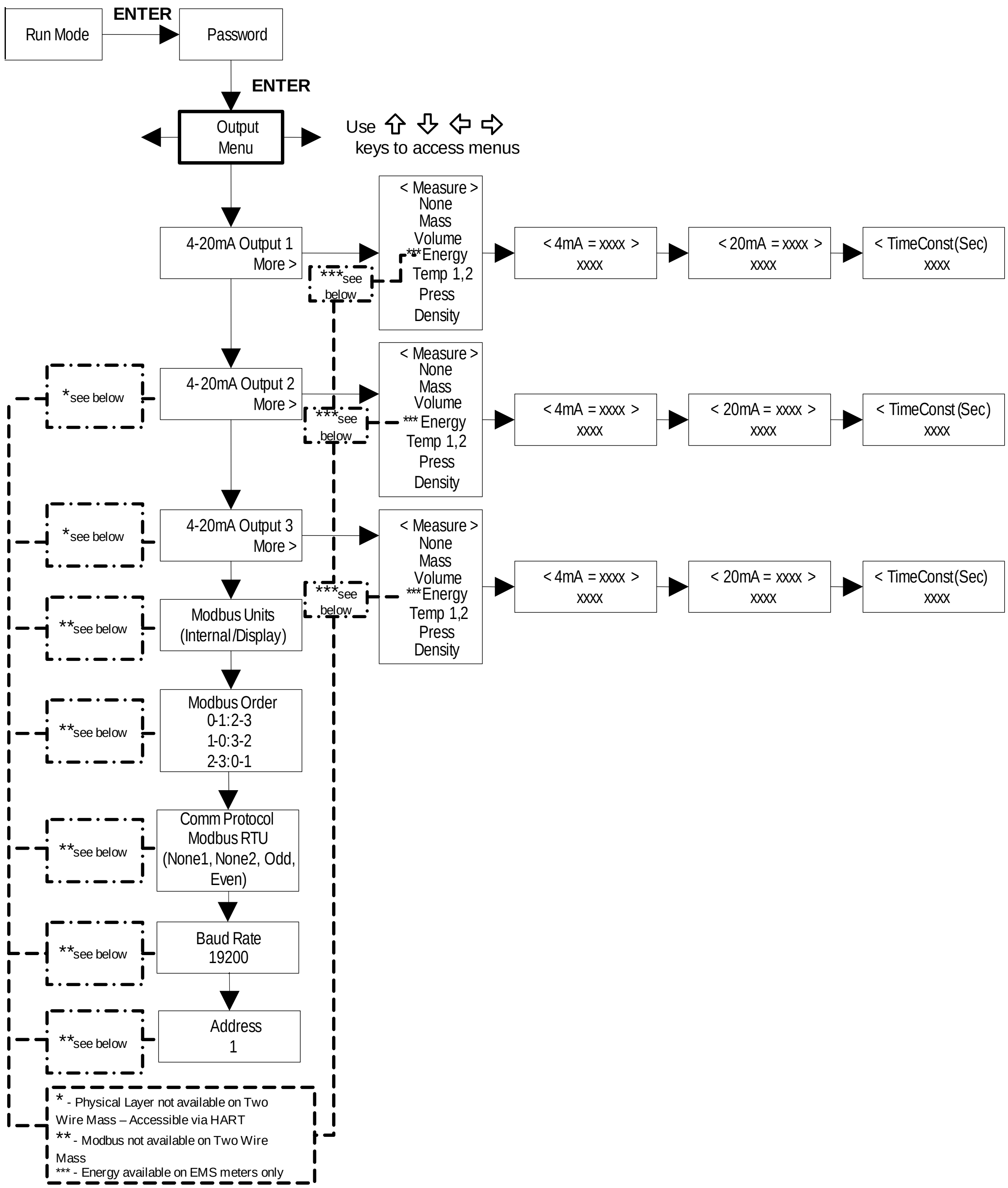
First, set the desired units of measurement:

1. Use the ← → keys to move to the Units Menu (see page 3-9).
2. Press the ↓ key until the Mass Flow Unit appears. Press ENTER.
3. Press the ↓ key until **lb** appears in the numerator. Press the → key to move the underline cursor to the denominator. Press the ↓ key until **hr** appears in the denominator. Press ENTER to select.
4. Press the ↑ key until the Units Menu appears.

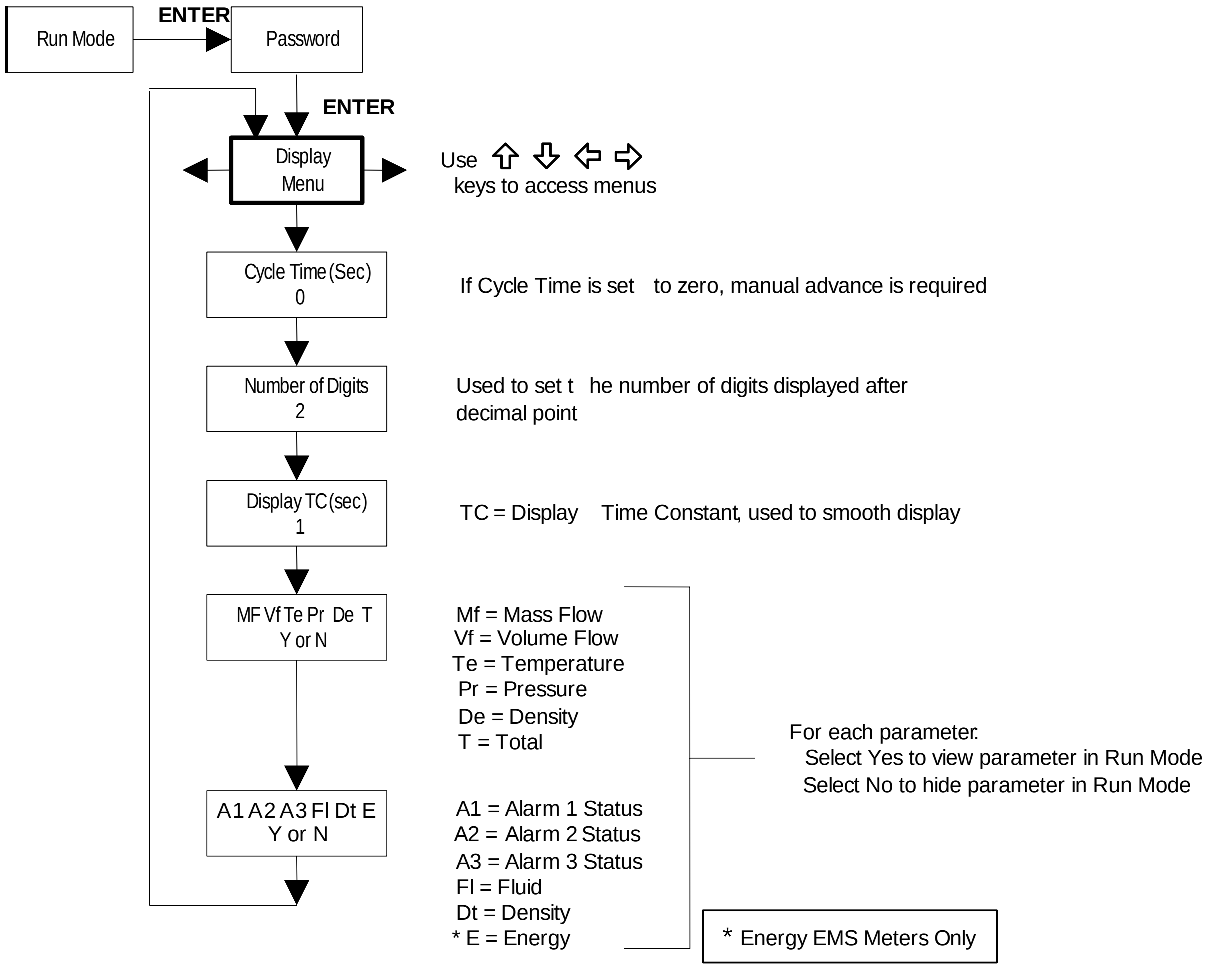
Second, set the analog output:

1. Use the ← → keys to move to the Output Menu.
2. Press the ↓ key until 4-20 mA Output 1 appears.
3. Press the → key to access Measure selections. Press ENTER and press the ↓ key to select Mass. Press ENTER.
4. Press the → key to set the 4 mA point in the units you have selected for mass of lb/hr. Press ENTER and use the ↑ ↓ ← → keys to set 0 or 0.0. Press ENTER.
5. Press the → key to set the 20 mA point. Press ENTER and use the ↑ ↓ ← → keys to set 100 or 100.0. Press ENTER.
6. Press the → key to select the Time Constant. Press ENTER and use the ↑ ↓ ← → keys to select 5. Press ENTER.
7. Press the EXIT key and answer YES to permanently save your changes.

Output Menu


Run Mode
ENTER
Password
ENTER
Output Menu
Use ⇧ ⇩ ⇦ ⇨ keys to access menus
4-20mA Output 1 More >
< Measure > None Mass Volume ***Energy Temp 1,2 Press Density
< 4mA = xxxx > xxxx
< 20mA = xxxx > xxxx
< TimeConst(Sec) xxxx
***see below
4-20mA Output 2 More >
*see below
4-20mA Output 3 More >
Modbus Units (Internal/Display)
**see below
Modbus Order 0-1:2-3 1-0:3-2 2-3:0-1
Comm Protocol Modbus RTU (None1, None2, Odd, Even)
Baud Rate 19200
Address 1
* - Physical Layer not available on Two Wire Mass – Accessible via HART
** - Modbus not available on Two Wire Mass
*** - Energy available on EMS meters only

Display Menu



Use the Display Menu to set the cycle time for automatic screen sequencing used in the Run Mode, change the precision of displayed values, smooth the values or enable or disable each item displayed in the Run Mode screens.

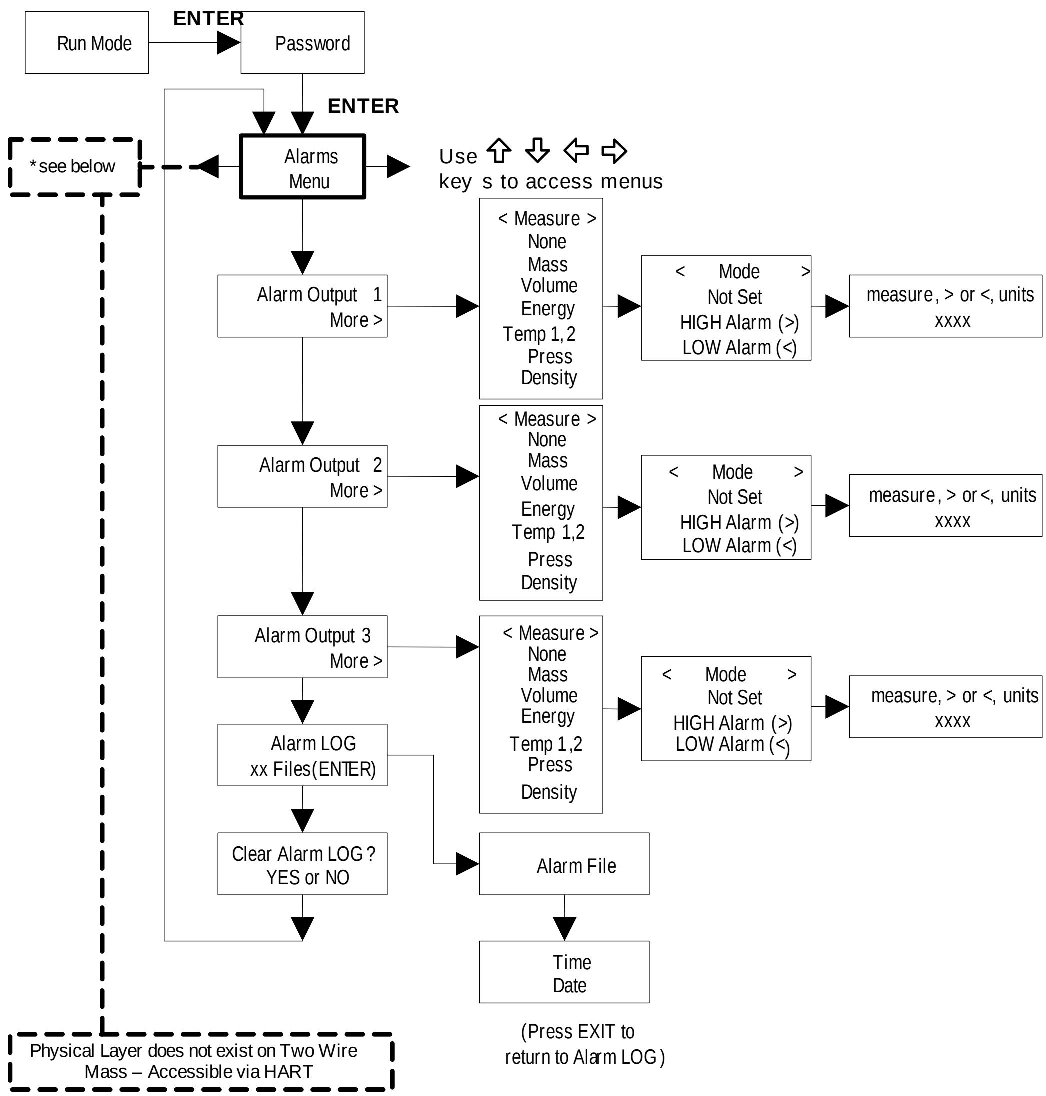
Example for Changing a Run Mode Display Item

The following shows how to remove the temperature screen from the Run Mode screens.

Note: *All outputs are disabled while using the Setup Menus.*

1. Use the ← → keys to move to the Display Menu.
2. Press the ↓ key until Mf Vf Pr Te De T appears.
3. Press ENTER to select. Press the → key until the cursor is positioned below Te.
4. Press the ↓ key until N appears. Press ENTER to select.
5. Press EXIT and then ENTER to save changes and return to the Run Mode.

Alarms Menu



Example for Setting an Alarm

The following shows how to set Alarm 1 to activate if the mass flow rate is greater than 100 lb/hr. You can check the alarm configuration in the Run Mode by pressing the ↑ ↓ keys until Alarm [1] appears. The lower line displays mass flow rate at which the alarm activates.

Note: *All outputs are disabled while using the Setup Menus.*

First, set the desired units of measurement:

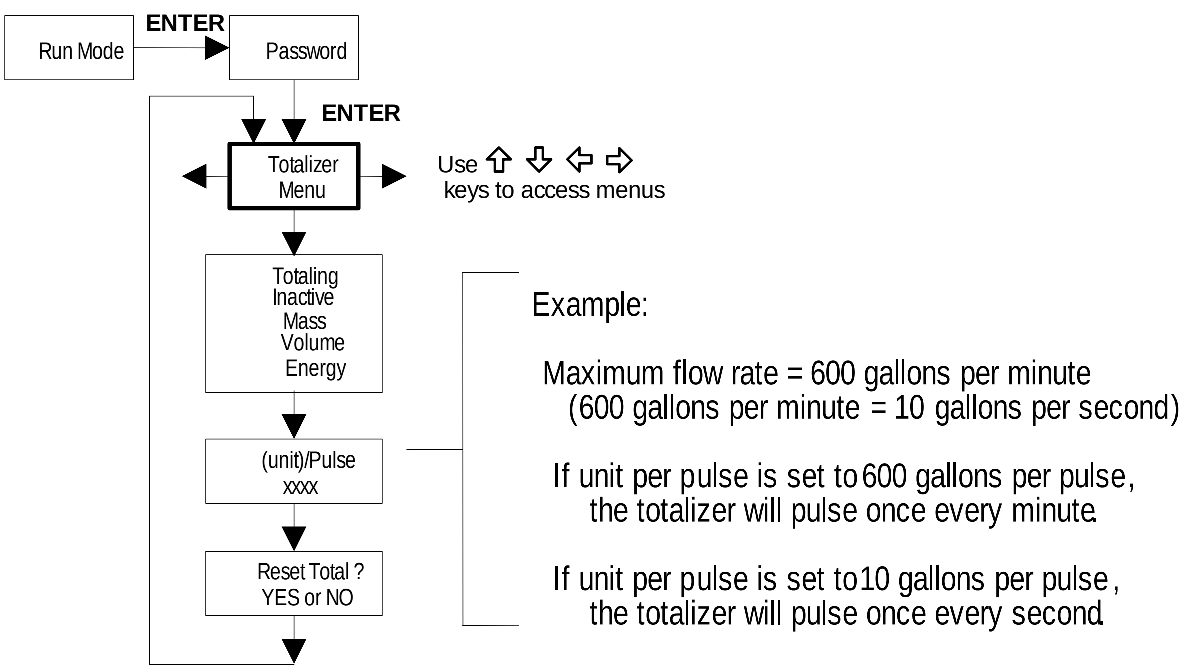
1. Use the ←→ keys to move to the Units Menu.
2. Press the ↓ key until Mass Flow Unit appears. Press ENTER.
3. Press the ↓ key until **lb** appears in the numerator. Press the → key to move the underline cursor to the denominator. Press the ↓ key until **hr** appears in the denominator. Press ENTER to select.
4. Press the ↑ key until the Units Menu appears.

Example for Setting an Alarm (cont.)

Second, set the alarm:

1. Use the ← → keys to move to the Alarms Menu.
2. Press the ↓ key until Alarm Output 1 appears.
3. Press the → key to access Measure selections. Press ENTER and use the ↓ key to select Mass. Press ENTER.
4. Press the → key to select the alarm Mode. Press ENTER and use the ↓ key to select HIGH Alarm. Press ENTER.
5. Press the → key to select the value that must be exceeded before the alarm activates. Press ENTER and use the ↑ ↓ ← → keys to set 100 or 100.0. Press ENTER.
6. Press the EXIT key to save your changes. (Alarm changes are always permanently saved.) (Up to three alarm outputs are available depending on meter configuration.)

Totalizer #1 Menu



Use the Totalizer Menu to configure and monitor the totalizer. The totalizer output is a 50 millisecond (.05 second) positive pulse (relay closed for 50 milliseconds). The totalizer cannot operate faster than one pulse every 100 millisecond (.1 second). A good rule to follow is to set the unit per pulse value equal to the maximum flow in the same units per second. This will limit the pulse to no faster than one pulse every second.

Example for Setting the Totalizer

The following sets the totalizer to track mass flow in kg/sec.

Note: *All outputs are disabled while using the Setup Menus.*

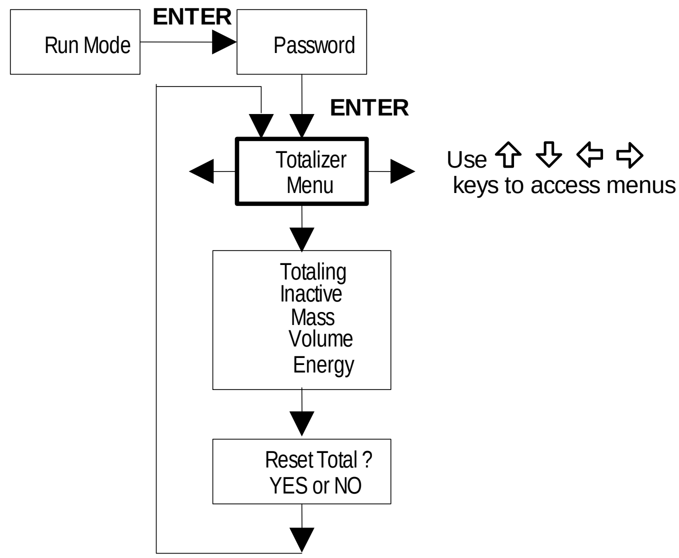
First, set the desired units of measurement:

1. Use the ← → keys to move to the Units Menu.
2. Press the ↓ key until Mass Flow Unit appears. Press ENTER.
3. Press the ↓ key until **kg** appears in the numerator. Press the → key to move the underline cursor to the denominator. Press the ↓ key until **sec** appears in the denominator. Press ENTER to select.
4. Press the ↑ key until the Units Menu appears.

Second, set the pulse output:

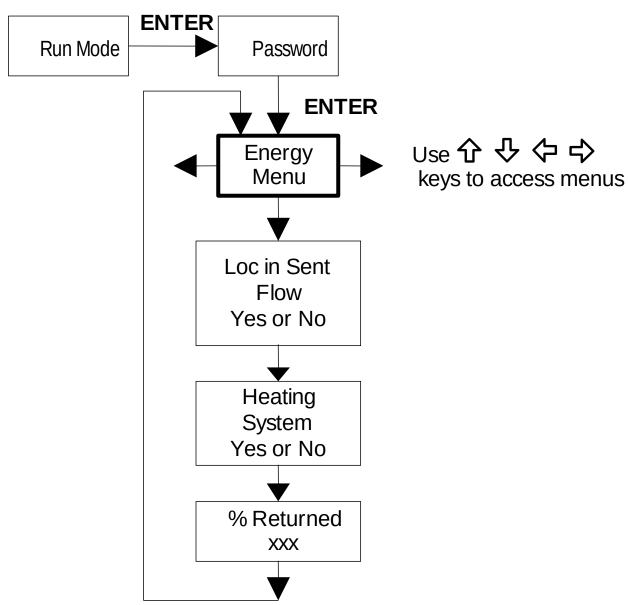
1. Use the ← → keys to move to the Totalizer Menu.
2. Press the ↓ key until **Totaling** appears.
3. Press ENTER and press the ↓ key to select Mass. Press ENTER.
4. Press the ↓ key to set the pulse output in the units you have selected for mass flow of kg/sec. Press ENTER and use the ↑ ↓ ← → keys to set the pulse value equal to the maximum flow in the same units per second. Press ENTER.
5. To reset the totalizer, press the ↓ key until **Reset Total?** appears. Press ENTER and the ↓ key to reset the totalizer if desired. Press ENTER.
6. Press the EXIT key and answer YES to permanently save your changes.

Totalizer #2 Menu



Use the Totalizer #2 to Monitor Flow or Energy. Note that Totalizer #2 does not operate a relay; it is for monitoring only.

Energy Menu - For EMS Energy Meters Only



Configuration:

There are several possibilities regarding the measurement of water or steam energy given the location of the meter and the use of a second RTD. Table 3-1 below summarizes the possibilities:

Table 3-1: Measurement Possibilities

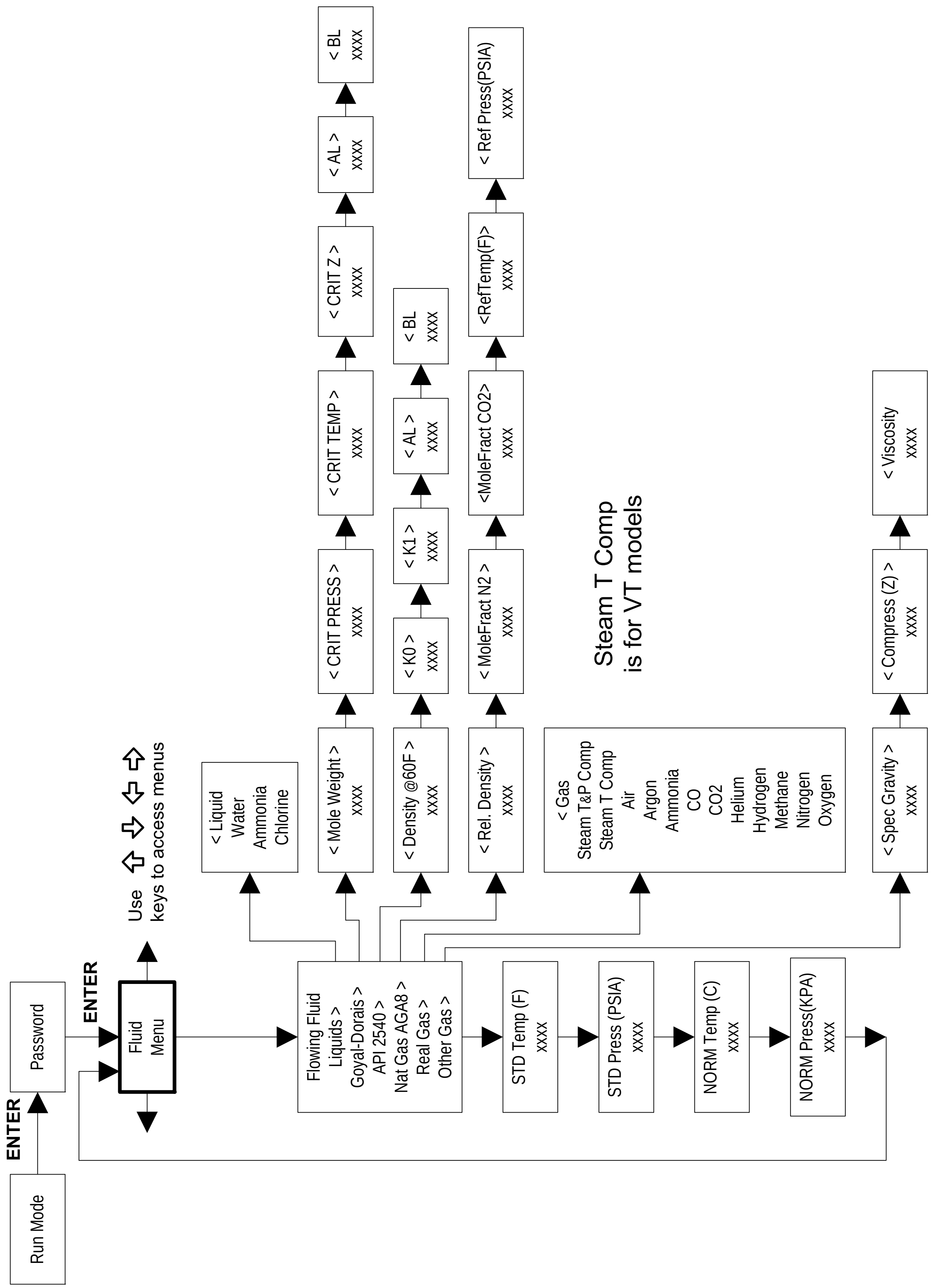
Fluid	Meter Location	Second RTD	Measurement
Water	"Sent" Flow Line	"Return" Flow Line	Change in Energy
Water	"Return" Flow Line	"Sent" Flow Line	Change in Energy
Water	"Sent" Flow Line	None	Outgoing Energy
Steam	"Sent" Flow Line	"Return" Flow Line (condensate)	Change in Energy
Steam	"Sent" Flow Line	None	Outgoing Energy

As above, you must properly configure the meter in the Energy Menu.

1. Loc in Sent Flow? Select Yes or No based on where the meter is located. Refer to the above table.
2. Heating System? Select Yes for a hot water system used for heating. Select No for a chilled water system used for cooling. Always select Yes for a steam system.
3. % Returned. Select a number between 0% and 100%. Estimate the amount of water that returns. It is usually 100%, or can be less than 100% if historical data shows the amount of makeup water used. If a second RTD is not used, set to 0%. When 0% is selected, the energy calculation represents the outgoing energy only (no return energy is subtracted).

Note: *The meter ships from the factory assuming 0% return and has a 1000 ohm resistor installed in the RTD #2 wiring location. This needs to be removed if the meter is to be used in a manner other than with 0% return and with the customer supplied RTD in its place.*

Fluid Menu


Run Mode
ENTER
Password
ENTER
Fluid Menu
Use keys to access menus
Flowing Fluid
Liquids >
Goyal-Dorais >
API 2540 >
Nat Gas AGA8 >
Real Gas >
Other Gas >
STD Temp (F) xxxx
STD Press (PSIA) xxxx
NORM Temp (C) xxxx
NORM Press(KPA) xxxx
< Liquid
Water
Ammonia
Chlorine
< Mole Weight > xxxx
< CRIT PRESS > xxxx
< CRIT TEMP > xxxx
< CRIT Z > xxxx
< AL > xxxx
< BL xxxx
< Density @60F > xxxx
< K0 > xxxx
< K1 > xxxx
< AL > xxxx
< BL xxxx
< Rel. Density > xxxx
< MoleFract N2 > xxxx
<MoleFract CO2> xxxx
<RefTemp(F)> xxxx
< Ref Press(PSIA) xxxx
< Gas
Steam T&P Comp
Steam T Comp
Air
Argon
Ammonia
CO
CO2
Helium
Hydrogen
Methane
Nitrogen
Oxygen
Steam T Comp
is for VT models
< Spec Gravity > xxxx
< Compress (Z) > xxxx
< Viscosity xxxx

Fluid Menu (cont.)

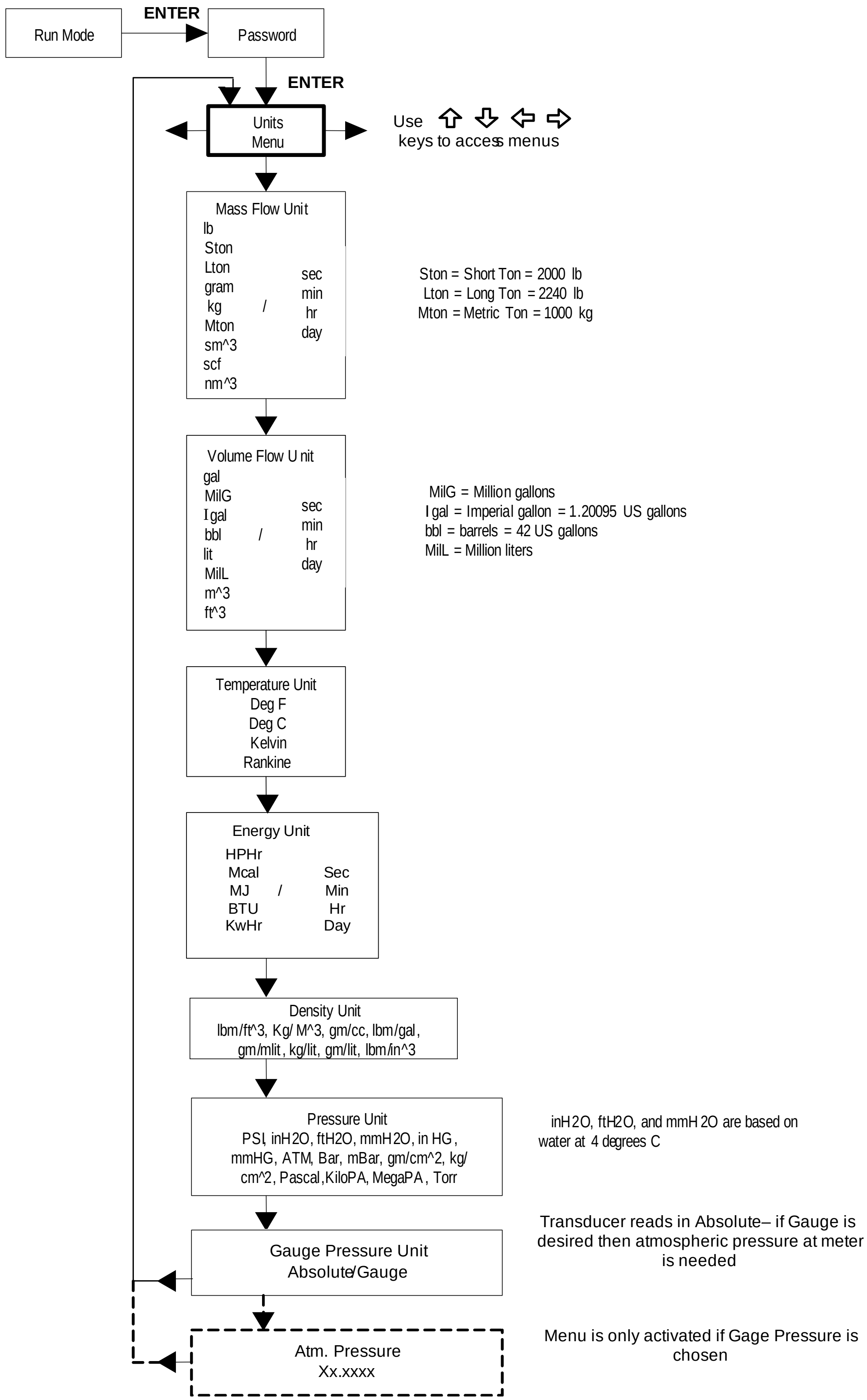
Use the Fluid Menu to configure the flowmeter for use with common gases, liquids and steam. Your flowmeter is pre-programmed at the factory for your application's process fluid.

Reference Richard W. Miller, *Flow Measurement Engineering Handbook (Second Edition, 1989)*, page 2-67 for definition and use of the Goyal-Doraiswamy equation and page 2-68 for the definition and use of the API 2540 equation. Also, see Appendix C of this manual for Fluid Calculation equations.

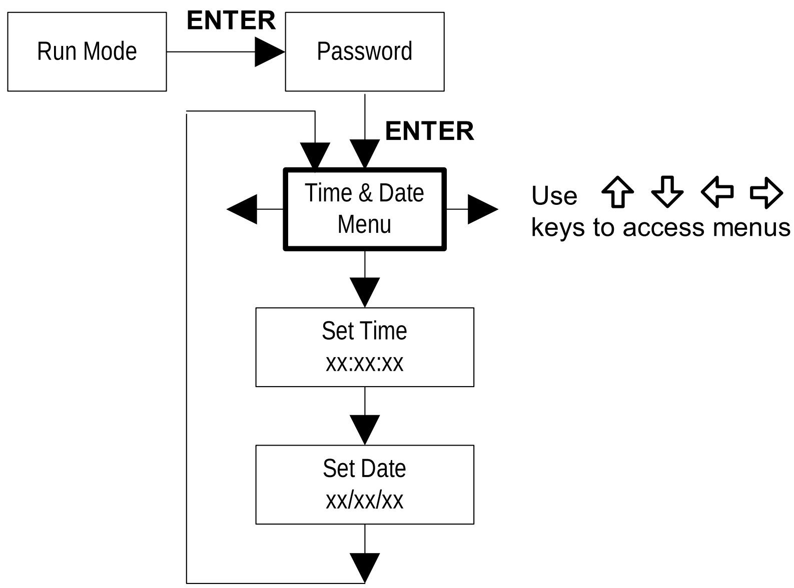
The units of measurement used in the Fluid Menu are preset and are as follows:
Mole Weight = $lb_m/(lb_m \cdot mol)$
CRIT PRESS = psia
CRIT TEMP = °R
Density = Kg/m^3
Viscosity = cP (centipoise)

Units Menu

Use the Units Menu to configure the flowmeter with the desired units of measurement. (These are global settings and determine what appears on all screens.)



Time and Date Menu



Use the Time and Date Menu to enter the correct time and date into the flowmeter's memory. The parameters are used in the Run Mode and the alarm and system log files.

Note: *Time is displayed in AM/PM format, but military format is used to set the time. For example, 1:00 PM is entered as 13:00:00 in the Set Time menu.*

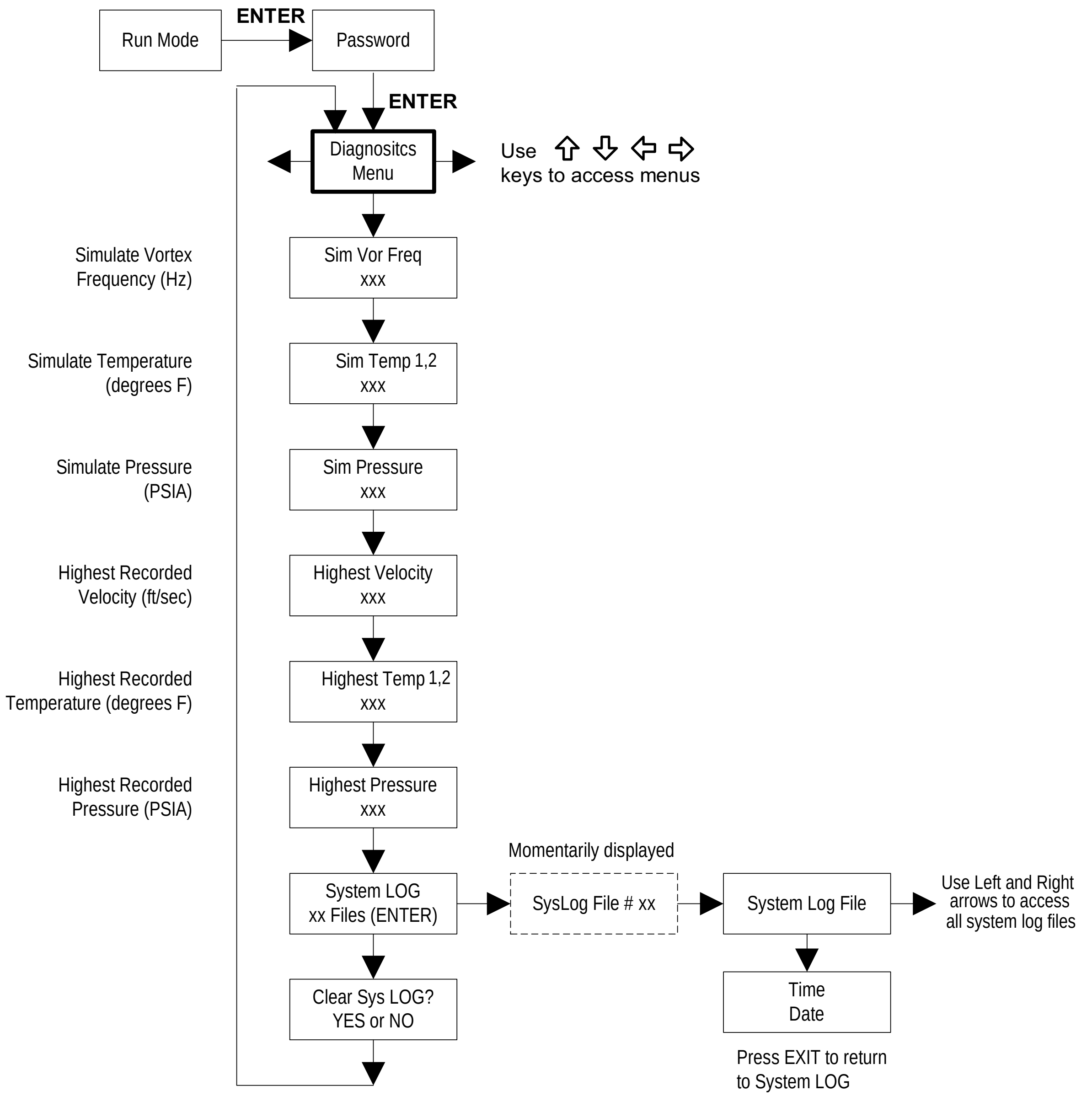
Example for Setting the Time

How to set the time to 12:00:00. You can check the time in the Run Mode by pressing the ↑ ↓ keys until the Time & Date screen appears.

Note: *All outputs are disabled while using the Setup Menus.*

1. Use the ← → keys to move to the Time and Date Menu.
2. Press the ↓ key until Set Time appears. Press ENTER.
3. Press the ↓ key until 1 appears. Press the → key to move the underline cursor to the next digit. Press the ↓ key until 2 appears. Continue the sequence until all the desired parameters are entered. Press ENTER to return to the Time and Date Menu.
4. Press EXIT to return to the Run Mode.

Diagnostics Menu



Diagnostics Menu (cont.)

Use the Diagnostics Menu to simulate operation and review the system files. The system log files contain time/date stamped messages including: power on, power off, programming time outs, parameter faults, incorrect password entry and other various information relative to system operation and programming.

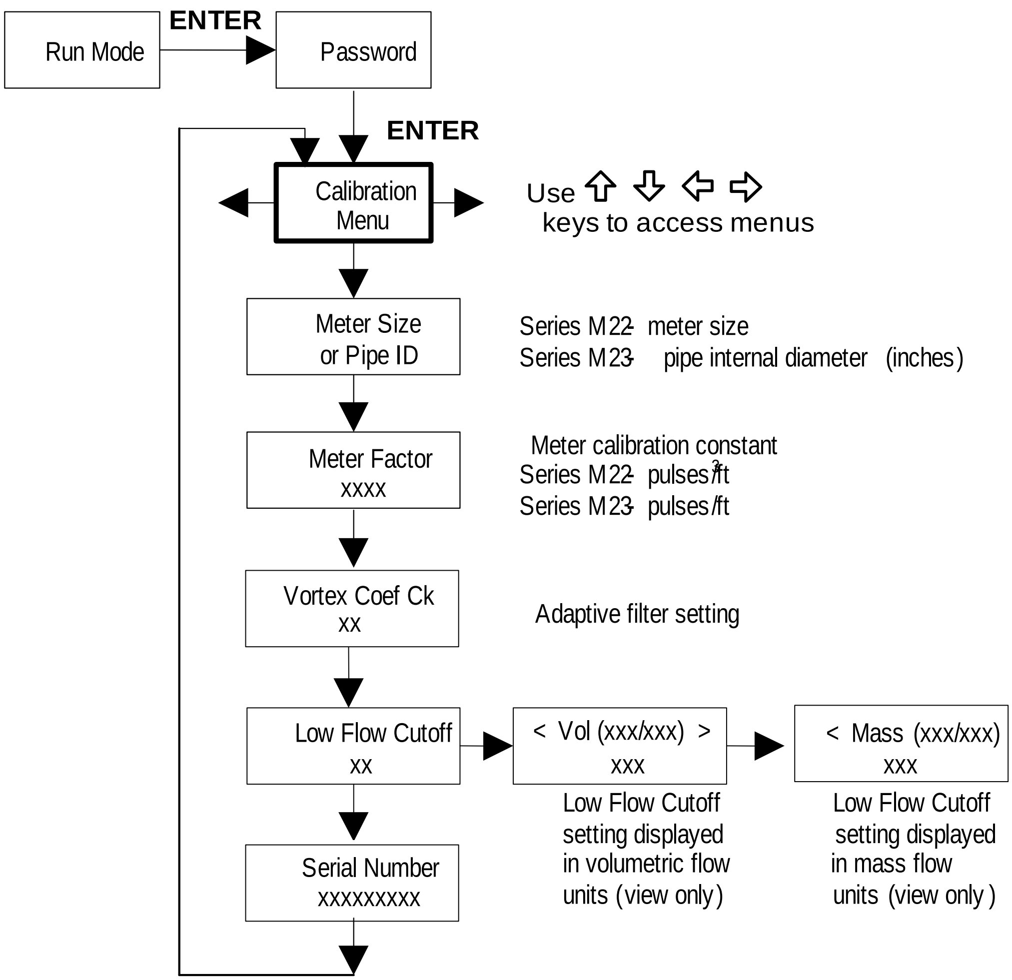
The simulated inputs are for testing the meter to verify that the programming is correct. Simulated vortex frequency allows you to enter any value for the sensor input in Hz. The meter will calculate a flow rate based on the corresponding value and update all analog outputs (**the totalizer display and output is not affected by a simulated frequency**). The simulated pressure and temperature settings work the same way. The meter will output these new values and will use them to calculate a new density for mass flow measurement.

Note: *When your diagnostic work is complete, make sure to return the values to zero to allow the electronics to use the actual transducer values.*

If the meter display indicates a temperature or pressure fault, a substitute value can be entered to allow flow calculations to continue at a fixed value until the source of the fault is identified and corrected. **Use only the units listed above for simulated values**. If different units are displayed, the value must be converted into the units listed above, and the displayed value will be automatically converted into the display units.

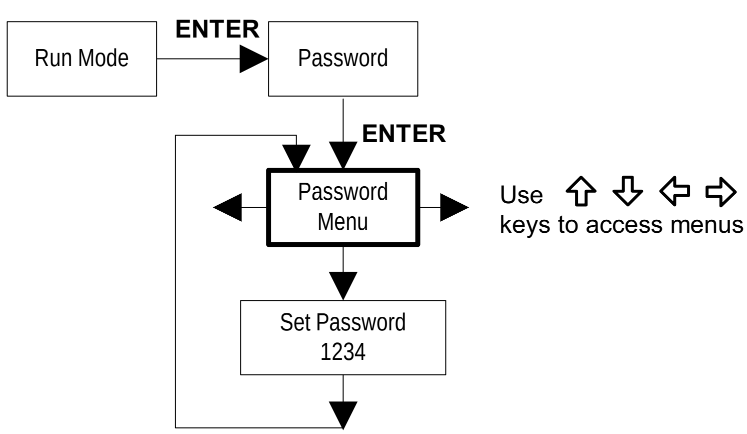
Calibration Menu

The Calibration Menu contains the calibration coefficients for the flowmeter. These values should by changed only by properly trained personnel. The Vortex Coef Ck and Low Flow Cutoff are set at the factory. Consult the factory for help with these settings if the meter is showing erratic flow rate.



Password Menu

Use the Password Menu to set or change the system password. The factory-set password is 1234.



Chapter 4

Troubleshooting

Hidden Diagnostics Menus

The menus shown on page 4-2 can be accessed using the password 16363, then moving to the display that reads “Diagnostics Menu” and pressing ENTER (rather than one of the arrow keys).

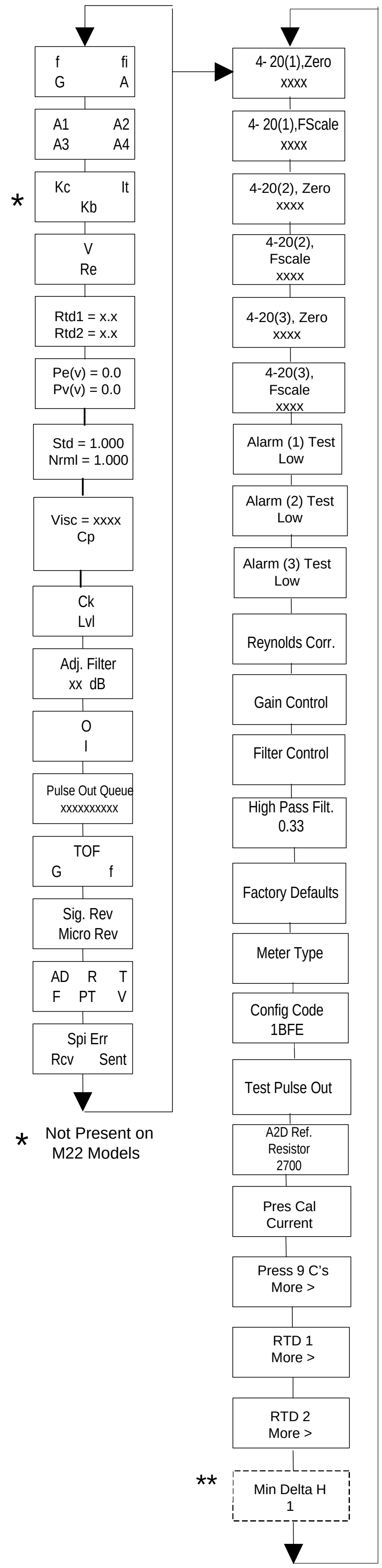
Use the right arrow key to move to the second column. Press EXIT to move from the second column back to the first, press EXIT while in the first column to return to the setup menus.

Caution!
Password 16363 will allow full access to the configuration and should be used carefully to avoid changes that can adversely alter the function of the meter.

Each of the menus on page 4-2 will first be defined, followed by specific troubleshooting steps.

!WARNING!
Before attempting any flowmeter repair, verify that the line is not pressurized. Always remove main power before disassembling any part of the mass flowmeter.

Hidden Diagnostics (cont.)



Column One Hidden Diagnostics Values

Table 4-1: Column One Hidden Diagnostic Values

Designation	Description
f	Vortex shedding frequency (Hz)
fi	Adaptive filter – Should be approximately 25% higher than the vortex shedding frequency, this is a low-pass filter. **Note:** If the meter is using the Filter Control (see below) in the manual mode, **fi** will be displayed as **fm**.
G	Gain (applied to vortex signal amplitude). Gain defaults to 1.0 and can be changed using the Gain Control (see below).
A	Amplitude of vortex signal in Volts rms.
A1, A2, A3, A4	A/D counts representing the vortex signal amplitude. Each stage (A1-A4) cannot exceed 512. Beginning with stage A1, the A/D counts increase as the flow increases. When stage A1 reaches 512, it will shift to stage A2. This will continue as the flow rate increases until all 4 stages read 512 at high flow rates. Higher flow rates (stronger signal strength) will result in more stages at 512.
Kc, It, Kb	Profile equation (factory use only). Model MV82 only.
V	Calculated average pipe velocity (ft/sec).
Re	Calculated Reynolds number.
RTD1	Resistance value of integral RTD in ohms.
RTD2	Optional RTD resistance value same as above.
Pe(v)	Pressure transducer excitation voltage.
Pv(v)	Pressure transducer sense voltage.
Stnd	Density of fluid at standard conditions.
Nrml	Density of fluid at normal conditions.
Viscosity	Calculated viscosity of flowing fluid.
Ck	Calculated Ck at current operating conditions. Ck is a variable in the equation that relates signal strength, density, and velocity for a given application. It is used for noise rejection purposes. Ck directly controls the **fi** value (see above). If the Ck is set too low (in the calibration menu), then the **fi** value will be too low and the vortex signal will be rejected resulting in zero flow rate being displayed. The calculated Ck valun in this menu can be compared to the actual Ck setting in the calibration menu to help determine if the Ck setting is correct.
Lvl	Threshold level. If the Low Flow Cutoff in the calibration menu is set above this value, the meter will read zero flow. The Lvl level can be checked at no flow. At no flow, the Lvl must be below the Low Flow Cutoff setting or the meter will have an output at no flow
Adj. Filter	Adjustable filter. Displays filtering in decibels. Normally reads zero. If value is consitently –5 or –10, for example, the Ck or density setting may be wrong.
O,I	Factory use only.

Table 4-1: Column One Hidden Diagnostic Values

Designation	Description
Pulse Out Queue	Pulse output queue. This value will accumulate if the totalizer is accumulating faster than the pulse output hardware can function. The queue will allow the pulses to "catch up" later if the flow rate decreases. A better practice is to slow down the totalizer pulse by increasing the value in the (unit)/pulse setting in the totalizer menu.
TOF, G, f	Factory use only.
Sig. Rev	Signal board hardware and firmware revision.
Miro Rev	Microprocessor board hardware and firmware revision.
AD, R, T, F, PT, V	Factory use only.
SPR Err, Rcv, Sent	Factory use only.

Column Two Hidden Diagnostic Values

Table 4-2: Column Two Hidden Diagnostic Values

Designation	Description
4-20(1) Zero	Analog counts to calibrate zero on analog output 1.
4-20(1) FScale	Analog counts to calibrate full scale on analog output 1.
4-20(2) Zero	Analog counts to calibrate zero on analog output 2.
4-20(2) FScale	Analog counts to calibrate full scale on analog output 2.
4-20(3) Zero	Analog counts to calibrate zero on analog output 3.
4-20(3) FScale	Analog counts to calibrate full scale on analog output 3.
Alarm (1) Test	Used as a test to verify that the alarm circuit is functioning. When low is selected the alarm will initiate a low alarm on the output. When High is selected it will give a high alarm on the output.
Alarm (2) Test	Used as a test to verify that the alarm circuit is functioning. When low is selected the alarm will initiate a low alarm on the output. When High is selected it will give a high alarm on the output.
Alarm (3) Test	Used as a test to verify that the alarm circuit is functioning. When low is selected the alarm will initiate a low alarm on the output. When High is selected it will give a high alarm on the output.
Reynolds Corr.	Reynolds number correction for the flow profile. Set to Enable for MV82 insertion and set to Disable for MV80 inline.
Gain Control	Manual gain control (factory use only). Leave set at 1.
Filter Control	Manual filter control. This value can be changed to any number to force the **fi** value to a constant. A value of zero activates the automatic filter control which sets **fi** at a level that floats above the **f** value.
High Pass Filter	Filter setting (factory use only).

Table 4-2: Column Two Hidden Diagnostic Values

Designation	Description
Factory Defaults	Reset factory defaults. If you change this to YES and press ENTER, all factory configuration is lost and you must reconfigure the entire program. Consult the factory before performing this process. It is required only in very rare cases.
Meter Type	Insertion MV82 or Inline (MV80) meter.
Config Code	Factory use only.
Test Pulse Out	Force totalizer pulse. Set to **YES** and press enter to send one pulse. Very useful to test totalizer counting equipment.
A2D Ref. Resistor	Factory use only.
Factory Defaults	Reset to factory defaults. If you change this to **YES** and press ENTER, all factory configuration is lost and you must reconfigure the entire program. Consult the factory before performing this process. It is required only in very rare cases.
Force Tot Pulse	Force totalizer pulse. Set to YES and press ENTER to send one pulse. Very useful to test totalizer counting equipment.
Pressure 9Cs	Nine pressure coefficients unique to the pressure transducer. Use the RIGHT ARROW to access all nine coefficients.
Pressure Cal Current	Calibration value for the electronics and pressure transducer combination. Consult factory for value.
RTD1	Press the RIGHT ARROW to access:
• Ro	RTD resistance at 0°C (1000 ohms).
• A	RTD coefficient A (.0039083).
• B	RTD coefficient B (-5.775e-07).
• Slope	Unique value for each set of electronics.
• Int	Unique value for each set of electronics.
RTD2	Second RTD configuration, for special applications only.
Min. Delta H	Energy EMS meters only. Sets the deadband for totalization to begin. Must be greater than this number (1 default) to initiate the totalizer.

Analog Output Calibration

To check the 4–20 mA circuit, connect a DVM in series with the output loop. Select zero or full scale (from the second column of the hidden diagnostics) and then actuate the ENTER key twice. This action will cause the meter to output its 4 mA or 20 mA condition. If the DVM indicates a current greater than ± 0.006 mA from 4 or 20, adjust the setting up or down until the output is calibrated.

Note: *These settings are not for adjusting the output zero and span to match a flow range. That function is located in the Output Menu.*

Troubleshooting the Flowmeter

Symptom: Output at no Flow

The low flow cutoff is set too low. At no flow, go to the first column of the hidden diagnostics menu and record the Lvl value. The low flow cutoff must be set above this value.

Example: At no flow, Lvl = 25. Set the low flow cutoff in the Calibration Menu to approximately 28 and the meter will no longer read a flow rate at no flow.

Symptom: Erratic Output

1. The flow rate may be too low, just at the cutoff of the meter range, and the flow cycles above and below the cutoff making an erratic output. The meter range is stamped on the label on the outside of the electronics enclosure cover (based on application conditions when the meter was ordered). Consult the factory if necessary to confirm the meter range based on current operating conditions. It may be possible to lower the low flow cutoff to increase the meter range. See the example above for output at no flow, only this time the low flow cutoff is set too high. You can lower this value to increase the meter range as long as you do not create the output at no flow condition previously described.

2. Mechanical installation may be incorrect. Verify the straight run is adequate as described in Chapter 2. For in-line meters, make sure the meter is not installed backwards and there are no gaskets protruding into the flow stream. For insertion meters, verify the insertion depth and flow direction.

3. The meter may be reacting to actual changes in the flow stream. The output can be smoothed using a time constant. The displayed values can be smoothed using the time constant in the Display Menu. The analog outputs can be smoothed using the time constant in the Output Menu. A time constant of 1 will result in the change in value reaching 63% of its final value in one second. A time constant of 4 is 22%, 10 is 9.5% and 50 is 1.9% of the final value in one second. The time constant equation is shown below (TC = Time Constant).

   $$\%\text{ change to final value in one second} = 100\,(1 - e^{(-1/TC)})$$

4. The vortex coefficient Ck may be incorrectly set. The Ck is a value in the equation used to determine if a frequency represents a valid vortex signal given the fluid density and signal amplitude. In practice, the Ck value controls the adaptive filter, **fi**, setting. During flow, view the **f** and **fi** values in the first column of the hidden diagnostics. The **fi** value should be approximately 10-20 % higher than the **f** value. If you raise the Ck setting in the Calibration Menu, then the **fi** value will increase. The **fi** is a low pass filter, so by increasing it or lowering it, you can alter the range of frequencies that the meter will accept. If the vortex signal is strong, the **fi** value will increase to a large number – this is correct.

Note: *At high frequencies, the display may not be able to display all the digits of the **fi** value (for example, 114 may be displayed and the actual value is 1140).*

Symptom: No Output

1. For remote mounted electronics, carefully check all the wiring connections in the remote mount junction box. There are 18 connections that must be correct, verify each color (black and red), shield, and wire number.
2. Turn on the pressure and temperature display in the Display Menu and verify that the pressure and temperature are correct.
3. Using ESD precautions and hazardous area precautions, remove the electronics enclosure window cover. Disconnect the vortex sensor from the analog board (the analog board is the first board below the microprocessor (display) board. Measure the resistance from each outside pin to the meter ground - each should be open. Measure the resistance from the center pin to the meter ground – this should be grounded to the meter. With the sensor still disconnected, go to the first column of the hidden diagnostics and display the vortex shedding frequency, **f**. Hold a finger on the three exposed pins on the analog board. The meter should read electrical noise, 60 Hz for example. If all readings are correct, re-install vortex sensor wires.
4. Verify all meter configuration and troubleshooting steps previously described. There are many possible causes of this problem, consult factory if necessary.

Symptom: Meter Displays Temperature Fault

1. For remote mounted electronics, carefully check all the wiring connections in the remote mount junction box. There are 18 connections that must be correct, verify each color (black and red), shield, and wire number.
2. Go to the first column of the hidden diagnostics and check the resistance of the rtd1. It should be about 1080 ohms at room temperature.
3. Using ESD precautions and hazardous area precautions, remove the electronics enclosure window cover. Disconnect the temperature sensor (on the right) from the pressure / temperature board (the pressure / temperature board is the second board below the microprocessor (display) board. Measure the resistance across the outside pins of the temperature sensor connector. It should read approximately 1080 ohms at room temperature (higher resistance at higher temperatures). With the temperature sensor still disconnected, measure the current across the two outside pins of the exposed connector on the temperature / pressure board. The current should be approximately .0002 amps. Now reconnect the temperature sensor and measure the voltage across the two inside pins (insert probes into the connector where the wires enter it). This value should be approximately .2 volts (or .0002 amps times measured resistance, .216 volts at room temperature).
4. Consult factory with findings.

Symptom: Meter Displays Pressure Fault

1. For remote mounted electronics, carefully check all the wiring connections in the remote mount junction box. There are 18 connections that must be correct, verify each color (black and red), shield, and wire number.
2. Using ESD precautions and hazardous area precautions, remove the electronics enclosure window cover. Disconnect the pressure sensor (on the left) from the pressure / temperature board (the pressure / temperature board is the second board below the microprocessor (display) board. Measure the resistance across the outside pins of the pressure sensor connector, then across the inside pins. Both readings should be approximately 4000 ohms. With the pressure sensor still disconnected, measure the current across the two outside pins of the exposed connector on the temperature / pressure board. The current should be approximately .0004 amps.
3. Go to the first column of the hidden diagnostics and record the Pe(V) and Pv(V) values and consult the factory with findings.

Electronics Assembly Replacement (All Meters)

!WARNING!
Before attempting any flowmeter repair, verify that the line is not pressurized. Always remove main power before disassembling any part of the mass flowmeter.

The electronics boards are electrostatically sensitive. Wear a grounding wrist strap and make sure to observe proper handling precautions required for static-sensitive components.

1. Turn off power to the unit.
2. Locate and loosen the small set screw which locks the larger enclosure cover in place. Unscrew the cover to expose the electronics stack.
3. Locate the sensor harnesses which come up from the neck of the flowmeter and attach to the circuit boards. Use small pliers to pull the sensor wiring connectors off of the circuit boards.
4. Locate and loosen the small set screw which locks the smaller enclosure cover in place. Unscrew the cover to expose the field wiring strip. Tag and remove the field wires.
5. Remove the screws that hold the black wiring label in place. Remove the label.
6. Locate the 4 Phillips head screws which are spaced at 90° around the terminal board. These screws hold the electronics stack in the enclosure. Loosen these screws.

Note: *These are captive screws. They will stay inside the enclosure.*

Electronics Assembly Replacement (All Meters) (cont.)

7. Carefully remove the electronics stack from the opposite side of the enclosure. If the electronics stack will not come out, gently tap the terminal strip with a screw driver handle. This will loosen the rubber sealing gasket on the other side of the enclosure wall. Be careful that the stack does not hang up on loose sensor harnesses.
8. Repeat steps 1 through 6 in reverse order to install the new electronics stack.

Pressure Sensor Replacement (Series MV80 Only)

1. For local mounted electronics, remove the electronics stack as previously described. For remote mount electronics, remove all wires and sensor connectors from the remote feedthrough board in the junction box at the meter.
2. Loosen the three set screws at the center of the adapter between the meter and the enclosure.
3. Remove the top half of the adapter to expose the pressure transducer.
4. Remove the transducer and replace it with the new one using appropriate thread sealant.
5. Reassemble in reverse order.

Returning Equipment to the Factory

Before returning any PanaFlow MV flowmeter to the factory, contact Customer Service. When contacting Customer Service, be sure to have the meter serial number and model code.

When requesting further troubleshooting guidance, record the following values first:

f, **fi**, **G**, and **A** at no flow and during flow if possible.
Pressure, temperature, and flow rate

Appendix A

Specifications

Performance

Accuracy:

Table A-1: Accuracy Specifications

Process Variables	MV80 Series In-Line Meters		MV82 Series Insertion Meters[1]	
	Liquids	Gas & Steam	Liquids	Gas & Steam
Mass Flow Rate	±1% of rate over a 30:1 range[3]	±1.5% of rate[2] over a 30:1 range[3]	±1.5% of rate over a 30:1 range[3]	±2% of rate[2] over a 30:1 range[3]
Volumetric Flow Rate	±0.7% of rate over a 30:1 range[3]	±1% of rate over a 30:1 range[3]	±1.2% of rate over a 30:1 range[3]	±1.5% of rate over a 30:1 range[3]
Temperature	± 2° F (± 1° C)	± 2° F (± 1° C)	± 2° F (± 1° C)	± 2° F (± 1° C)
Pressure	0.4% of transducer full scale	0.4% of transducer full scale	0.4% of transducer full scale	0.4% of transducer full scale
Density	0.3% of reading	0.5% of reading[2]	0.3% of reading	0.5% of reading[2]

Notes: 1. Accuracies stated are for the total mass flow through the pipe.
2. Over 50 to 100% of the pressure transducer's full scale.
3. Nominal rangeability is stated. Precise rangeability depends on fluid and pipe size

Repeatability: Mass Flow Rate: 0.2% of rate.
Volumetric Flow Rate: 0.1% of rate.
Temperature: ± 0.2° F (± 0.1° C).
Pressure: 0.05% of full scale.
Density: 0.1% of reading.

Stability Over 12 Months: Mass Flow Rate: 0.2% of rate maximum.
Volumetric Flow Rate: Negligible error.
Temperature: ± 0.1° F (± 0.5° C) maximum.
Pressure: 0.1% of full scale maximum.
Density: 0.1% of reading maximum.

Response Time: Adjustable from 1 to 100 seconds.

Material Capability: Series MV80 In-Line Flowmeter:
Any gas, liquid or steam compatible with 316L stainless steel, C276 hastelloy or A105 carbon steel.
Not recommended for multi-phase fluids.

Series MV82 Insertion Flowmeter:
Any gas, liquid or steam compatible with 316L stainless steel.
Not recommended for multi-phase fluids.

Flow Rates: Typical mass flow ranges are given in Table A-2 on page A-2. Precise flow depends on the fluid and pipe size. MV82 insertion meters are applicable to pipe sizes from 2 inch and above. Consult factory for sizing program.

Flow Rates (cont.):

Table A-2: Water Minimum and Maximum Flow Rates

Units	Nominal Pipe Size (inches)								
	0.5	0.75	1	1.5	2	3	4	6	8
gpm	1 22	1.3 40	2.2 67	5.5 166	9.2 276	21 618	36 1076	81 2437	142 4270
m^3/hr	0.23 5	0.3 9.1	0.5 15	1.3 38	2.1 63	4.7 140	8.1 244	18 554	32 970

Table A-3: Typical Air Minimum and Maximum Flow Rates (SCFM) - Air at 70°F

Pressure	Nominal Pipe Size (inches)								
	0.5	0.75	1	1.5	2	3	4	6	8
0 psig	1.8 18	3 41	5 90	13 221	22 369	50 826	87 1437	198 3258	347 5708
100 psig	5 138	9 325	15 704	38 1730	63 2890	141 6466	245 11254	555 25515	972 44698
200 psig	7 258	13 609	21 1322	52 3248	86 5427	193 12140	335 21131	761 47911	1332 83931
300 psig	8 380	15 896	25 1944	63 4775	104 7978	234 17847	407 31064	922 70431	1615 123375
400 psig	10 502	18 1183	29 2568	72 6309	120 10542	269 23580	467 41043	1060 93057	1857 163000
500 psig	11 624	20 1472	33 3195	80 7849	134 13115	300 28034	521 51063	1182 115775	2071 203000

Table A-4: Typical Air Minimum and Maximum Flow Rates (nm^3/hr) - Air at 20°C

Pressure	Nominal Pipe Size (mm)								
	15	20	25	40	50	80	100	150	200
0 barg	3 28	5 66	9 142	21 350	36 584	79 1307	138 2275	313 5157	549 9034
5 barg	7 165	13 390	21 847	52 2080	87 3476	194 7775	337 13533	764 30682	1339 53749
10 barg	9 304	17 716	29 1554	70 3819	117 6381	262 14273	457 24844	1035 56329	1814 98676
15 barg	11 442	21 1044	34 2265	85 5565	142 9299	317 20801	551 36205	1250 82087	2190 143801
20 barg	13 582	24 1373	40 2979	97 7318	162 12229	363 27354	632 47612	1434 107949	2511 189105
30 barg	16 862	29 2034	48 4414	118 10843	198 18119	442 40529	770 70544	1745 159942	3057 280187

Flow Rates (cont.):

Table A-5: Typical Saturated Steam Minimum and Maximum Flow Rates (lb/hr)

	Nominal Pipe Size (in)								
Pressure	**0.5**	**0.75**	**1**	**1.5**	**2**	**3**	**4**	**6**	**8**
5 psig	6.5 52	12 122	20 265	49 650	82 1087	183 2431	318 4231	722 9594	1264 16806
100 psig	15 271	27 639	46 1386	112 3405	187 5690	419 12729	728 22156	1652 50233	2893 87998
200 psig	20 493	37 1163	62 2525	151 6203	253 10365	565 23184	983 40354	2229 91494	3905 160279
300 psig	24 716	45 1688	74 3664	182 9000	304 15040	680 33642	1184 58556	2685 132763	4704 232575
400 psig	28 941	51 2220	85 4816	209 11831	349 19770	780 44222	1358 76971	3079 174516	5393 305717
500 psig	31 1170	57 2760	95 5988	233 14711	389 24582	870 54987	1514 95710	3433 217001	6014 380148

Table A-6: Typical Saturated Steam Minimum and Maximum Flow Rates (kg/hr)

	Nominal Pipe Size (mm)								
Pressure	**0.5**	**0.75**	**1**	**1.5**	**2**	**3**	**4**	**6**	**8**
0 barg	3 18	5 42	8 91	19 224	32 375	72 838	126 1459	286 3309	500 5797
5 barg	6 95	11 224	18 485	45 1192	75 1992	167 4455	290 7754	658 17581	1153 30799
10 barg	8 168	15 397	24 862	59 2118	99 3539	222 7915	387 13777	877 31237	1537 54720
15 barg	9 241	17 569	29 1236	71 3036	119 5073	266 11347	463 19750	1050 44779	1840 78444
20 barg	11 314	20 742	33 1610	81 3956	136 6611	304 14787	529 25738	1199 58355	2100 102226
30 barg	13 463	24 1092	40 2370	99 5822	165 9729	369 21763	642 37880	1455 85884	2548 150451

Linear Range: Smart electronics corrects for lower flow down to a Reynolds number of 5,000. The Reynolds number is calculated using the fluid's actual temperature and pressure monitored by the meter. Rangeability depends on the fluid, process connections and pipe size. Consult the factory for your application. Velocity rangeability under ideal conditions is as follows:

Liquids 30:1 - 1 foot per second velocity minimum
30 feet per second velocity maximum

Gases 30:1 - 10 feet per second velocity minimum
300 feet per second velocity maximum

Process Fluid Pressure:

Table A-7: MV80 Pressure Ratings

Process Connection	Material	Rating
Flanged	316 SS, A105 Carbon Steel, C276 Hastelloy	150, 300, 600 lb, PN16, PN40, PN64
Wafer	316 SS, A105 Carbon Steel, C276 Hastelloy	600 lb, PN64

Table A-8: MV82 Pressure Ratings

Probe Seal	Process Connection	Material	Rating	Ordering Code
Compression Fitting	2-inch MNPT	316L SS	ANSI 600 lb	CNPT
	2-inch 150 lb flange, DN50 PN16	316L SS	ANSI 150 lb, PN16	C150, C16
	2-inch 300 lb flange, DN50 PN40	316L SS	ANSI 300 lb, PN40	C300, C40
	2-inch 600 lb flange, DN50 PN64	316L SS	ANSI 600 lb, PN64	C600, C64
Packing Gland	2-inch MNPT	316L SS	50 psig	PNPT
	2-inch 150 lb flange, DN50 PN16	316L SS	50 psig	P150, P16
	2-inch 300 lb flange, DN50 PN40	316L SS	50 psig	P300, P40
Packing Gland with Removable Retractor	2-inch MNPT	316L SS	ANSI 300 lb	PM, RR
	2-inch 150 lb flange, DN50, PN16	316L SS	ANSI 150 lb	P150, P16, RR
	2-inch 300 lb flange	316L SS	ANSI 300 lb	P300, P40, RR
Packing Gland with Permanent Retractor	2-inch MNPT	316L SS	ANSI 600 lb	PNPTR
	2-inch 150 lb flange, DN50 PN16	316L SS	ANSI 150 lb	P150R, P16R
	2-inch 300 lb flange, DN50, PN40	316L SS	ANSI 300 lb	P300R, P40R
	2-inch 600 lb flange, DN50 PN64	316L SS	ANSI 600 lb	P600R, P64R

Pressure Transducer Ranges:

Table A-9: Pressure Sensor Ranges[1]

Full Scale Operating Pressure		Maximum Over-Range Pressure	
psia	**(bara)**	**psia**	**(bara)**
30	2	60	4
100	7	200	14
300	20	600	40
500	35	1000	70
1500	100	2500	175

[1]To maximize accuracy, specify the lowest full scale operating pressure range for the application. To avoid damage, the flowmeter must never be subjected to pressure above the over-range pressure shown above.

Operation

Power Requirements: 12 to 36 VDC, Loop Powered for the Volumetric option only.
12 to 36 VDC, 100 mA for the Multiparameter Mass options.
100 to 240 VAC, 50/60 Hz, 25W for Multiparameter Mass options.

Display: Alphanumeric 2 x 16 LCD digital display.
Six push-button switches (up, down, right, left, ENTER, EXIT) operable through explosion-proof window using hand-held magnet.
Viewing at 90-degree mounting intervals.

Process Fluid Temperature: Standard temperature sensor: –40°F to 500°F (–40°C to 260°C).
High temperature sensor: to 750°F (to 400°C).

Ambient Temperature: Operating: –5°F to 140°F (–20°C to 60°C).
Storage: –40° F to 150° F (–40° C to 65° C).
0-98% relative humidity, non-condensing conditions.

Output Signals[1]: Analog Volumetric Meter: Field rangeable linear 4-20 mA output signal (1000 Ohms maximum loop resistance) selected by user for mass flow rate or volumetric flow rate.

Communications: HART, MODBUS, RS485

Multiparameter Meter: Up to three field rangeable linear 4-20 mA output signals (1000 Ohms maximum loop resistance) selected from the five parameters–mass flow rate, volumetric flow rate, temperature, pressure and density.

Pulse: Pulse output for totalization is a 50-millisecond duration pulse operating a solid-state relay capable of switching 40VDC, 40mA max.

[1]All outputs are optically isolated and require external power for operation.

Alarms: Up to three programmable solid-state relays for high, low or window alarms capable of switching 40 VDC, 40 mA maximum.

Totalizer: Based on user-determined flow units, six significant figures in scientific notation. Total stored in non-volatile memory.

Physical

Wetted Materials: Series MV80 In-Line Flowmeter:
316L stainless steel standard.
C276 hastelloy or A105 carbon steel optional.

Series MV82 Insertion Flowmeter:
316L stainless steel standard.
PTFE packing gland below 500° F (260° C).
Graphite packing gland above 500° F (260° C).

Enclosure: NEMA 4X cast enclosure.

Electrical Ports: Two 3/4-inch female NPT ports.

Mounting Connections: Series MV80:
Wafer, 150, 300, 600 lb ANSI flange, PN16, PN40, PN64 flange.

Series MV82 Permanent installation:
2-inch MNPT; 150, 300, 600 lb ANSI flange, PN16, PN40, PN64 flange with compression fitting probe seal.

Series MV82 Hot Tap[1] Installation:
2-inch MNPT; 150, 300, 600 lb ANSI flange, PN16, PN40, PN64 flange and optional retractor with packing gland probe seal.

[1]Removable under line pressure.

Mounting Position: Series MV80 In-Line Flowmeter: No effect.
Series MV82 Insertion Flowmeter: Meter must be perpendicular within ± 5° of the pipe centerline.

Certifications

Construction Inspection (ANSI/ASME B31.3).
Materials (NACE MR-01-75[90]).
CE and FM approved.
CSA, CENELEC approval pending.

FM approvals: Class I, Division 1, Groups B, C, & D, T6 at Tamb = 60°C
Class II/III, Division 1, Groups E, F, & G
IP66, NEMA 4X

Appendix B

Glossary

A Cross sectional area.

ACFM Actual Cubic Feet Per Minute (volumetric flow rate).

ASME American Society of Mechanical Engineers.

Bluff Body A non-streamlined body placed into a flow stream to create vortices. Also called a Shedder Bar.

BTU British Thermal Unit, an energy measurement.

Cenelec European Electrical Code.

Compressibility Factor A factor used to correct for the non-ideal changes in a fluid's density due to changes in temperature and/or pressure.

CSA Canadian Standards Association.

d Width of a bluff body or shedder bar.

D Diameter of a flow channel.

f Frequency of vortices generated in a vortex flowmeter, usually in Hz.

Flow Channel A pipe, duct, stack, or channel containing flowing fluid.

Flow Profile A map of the fluid velocity vector (usually nonuniform) in a cross-sectional plane of a flow channel (usually along a diameter).

FM Factory Mutual.

Ft Foot, 12 inches, a measure of length.

Ft^2 Square feet, measure of area.

Ft^3 Cubic feet, measure of volume.

GPM Gallons Per Minute.

Hz Hertz, cycles per second.

In-Line Flowmeter A flowmeter which includes a short section of piping which is put in-line with the user's piping.

Insertion Flowmeter A flowmeter which is inserted into a hole in the user's pipeline.

Joule A unit of energy equal to one watt for one second. Also equal to a Newton-meter.

LCD Liquid crystal display.

$\dot{m}$ Mass flow rate.

mA Milli-amp, one thousandth of an ampere of current.

μ Viscosity, a measure of a fluid's resistance to shear stress. Honey has high viscosity, alcohol has low viscosity.

ΔP Permanent pressure loss.

P Line pressure (psia or bar absolute).

ρ act The density of a fluid at the actual temperature and pressure operating conditions.

ρ std The density of a fluid at standard conditions (usually 14.7 psia and 20° C).

Permanent Pressure Loss Unrecoverable drop in pressure.

Piezoelectric Crystal A material which generates an electrical charge when the material is put under stress.

PRTD An resistance temperature detector (RTD) with platinum as its element. Used because of high stability.

psia Pounds per square inch absolute (equals psig + atmospheric pressure). Atmospheric pressure is typically 14.696 psi at sea level.

psig Pounds per square inch gauge.

P_V Liquid vapor pressure at flowing conditions (psia or bar absolute).

Q Flow rate, usually volumetric.

Rangeability Highest measurable flow rate divided by lowest measurable flow rate.

Reynolds Number or **Re** A dimensionless number equal to the density of a fluid, times the velocity of the fluid, times the diameter of the fluid channel, divided by the fluid viscosity (i.e., $Re = \rho VD/\mu$). The Reynolds number is an important number for vortex flowmeters because it is used to determine the minimum measurable flow rate. It is the ratio of the inertial forces to the viscous forces in a flowing fluid.

RTD Resistance temperature detector, a sensor whose resistance increases as the temperature rises.

scfm Standard cubic feet per minute (flow rate converted to standard conditions, usually 14.7 psia and 20° C).

Shedder Bar A non-streamlined body placed into a flow stream to create vortices. Also called a Bluff Body.

Strouhal Number or **St** A dimensionless number equal to the frequency of vortices created by a bluff body, times the width of the bluff body, divided by the velocity of the flowing fluid (i.e., St = fd/V). This is an important number for vortex flowmeters because it relates the vortex frequency to the fluid velocity.

Totalizer An electronic counter which records the total accumulated flow over a certain range of time.

Traverse The act of moving a measuring point across the width of a flow channel.

Uncertainty The closeness of agreement between the result of a measurement and the true value of the measurement.

V Velocity or voltage.

VAC Volts, alternating current.

VDC Volts, direct current.

VORTEX An eddy of fluid.

Appendix C

Fluid Calculations

Calculations for Steam T & P

When “Steam T & P” is selected in the “Real Gas” selection of the Fluid Menu, the calculations are based on the equations below.

Density

The density of steam is calculated from the formula given by Keenan and Keys. The given equation is for the volume of the steam.

$$v = \frac{4,555.04 \bullet T}{p} + B$$

$$B = B_0 + B_0^2\, g_1(\tau)\tau \bullet p + B_0^4 g_2(\tau)\tau^3 \bullet p^3 - B_0^{13} g_3(\tau)\tau^{12} \bullet p^{12}$$

$$B_0 = 1.89 - 2641.62 \bullet \tau \bullet 10^{80870r^2}$$

$$g_1(\tau) = 82.546 \bullet \tau - 1.6246 \bullet 10^5 \bullet \tau^2$$

$$g_2(\tau) = 0.21828 - 1.2697 \bullet 10^5 \bullet \tau^2$$

$$g_3(\tau) = 3.635 \bullet 10^{-4} - 6.768 \bullet 10^{64} \bullet \tau^{24}$$

Where tau is 1/ temperature in Kelvin.

The density can be found from 1/(v/ standard density of water).

Viscosity

The viscosity is based on an equation given by Keenan and Keys.

$$\eta(\text{poise}) = \frac{1.501 \bullet 10^{-5}\sqrt{T}}{1 + 446.8/T}$$

Where T is the temperature in Kelvin

Calculations for Gas ("Real Gas" and "Other Gas")

Use this formula to determine the settings for "Real Gas; Gas" selections and "Other Gas" selections entered in the Fluid Menu. The calculations for gas were taken from Richard W. Miller, Flow Measurement Engineering Handbook (Second Edition, 1989).

Density

The density for real gases is calculated from the equation:

$$\rho = \frac{GM_{w,\,Air}p_f}{Z_f R_0 T_f}$$

Where G is the specific gravity, M_w is the molecular weight of air, p_f is the flowing pressure, Z is flowing compressibility, R_0 is the universal gas constant, and T is the flowing temperature.

The specific gravity, and R_0 are known and are stored in a table used by the Vortex meter.

The hard coefficient to find is the compressibility, Z. Z is found using the Redlich-Kwong Equation (Miller page 2-18).

The Redlich-Kwong Equation uses the reduced temperature and pressure to calculate the compressibility factor. The equations are non-linear and an iterative solution is used. The Vortex program uses Newton's Method on the Redlich-Kwong equations to iteratively find the compressibility factor. The critical temperature and pressure used in the Redlich-Kwong equation are stored in the fluid data table with the other coefficients.

Viscosity

The viscosity for real gases is calculated using the exponential equation for two known viscosities. The equation is:

$$\mu_{cP} = aT_K{}^n$$

Where **a** and **n** are found from two known viscosities at two temperatures.

$$n = \frac{1n\left|(\mu_{cP})_2/(\mu_{cP})_1\right|}{1n(T_{K2}/T_{K1})}$$

and

$$a = \frac{(\mu_{cP})_1}{T_{K1}{}^n}$$

Calculations for Liquid

Use this formula to determine the settings for “Goyal-Dorais” selections and “Other Liquid” selections entered in the Fluid Menu. The liquid calculations were taken from Richard W. Miller, Flow Measurement Engineering Handbook (Second Edition, 1989).

Density

The liquid density is found using the Goyal-Doraiswamy Equation. Goyal-Doraiswamy uses the critical compressibility, critical pressure and critical temperature, along with the molecular weight to find the density. The equation for specific gravity is:

$$G_F = \frac{p_c Mw}{T_c}\left[\frac{0.008}{Z_c^{0.773}} - 0.01102\frac{T_f}{T_C}\right]$$

Viscosity

The liquid viscosity is found by Andrade's equation. This uses two viscosities at different temperatures to extrapolate the viscosity.

Andrade's equation:

$$\mu = A_L \exp\frac{B_L}{T_{degR}}$$

To find A and B

$$B_L = \frac{T_{degR1} T_{degR2} 1n(\mu_1 / \mu_2)}{T_{degR2} - T_{degR1}}$$

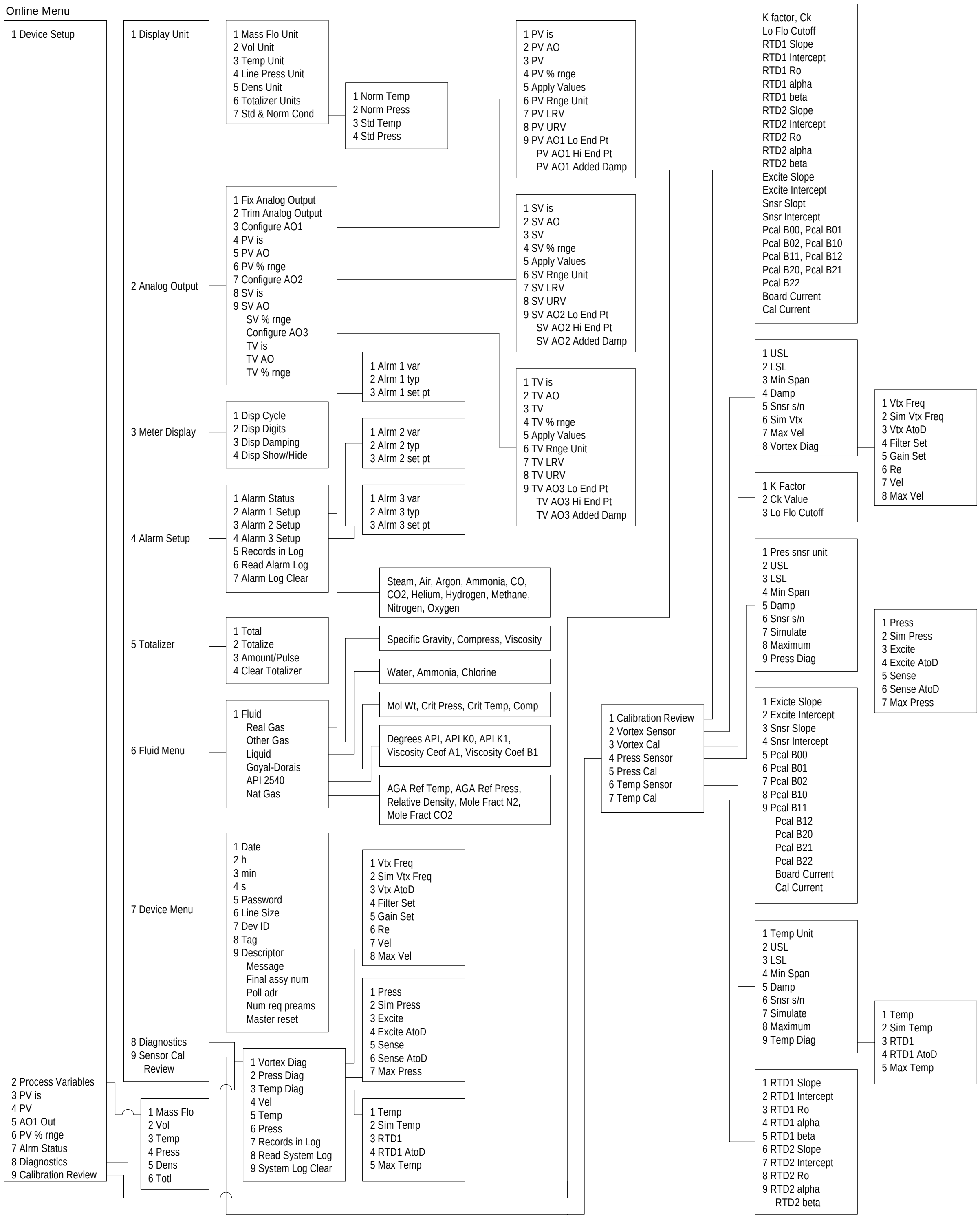
$$A_L = \frac{\mu_1}{\exp(B_L / T_{degR1})}$$

The temperatures are all in degrees Rankin. (The subscript R does not mean they are reduced temperatures.)

Appendix D

HART Commands

With DD Menu


Online Menu
1 Device Setup
2 Process Variables
3 PV is
4 PV
5 AO1 Out
6 PV % rnge
7 Alrm Status
8 Diagnostics
9 Calibration Review
1 Display Unit
2 Analog Output
3 Meter Display
4 Alarm Setup
5 Totalizer
6 Fluid Menu
7 Device Menu
8 Diagnostics
9 Sensor Cal Review
1 Mass Flo Unit
2 Vol Unit
3 Temp Unit
4 Line Press Unit
5 Dens Unit
6 Totalizer Units
7 Std & Norm Cond
1 Norm Temp
2 Norm Press
3 Std Temp
4 Std Press
1 Fix Analog Output
2 Trim Analog Output
3 Configure AO1
4 PV is
5 PV AO
6 PV % rnge
7 Configure AO2
8 SV is
9 SV AO
SV % rnge
Configure AO3
TV is
TV AO
TV % rnge
1 PV is
2 PV AO
3 PV
4 PV % rnge
5 Apply Values
6 PV Rnge Unit
7 PV LRV
8 PV URV
9 PV AO1 Lo End Pt
PV AO1 Hi End Pt
PV AO1 Added Damp
1 SV is
2 SV AO
3 SV
4 SV % rnge
5 Apply Values
6 SV Rnge Unit
7 SV LRV
8 SV URV
9 SV AO2 Lo End Pt
SV AO2 Hi End Pt
SV AO2 Added Damp
1 TV is
2 TV AO
3 TV
4 TV % rnge
5 Apply Values
6 TV Rnge Unit
7 TV LRV
8 TV URV
9 TV AO3 Lo End Pt
TV AO3 Hi End Pt
TV AO3 Added Damp
1 Disp Cycle
2 Disp Digits
3 Disp Damping
4 Disp Show/Hide
1 Alrm 1 var
2 Alrm 1 typ
3 Alrm 1 set pt
1 Alrm 2 var
2 Alrm 2 typ
3 Alrm 2 set pt
1 Alrm 3 var
2 Alrm 3 typ
3 Alrm 3 set pt
1 Alarm Status
2 Alarm 1 Setup
3 Alarm 2 Setup
4 Alarm 3 Setup
5 Records in Log
6 Read Alarm Log
7 Alarm Log Clear
1 Total
2 Totalize
3 Amount/Pulse
4 Clear Totalizer
Steam, Air, Argon, Ammonia, CO, CO2, Helium, Hydrogen, Methane, Nitrogen, Oxygen
Specific Gravity, Compress, Viscosity
Water, Ammonia, Chlorine
Mol Wt, Crit Press, Crit Temp, Comp
Degrees API, API K0, API K1, Viscosity Ceof A1, Viscosity Coef B1
AGA Ref Temp, AGA Ref Press, Relative Density, Mole Fract N2, Mole Fract CO2
1 Fluid
Real Gas
Other Gas
Liquid
Goyal-Dorais
API 2540
Nat Gas
1 Date
2 h
3 min
4 s
5 Password
6 Line Size
7 Dev ID
8 Tag
9 Descriptor
Message
Final assy num
Poll adr
Num req preams
Master reset
1 Vtx Freq
2 Sim Vtx Freq
3 Vtx AtoD
4 Filter Set
5 Gain Set
6 Re
7 Vel
8 Max Vel
1 Press
2 Sim Press
3 Excite
4 Excite AtoD
5 Sense
6 Sense AtoD
7 Max Press
1 Vortex Diag
2 Press Diag
3 Temp Diag
4 Vel
5 Temp
6 Press
7 Records in Log
8 Read System Log
9 System Log Clear
1 Temp
2 Sim Temp
3 RTD1
4 RTD1 AtoD
5 Max Temp
1 Mass Flo
2 Vol
3 Temp
4 Press
5 Dens
6 Totl
1 Calibration Review
2 Vortex Sensor
3 Vortex Cal
4 Press Sensor
5 Press Cal
6 Temp Sensor
7 Temp Cal
K factor, Ck
Lo Flo Cutoff
RTD1 Slope
RTD1 Intercept
RTD1 Ro
RTD1 alpha
RTD1 beta
RTD2 Slope
RTD2 Intercept
RTD2 Ro
RTD2 alpha
RTD2 beta
Excite Slope
Excite Intercept
Snsr Slopt
Snsr Intercept
Pcal B00, Pcal B01
Pcal B02, Pcal B10
Pcal B11, Pcal B12
Pcal B20, Pcal B21
Pcal B22
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Cal Current
1 USL
2 LSL
3 Min Span
4 Damp
5 Snsr s/n
6 Sim Vtx
7 Max Vel
8 Vortex Diag
1 Vtx Freq
2 Sim Vtx Freq
3 Vtx AtoD
4 Filter Set
5 Gain Set
6 Re
7 Vel
8 Max Vel
1 K Factor
2 Ck Value
3 Lo Flo Cutoff
1 Pres snsr unit
2 USL
3 LSL
4 Min Span
5 Damp
6 Snsr s/n
7 Simulate
8 Maximum
9 Press Diag
1 Press
2 Sim Press
3 Excite
4 Excite AtoD
5 Sense
6 Sense AtoD
7 Max Press
1 Exicte Slope
2 Excite Intercept
3 Snsr Slope
4 Snsr Intercept
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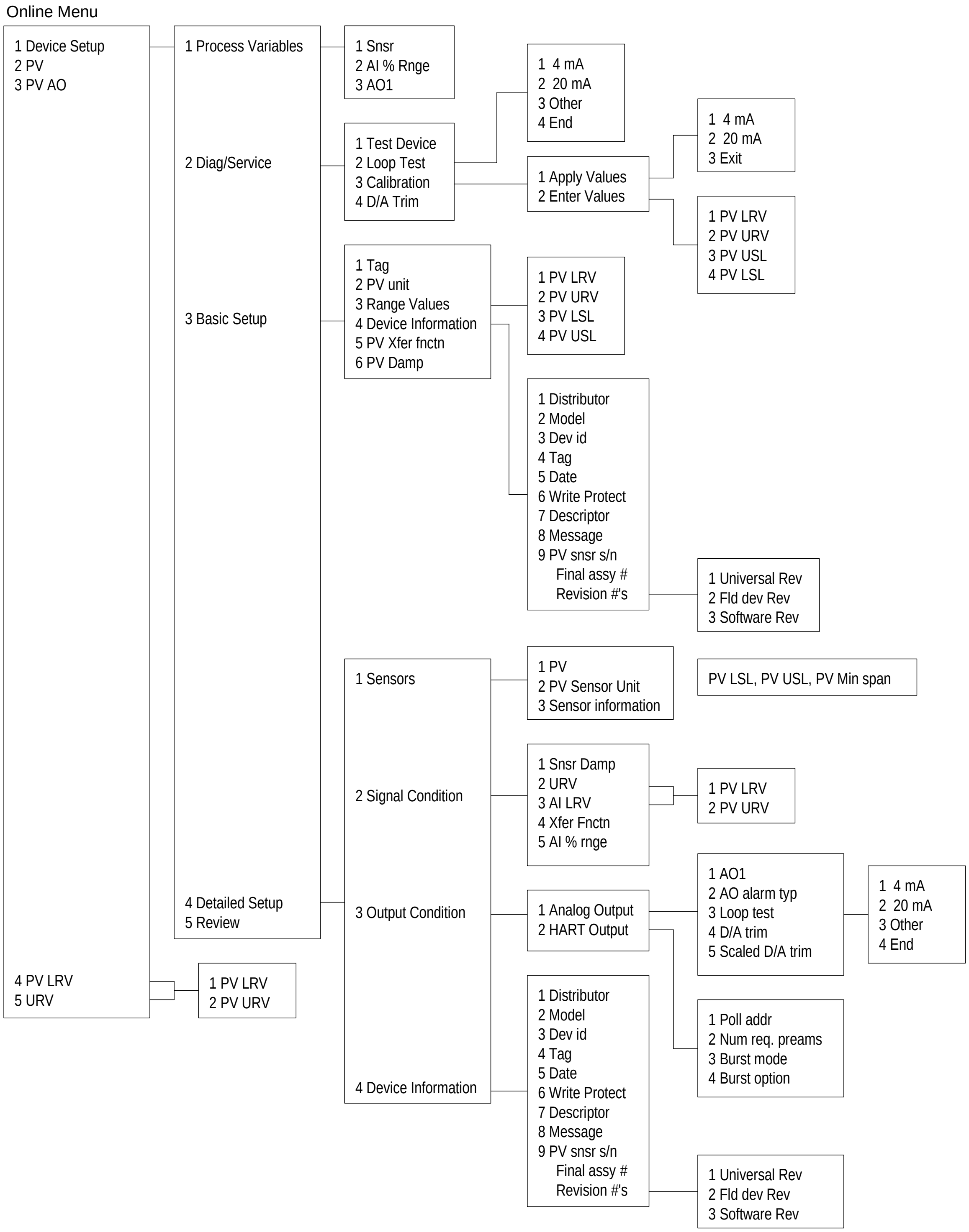
7 Simulate
8 Maximum
9 Temp Diag
1 Temp
2 Sim Temp
3 RTD1
4 RTD1 AtoD
5 Max Temp
1 RTD1 Slope
2 RTD1 Intercept
3 RTD1 Ro
4 RTD1 alpha
5 RTD1 beta
6 RTD2 Slope
7 RTD2 Intercept
8 RTD2 Ro
9 RTD2 alpha
RTD2 beta

Without DD Menu



Appendix E

MODBUS Communications

Overview

This section describes the preliminary implementation of MODBUS communication protocol for use in monitoring common process variables in the PanaFlow™ MV Vortex Flowmeter. The physical layer uses the half-duplex RS-485 port, and the MODBUS protocol.

Reference Documents

The following documents are available online from www.modbus.org.

- MODBUS Application Protocol Specification V1.1
- MODBUS Over Serial Line Specification & Implementation Guide V1.0
- Modicon MODBUS Protocol Reference Guide PI-MBUS-300 Rev. J

Menu Items

The following menu items are in the Output Menu and enable selection and control of the MODBUS communication protocol.

Address

When the MODBUS protocol is selected, the MODBUS address is equal to the user programmable device address if it is in the range 1…247, in accordance with the MODBUS specification. If the device address is zero or is greater than 247, the MODBUS address is internally set to 1.

Comm Protocol

The Comm Protocol menu enables selection of "MODBUS RTU Even," "MODBUS RTU Odd," or "MODBUS RTU None2," or "MODBUS RTU None1," (non-standard MODBUS) with Even, Odd and None referring to the parity selection. When even or odd parity is selected, the unit is configured for 8 data bits, 1 parity bit and 1 stop bit. With no parity, the number of stop bits is 1 (non-standard) or 2. When changing the protocol, the change is made as soon as the Enter key is pressed.

MODBUS Units

The MODBUS Units menu is to control the units, where applicable, in which the meter's variables will be displayed.

- Internal - the base units of the meter (°F, psia, lbm/sec , ft^3/sec, Btu/sec , lbm/ft^3)
- Display - variables are displayed in user-selected display units.

MODBUS Order

The byte order within registers, and the order in which multiple registers containing floating point or long integer data are transmitted, may be changed with this menu item. According to the MODBUS specification, the most significant byte of a register is transmitted first, followed by the least significant byte. The MODBUS specification does not prescribe the order in which registers are transmitted when multiple registers represent values longer than 16 bits. Using this menu item, the order in which registers representing floating point or long integer data and/or the byte order within the registers, may be reversed for compatibility with some PLCs and PC software.

The four selections in Table E-1 below are available in this menu. When selecting an item, the protocol is changed immediately without having to press the Enter key.

Table E-1: MODBUS Order Selections

Selection	Discription
0-1:2-3	Most significant register first, most significant byte first (default)
2-3:0-1	Least significant register first, most significant byte first
1-0:3-2	Most significant register first, least significant byte first
3-2:1-0	Least significant register first, least significant byte first

Note: *All of the registers are affected by the byte order, including strings and registers representing 16-bit integers. The register order affects the order of those registers representing 32-bit floating point and long integer data only. It does not affect single 16-bit integers or strings.*

MODBUS Protocol

The MODBUS RTU protocol is supported in this implementation. Supported baud rates are 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200. The default baud rate is 19200 baud. Depending upon the MODBUS protocol selected, data is transmitted in 8-bit data frames with even or odd parity and 1 stop bit, or no parity and 2 or 1 (non-standard) stop bits.

The current MODBUS protocol specification does not define register usage, but there is an informal register numbering convention derived from the original Modicon MODBUS protocol specification (now obsolete), and used by many vendors of MODBUS capable products (see Table E-2 below).

Table E-2: MODBUS Protocol Specifications

Registers	Usage	Valid Function Codes
00001-09999	Read/write bits ("coils")	01 (read coils) 05 (write single coil) 15 (write multiple coils)
10001-19999	Read-only bits ("discrete inputs")	02 (read discrete inputs)
30001-39999	Read-only 16 bit registers ("input registers"), IEEE 754 floating point register pairs, arbitrary length strings encoded as two ASCII characters per 16-bit register	03 (read holding registers) 04 (read input registers)
40001-49999	Read/write 16-bit registers ("holding registers"), IEEE 754 floating point register pairs, arbitrary length strings encoded as two ASCII characters per 16-bit register	03 (read holding registers) 06 (write single register) 16 (write multiple registers)

Each range of register numbers maps to a unique range of addresses that are determined by the function code and the register number. The address is equal to the least significant four digits of the register number minus one, as shown in the below.

Table E-3: Register Number Addresses

Registers	Function Codes	Data Type and Address Range
00001-09999	01, 05, 15	Read/write bits 0000-9998
10001-19999	02	Read-only bits 0000-9999
30001-39999	03, 04	Read-only 16-bit registers 0000-9998
40001-49999	03, 06, 16	Read/write 16-bit registers 0000-9998

Register Definitions

The meter serial number and those variables that are commonly monitored (mass, volume and energy flow rates, total, pressure, temperature, density, viscosity, Reynolds number, and diagnostic variables such as frequency, velocity, gain, amplitude and filter setting) are accessible using the MODBUS protocol. Long integer and floating point numbers are accessed as pairs of 16-bit registers in the register order selected in the MODBUS Order menu. Floating point numbers are formatted as single precision IEEE 754 floating point values.

The flow rate, temperature, pressure, and density variables may be accessed as either the flow meter internal base units or in the user-programmed display units, which is determined by the programming Output Menu's "MODBUS Units" item. The display units strings may be examined by accessing their associated registers. Each of these units string registers contain 2 characters of the string, and the strings may be 2 to 12 characters in length with unused characters set to zero.

Note: *The byte order affects the order in which the strings are transmitted.*

If the MODBUS Order menu (see page 2) is set to 0-1:2-3 or 2-3:0-1, the characters are transmitted in the correct order. If it is set to 1-0:3-2 or 3-2:1-0, each pair of characters will be transmitted in reverse order.

Table E-4: Register Definitions

Registers	Variable	Data Type	Units	Function Code	Addresses
65100-65101	Serial Number	unsigned long	–	03, 04	
30525-30526	Totalizer	unsigned long	display units*	03, 04	524-525
32037-32042	Totalizer Units	string	–	03, 04	2036-2041
30009-30010	Mass Flow	float	display units*	03, 04	8-9
30007-30008	Volume Flow	float	display units*	03, 04	6-7
30005-30006	Pressure	float	display units*	03, 04	4-5
30001-30002	Temperature	float	display units*	03, 04	0-1
30029-30030	Velocity	float	ft/sec	03, 04	28-29
30015-30016	Density	float	display units*	03, 04	14-15
30013-30014	Viscosity	float	cP	03, 04	12-13
30031-30032	Reynolds Number	float	–	03, 04	30-31
30025-30026	Vortex Frequency	float	Hz	03, 04	24-25
34532	Gain	char	–	03, 04	4531
30085-30086	Vortex Amplitude	float	Vrms	03, 04	84-85
30027-30028	Filter Setting	float	Hz	03, 04	26-27

Table E-4: Register Definitions

Registers	Variable	Data Type	Units	Function Code	Addresses
The following registers are available with the energy meter firmware:					
30527-30528	Totalizer #2	unsigned long	display units*	03, 04	526-527
32043-32048	Totalizer #2 Units	string	–	03, 04	2042-2047
30003-30004	Temperature #2	float	display units*	03, 04	2-3
30011-30012	Energy Flow	float	display units*	03, 04	10-11
The following registers contain the display units strings:					
32007-32012	Volume Flow Units	string	–	03, 04	2006-2011
32001-32006	Mass Flow Units	string	–	03, 04	2000-2005
32025-32030	Temperature Units	string	–	03, 04	2024-2029
32019-32024	Pressure Units	string	–	03, 04	2018-2023
32031-32036	Density Units	string	–	03, 04	2030-2035
32013-32017	Energy Flow Units	string	–	03, 04	2012-2017

Function codes 03 (read holding registers) and 04 (read input registers) are the only codes supported for reading these registers, and function codes for writing holding registers are not implemented. We recommend that the floating point and long integer registers be read in a single operation with the number of registers being a multiple of two. If these data are read in two separate operations, each reading a single 16-bit register, then the value will likely be invalid.

The floating point registers with values in display units are scaled to the same units as are displayed, but are instantaneous values that are not smoothed. If display smoothing is enabled (non-zero value entered in the Display TC item in the Display Menu), then the register values will not agree exactly with the displayed values.

Exception Status Definitions

The Read Exception Status command (function code 07) returns the exception status byte, which is defined as follows. This byte may be cleared by setting "coil" register #00003 (function code 5, address 2, data = 0xff00).

Table E-5: Exception Status Definitions

Bit(s)	Definition
0-1	Byte order (see MODBUS Order on page 2) 0 = 3-2:1-0, 1 = 2-3:0-1, 2 = 1-0:3-2, 3 = 0-1:2-3
2	Temperature sensor fault
3	Pressure sensor fault
4	A/D converter fault
5	Period overflow
6	Pulse overflow
7	Configuration changed

Discrete Input Definitions

The status of the three alarms may be monitored using the MODBUS Read Discrete Input command (function code 02). The value returned indicates the state of the alarm, and will be 1 only if the alarm is enabled and active (see Table E-6 below). A zero value is transmitted for alarms that are either disabled or inactive.

Table E-6: Discrete Input Definitions

Registers	Variable	Function Code	Address
10001	Alarm #1 state	02	0
10002	Alarm #2 state	02	1
10003	Alarm #3 state	02	2

Control Register Definitions

The only writeable registers in this implementation are the Reset Exception Status, Reset Meter and Reset Totalizer functions. They are implemented as "coils" which may be written with the Write Single Coil command (function code 05) to address 8 through 10, respectively, (register #00009 through #00011). The value sent with this command must be either 0x0000 or 0xff00, or the meter will respond with an error message. The totalizer will be reset or the exception status cleared only with a value of 0xff00.

Error Responses

If an error is detected in the message received by the unit, the function code in the response is the received function code with the most significant bit set, and the data field will contain the exception code byte, as shown in below.

Table E-7: Error Responses

Exception Code	Description
01	Invalid function code - function code not supported by device
02	Invalid data address - address defined by the start address and number of registers is out of range
03	Invalid data value - number of registers = 0 or >125 or incorrect data with the Write Single Coil command

If the first byte of a message is not equal to the unit's MODBUS address, if the unit detects a parity error in any character in the received message (with even or odd parity enabled), or if the message CRC is incorrect, the unit will not respond.

Command Message Format

The start address is equal to the desired first register number minus one. The addresses derived from the start address and the number of registers must all be mapped to valid defined registers, or an invalid data address exception will occur.

Table E-8: Command Message Format

Device Address	Function Code	Start Address	N = Number of Registers	CRC
8 bits, 1...247	8 bits	16 bits, 0...9998	16 bits, 1...125	16 bits

Table E-9: Normal Response Message Format

Device Address	Function Code	Byte Count = 2 x N	Data	CRC
8 bits, 1...247	8 bits	8 bits	(N) 16-bit registers	16 bits

.

Table E-10: Exception Response Message Format

Device Address	Function Code + 0x80	Exception Code	CRC
8 bits, 1...247	8 bits	8 bits	16 bits

Examples

Read the exception status byte from the device with address 1:

01 07 41 E2

01 Device address
07 Function code, 04 = read exception status

A typical response from the device is as follows:

01 07 03 62 31

01 Device address
07 Function code
03 Exception status byte
62 31 CRC

Request the first 12 registers from device with address 1:

01 04 00 00 00 0C F0 0F

01 Device address
04 Function code, 04 = read input register
00 00 Starting address
00 0C Number of registers = 12
F0 0F CRC

Examples (cont.)

A typical response from the device is as follows: *note these are the older register definitions

```
01 04 18 00 00 03 E8 00 00 7A 02 6C 62 00 00 41
   BA 87 F2 3E BF FC 6F 42 12 EC 8B 4D D1

01 Device address
04 Function code
18 Number of data bytes = 24
00 00 03 E8 Serial number = 1000 (unsigned long)
00 00 7A 02 Totalizer = 31234 lbm (unsigned long)
6C 62 00 00 Totalizer units = "lb" (string,
   unused characters are 0)
41 BA 87 F2 Mass flow rate = 23.3164 lbm/sec
   (float)
3E BF FC 6F Volume flow rate = 0.3750 ft3/sec
   (float)
42 12 EC 8B Pressure = 36.731 psia (float)
4D D1 CRC
```

An attempt to read register(s) that don't exist:

```
01 04 00 00 00 50 F1 D2

01 Device address
04 Function code 4 = read input register
00 00 Starting address
00 50 Number of registers = 80
F0 36 CRC
```

results in an error response as follows:

```
01 84 02 C2 C1

01 Device address
84 Function code with most significant bit set
indicates error response
02 Exception code 2 = invalid data address
C2 C1 CRC
```

Request the state all three alarms:

```
01 02 00 00 00 03 38 0B

01 Device address
02 Function code 2 = read discrete inputs
00 00 Starting address
00 03 Number of inputs = 3
38 0B CRC
```

Examples (cont.)

and the unit responds with:

01 02 01 02 20 49

01 Device address
02 Function code
01 Number of data bytes = 1
02 Alarm #2 on, alarms #1 and #3 off
20 49 CRC

To reset the totalizer:

01 05 00 00 FF 00 8C 3A

01 Device address
05 Function code 5 = write single coil
00 09 Coil address = 9
FF 00 Data to reset totalizer
8C 3A CRC (not the correct CRC EJS-02-06-07)

The unit responds with an identical message to that transmitted, and the totalizer is reset. If the "coil" is turned off as in the following message, the response is also identical to the transmitted message, but the totalizer is not affected.

01 05 00 00 00 00 CD CA

01 Device address
05 Function code 5 = write single coil
00 00 Coil address = 0
00 00 Data to "turn off coil" does not reset totalizer
CD CA CRC

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