

Lecture 8 Chapter 8 Flow



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Maritime Engineering and Hydrodynamics

Chapter 8

- Learning outcomes
 - P8-3
- Contents of Chapter 8
 - Basic theory and principle
 - Flowmeters: orifice plate, venturi tube, pitot tube, flow nozzle, rotameter
 - Flow transmitters: a complete flow measuring system = flowmeter + transmitter
 - Applications
 - Calibration and maintenance

Chapter 8 Flow

- Basic theory:
 - Various physical properties are considered: density, pressure, flow rate (velocity, volume flow rate and mass flow rate) and viscosity
 - Flow measurement involves liquids (water, oil), gasses (compressed air) and pneumatic and hydraulic systems
 - Piping and pumping systems
 - Offshore gas and oil industry

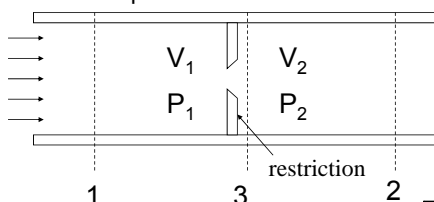
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- Basic Theory - Flow Rate:
Volumetric flow rate is defined as follows:
 $Q = V \times A$
- where
 - Q = liquid flow rate through the pipe (m³/s)
 - V = average velocity of the flow (m/s)
 - A = cross-sectional area of the pipe (m²)
- Factors that affect liquid flow rate:
 1. liquid's viscosity and density,
 2. the friction of the liquid in contact with the pipe.
 3. Reynold number: a dimensionless unit defined as the ratio of the liquid's inertial forces to its drag forces.

$$Re = 3160(SG)(Q)/(ID)\mu$$

Bernoulli's equation

- Basic theory: Bernoulli's equation
 - Relationship between F.R. & D/Pressure



$$\frac{V_1^2}{2} + \frac{P_1}{\rho} = \frac{V_2^2}{2} + \frac{P_2}{\rho} + \sum f \quad V_2 = K \sqrt{\frac{\Delta P}{\rho}}$$

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Velocity, Volume & Mass Flows

- Velocity $V = K \sqrt{\frac{\Delta P}{\rho}}$
- Volume flow $Q = VA = KA \sqrt{\frac{\Delta P}{\rho}}$
- Mass flow $W = Q\rho = KA \sqrt{\Delta P \rho}$

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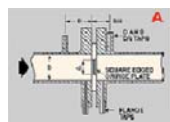
Flow measuring methods:

Numerous types of flowmeters are available for closed-piping systems. In general, the equipment can be classified as *differential pressure, positive displacement, velocity, and mass meters.*

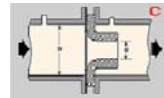
Differential pressure devices (also known as head meters) include *orifices, venturi tubes, pitot tubes, flow nozzles, elbow-tap meters,*

Other methods: *variable-area meters (rotameters), ultrasonic flowmeters, vortex flowmeters, magnetic flowmeters, turbine flowmeters, etc.*

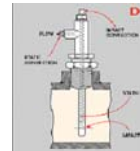
Flow Measurement Methods D/P Sensors



Orifice



Flow Nozzle



Pitot Tube



Venturi Tube



Elbow Tap

Other methods:
Variable-area (rotameter)
Positive displacement
Velocity methods
Mass-related methods

Ref: <http://www.omega.com/techref/flowcontrol.html>

Chapter 8 Flow

- Orifice plate:
 - Construction
 - Principle

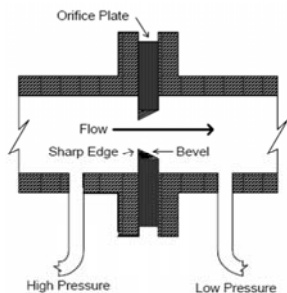
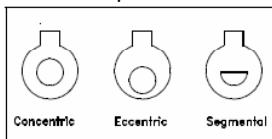


Figure 4 A typical orifice plate

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- Orifice plate

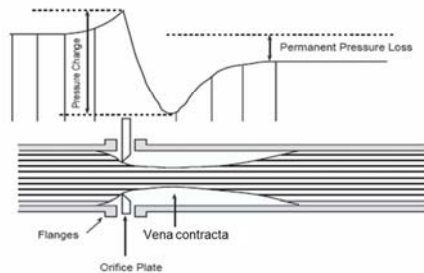
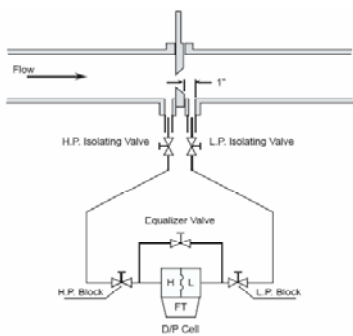


Figure 5 Orifice plate installation with pressure profile

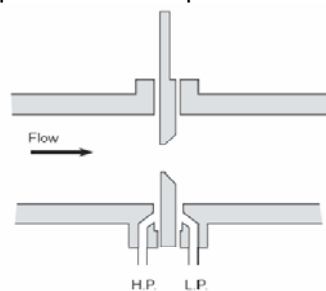
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- Orifice plate
 - Flange taps and three-valve manifold



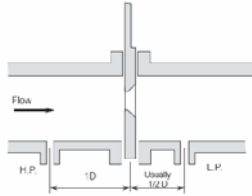
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- Orifice plate: Corner taps



Chapter 8 Flow

- Orifice plate: vena contracta taps



Orifice plate: pipe taps – upstream: two and a half pipe inner diameters, downstream: 8D

Chapter 8 Flow

- Orifice plate
- Advantages of orifice plates include:
 - High differential pressure generated
 - Exhaustive data available
 - Low purchase price and installation cost
 - Easy replacement
- Disadvantages:
 - High permanent pressure loss implies higher pumping cost.
 - Cannot be used on dirty fluids, slurries or wet steam as erosion will alter the differential pressure generated by the orifice plate.

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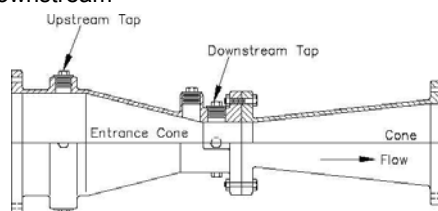
- Orifice plate
- Example
 - An orifice plate is being used to measure the flow of sea water through a pipe. The differential pressure measured across the orifice is 5.0 kPa when the rate of flow is 40 tonne/hour. Determine the flow rate when the differential pressure is indicated as 8.0 kPa (density of s.w. = 1025 kg/m³).

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- Orifice plate – Activity
 - Flow control system: orifice plate has a flowmeter constant of 1.41, inner diameter of pipe is 50 mm
 - Rotameter: 220 litre/min – DP Cell: 20 mA
 - Rotameter: 20 litre/min – DP Cell: 4 mA
 - Water density: 1000 kg/m³
- Determine the range of differential pressure sensed by the orifice
- Determine the sensitivity of the flow measuring system

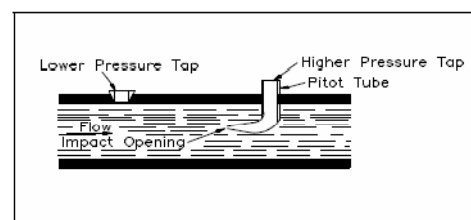
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- Venturi:
 - Construction: consists of a relatively long convergent section upstream of the 'throat' followed by another long divergent section downstream



Chapter 8 Flow

- Pitot tube
 - Construction
 - Principle



Chapter 8 Flow

- Flow nozzle

Chapter 8 Flow

- Variable area flowmeter (rotameter):

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- Flow transmitters

Figure 13 Common construction of a flow transmitter

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D/P Transmitters (electronic)

- Digital D/P transmitter (Foxboro)

Piezo-resistive sensor

Chapter 8 Flow

Flow transmitters

ΔP

Upstream P1
Downstream P2

0-5V, -5+5V
0-10V, -10+10V

4-20mA
0-20mA

Sensor
Orifice
Venturi
Elbow

Signal conditioner (converter, amplifier)
Inductance (Ivdt)
Capacitance
Piezo-electric
Piezo-resistive

Recorder or Indicator (digital)

<http://www.enercorp.com>

Examples: D/P Typed Flowmeters

The Model 340S SteaMeter is a differential pressure type flowmeter capable of measuring saturated steam flow.

The SITRANS DS III transmitter is available for measuring pressure, absolute pressure, differential pressure, flow or level.

Ref: <http://www.sea.siemens.com>

Examples: Orifice Plate Flowmeter



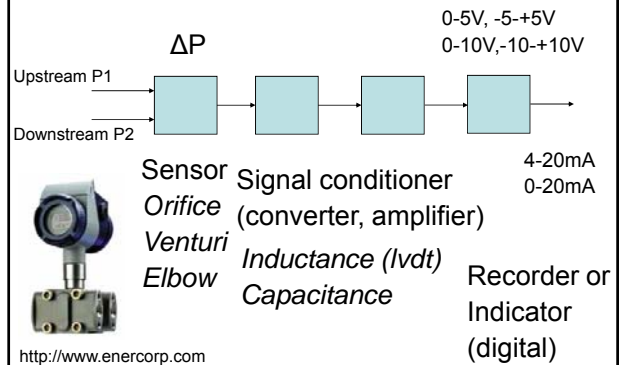
Daniel® Senior® Orifice Flow Meter provides a convenient way to change orifice plates under pressure during line flow. The “Senior” meter saves users time and dollars by eliminating costly by-passes, valves and other fittings.



Daniel® Simplex® Orifice Plate Holders have universal orifice plates and sealing units, and users trust them for fast, economical removal and insertion of orifice plates.

Ref: <http://www.emersonprocess.com/>

Flowmeter (D/P Type)



Examples: D/P Typed Flowmeters



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Adv & Disadv of some flow sensors

Sensor	Rangeability	Accuracy ²	Dynamics (s)	Advantages	Disadvantages
orifice	3.5:1	2-4% of full span	-	-low cost -extensive industrial practice	-high pressure loss -plugging with slurries
venturi	3.5:1	1% of full span	-	-lower pressure loss than orifice -slurries do not plug	-high cost -line under 15 cm
flow nozzle	3.5:1	2% full span	-	-good for slurry service -intermediate pressure loss	-higher cost than orifice plate -limited pipe sizes
elbow meter	3:1	5-10% of full span	-	-low pressure loss	-very poor accuracy
annubar	3:1	0.5-1.5% of full span	-	-low pressure loss -large pipe diameters	-poor performance with dirty or sticky fluids
turbine	20:1	0.25% of measurement	-	-wide rangeability -good accuracy	-high cost -strainer needed, especially for slurries
vortex shedding	10:1	1% of measurement	-	-wide rangeability -insensitive to variations in density, temperature, pressure, and viscosity	-expensive
positive displacement	10:1 or greater	0.5% of measurement	-	-high rangeability -good accuracy	-high pressure drop -damaged by flow surge or solids

Calibration of Flowmeters

All flowmeters require an initial calibration. Most of the time, the instrument is calibrated by the manufacturer for the specified service conditions. However, if qualified personnel are available in the plant, the user can perform his own calibrations. The need to recalibrate depends to a great extent on how well the meter fits the application. Some liquids passing through flowmeters tend to be abrasive, erosive, or corrosive. In time, portions of the device will deteriorate sufficiently to affect performance. Some designs are more susceptible to damage than others. For example, wear of individual turbine blades will cause performance changes. If the application is critical, flowmeter accuracy should be checked at frequent intervals. In other cases, recalibration may not be necessary for years because the application is noncritical, or nothing will change the meter's performance. Some flowmeters require special equipment for calibration. Most manufacturers will provide such service in their plant or in the user's facility, where they will bring the equipment for on-site calibration.

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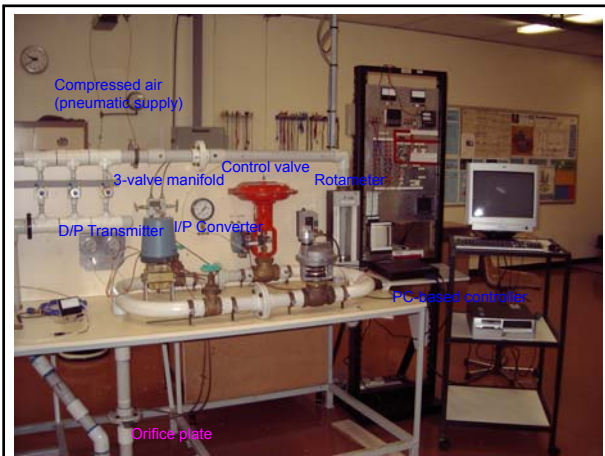
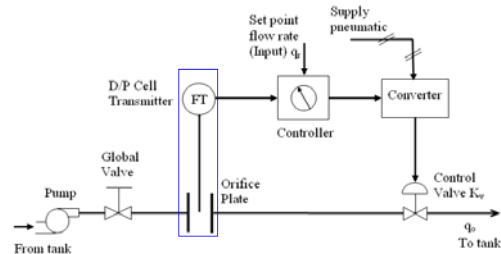
Maintenance

- A number of factors influence maintenance requirements and the life expectancy of flowmeters. The major factor, of course, is matching the right instrument to the particular application. Poorly selected devices invariably will cause problems at an early date. Flowmeters with no moving parts usually will require less attention than units with moving parts. But all flowmeters eventually require some kind of maintenance.
- Primary elements in differential pressure flowmeters require extensive piping, valves, and fittings when they are connected to their secondary elements, so maintenance may be a recurring effort in such installations. Impulse lines can plug or corrode and have to be cleaned or replaced. And, improper location of the secondary element can result in measurement errors. Relocating the element can be expensive.
- Flowmeters with moving parts require periodic internal inspection, especially if the liquid being metered is dirty or viscous. Installing filters ahead of such units will help minimize fouling and wear. Obstructionless instruments, such as ultrasonic or electromagnetic meters, may develop problems with their secondary element's electronic components. Pressure sensors associated with secondary elements should be periodically removed and inspected.
- Applications where coatings may occur are also potential problems for obstructionless instruments such as magnetic or ultrasonic units. If the coating is insulating, the operation of magnetic flowmeters will ultimately be impaired if the electrodes are insulated from the liquid. This condition will be prevented by periodic cleaning. With ultrasonic flowmeters, refraction angles may change and the sonic energy absorbed by the coating will cause the meter to become inoperative.

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Chapter 8 Flow Applications

- Flow control system



Chapter 8

- Applications of flowmeters and flow transmitters
 - Flow control and indication
 - Level measurement
 - Differential pressure measurement

Chapter 8 Flow

- Other methods:
 - Magnetic
 - Ultrasonic
 - Thermal mass
 - Coriolis
 - Vortex
 - Turbine
 - Positive displacement

Chapter 8 Flow

- Summary of Chapter 8
- Basic theory: flow, units
- Flow measuring methods:
 - Orifice – construction, principle and tappings
 - Pitot tube, venturi, nozzle, etc.
- Differential pressure flow transmitters
- Calibration and maintenance
- Applications of flowmeters

Any Questions?



Control Lab Tour
Chapter 8 Flow

- Two groups