How the Micro Motion® Mass Flow and Density Sensor Works

Mass Flow Measurement: Theory of Operation

The Micro Motion flowmeter measures fluid mass in motion. A flowmeter is comprised of a sensor and a signal processing transmitter. Each sensor consists of **one or two** flow tubes enclosed in a sensor housing. The principle of operation is the same for all Micro Motion sensors.

The sensor operates by application of Newton's Second Law of Motion: Force = mass x acceleration (F = ma). The flowmeter uses this law to determine the precise amount of mass flowing through the sensor tubes.

Inside the sensor housing, the flow tube is vibrated at its natural frequency (Figure 1) by an electromagnetic drive coil located at the center of the bend in the tube. The vibration is similar to that of a tuning fork, covering less than a tenth of an inch and completing a full cycle about 80 times each second.

As the fluid flows into the sensor tube, it is forced to take on the vertical momentum of the vibrating tube. When the tube is moving upward during half of its vibration cycle (Figure 2), the fluid flowing into the sensor resists being forced upward by pushing down on the tube. Having the tube's upward momentum as it travels around the tube bend, the fluid flowing out of the sensor resists having its vertical motion decreased by pushing up on the tube (Figure 2). This causes the flow tube to twist (Figure 3). When the tube is moving downward during the second half of its vibration cycle, it twists in the opposite direction. This tube twisting characteristic is called the Coriolis effect.

Due to Newton's Second Law of Motion, the amount of sensor tube twist is directly proportional to the mass flow rate of the fluid flowing through the tube. Electromagnetic velocity detectors located on each side of the flow tube measure the velocity of the vibrating tube. The two velocity signals are sent to the transmitter where they are processed and converted to an output signal proportional to the mass flow rate. Sensor tube twist is proportional to mass flow and is determined by measuring the time difference exhibited by the velocity detector signals. During zero flow conditions, no tube twist occurs and both sides of the tube cross the midpoint simultaneously. With flow, a twist occurs along with a resultant time difference between midpoint crossing. This time difference appears as a phase shift between the two velocity signals and indicates mass flow.

Benefits of Mass Flow Measurement

Micro Motion flowmeters measure mass flow directly—not by inferred methods. The basis for all measurement is mass, length, and time. Since none of these is derived from another source, each is an ideal standard for accurate measurement. In the case of mass, this means that changes in fluid parameters such as temperature, pressure, density, viscosity, and conductivity have no affect on the mass of the fluid being measured.

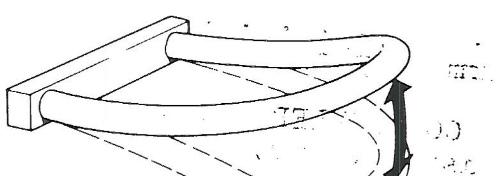


Figure 1
Vibrating flow tube (single flow tube shown)

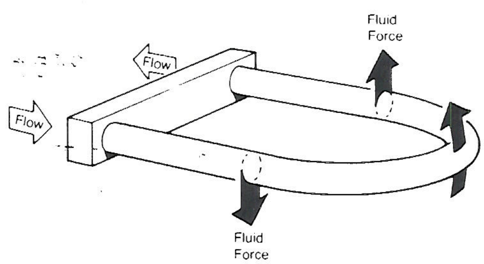


Figure 2
Fluid forces reacting to vibration of flow tube

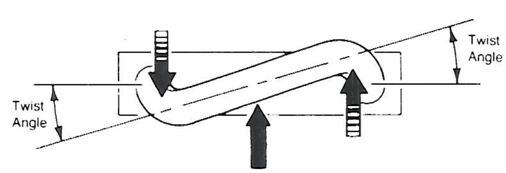


Figure 3

Density Measurement and Improved Process Control

Density Measurement: Theory of Operation

Coriolis flowmeters are excellent densitometers. The U-shaped sensor tubes are mounted in a fixed arrangement on one end and are free on the other end. This design configuration can be envisioned as a spring and mass assembly. The laws of physics describe the behavior of both systems; the relationship between density (mass of fluid in the tubes) and vibrational frequency can be quantified.

Once placed into motion, the spring and mass assembly will vibrate at its resonant frequency. The Coriolis sensor is also vibrated at its resonant frequency using a feedback circuit and drive coil.

A vibrating spring system can be mathematically described. It is important to emphasize that the mass of the Coriolis spring assembly is comprised of two parts; the mass of the tube and the mass of the fluid in the tube. The mass of the tubes is fixed for a given sensor. Since mass (fluid in the tubes) = density x tube volume, and the tube volume is a constant for any given sensor size, frequency of tube oscillation can be related to fluid density. Equation 1 shows how mass is determined. Equation 2 shows that fluid density is inversely proportional to the square of the frequency.

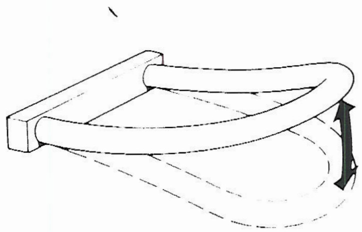
$$f = \frac{1}{2\pi}\sqrt{\frac{K}{m}} \qquad \text{equation 1}$$

$$\rho = \frac{K}{4\pi^2 V f^2} - \frac{m_{tube}}{V} \qquad \text{equation 2}$$

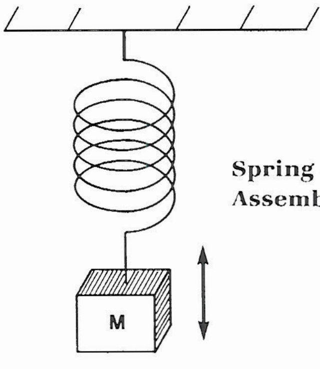
where f = frequency of oscillation
K = spring constant
m = mass
V = volume
ρ = density

Benefits of Density Measurement

Micro Motion density measurement products, in conjunction with a signal processing transmitter and sensor, offer accurate, on-line density measurement that enhances process measurement and control. Density is an important process parameter for what it indicates about product quality, uniformity, and concentration. For example, acid and base concentration, % solids of slurries, Brix, % solids black liquor, net oil, and many other variables can often be determined by density measurement.



Coriolis Flowmeter



Spring & Mass Assembly

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Product Profiles

Micro Motion, Inc. advances Coriolis technology

Model D65 Mass Flow and Density Sensor

Micro Motion, Inc. continues to expand its product line with the introduction of the Model D65 mass flow and density sensor. Incorporating the latest in Coriolis sensor design, the D65 is an in-line Model D sensor designed for flow ranges from 0 to 15 lb/minute (0 to 6.8 kg/minute) up to 0 to 300 lb/minute (0 to 136 kg/minute).

The D65 sensor offers all the benefits of a Model D sensor and is compatible with all Micro Motion transmitters, including the RFT SMART FAMILY® transmitter. It is offered with a variety of process connections; including ½-inch and 1-inch ANSI flanges and sanitary fittings. Consult the specifications for more information and for dimensions.

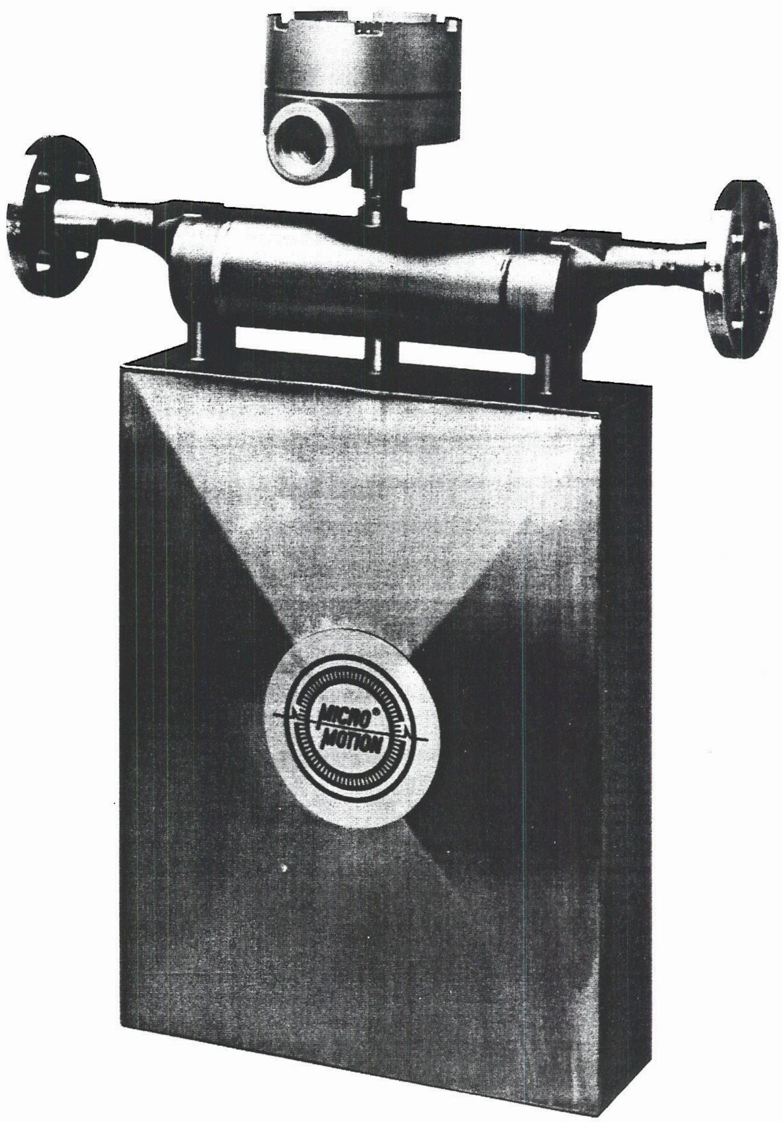
Accuracies for the D65 are ±0.2% ±0.03 lb/minute (0.014 kg/minute) for mass flow and as precise as ±0.001 g/cc for density.

Features

- Direct, mass flow measurement
- Simultaneous density measurement
- Non-intrusive sensor in compact, hermetically-sealed case
- No moving parts
- Remote electronics
- Independent of:
  - Temperature
  - Pressure
  - Density
  - Viscosity
  - Flow Profile

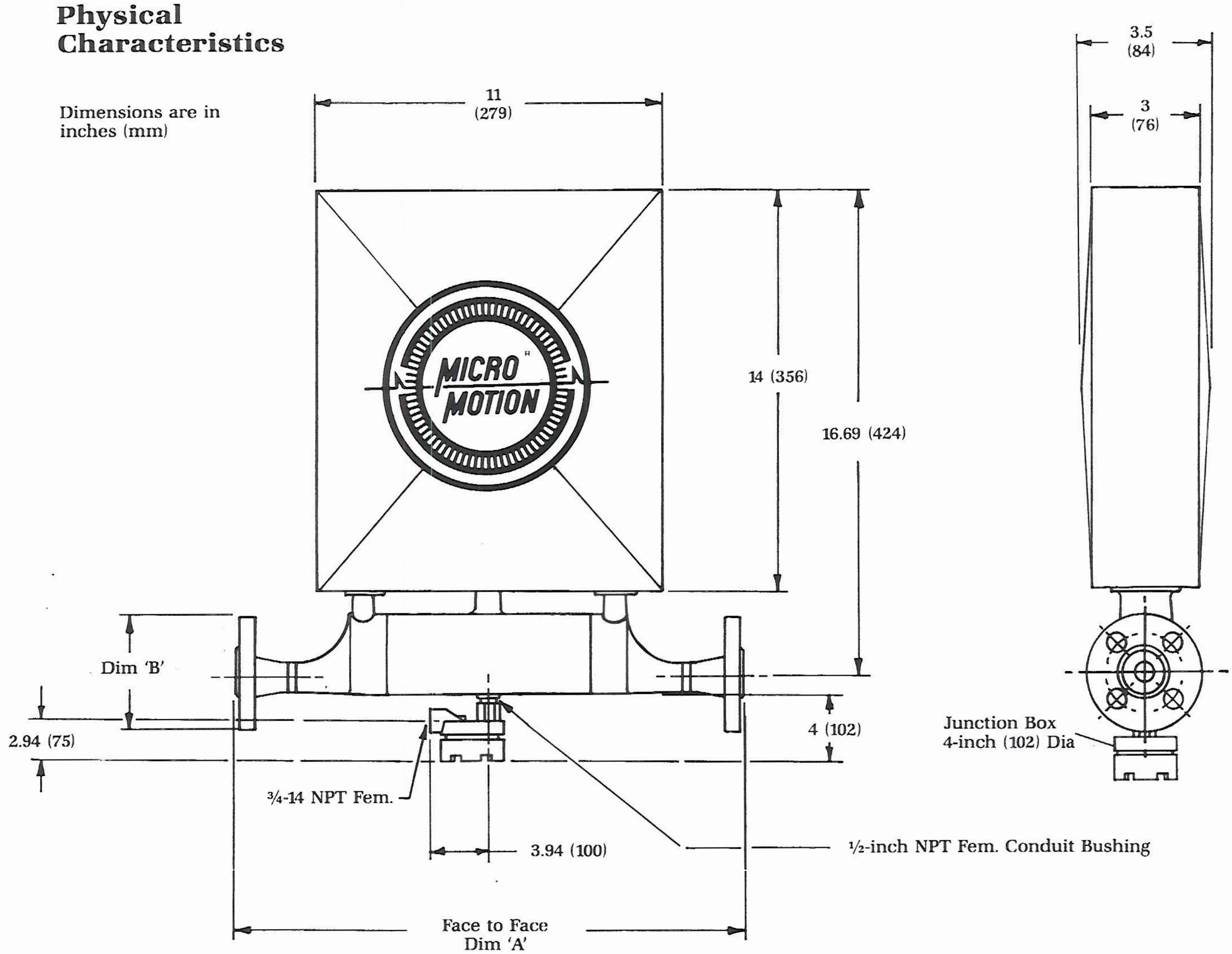
Benefits

- Superior accuracy
- Universal calibration in mass units
- Linear output
- Maintenance free
- No meter run requirement



Physical Characteristics

Dimensions are in inches (mm)



	Fitting	Dim 'A' ±.125 (3.2)	Dim 'B'
1/2-inch ANSI Raised Face Flange (B16.5)	150 lb (Shown)	16.19 (411)	3.5 (89)
	300 lb	16.56 (421)	3.75 (95)
	600 lb	17.06 (433)	3.75 (95)
	900 lb	17.69 (449)	4.75 (121)
	#12 Union -¾" NPT Fem.	14.31 (364)	1.19 (30)
	DIN PN40	15.44 (392)	3.75 (95)
	San-ftg 1"(1-½" Clamp)	16 (406)	2 (51)
	JS14	15.38 (391)	3.75 (95)
	JS12	15.19 (386)	3.75 (95)
1-inch ANSI Raised Face Flange (B16.5)	150 lb*	17.13 (435)	4.25 (108)
	300 lb*	17.63 (448)	4.88 (124)

*Matches face-to-face dimension of a D100 sensor with the same fitting.

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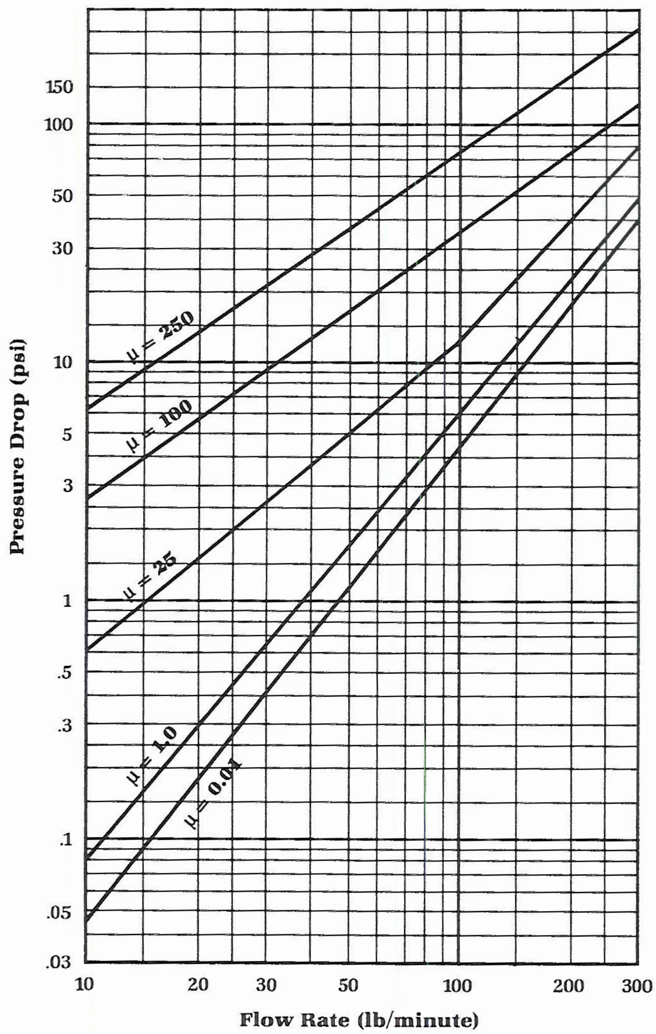
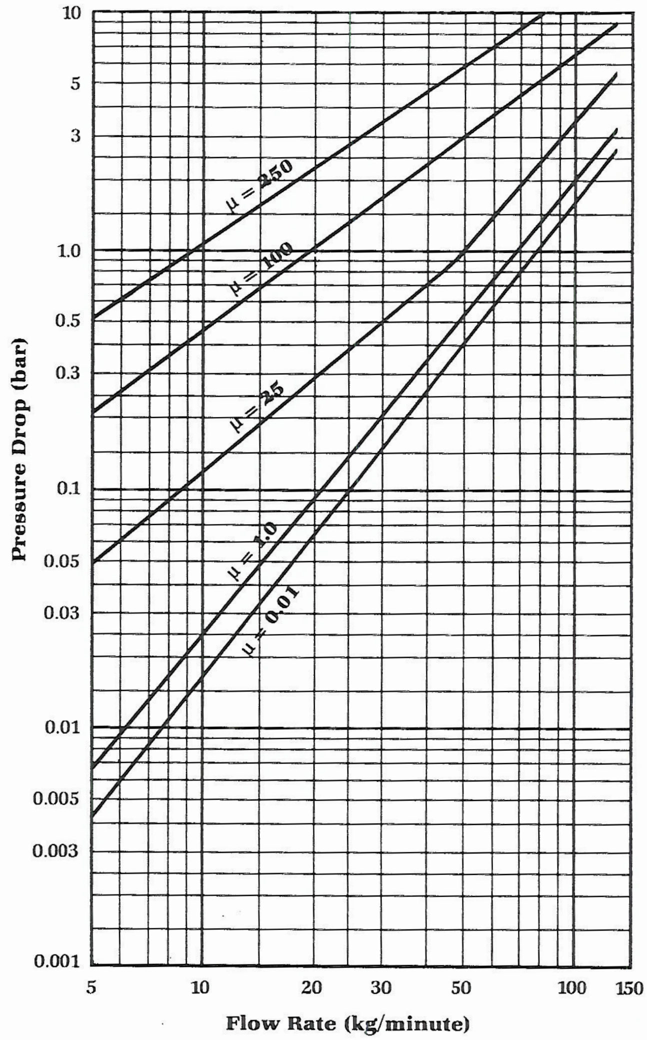
D65 Sensor Pressure Drop Charts





μ is fluid dynamic viscosity in centipoise. Pressure Drop Charts are for specific gravity = 1.0 SGU_W. Consult Mass Flowmeter Selection Guide when correcting for other densities.

D65 Sensor Sizing Information

Equivalent Pipe Lengths			
Sched 40 pipe size (in.)	Equiv. Pipe Length (ft.)	Pipe Internal Dia. (mm)	Equiv. Pipe Length (meters)
0.5	11	16	3.6
0.75	45	21	15
1	150	27	49

Velocity factor (V) = .17 (.11 metric)

For further information on use of the above sizing information consult the Micro Motion Mass Flowmeter Selection Guides.

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