

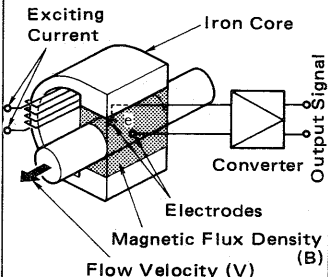
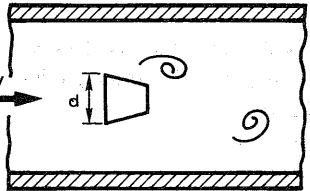
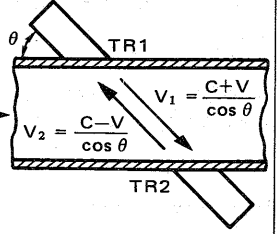
2. SELECTING CONDITIONS

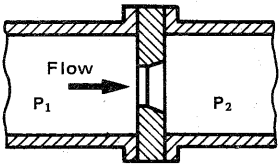
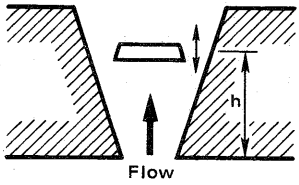
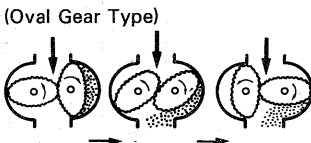
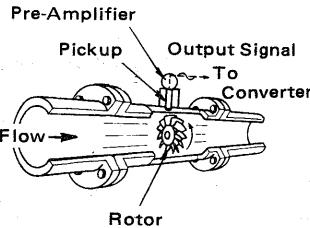
(1) Comparison of Measuring Principles

Table 2.1 compares the fundamental features of various flow measurement principles.

2.1 Comparisons between Several Flowmeter Types

Table 2-1. Comparison of Flowmeters According to Measuring Principles.

Type of flowmeters	Electromagnetic flowmeter	Vortex flowmeter	Ultrasonic flowmeter	
Principle or measuring method	 <p>The e.m.f (e) is proportional to (\propto) the flow velocity due to Faraday's law of electromagnetic induction.</p> $Q \propto e = B \cdot V \cdot D$ <p>(D: Diameter of Pipe)</p>	 <p>Vortices are generated, whose generation frequency (f) is proportional to (\propto) the flow velocity on the downstream side of the vortex shedder.</p> $Q \propto f = K \cdot V/d$	 <p>Difference of ultrasonic wave propagation times is utilized.</p> $Q \propto V = \frac{\cos \theta}{2} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$ <p>C: Sound Velocity</p>	
Corresponding YOKOGAWA product	YEW MAG	YEW FLO	YEW SONIC	
Process conditions	Measurable fluid	Conductive liquids	Gases, liquids and steam	
	Fluid pressure	20kg/cm ² Max. (Flange rating) 285PSIG Max. (Flange rating)	300kg/cm ² Max. (Flange rating) 4270PSIG Max. (Flange rating)	Liquids (Gases are measurable in principle)
	Fluid temperature	-10 to 160°C 14 to 320°F	-200 to 400°C -328 to 752°F	Same as in user's piping
	Rangeability	∞	1:20	∞
Performance	Required straight run of pipe	Upstream run 5D Downstream run 2D	Upstream run 10D Downstream run 5D	Upstream run 10D Downstream run 5D
	Accuracy	$\pm 0.5\%$ (of Rate)	$\pm 1\%$ (of Rate)	$\pm 1\%$ (of Span)
	Moving parts	None	None	None
	Pressure loss	Negligible	Low	Negligible
	Change of measuring span	Simple	Simple	Simple
Features	Available diameter	2.5 to 2600mm 0.1 to 106 inch	15 to 200mm 0.5 to 8 inch	150 to 3000mm 6 to 120 inch (Outer diameter of piping)
	Effect of Viscosity	None	Rangeability varies	Slight effects on accuracy
	Reverse flow measurement	Yes	Not recommended	Yes
Wetted part material	Pipe lining: Fluorocarbon resin Polyurethane rubber Electrode: 316L Stainless steel, Hastelloy C, Tantalum, Titanium, platinum	Stainless steel (1/2"-8") Hastelloy C (1"-2") Carbon steel (6"-8")	Not wetted	

Differential pressure flowmeter (with orifice plate)	Variable area flowmeter	Positive displacement flowmeter	Turbine flowmeter
 <p>Flow is calculated from the difference of pressures on the upstream and downstream sides of an orifice plate using Bernoulli's law.</p> $Q = K \sqrt{P_1 - P_2}$	 <p>The float enclosed in a tapered tube positioned vertically moves up to the height corresponding to the flowrate.</p> $Q = K \sqrt{h}$	 <p>Gears engaged without fluid leakage delivers a constant fluid volume at every revolution and thus shows revolutions (N) proportional to the flowrate.</p> $Q = KN$	 <p>The turbine rotor placed in the stream indicates revolutions (N) proportional to the flowrate.</p> $Q = KN$
Orifice and UNI Δ	—	—	—
Gases, liquids and steam	Gases, liquids and steam	Liquids	Liquids (Gases and steam are measurable in principle.)
300kg/cm ² Max. 4270 PSIG Max.	200kg/cm ² Max. 2844 PSIG Max.	46 kg/cm ² Max. 654 PSIG Max.	200kg/cm ² Max. 2844 PSIG Max.
500°C Max. 932°F Max.	400°C Max. 752°F Max.	300°C Max. 572°F Max.	-200 to 300°C -328 to 572°F
1:5	1:10	1:20	1:25
Upstream run 15 to 20D Upstream run 10D	Not necessary	Not necessary	Not necessary
± 2.0% (of Span)	1.0 to 2.0% (of Span)	0.2 to 0.5 (of Rate)	0.2 to 0.5 (of Rate)
None	Yes	Yes	Yes
Large	Large	Large	Moderate
Adjustment needed	Modification needed	—	—
15 to 1500 mm 0.5 to 60 inch plus integral flow orifices	3 to 150 mm 0.1 to 6 inch Unsuitable for large size pipes	25 to 250 mm 1 to 10 inch Unsuitable for large size pipes	6 to 600 mm 0.2 to 30 inch Unsuitable for large size pipes
Accuracy affected	Accuracy affected	Accuracy somewhat affected	Accuracy affected
No	No	Not recommended	No
Stainless steel	Tapered tube: Glass, Stainless steel, Hastelloy C, Fluorocarbon Resin Float: Stainless steel Tantalum, Ruby	Stainless steel	Stainless steel

2.2 Principle of Electromagnetic Flowmeter Measurement

The operating principle of an electromagnetic flowmeter employs Faraday's law of electromagnetic induction.

In brief, when a conductive liquid flows through the magnetic field of the flowmeter as shown in Figure 2.1, an emf proportional to the average flow velocity is generated in the direction perpendicular to both the applied magnetic field and the liquid flow. The generated emf is detected by electrodes attached to the meter pipe wall. The flow can be obtained by measuring this emf.

The emf is expressed in the equation below:

$$E = D \cdot \bar{V} \cdot B \dots\dots\dots (1)$$

- where E: emf (V)
- D: Inner diameter of meter pipe (m)
- V: Average flow velocity (m/s)
- B: Magnetic flux density (T/m²)

The volumetric flow Q is expressed with the following equation.

$$Q = \frac{\pi}{4} \cdot D^2 \cdot V \dots\dots\dots (2)$$

Thus, the emf E is expressed with the following equation using equation (1) and (2).

$$E = \frac{4}{\pi} \cdot \frac{B}{D} \cdot Q \text{ (V)} \dots\dots\dots (3)$$

From equation (3), it may be seen that the emf is proportional to the volumetric flow Q.

For obtaining error free accuracy, however, the following conditions must be met.

Fundamental Conditions for Obtaining Proper Accuracy
(1) Measured liquids must be conductive: Non-conductive liquids do not generate an emf.
(2) The meter tube must be filled with liquid:
(3) The liquid must be homogeneous:
(4) If the liquid is magnetic, the flowmeter's magnetic field distribution changes. This requires correction in the flowmeter.

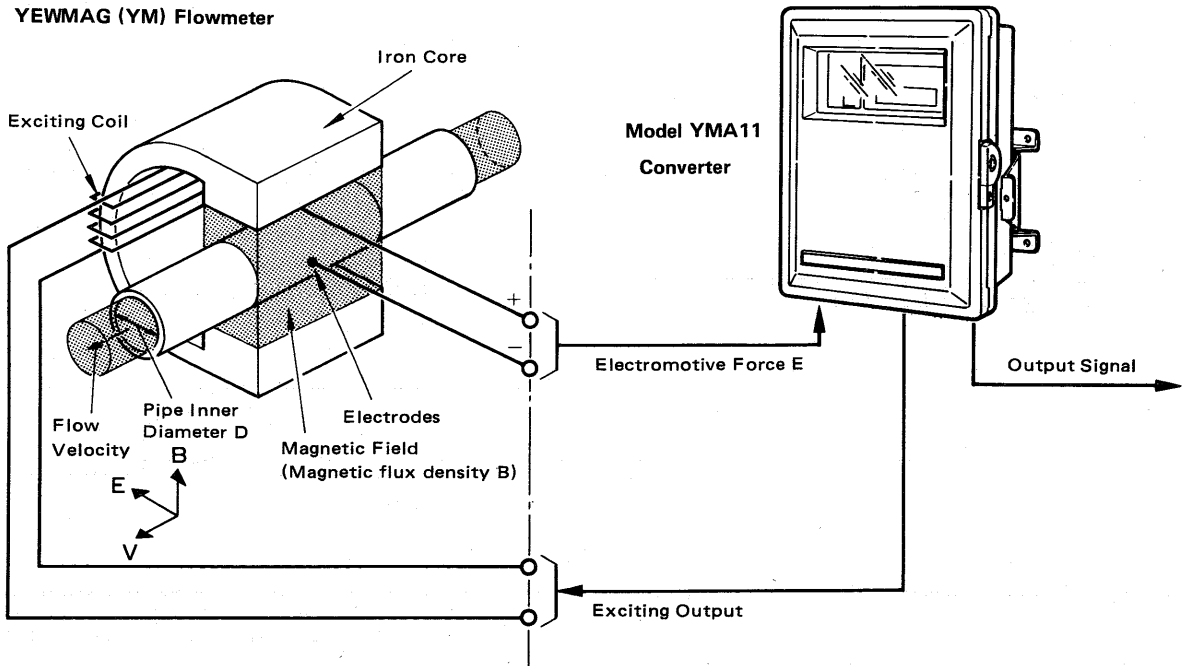


Figure 2-1. Principle of Operation.