PI 14-1
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Model 140MX Flowmeter Functional Overview

DESCRIPTION

The Model 140MX Flowmeter (Figure 1) works on the fluid phenomenon of momentum exchange (see page 6 for details), providing accurate flow measurement for difficult to handle, high viscosity, and/or low flowrate applications. It features:

- Accurate and repeatable flow measurement
- High turndown (typically 12 to 1)
- No moving parts to damage or wear
- Withstands flow overranges of up to 400% of full scale
- Two-wire transmitter or remote signal converter for installation flexibility
- No meter body calibration shift, minimizing maintenance requirements
- Output linear with flowrate
- Rugged and reliable sensors
- Highly immune to shock and vibration
- No piping run requirements, simplifying installation

The Model 140MX consists of a meter body and a two-wire transmitter; a remotely-mounted signal converter is also available as an alternative to the two-wire transmitter. The rugged meter body includes a self-contained strain gage sensor for direct, in-line installation into new or existing piping.

The Model 140MX Flowmeter is constructed to resist harsh industrial environments. It can be subjected to flow overranges and the resulting pressure surges of up to 400% of full scale with no damage to the meter body or sensor and no shift in calibration.

The Model 140MX Flowmeter also contains no moving parts, which minimizes maintenance and service needs. This design eliminates the need for costly, periodic meter recalibration. In addition, there are no gears that can bind or jam, resulting in interruption of flow.

The design of the 140MX does not require a maintained turbulent flow in the pipe for operation. This allows it to be used with high viscosity fluids and/or low flowrates. It operates within its specified accuracy at Reynolds Numbers as low as 400 and will continue to provide an output signal at Reynolds Numbers as low as 75. Fluids with viscosities up to 80 centistokes can be metered.

FIGURE 1 Model 140MX Flowmeter

The Model 140MX Flowmeter is well suited for use with viscous fluids, such as fuel oils #2 through #6, and has proven itself in combustion applications, metering of hot/cold mixes, and where sensor coating problems could be encountered.

PERFORMANCE SPECIFICATIONS

METER BODY

Accuracy

±2% of flowrate. Includes the combined effects of conformity, hysteresis, deadband, and repeatability errors. Table 1 lists minimum required Reynolds Number for stated accuracy.

TABLE 1 Minimum Reynolds Number

Meter Size (in/mm)	¾ (19)	1 (25)	1 ½ (38)
R_D Number	400	500	500

The Reynolds Number (R_D) is based on pipe diameter and can be determined from the following equation:

$$R_D = \frac{VD}{v}$$

where

R_D = Reynolds Number
V = Velocity in ft/s or m/s
D = Actual inside pipe diameter in ft or m
v = Kinematic viscosity in ft^2/s or m^2/s

For convenience, R_D can be determined from the following hybrid equation:

$$R_D = \frac{3162\ (GPM)}{(\text{Pipe ID. In.})\ (\text{Centistokes})}$$

Repeatability
0.25% of flow rate

Ambient Temperature Effect
1% of flowrate per 167^0C (300^0F)

Flow Overrange Protection
Flow overranges of up to 400% of full scale will not damage the meter body or the sensor.

Position Effect
The flowmeter can be mounted in horizontal, vertical, or inclined pipelines having an upwards direction of flow with no effect on performance. It is important that the pipe be kept full of fluid for accurate flow measurement.

Minimum Flowrates
¾" (19 mm) Meter: 0.35 GPM/√Sp. Gr. or 0.02 GPM/cSt, whichever represents the larger flowrate of the fluid being measured
1" (25 mm) Meter: 0.75 GPM/√Sp. Gr. or 0.04 GPM/cSt, whichever represents the larger flowrate for the fluid being measured
1 ½" (39mm) Meter: 2 GPM/√Sp. Gr. or 0.10 GPM/cSt, whichever represents the larger flowrate for the fluid being measured.

Minimum Flowrate vs. Liquid Viscosity
Figures 2 through 4 depict the effect of viscosity on the minimum linear flowrate and minimum operating flowrate. **As the viscosity increases above 20 cSt, the minimum flowrate also increases.**

FIGURE 2 Minimum Flowrate vs. Liquid Viscosity for ¾" (19 mm) Meter

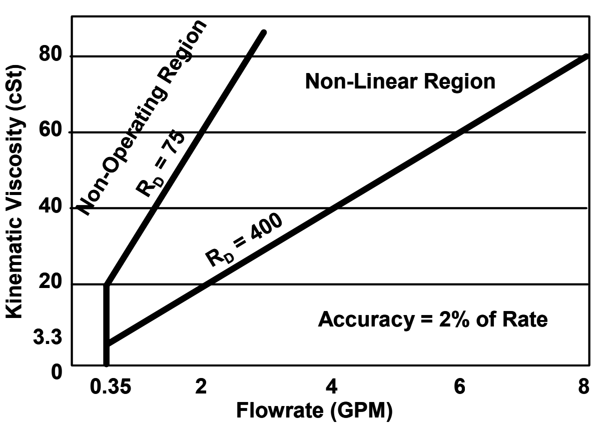


FIGURE 3 Minimum Flowrate vs. Liquid Viscosity for 1" (25 mm) Meter

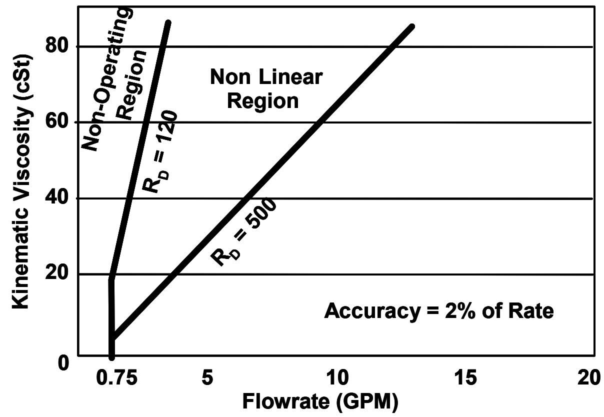
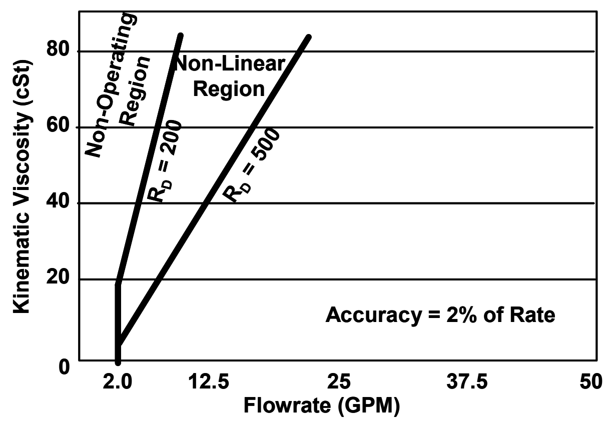


FIGURE 4 Minimum Flowrate vs. Liquid Viscosity for 1 ½" (38 mm) Meter



ELECTRONICS
Accuracy
0.1% of full scale for both the two-wire transmitter and the signal converter. Includes the combined effects of conformity, hysteresis, deadband, and repeatability errors.

Supply Voltage Effect
Two-Wire Transmitter: None within the transmitter's operating range
Signal Converter: Less than 0.1% per 10 Vac

FUNCTIONAL SPECIFICATIONS
METER BODY
Flowrate Limits
The flowrates in Table 2 are for water with a viscosity of 1.0 cSt. For fluids with other viscosities, use the relationships in the minimum flowrate section to determine the minimum flowrate. Table 3 lists the upper range limits (URL) for a 20 mA output; for example, a 1 ½" (38 mm) meter can be calibrated to have a 4-20 mA output for flow ranges from 0-15 to 0-50 GPM.

TABLE 2 Flowrate Limits

Flow Units	Meter Size (in/mm)					
	¾ (19)		1 (25)		1 ½ (38)	
	Min	Max	Min	Max	Min	Max
GPM	0.35	8	0.75	17	2.0	50
L/S	0.022	0.505	0.047	1.07	0.126	3.15

TABLE 3 Upper Range Limits

Flow Units	Meter Size (in/mm)		
	¾ (19)	1 (25)	1 ½ (38)
GPM	2-8	5-17	15-50
L/S	0.12-0.505	0.315-1.07	0.95-3.15

Static Pressure Limits

Maximum working pressure is equal to the flange ratings. Meters are available with 150 or 300 lb. flanges. Flange ratings are based on ANSI B16.5.

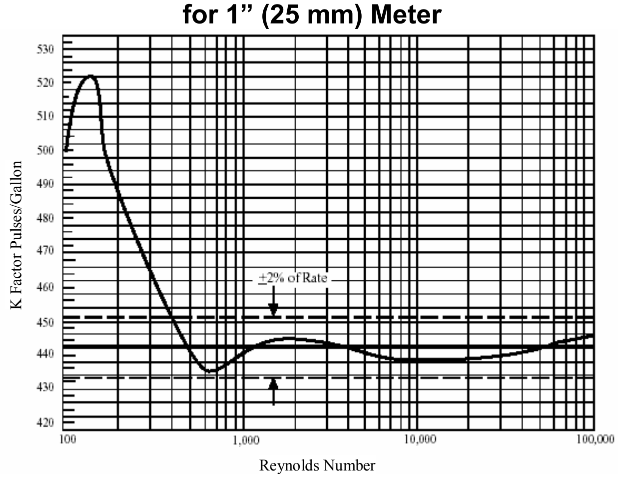
K Factor

The K factor is the ratio of pulses to gallons of flowing fluid. Nominal K factors are listed in Table 4. K factors will vary slightly from meter to meter. The K factor for a meter is determined by averaging its K factor over the operating range. Actual K factors are supplied for each flowmeter. Figure 5 shows a typical K factor vs. R_D curve for a 1" (25 mm) meter.

TABLE 4 Nominal K Factors

Meter Size (IN/mm)	¾ (19)	1 (25)	1 ½ (38)
K Factor (Pul/Gal)	1330	440	100

FIGURE 5 Typical K Factor vs. R_D Curve for 1" (25 mm) Meter



Operating Temperatures

Standard: -40 to 176^{0}C (-40 to 350^{0}F)

With Optional Cryogenic Sensor: -196 to 176^{0}C (-320 to 350^{0}F)

NOTE: Optional Cryogenic Sensor requires use of four-wire signal converter.

Pressure Loss

Figure 6 is a graph of pressure loss vs. flowrate. These pressures are for water with a density of 62.43 lb.ft. The pressure loss for water with other densities, or other fluids, can be found by using the following equation:

$\Delta P = X_1 Q^2 y$

where

- ΔP = Pressure loss in PSI or kPa
- X_1 = Pressure loss coefficient from Table 5
- Q = Flowrate in GPM or l/s
- y = Density at flowing conditions in lb/ft^3 or N/m^3

TABLE 5 Pressure Loss Coefficients

Meter Size (IN/mm)	Press. Loss Coef. English	Press. Loss Coef. Metric
¾ (19)	4.93×10^{-3}	5.30×10^{-2}
1 (25)	1.105×10^{-3}	1.129×10^{-2}
1 ½ (38)	1.002×10^{-4}	1.104×10^{-3}

Minimum Back Pressure

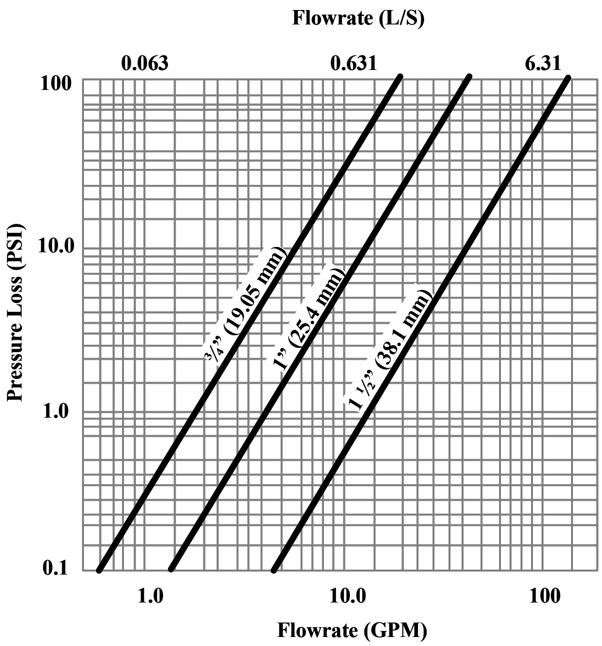
The minimum back pressure required to ensure proper operation of the flowmeter can be found by using the equation below. If the actual downstream pressure is less than the minimum back pressure, flashing may occur. Any condition that contributed to flashing or cavitation should be avoided because faulty signals may occur.

$P_G = (1.5\ \Delta P) + (1.25)\ (P_V) - (P_{ATM})$

where

- P_G = Gauge pressure in PSI or kPa five pipe diameters downstream of flowmeter
- ΔP = Calculated pressure loss
- P_V = Vapor pressure at line conditions in PSI or kPa absolute
- P_{ATM} = Atmospheric pressure in PSI or kPa absolute

FIGURE 6 Pressure Loss vs. Flowrate



ELECTRONICS

Operating Temperature

Two-Wire Transmitter: -40 to 85^{0}C (-40 to 185^{0}F)
Signal Converter: -30 to 50^{0}C (-22 to 122^{0}F)

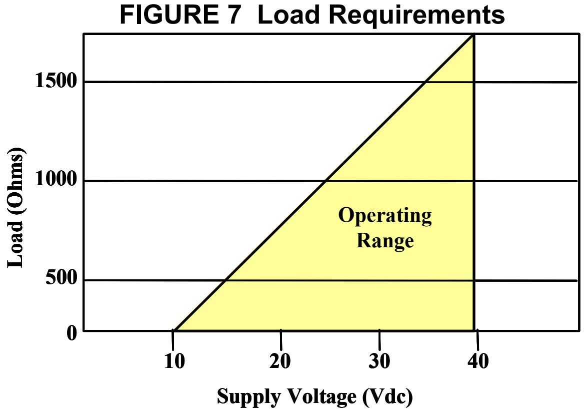
Output Signal

Two-Wire Transmitter: The analog output is 4-20 mA with a maximum load of 1500 ohms.
Signal Converter: The signal converter provides a pulse and analog output. The pulse has a rise/fall time of 1 µsec with a maximum of 500 µF. The scaled pulse width is 50-70 msec. The analog output is 4-20 mA with a maximum load of 600 ohms. NOTE: This converter must be used with Optional Cryogenic Sensor.

Power Requirements

Two-Wire Transmitter: Compliance voltage is 10 Vdc. See Figure 7 for operating range.
Signal Converter: 120 Vac, +10%, 50-60 Hz, 13 W (max.)

FIGURE 7 Load Requirements



$$\text{Max. Load} = \frac{(V_S - 10)\ \text{Volts}}{0.020\ \text{Amps}}$$

PHYSICAL SPECIFICATIONS

MATERIALS OF CONSTRUCTION

Process Wetted Parts

Meter Body: 316 LSS
Sensor: 316 L SS with Hastelloy® C
O-Ring: Viton® A

Non-Wetted Parts

Meter Body:
Cover: 18-8 SS
Gasket: Neoprene®
Two-Wire Transmitter:
Cover: Aluminum
Gasket: Neoprene
Housing: Low Cu Cast Aluminum
Signal Converter:
Enclosure: Carbon Steel
Gasket: Neoprene

Weights

Meter Body: See Table 6.

TABLE 6 Meter Body Weights

Meter Size (in/mm)	¾ (19) & 1 (25)		1 ½ (38)	
Flange Rating (lb)	150	300	150	300
Weight lb (kg)	24 (10.9)	27 (12.2)	56 (25.4)	61 (27.7)

Two-Wire Transmitter: 3 lbs. (1.86 kg)
Signal Converter: 12 lbs. (5.44 kg)

Electrical Connections

Meter Body: ½” NPT connection
Two-Wire Transmitter: Two ½” NPT conduit connections
Signal Converter: Three ½” conduit connections

Enclosure Specification

Meter Body: NEMA 4/IP 65
Two-Wire Transmitter: NEMA 4/IP 65
Signal Converter: NEMA 4/IP 65

Process Connections

Standard 150 or 300 lb. raised face flanges. Flange ratings are based on ANSI B16.5

HAZARDOUS AREA CLASSIFICATIONS

Model 140MX Flowmeter

FM approved for Class I, Division 1, Groups A, B. C & D; Class II, Division 1, Groups E, F & G; and Class III, Division 1 when connected per drawing number 15032-1419 or 15032-1420 and installed per manufacturer’s instructions.

Model 14 Deflection Sensor Signal Converter

FM approved for Class I, Division 2, Groups A, B, C & D; NEMA 4. The Model 14 Converter acts as a barrier for flowmeter equipment located in hazardous locations as follows: Class I, Division 1, Groups A, B, C & D; Class II, Division 1, Groups E, F & G; and Class III, Division 1 when connected per drawing number 15032-1419 and installed per manufacturer's instructions.

Model 14 Two-Wire Transmitter (P/N 15973-10)

FM approved for Class I, division 1, Groups A, B, C & D; Class II, division 1, Groups E, F & G; and Class III, Division 1 when connected per drawing number 15032-1420 and installed per manufacturer's instructions. FM approved without barriers for Class I, Division 2, Groups A, B, C & D; NEMA 4.

FLOWMETER SELECTION PROCEDURE

Use the following procedure to select the proper flowmeter.

Step 1

TABLE 7 Fluid Specifications

Fluid:		
Flowrates (GPM):	**Max.**	
	Min.	
	Normal	
Temperature (^{0}F):	**Max.**	
	Min.	
	Normal	
Viscosity (centistokes) @ Normal Temp:		
Specific Gravity:		
Pressure (PSIG):	**Max.**	

Step 2

Determine which electronics are best suited for the process. The choices are the two-wire transmitter and the deflection sensor signal converter. The two-wire transmitter is the most economical and provides a 4-20 mA analog signal. If a pulse output or a pulse output and a 4-20 mA signal are required, the deflection sensor signal converter is required.

Step 3

Determine which size meter is required. To do this, compare the maximum flowrate with the values listed in Table 3. The best meter body to use is the smallest one that will handle the maximum flow. For example, a maximum flow of 15 GPM can be handled by a 1" (25 mm) or 1 ½" (38 mm) meter body. However, choosing the 1" (25 mm) meter body will provide the lowest minimum flowrate, which will result in the highest turndown, and is the most economical choice.

Step 4

Determine the minimum measurable flow. By using the performance specifications, calculate the minimum measurable flowrate for the meter body chosen. If a larger flowmeter is needed, try the Model 141 general service flowmeters.

Step 5

Verify the remaining specifications. Check the temperature and pressure requirements with the functional specifications.

Step 6

Define the model and part numbers required using the catalog model selection guides. The full catalog and the Fluidic Flowmeter section are only available for downloading on our web site, www.fluidicflowmeters.com.

FIGURE 8 Two-Wire Transmitter

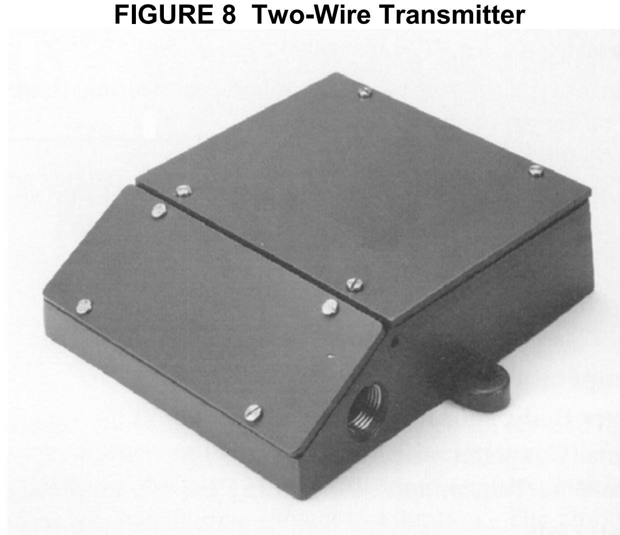


FIGURE 9 Deflection Sensor Signal Converter

OSCILLATORY FLOWMETERS

Oscillatory Flowmeters utilize specially designed geometric shapes to create an environment where self-induced, sustained oscillations will occur. Oscillating flowmeters are inherently digital devices, that is, the basic measurement they read is a frequency. In a properly executed flowmeter, the frequency of its oscillations is proportional to volumetric flowrate. There are several categories of oscillatory flowmeters, each with a unique shape.

Volumetric Flowrate vs. Frequency

For any point in the operating region of the flowmeter, the frequency of oscillation will be related to the volumetric flowrate by the following equation:

$$F = KQ$$

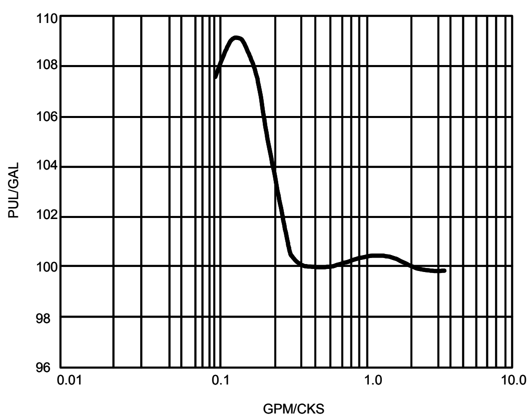
where

F is the frequency of oscillation
K is the calibration factor of the meter
Q is the volumetric flowrate

K Factor

It has been found that the K factor of oscillatory meters varies with Reynolds number. Because of this, it is convenient to plot the K factor versus the Reynolds number. If the meter was perfect, it would have a constant K factor at the Reynolds numbers, but this is not the case. All oscillatory meters exhibit a K factor curve that looks similar to Figure 10.

FIGURE 10 K Factor vs. Reynolds Number



How well the actual meter performs is a function of the design of the meter as well as the influence of the fluid flowing through it. There is a region on the curve where the K factor is essentially constant. This is the normal operating region for oscillating flowmeters. In this region, the accuracy is good enough to be stated as a percent of instantaneous flowrate.

Momentum Exchange Flowmeters

Momentum Exchange flowmeters are based on the fluid phenomenon of momentum exchange. The momentum exchange flowmeter is similar to the Coanda flowmeter, but differs in the mechanism used to produce oscillations.

The geometric design of the momentum exchange meter body produces a continuous, self-induced oscillation at a frequency that is linearly proportional to volumetric flowrate.

The fluid oscillations are developed by the fluidic phenomenon of Momentum Exchange (MX). The geometric shape of the meter body creates a main flow of fluid, which passes through the nozzle, and is directed toward one side of the meter body or the other. The force of the jet of fluid will create a flow pulse in a feedback passage. This flow pulse will travel through the feedback passage and exert a force on the main jet. The momentum of the feedback fluid will deflect the main flow in such a manner that it will exert a force on the fluid in the other feedback passage, while the feedback action is repeated and results in a sustained oscillation. The sensor located in the feedback passage detects the fluid pulses, and the sensor signal is conditioned by a signal converter. Figure 11 shows the cross-section of a momentum exchange flowmeter.

FIGURE 11 Cross-section of a Momentum Exchange Flowmeter