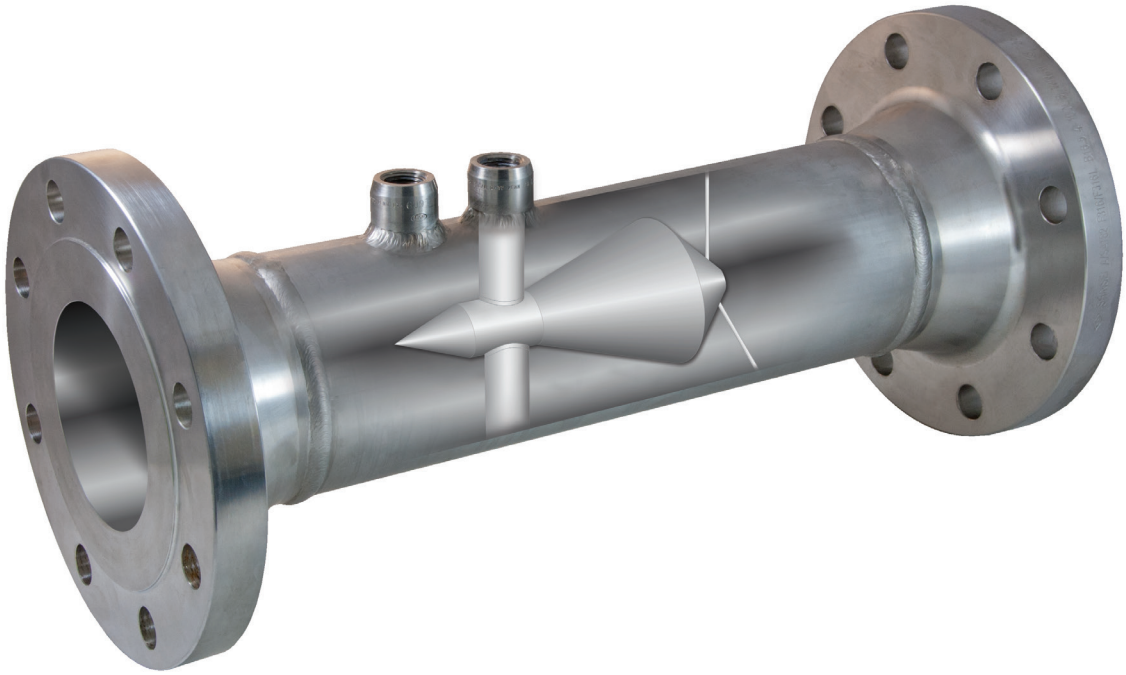
Preso®
Differential Pressure Flow Meters

Differential Pressure Flow Meter

Cone



Badger Meter

DPM-UM-00206-EN-05 (August 2021)

User Manual

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SCOPE OF THIS MANUAL

This manual contains instructions for installing and operating the Preso® Cone Differential Pressure Flow Meter.

IMPORTANT

Read this manual carefully before attempting any installation or operation. Keep the manual accessible for future reference.

SAFETY

Terminology and Symbols

⚠DANGER	Indicates a hazardous situation, which, if not avoided, will result in death or serious personal injury.
⚠WARNING	Indicates a hazardous situation, which, if not avoided, could result in death or serious personal injury.
⚠CAUTION	Indicates a hazardous situation, which, if not avoided, could result in minor or moderate personal injury or damage to property.

Considerations

⚠WARNING

NEVER OPEN A MANIFOLD VALVE OR FLANGE UNLESS YOU HAVE FIRST VERIFIED THAT THE SYSTEM IS COMPLETELY DEPRESSURIZED. DURING LIQUID OR WET GAS SERVICE, OPEN VALVES VERY SLOWLY TO AVOID SLUGGING IN THE METER RUN.

⚠WARNING

SECURE ALL CONNECTIONS PROPERLY BEFORE STARTING UP A SYSTEM. KEEP A SAFE DISTANCE AWAY FROM THE PROCESS UPON STARTUP.

⚠WARNING

BE MINDFUL OF STATIC ELECTRICITY GENERATED BY INSULATED FOOTWEAR ETC., AND ALWAYS GROUND YOURSELF BEFORE TOUCHING PIPES IN THE HAZARDOUS AREA WHERE FLAMMABLE GAS IS BEING METERED OR MAY BE PRESENT.

UNPACKING AND INSPECTION

Upon opening the shipping container, visually inspect the product and applicable accessories for any physical damage such as scratches, loose or broken parts, or any other sign of damage that may have occurred during shipment.

NOTE: If damage is found, request an inspection by the carrier's agent within 48 hours of delivery and file a claim with the carrier. A claim for equipment damage in transit is the sole responsibility of the purchaser.

⚠WARNING

ALWAYS USE PROPER PROCEDURES AND EQUIPMENT FOR LIFTING AND MOVING THE CONE METER TO AVOID RISK OF INJURY.

INTRODUCTION

The Preso Cone meter is a differential pressure device that combines excellent performance with many benefits including low maintenance, low head loss and a unique ability to have none/minimum straight pipe runs in front of the meter. The Cone meter produces a pressure differential across a pair of pressure measurement ports. The movement of a fluid around the cone-shaped element creates a pressure differential between an upstream and a downstream pressure port, which is processed by a differential pressure transmitter to provide the flow rate. The conical shape of the element also causes the flow meter to act as a flow straightener, pre-conditioning the flow and making the Cone meter a versatile measuring instrument for many applications. Badger Meter takes pride in designing an optimized differential pressure metering solution for your system.

Theory of Operation

The Preso Cone meter creates a differential pressure that is proportional to the rate fluid flow. A transmitter measures the differential pressure and outputs an integrated electronic signal, typically via Modbus or a 4…20 mA output, to a flow computer or other process controller for interpretation and readout. For compressible fluids, line pressure and temperature measurements are required for accurate flow rate calculations as well as compensation for the adiabatic change in the expansion factor. As fluid flowing through the pipe flows around the cone, a pressure drop occurs. The static line pressure (P1) is measured via a wall tap located just upstream of the cone. Pressure is also measured via a sensing tap that is connected to the cone and measures pressure at a point immediately downstream of the cone (P2). The fluid flow rate is calculated from the difference between the two pressures using variations of the Bernoulli flow principles and equations.

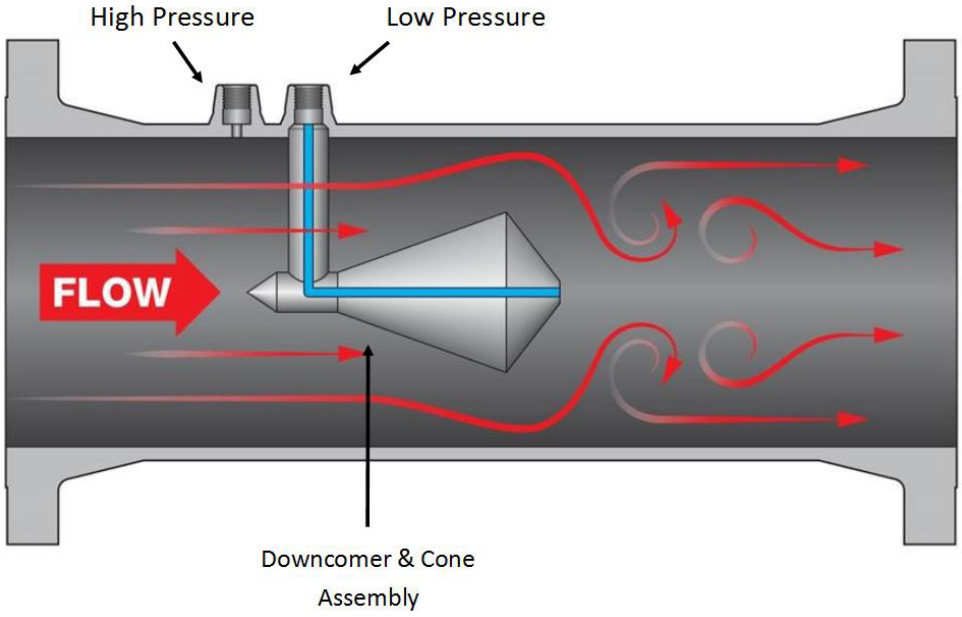


Figure 1: Principles of operation

Applications

The Cone meter is designed to work in unprocessed and processed applications, and is ideal for applications that present a wide range of measurement challenges. The Cone meter is a great solution for steam and boilers, coke oven gas, multiphase (non-homogeneous) fluids, biogas and industrial gas management.

Meter Components

The meter comprises three primary elements, as shown in *Figure 1 on page 6*:

- A meter body or tube with various available end connections.
- A cone assembly, either fabricated or machined from a solid piece of metal, positioned in the center of the meter tube.
- A pair of pressure taps—a wall tap upstream and an integral sensing tap downstream—for reading the differential pressure across the center of the meter tube. (Alternately a downstream tap may be used under certain process measurement conditions.)

The meter can be manufactured from various materials (carbon and stainless steels are standard, but more exotic materials such as duplex stainless steel or nickel-based alloys are also available upon request) to meet the specific requirements for metering steam, air, natural gas, digester gas, nitrogen, ethanol, and a host of media from crude oil to industrial gases.

Preso Cone meters are differential pressure flow devices providing highly accurate and repeatable measurements of liquids, gases and steam. The meter design provides longer lasting accuracy and lower permanent pressure loss than orifice type meters, reducing maintenance and operating costs. The Cone can be built to meet the highest pressure and temperature specifications often limited in other flow meter technologies. All models can also be supplied with RTD's and transmitters to provide an economical mass flow measurement solution.

System Components

Valve Manifolds

A 3-way or 5-way valve manifold isolates the transmitter from the process lines. A manifold allows the operator to calibrate the transmitter without removing it from the impulse tubing, draining the transmitter and impulse tubing or venting it to atmosphere. Valve manifolds must be oriented according to the manufacturer's instructions to prevent trapping air or liquid.

Shutoff Valves

Choose a blocking valve that is rated for the operating pressure of the pipe in which it will be installed. Where dangerous or corrosive fluids or gases like oxygen are likely, the blocking valve and packing must provide ample protection. The valves must not affect the transmission of the differential pressure signal.

Install blocking valves next to the Cone meter pressure taps.

Differential Pressure Transmitter

A differential pressure transmitter interprets the differential pressures generated by the cone within the meter body and provides an analog or serial output to a flow computer or data control system. Select a transmitter that is rated for accuracy and safety for your particular operating conditions.

Differential pressure devices must be zeroed following installation. The procedure varies somewhat for liquid, gas, and steam applications and by manufacturer. See the manufacturer's literature for complete procedures on zeroing the transmitter.

Meter Nameplate

This name plate identifies the proper specifications associated with the meter designed for the defined application. The direction of the flow is also indicated on each tag.

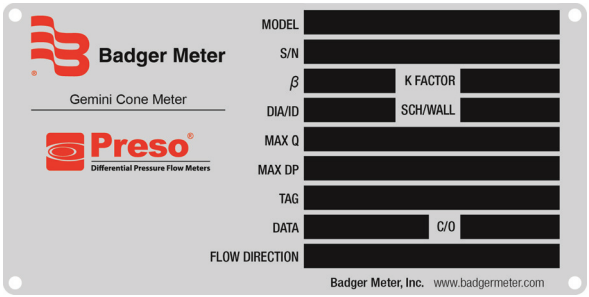
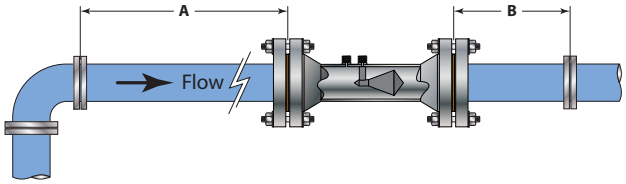
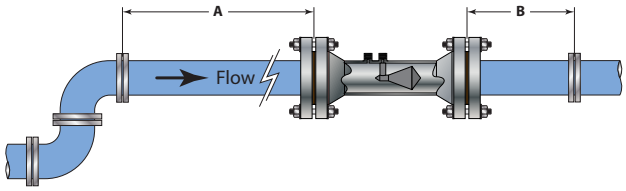
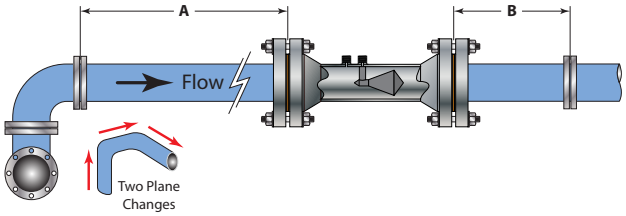
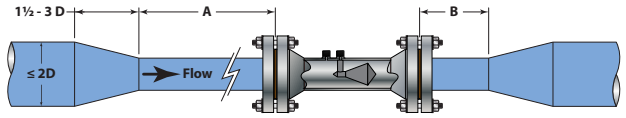


Figure 2: Nameplate

STRAIGHT PIPE RUN REQUIREMENTS

With most flow elements, proper operation and performance is dependent on the required lengths of unrestricted upstream and downstream piping. One of the advantages of the Cone meter is that a fully developed symmetrical flow profile is achieved with relatively short upstream and downstream lengths, so it needs minimal if any upstream and downstream straight pipe runs. We recommend that the Cone meter be installed with zero to five pipe diameters and zero to three pipe diameters downstream.

		0.4	0.5	0.6	0.7	0.8
 Single Elbow	**A**	0	0	0	1	1
	B	0	0	0	1	1
 Two Elbows In-Plane	**A**	0	0	0	1	1
	B	0	0	0	1	1
 Two Elbows Out of Plane	**A**	0	0	0	1	1
	B	0	0	0	1	1
 Pipe Reduction	**A**	1	1	1	2	2
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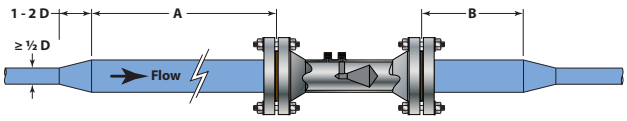
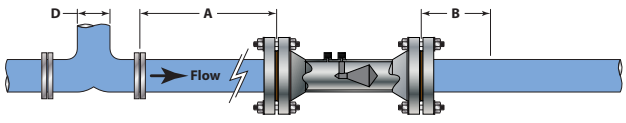
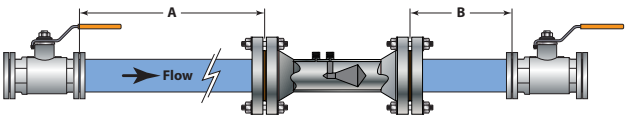
 Pipe Enlargement	**A**	1	1	1	2	2
	B	1	1	1	2	2
 Pipe With Tee	**A**	0	0	0	1	1
	B	0	0	0	1	1
 Gate/Globe Valve Fully Open/Partially Open	**A**	3	3	3	4	4
	B	0	0	0	1	1
	A	3	3	3	4	4
	B	3	3	3	4	4

INSTALLATION

Installation Basics

Here are the basic steps for installing a Cone meter system:

1. Install the meter in the meter run in accordance with the flow run requirements. See *"Straight Pipe Run Requirements" on page 8*.
2. Secure the manifold to the meter taps.
3. Connect the differential pressure transmitter to the manifold, following the guidelines in *"Mounting Location" on page 10*.
4. Connect the transmitter to the flow computer according to instructions in the transmitter user manual.
5. Zero the transmitter.

⚠CAUTION

NEVER USE EXCESSIVE PRESSURE OR FORCE WHEN CONNECTING TUBING TO A DIFFERENTIAL PRESSURE TRANSMITTER.

⚠CAUTION

IF HIGH-TEMPERATURE FLUIDS ARE LIKELY TO BE ENCOUNTERED, MAKE SURE THE CONNECTION TUBING IS RATED FOR THE ANTICIPATED TEMPERATURE RANGE.

Installation Checkpoints for the Transmitter

Before putting the Cone meter into service, verify that the transmitter is installed properly by reviewing the following checkpoints:

- Is the transmitter full scale correct?
- Has the transmitter zero been checked and/or adjusted?
- Are the transmitter and flow computer set to the appropriate modes—linear or square root?
- Have the transmission lines to the transmitter been purged?
- Are there any leaks in the transmission lines?
- Is the manifold bypass valve closed?
- Is the Cone meter's high pressure port located upstream of the low pressure port?

Mounting Location

The Cone meter should be installed with zero to five pipe diameters of straight run upstream of the meter and zero to three pipe diameters downstream (see *"Straight Pipe Run Requirements" on page 8*) . The meter can be used in pipelines that are slightly larger than the meter tube; however, if the meter tube is larger than the pipeline, operators should contact Badger Meter or installation requirements. This is usually determined before supply according to application and the degree of accuracy and performance required.

Meter Orientation and Transmitter Position

The location of the transmitter with respect to the meter should be based on the properties of the fluid being measured and the direction of flow through the pipeline. The direction of flow is clearly labeled on the body of every Cone meter. The meter must be installed so that the high pressure tap (labeled *P1* in *Figure 1 on page 6*) is always upstream of the low pressure tap labeled *P2*.

Vertical installations measuring liquids may introduce a slight hydrostatic head effect, which must be considered when zeroing a transmitter. With liquid applications, the meter should be installed so flow is moving UP to ensure a full pipe. Use of a 3-valve manifold for zeroing a transmitter. Before installation of any Cone meter, inspect the meter for damage, particularly at the sealing surfaces. Any damage should be reported to Badger Meter as soon as possible. Each flow element has an arrow indicating the required direction of flow. Failure to properly orient the meter according to the direction of flow will cause improper results and potentially damage the meter.

For vertical installations, the location of differential pressure taps is unrestricted, as long as the static pressure tap is upstream of the lower-pressure tap.

⚠ WARNING

NEVER EXCEED THE MAXIMUM PRESSURE OR TEMPERATURE RECOMMENDED FOR THE MEASURED PROCESS. EXCEEDING PROPER PRESSURE OR TEMPERATURE RATINGS CAN LEAD TO PERSONAL INJURY OR EQUIPMENT DAMAGE. THE PROCESS PIPING FLANGES SHOULD BE IDENTICAL TO THOSE ON THE CONE BOTH IN PRESSURE CLASS AND INSIDE DIAMETER. THE PROCESS TEMPERATURE AND PRESSURE SHOULD NEVER EXCEED THOSE FOR WHICH THE ELEMENT HAS BEEN DESIGNED.

⚠ CAUTION

IF HIGH-TEMPERATURE FLUIDS ARE LIKELY TO BE ENCOUNTERED, MAKE SURE THE CONNECTION FITTINGS VALVES AND TUBING ARE RATED FOR THE ANTICIPATED TEMPERATURE RANGE.

Pressure Tap Location

Location of the pressure taps will vary with the product flowing through the pipeline (liquid, gas, or steam) and the orientation of the meter (vertical or horizontal).

For horizontal installations, the following installation guidelines apply:

- For measuring liquid, differential pressure taps should be located in the bottom half of the pipeline, between 4 o'clock and 5 o'clock positions, or between 7 o'clock and 8 o'clock positions.
- For measuring gas, differential pressure taps should be located in the top half of the pipeline. For wet gas, taps should be located between the 10 o'clock and 2 o'clock positions to allow proper drainage of condensate.
- For steam, differential pressure taps should be located in the side of the pipeline at 3 o'clock or 9 o'clock.

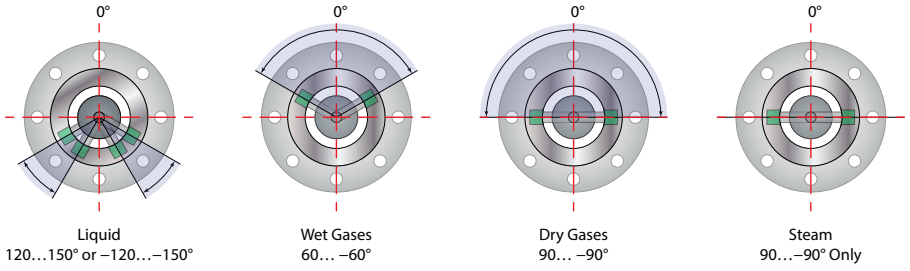


Figure 3: Typical piping configurations for liquid, gas, and steam

Line Installation

All flanged Cone meters require a gasket between the flange on the process line and the mating flange on the meter itself. Select gaskets that match the pressure and temperature ratings of the Cone flanges and resist corrosive properties of the process fluid.

Before completing the bolting process, make sure that the gaskets are properly centered so that protrusion into the pipe opening is minimized. Misalignment may cause added flow turbulence which can affect meter performance, although such effects are typically minimal (depending upon the application). Bolt the element in line with suitable hardware using recommended bolt torques for the type and class rating of the flanges.

⚠CAUTION

TORQUE ALL MODELS PER ANSI FLANGE RATINGS.

⚠CAUTION

DO NOT EXCEED SPECIFIED TORQUE.

NOTE: Tighten the flange bolts in a progressive star pattern to avoid localized stress on the gaskets.

Differential Pressure Connections

The high pressure connection is always on the upstream side of the flow direction arrow and the low pressure connection on the downstream side. Fittings used must be able to withstand the process temperature and pressure conditions, as well as provide proper corrosion resistance. See the appropriate secondary instrument instructions for connections to the secondary instrument high and low ports. Coat all fitting threads with a process compliant thread sealant prior to tightening. Once tightened, torque mark all fittings for future reference.

Transmitter Connection Tubing

Before connecting the Cone meter to the transmitter, consider the following tips for optimizing your system's measurement accuracy. In a well-designed installation, fluids will drain freely from the process lines and gases will vent to the atmosphere.

Full Port Block Valves

Adding block valves to the pressure taps of the meter will simplify any type of calibration or maintenance to any upstream components. Select valves that are compatible to the pressures, temperatures and system media.

Impulse Tubing Size Selection

Transmitter connection tubing, the tubing that connects the Cone meter taps to the transmitter, can vary in diameter for different applications. A minimum diameter of 3/8 inch (10 mm) for the internal diameter (ID) of the tubing is recommended, and as a general rule it should be no smaller than 1/4 inch (6 mm). The tubing ID must not exceed 1 inch (25 mm) at the maximum.

In most applications, the primary concern is measurement reliability. If the pressure taps or the connecting tubes become plugged, the reliability of the flow measurement is lost creating a safety risk. High reliability is required for any flow signals used to manage safety processes. A minimum tubing ID of 5/8 inch (16 mm) is recommended in industrial applications.

For steam applications, the ID should be 3/8… 1 in. (10…25 mm).

Impulse Tubing Length and Configuration

Impulse tubing is used to connect the sensing taps of the cone meter to the manifold connected to the differential pressure transmitter. One section of tubing should connect the high-pressure tap to the high-pressure side of the differential pressure transmitter; another section of tubing should connect the low-pressure tap to the low-pressure side of the differential pressure transmitter.

- Impulse tubing should be installed with a gradient of 1:12 at a minimum to help prevent undesirable fluids from being transferred to the differential pressure transmitter.
- If tubing is installed in a horizontal orientation, install a gas/liquid separator device.
- Avoid abrupt bends in impulse tubing.
- If impulse tubing sections are long, use mounting brackets to support them.
- Tubing length must be short enough for a high degree of accuracy, and long enough for proper cooling of high-temperature fluids before they reach the transmitter.
- Make sure the installation permits access to the connection tubes, valves, valve manifolds and transmitters for maintenance.
- Limit the number of fittings and avoid long tubing sections that can impair measurement accuracy and increase the risk of plugging.
- Avoid changes in tubing elevation. Differences in elevation will cause a difference in the hydrostatic pressure of the liquid column in the process lines, which can result in inaccurate differential pressure measurements. Fasten the process lines together, if possible, to keep their relative elevations consistent.
- Install process lines so that they slope in only one direction (up or down). If piping must slope in more than one direction, do not allow more than one bend. Install a liquid or gas trap at the lowest point in a gas service installation. Install gas trap at the highest point in a liquid service installation.

METER INSTALLATION FOR LIQUID SERVICE

Installation Options

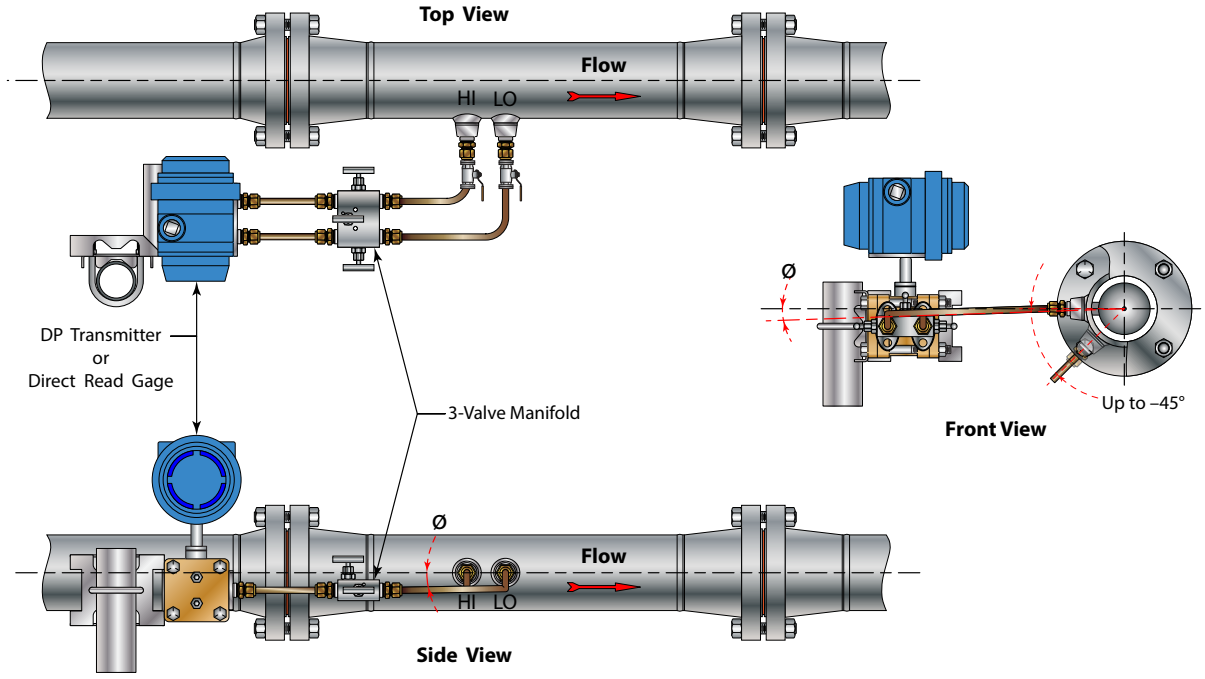
- **Meter Orientation**— Cone meters can be installed in a horizontal or vertical position. Horizontal is the standard orientation, however where space is very limited, a vertical position may prove to be the best option.
- **Pipe Orientation**—The orientation of piping is dictated by the position of the meter, the type of product being measured, and for vertical meter installations, the direction of flow. When a vertical piping system is used, the operator must give special consideration to the piping configuration to prevent gas from being trapped in liquid differential pressure lines.

Horizontal Meter Installation

For horizontal installations, pressure taps must be positioned 30…60° below the horizontal centerline (4…5 o'clock or 7…8 o'clock). Taps at the bottom of the pipe may become plugged with solids from the liquid; taps above the centerline can accumulate air or non-condensing gases. In liquid service, the connecting lines from the meter shall slope downward to the transmitter with no upturns or pockets. The minimum recommended slope for self-venting is 1:12.

Bubble Pot Installation (Optional)

In liquid applications where the transmitter must be mounted above the metering line, gas or vapor in the liquid can collect at the highest point in the instrument tubing and give a false differential pressure reading. Bubble pots may be the only effective solution for such installations. The piping from the meter connects to the bubble pot anywhere between the 10 o'clock and 2 o'clock positions on a horizontal plane.



Notes:
1. ø = 1 in/ft (80 mm/m) for water; 2…4 in/ft (160…320 mm/m) for more viscous fluids.
2. Minimize all lead line lengths.

Figure 4: Typical horizontal installation for liquids

Vertical Meter Installation

In most process applications, some level of gas or vapor exists in a liquid service, even if the liquid is water. As a result, the piping configuration must be designed so gas can rise back into the flow stream. The process piping should be extended horizontally a very short distance from the downstream tap and then sloped at a nominal 1:12 angle to the top of the manifold block. Mount the manifold block horizontally below the upstream tap so that piping from the upstream tap to the manifold slopes downward also.

⚠CAUTION

WHEN THE PROCESS IS TURNED OFF, PARTICULATES MAY SETTLE IN THE LOW-PRESSURE PORT. FLUSH THE LOW-PRESSURE PORT WITH AN INERT FLUID BEFORE STARTING THE METER.

NOTE: Do not use downward flow piping configurations that use the standard upstream and downstream pressure ports for liquid applications due to the risk of trapping gas.

Transmitter Calibration

Calibrate transmitters (differential pressure and/or multi-variable) according to the manufacturer's recommendations, appropriate national or company standards and contractually agreed methodology. Consider the process conditions in which the Cone meter and transmitter are installed and operated.

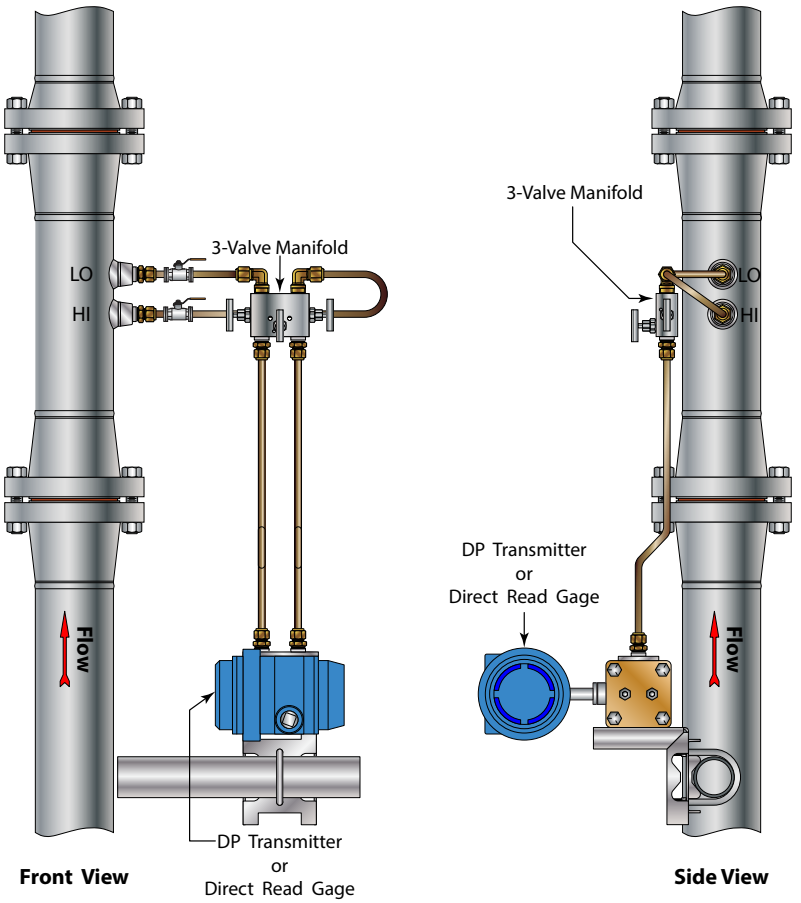


Figure 5: Typical vertical installation for liquids

METER INSTALLATION FOR GAS SERVICE

Installation Options

- **Meter Orientation**— Cone meters can be installed in a horizontal or vertical position. Horizontal is the standard orientation, however where space is very limited, a vertical position may be the best option.
- **Connection Tube Orientation**—The orientation of connection tubing is dictated by the position of the meter, the type of product being measured and, for vertical meter installations, the direction of flow. When a vertically oriented metering system is used, give special consideration to the tubing configuration to prevent liquid being trapped in gas differential pressure lines.

Horizontal Meter Installation

The pressure taps on the Cone meter should be between the horizontal centerline and the top of the pipe (3…12 o'clock or 9…12 o'clock). If the fluid is a wet gas (that is, a gas containing small quantities of liquids or condensate), situate the pressure taps in a vertical position (12 o'clock) to allow all liquids to drain away from the transmitter. If the connecting tubing extending from the cone meter to the transmitter is not installed in a vertical position, it should slope upward (at least 1:12) for proper drainage.

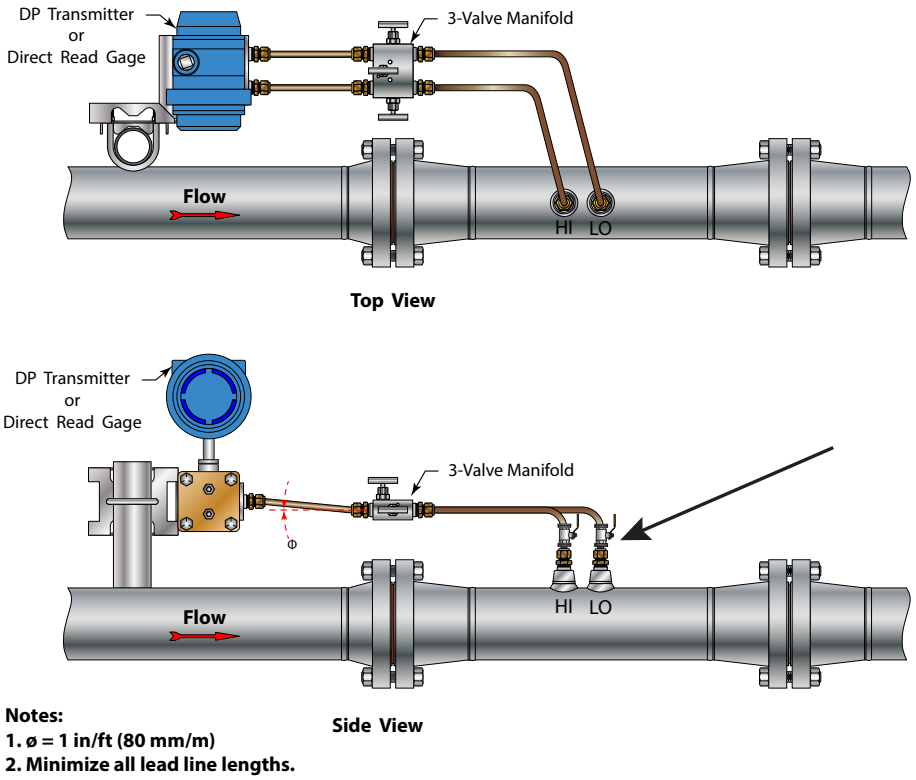


Figure 6: Typical horizontal installation for gases

Condensate Chamber (Drip Pot) (Optional for Wet Gas)

The condensate chamber is a collection vessel that helps prevent liquid pockets from collecting in gas instrument tubing.

If drip pots are used, they should ideally be mounted immediately following the shutoff valves installed near the upstream and downstream pressure taps of the meter. For wet gas applications, the piping from the meter connects to the condensate chamber in a 3 o'clock or 9 o'clock position on a horizontal plane. The chambers are positioned vertically so that the meter connection and instrument connection points are at the top and drain points are at the bottom of the chambers.

Vertical Meter Installation

When installing the meter in a vertical position, make sure that no trap forms in the downstream tap such that gas is trapped in a liquid or liquid is trapped in a gas.

When measuring dry, non-condensing gases, where there is absolutely no risk for liquid being present, extend the piping from the downstream pressure tap of the cone meter horizontally and then angle it upward to connect to the manifold block. Mount the manifold block horizontally. Slope the tubing from the upstream tap of the cone meter 1 in./ft to the same level as the downstream tap piping to connect to the manifold (see *Figure 7*).

⚠CAUTION

IF THERE IS ANY LIQUID PRESENT IN THE GAS, DO NOT USE THE PIPING ARRANGEMENT SHOWN IN Figure 7. THE "U" CONFIGURATION COULD TRAP LIQUID IN THE CONE, CHANGING THE DOWNSTREAM PRESSURE.

Transmitter Calibration

Calibrate transmitters (differential pressure and/or multi-variable) according to the manufacturer's recommendations, appropriate national or company standards and contractually agreed methodology. Consider the process conditions in which the Cone meter and transmitter are installed and operated.

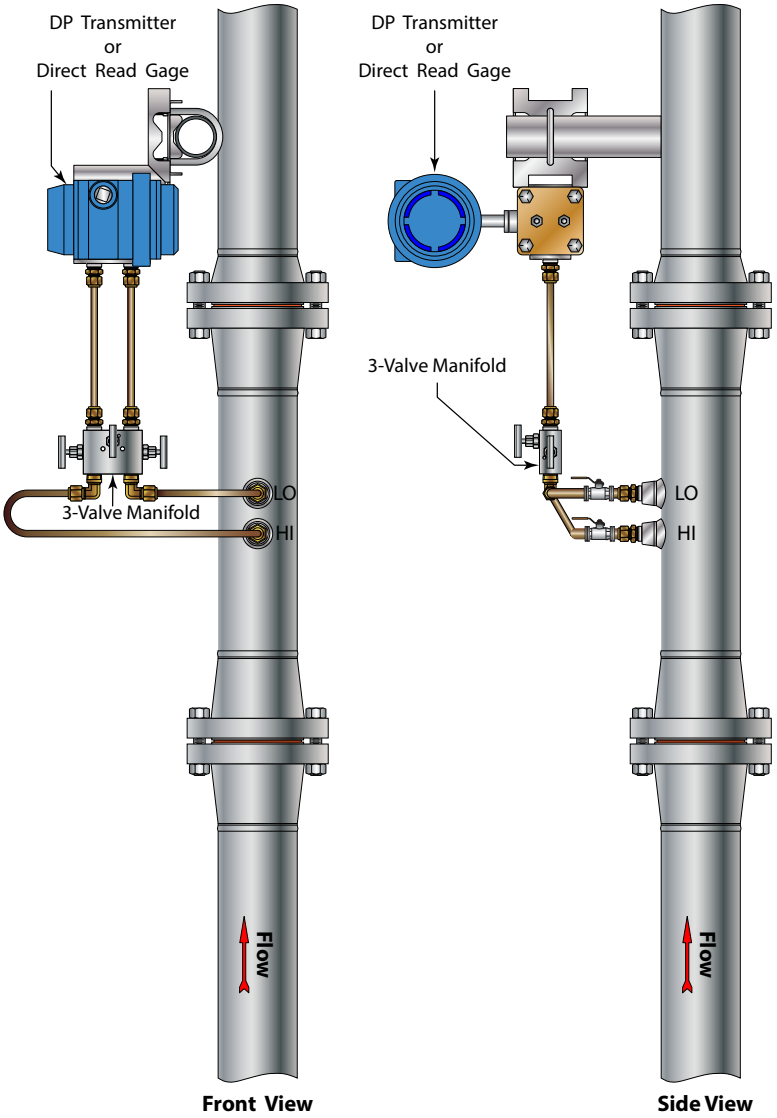


Figure 7: Typical vertical installation for gases

METER INSTALLATION FOR STEAM SERVICE

Steam measurement is one of the most difficult applications for differential pressure transmitter tubing and requires careful consideration during installation. Steam is usually at a high temperature, which will damage the transmitter. In addition, steam can vary between liquid or gaseous phase depending on temperature and pressure. Due to this, the differential pressure impulse tubing must be oriented in such a manner that it can operate with gas liquid, or a combination of the two present.

Installation Options

- **Meter Orientation**— Cone meters can be installed in a horizontal or vertical position. Horizontal is the standard orientation, however where space is very limited, a vertical position may prove to be the best option.
- **Connection Tubing Orientation**—The orientation of the impulse tubing is dictated by the orientation of the meter, the type quality of the steam being measured, and for vertical meter installations, the direction of flow. When a vertical meter run is used, the operator must give special consideration to the impulse tubing configuration to prevent liquid from being trapped in gas differential pressure lines.
- **Condensate Chamber**—The condensate chamber is a liquid reservoir that helps prevent steam from entering the differential pressure transmitter. In most cases, a large-diameter tee is all that is required to collect the liquid. However, if the DP measuring instrument is designed with hydraulic/pneumatic bellows (such a Barton 202E chart recorder), a larger volume condensate chamber will be required. Modern DP transmitters have very little diaphragm movement and do not require the large-volume condensate chamber.

Horizontal Meter Installation

Install the pressure taps above the horizontal centerline (9…3 o'clock) of the primary device. In condensing hot vapor service such as steam, the fluid in the impulse lines is liquid that has been condensed from the vapor. The use of a condensate chamber is mandatory to prevent hot process fluid from damaging the transmitter. Slope the impulse tubing upwards from the cone meter to the condensate pots. A condensate pot can be a tubing tee (for low volume DP instruments) or a full-size condensate chamber (for high volume DP instruments). In either case, install the condensate pots at exactly the same level to ensure accurate differential pressure readings. Fill the line from the bottom of the tee to the transmitter mounted below the tee to the point where excess fluid can drain back into the meter.

In many cases, water (steam condensate) is used for the fluid fill. However, in cold weather, the fluid must be protected from freezing. The fluid fill requires careful design with heat tracing and insulation to keep it in the liquid phase and to keep both the high-pressure and low-pressure legs of the tubing at the same temperature (maintaining the liquid fill at the same density). If practical, use a liquid leg fill fluid other than water. Methanol is a possible substitute, but dibutyl phthalate is the recommended fill fluid because it does not mix with water and remains liquid throughout a broad temperature range of, –31…644° F (–35…340° C).

IMPORTANT

Be careful when using dibutyl phthalate. Follow all hazardous material guidelines (CAS No: 87-74-2).

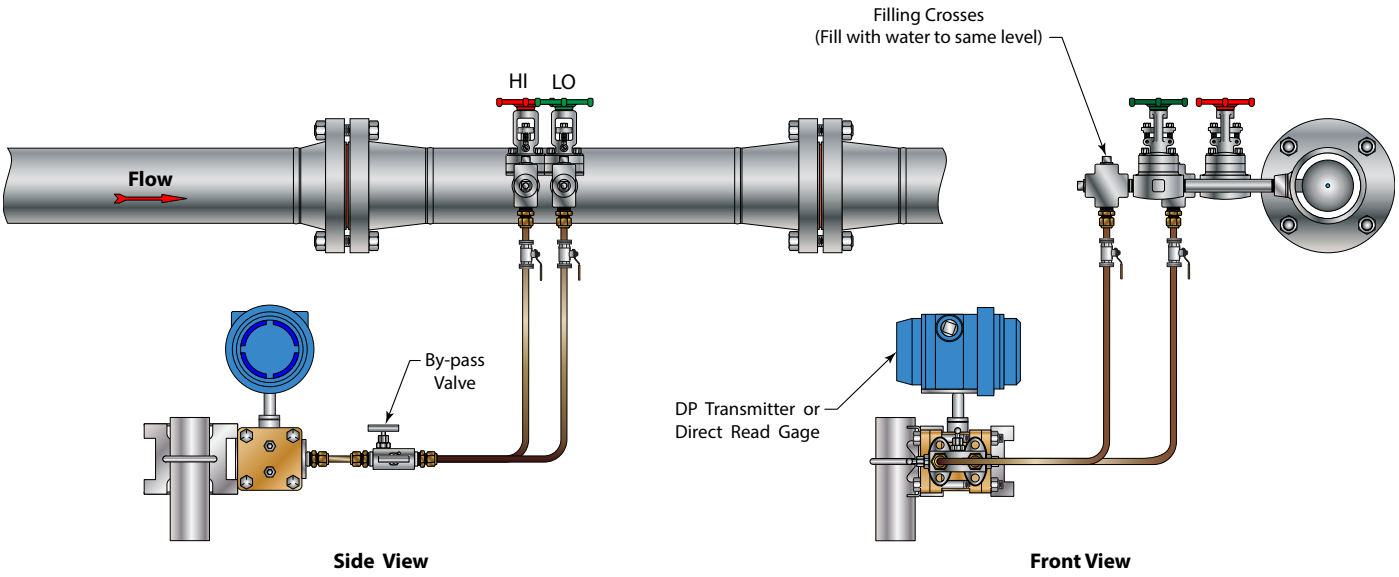


Figure 8: Typical horizontal installation for steam

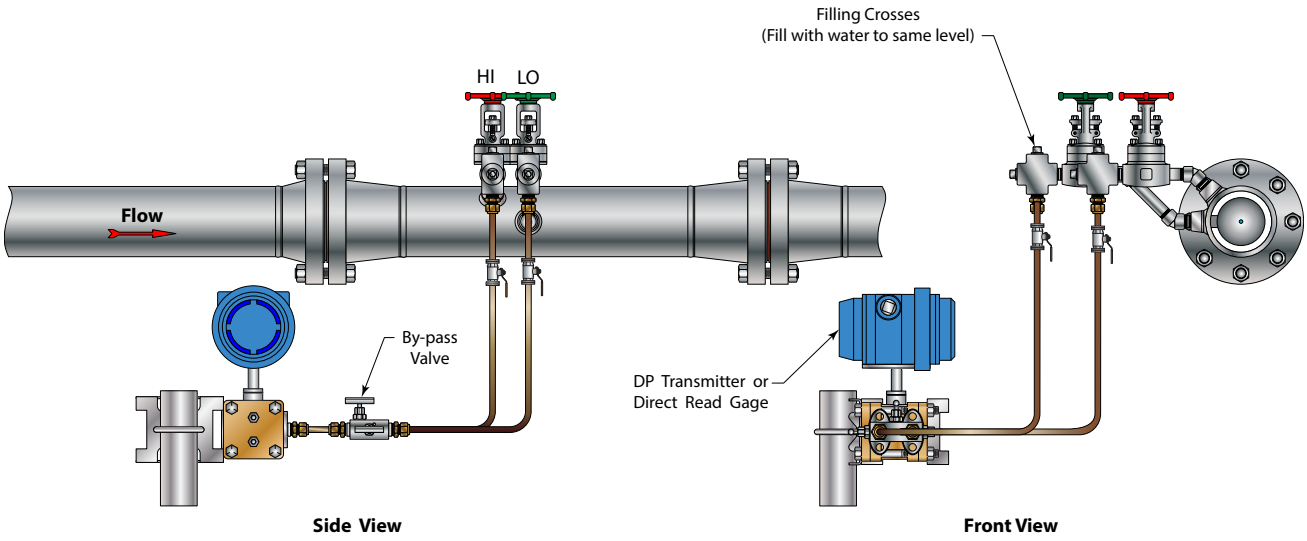


Figure 9: Optional horizontal installation for steam

Vertical Meter Installation

For steam service installations in which the meter is oriented vertically, extend the piping from the upstream pressure tap horizontally to a T-connector. The T-connector enables a plug to be installed at the top for liquid filling purposes to avoid overheating of the differential pressure cell. Position the manifold block directly below, at a distance that keeps the steam at a safe operating temperature when it reaches the differential pressure transmitter. Extend both lines to the T-connectors.

NOTE: This configuration results in a head difference in the differential pressure lines and the differential pressure transmitter must be zeroed when zero flow has been established in the main line.

When the process is turned off, particulates may settle into the low-pressure port. Flush the low-pressure port with an inert fluid before starting the meter.

Transmitter Calibration

Calibrate the transmitters (differential pressure and/or multi-variable) according to the manufacturer's recommendations, appropriate national or company standards and contractually agreed methodology. Consider the service in which the Cone meter and transmitter are installed and operated.

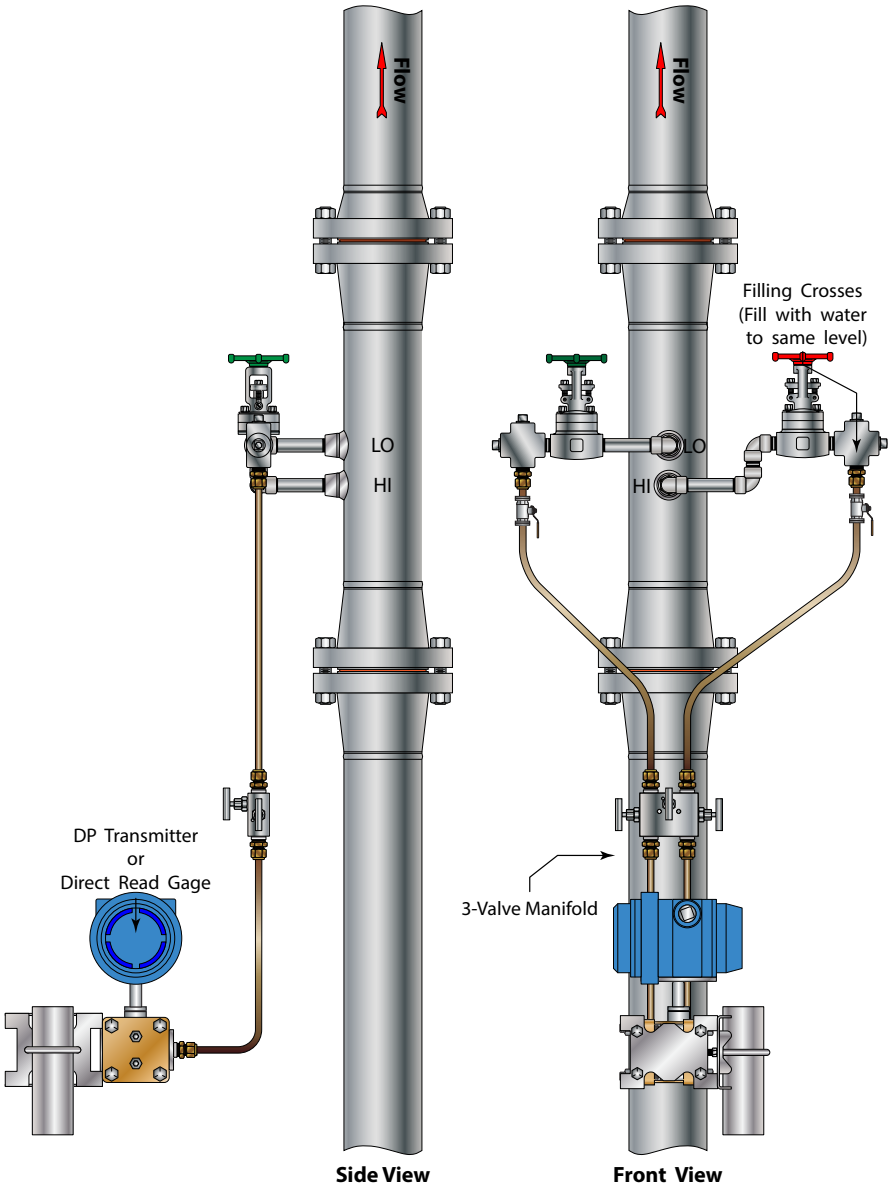


Figure 10: Typical vertical installation for steam

SYSTEM MODIFICATIONS

Square Root Error

Differential pressure measurement is only accurate for steady-state flow. Flow pulsation caused by reciprocating compressors, defective regulators, and like equipment can cause mis-registration of delivered volumes.

Significant errors occur when using differential pressure devices at the discharge of a reciprocating gas compressor where pressure pulses may exceed 10% of static pressure. This causes a condition called square root error, which may be reduced by the use of an acoustic filter.

Gauge Line Error

Gaseous fluids in small-bore pipes may start to oscillate due to an effect called gauge line error. It is a type of acoustic resonance comprising of standing pressure waves, and usually occurs at a maximum of 1/4 wavelengths. A common cause of this phenomenon is the use of impulse lines with a high length to diameter ratio. To help prevent gauge line error, keep impulse lines as short as possible, and use large impulse line diameters where possible. It also helps to keep impulse line diameters constant along their length. The direct mounting of the transmitter to the meter can help reduce or even eliminate the effects of gauge line error. Direct-mount manifolds are available from leading manifold manufacturers.

Elevation and Temperature Effects in Piping

In liquid service, it is important to keep vertical elevation equal between the two impulse lines. If one liquid-filled leg is longer than the other, the hydrostatic head of the lines will vary, resulting in inaccurate differential pressure measurement.

Similarly, if the temperature of liquid in one leg is different from the temperature of liquid in the other leg, the density of the fluid will be different, resulting in inaccurate differential pressure measurement. This most often occurs when one leg of the tubing is in bright sun and the other leg is shaded. To minimize the effects of temperature differences in the vertical legs of impulse lines, shade both of the legs from the sun. The effect of temperature differences is more notable in liquid service installations; gas service is not as prone to DP error due to varying line temperatures.

SPECIFICATIONS

Applications	Liquids, steam, air and industrial gases	
Pipe Sizes	*Wafer*	1…4 in. (25…102 mm)
	Threaded and Socket Weld	1/2…2 in. (12…51 mm)
	Flanged Mount	1…24 in. (25…609 mm)
	Butt Weld	1/2…24 in. (12…609 mm)
Repeatability	± 0.1% or better	
Flow Range	10:1 and greater	
Accuracy	± 0.5% of actual flow	
Standard Beta Ratio	0.40…0.80 (special betas available)	
Permanent Pressure Loss	Varies with beta ratio and DP	
Installation Piping Requirements	Typically 0…3 diameters upstream and 0…1 diameters downstream of the cone are required, depending on fittings or valves in the adjacent pipeline (See *"Installation" on page 9* for the straight pipe requirements of your application)	
Construction Materials	304/304L, 316/316L stainless steel, A106 carbon steel, other materials on request	
End Fittings	Threaded (NPT), flange, wafer, socket, and butt weld, other end connections on request	
Approvals	CRN	

PART NUMBER CONSTRUCTION

Wafer Mount

P G W ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Pipe Size
- **C)** 1"
- **D)** 1-1/4"
- **E)** 1-1/2"
- **F)** 2"
- **G)** 2-1/2"
- **H)** 3"
- **I)** 4"
- **X)** Other

Pipe Schedule
- **A)** Standard**
- **B)** 10
- **C)** 20
- **D)** 30
- **E)** 40
- **J)** 120
- **L)** 160
- **M)** XH
- **N)** XXH
- **O)** 5S
- **P)** 40S
- **Q)** 80S
- **X)** Other

Body-Element Material
- **1)** CS body-316/316L element
- **2)** 316/316L body-316/316L element
- **3)** 304/304L body-316/316L element
- **X)** Other

Process Connection
- **A)** RF flange 150#
- **B)** RF flange 300#
- **C)** RF flange 600#
- **D)** RF flange 900#
- **X)** Other

Instrument Connection
- **H)** 1/4" NPT (1…3" NPS)
- **I)** 1/2" NPT (3" and up)
- **J)** 1/2" socket weld
- **X)** Other

Beta Ratio
- **4)** 0.4
- **5)** 0.5
- **6)** 0.6
- **7)** 0.7
- **8)** 0.8
- **X)** Custom

Instrument Valve
- **A)** 1/4" Needle valve CS
- **B)** 1/2" Needle valve CS
- **C)** 1/4" Needle valve SS
- **D)** 1/2" Needle valve SS
- **E)** 1/2" Gate w/cross CS (steam)
- **F)** 1/2" Gate w/cross SS (steam)
- **X)** Other
- **Z)** Not required

Calibration
- **1)** Factory calibration
- **2)** Special calibration*
- **Z)** Not required

Transmitter Bracket
- **1)** SS bracket
- **2)** With three valve
- **3)** With five valve
- **4)** None

Hydrostatic Testing
- **1)** Hydro with certificate
- **0)** None

Material Certificate
- **1)** Material certificates
- **2)** PMI
- **3)** Combination of one and two above
- **4)** NACE (MR0175)
- **5)** NACE (MR0103)
- **X)** Other
- **0)** None

Welding Standard
- **A)** Standard
- **B)** ASME B31.1
- **C)** ASME B31.3
- **X)** Other

NDE Testing
- **A)** X-ray/Dye Pen 5%
- **X)** Other
- **0)** None

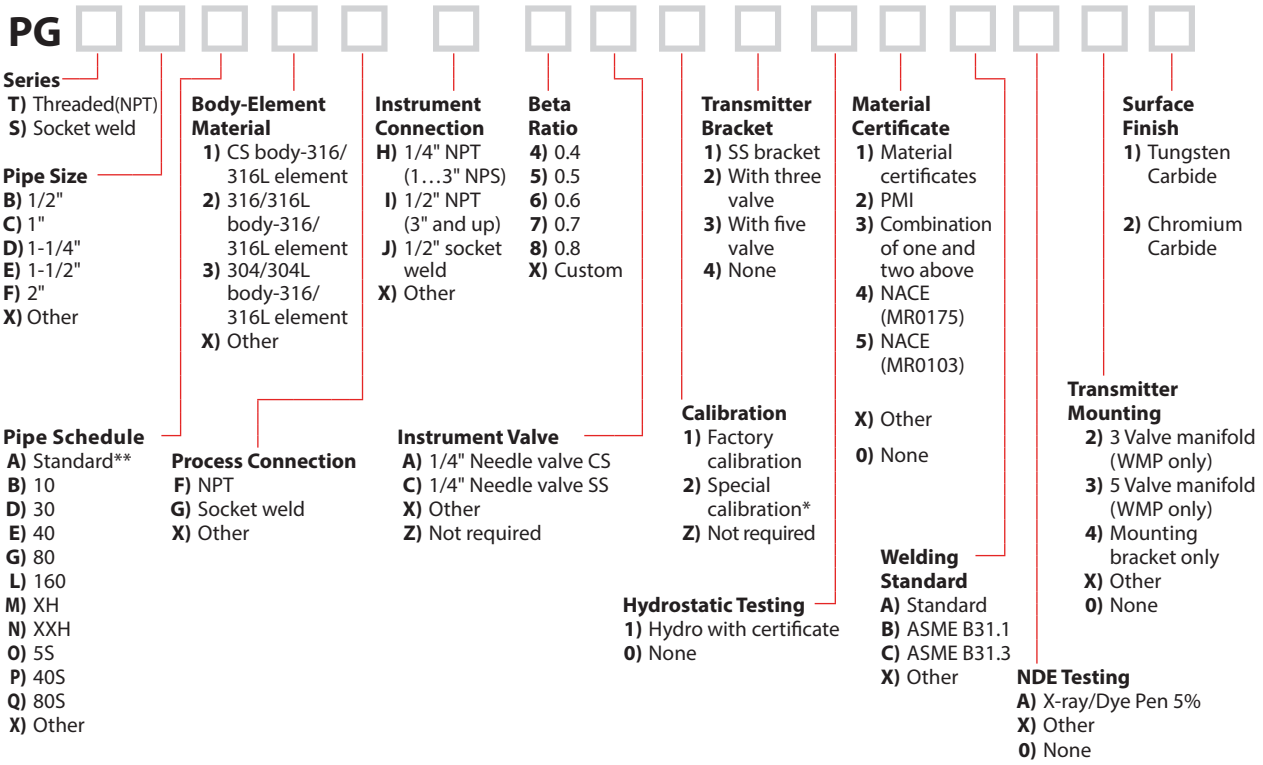
Surface Finish
- **1)** Tungsten Carbide
- **2)** Chromium Carbide

Transmitter Mounting
- **2)** 3 Valve manifold (WMP only)
- **3)** 5 Valve manifold (WMP only)
- **4)** Mounting bracket only
- **X)** Other
- **0)** None

* Standard calibration is performed at Badger Meter with five data points (0.5 percent accuracy)

** Pipe schedule "Standard" is schedule 40 up to 10 in. and 3.75 in. wall at 12 in. and larger.

Threaded and Socket Weld Mount



* Standard calibration is performed at Badger Meter with five data points (0.5 percent accuracy)
** Pipe schedule "Standard" is schedule 40 up to 10 in. and 3.75 in. wall for 12 in. and larger.

Flanged Mount

P G F ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Pipe Size
- **C)** 1"
- **D)** 1-1/4"
- **E)** 1-1/2"
- **F)** 2"
- **G)** 2-1/2"
- **H)** 3"
- **I)** 4"
- **J)** 5"
- **K)** 6"
- **L)** 8"
- **M)** 10"
- **N)** 12"
- **O)** 14"
- **P)** 16"
- **X)** Other

Pipe Schedule
- **A)** Standard**
- **B)** 10
- **C)** 20
- **D)** 30
- **E)** 40
- **F)** 60
- **G)** 80
- **H)** 100
- **J)** 120
- **K)** 140
- **L)** 160
- **M)** XH
- **N)** XXH
- **O)** 5S
- **P)** 40S
- **Q)** 80S
- **X)** Other

Body-Element Material
- **1)** CS body-316/316L element
- **2)** 316/316L body-316/316L element
- **3)** 304/304L body-316/316L element
- **X)** Other

Process Connection
- **A)** RF flange 150#
- **B)** RF flange 300#
- **C)** RF flange 600#
- **D)** RF flange 900#
- **X)** Other

Instrument Connection
- **A)** 2" RF flange 150# (2" and up)
- **B)** 2" RF flange 300# (2" and up)
- **C)** 2" RF flange 600# (2" and up)
- **D)** 3" RF flange 150# (3" and up)
- **E)** 3" RF flange 300# (3" and up)
- **F)** 3" RF flange 600# (3" and up)
- **G)** 3″ RF flange 900# (3" and up)
- **H)** 1/4" NPT (1"…3" NPS)
- **I)** 1/2" NPT (>3" NPS)
- **J)** 1/2" socket weld
- **X)** Other

Instrument Valve
- **A)** 1/4" Needle valve CS
- **B)** 1/2" Needle valve CS
- **C)** 1/4" Needle valve SS
- **D)** 1/2" Needle valve SS
- **E)** 1/2" Gate w/cross CS (steam)
- **F)** 1/2" Gate w/cross SS (steam)
- **X)** Other
- **Z)** Not required

Beta Ratio
- **4)** 0.4
- **5)** 0.5
- **6)** 0.6
- **7)** 0.7
- **8)** 0.8
- **X)** Other

Calibration
- **1)** Factory calibration
- **2)** Special calibration*
- **Z)** Not required

Transmitter Bracket
- **1)** SS bracket
- **2)** With three valve
- **3)** With five valve
- **4)** None

Hydrostatic Testing
- **1)** Hydro with certificate
- **0)** None

Material Certificate
- **1)** Material certificates
- **2)** PMI
- **3)** Combination of one and two above
- **4)** NACE (MR0175)
- **5)** NACE (MR0103)
- **X)** Other
- **0)** None

Welding Standard
- **A)** Standard
- **B)** ASME B31.1
- **C)** ASME B31.3
- **X)** Other

NDE Testing
- **A)** X-ray/Dye Pen 5%
- **X)** Other
- **0)** None

Surface Finish
- **1)** Tungsten Carbide
- **2)** Chromium Carbide

Transmitter Mounting
- **2)** 3 Valve manifold (WMP only)
- **3)** 5 Valve manifold (WMP only)
- **4)** Mounting bracket only
- **X)** Other
- **0)** None

* Standard calibration is performed at Badger Meter with five data points (0.5 percent accuracy)
** Pipe schedule "Standard" is schedule 40 up to 10 in. and 3.75 in. wall at 12 in. and larger.

Butt Weld Mount

P G B ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Pipe Size
- **B)** 1/2"
- **C)** 1"
- **D)** 1-1/4"
- **E)** 1-1/2"
- **F)** 2"
- **G)** 2-1/2"
- **H)** 3"
- **I)** 4"
- **J)** 5"
- **K)** 6"
- **L)** 8"
- M) 10"
- **N)** 12"
- **O)** 14"
- **P)** 16"
- **X)** Other

Pipe Schedule
- **A)** Standard**
- **B)** 10
- **C)** 20
- **D)** 30
- **E)** 40
- **F)** 60
- **G)** 80
- **H)** 100
- **J)** 120
- **K)** 140
- **L)** 160
- **M)** XH
- **N)** XXH
- **O)** 5S
- **P)** 40S
- **Q)** 80S
- **X)** Other

Body-Element Material
- **1)** CS body-316/316L element
- **2)** 316/316L body-316/316L element
- **3)** 304/304L body-316/316L element
- **X)** Other

Process Connection
- **E)** Butt weld
- **X)** Other

Instrument Connection
- **A)** 2" RF flange 150# (2" and up)
- **B)** 2" RF flange 300# (2" and up)
- **C)** 2" RF flange 600# (2" and up)
- **D)** 3" RF flange 150# (3" and up)
- **E)** 3" RF flange 300# (3" and up)
- **F)** 3" RF flange 600# (3" and up)
- **G)** 3" RF flange 900# (3" and up)
- **H)** 1/4" NPT (1…3" NPS)
- **I)** 1/2" NPT (>3" NPS)
- **J)** 1/2" socket weld
- **X)** Other

Instrument Valve
- **A)** 1/4" Needle valve CS
- **B)** 1/2" Needle valve CS
- **C)** 1/4" Needle valve SS
- **D)** 1/2" Needle valve SS
- **E)** 1/2" Gate w/cross CS (steam)
- **F)** 1/2" Gate w/cross SS (steam)
- **X)** Other
- **Z)** Not required

Beta Ratio
- **4)** 0.4
- **5)** 0.5
- **6)** 0.6
- **7)** 0.7
- **8)** 0.8
- **X)** Custom

Calibration
- **1)** Factory calibration
- **2)** Special calibration*
- **Z)** Not required

Transmitter Bracket
- **1)** SS bracket
- **2)** With three valve
- **3)** With five valve
- **4)** None

Hydrostatic Testing
- **1)** Hydro with certificate
- **0)** None

Material Certificate
- **1)** Material certificates
- **2)** PMI
- **3)** Combination of one and two above
- **4)** NACE (MR0175)
- **5)** NACE (MR0103)
- **X)** Other
- **0)** None

Welding Standard
- **A)** Standard
- **B)** ASME B31.1
- **C)** ASME B31.3
- **X)** Other

NDE Testing
- **A)** X-ray/Dye Pent 5%
- **X)** Other
- **0)** None

Surface Finish
- **1)** Tungsten Carbide
- **2)** Chromium Carbide

Transmitter Mounting
- **2)** 3 Valve manifold (WMP only)
- **3)** 5 Valve manifold (WMP only)
- **4)** Mounting bracket only
- **X)** Other
- **0)** None

* Standard calibration is performed at Badger Meter with five data points (0.5 percent accuracy)
** Pipe schedule "Standard" is schedule 40 up to 10 in. and 3.75 in. wall at 12 in. and larger.

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