Fire Protection Hydraulics and Water Supply Analysis

FPST 2483

Application of Bernoulli equation:

Flow Measuring Devices

Learning objectives

- Upon completing this module, the student should understand
  - Understand the pressure-driven vent/orifice flows
  - Understand the principles for measuring dynamic pressures
  - Understand common flow measuring devices

Pitot Tubes

Air France Flight 447

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Calculating flow from pitot gauge readings

Based upon the equation Q=AV,

$$Q = 29.83\, c_d d^2 \sqrt{P}$$

Where c_d is the coefficient of discharge
d is the orifice diameter in inches
P is the pitot pressure in psi
Q is the flow in gpm

It is also important to be able to use this equation to solve for P when you know Q, as follows:

$$P = \left(Q/29.83 c_d d^2 \right)^2$$

It is always important to determine the coefficient of discharge and the orifice diameter

The Standard Orifice:

BUT FRICTION AND OTHER FACTORS DO EXIST:

VENA CONTRACTA

IT WAS FOUND THROUGH TESTS THAT THE ACTUAL WATER VELOCITY IS NOT EQUAL (IS LESS THAN)
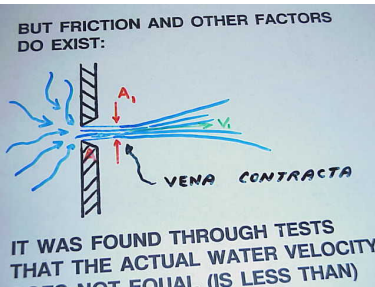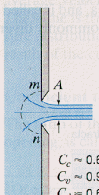
Role of Cd

• Vent flow

$C_c \approx 0.62$
$C_v \approx 0.98$
$C_d \approx 0.61$
(a) Sharp-edge

$C_c \approx 0.62$
$C_v \approx 0.98$
$C_d \approx 0.61$
(b) Square shoulder

$C_c = 1.0$
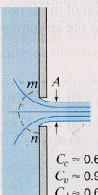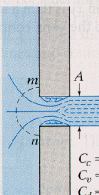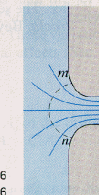$C_v \approx 0.86$
$C_d \approx 0.86$
(c) Thick-plate, square edge

$C_c = 1.0$
$C_v \approx 0.98$
$C_d \approx 0.98$
(d) Rounded

Figure 4.5 Discharge coefficients of nozzles and common appliances.

Since these hydrants are constantly under pressure, you cannot get your hand inside them unless you are very strong and will-ing to get very wet. With wet barrel hydrants it is best to depend upon manufacturer's information. However, using a value of 0.8 is generally a good estimate.

Figure 8.6 The three most common designs of hydrant outlets.

MEASURING THE DIAMETER OF THE HYDRANT OUTLET

Another important technique is to measure the diameter of

Venturi Meter

Giovanni Battista Venturi
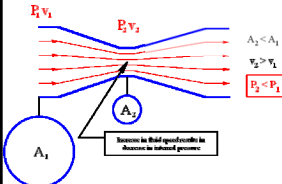
Venturi Calculation

$$2.31P_1 + \frac{V_1^2}{2g} + h_1 = 2.31P_2 + \frac{V_2^2}{2g} + h_2 + h_f$$

$$V_2 = \frac{A_1}{A_2}V_1$$

$$\Delta h + \frac{V_1^2}{2g} = \left(\frac{A_1}{A_2}\right)^2 \frac{V_1^2}{2g}$$

$$V_1 = \sqrt{\frac{2g\Delta h}{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$
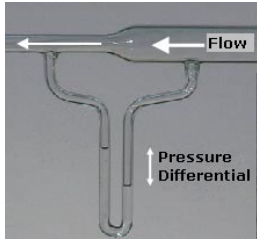
$$Q_1 = Q_2 = A_1 V_1$$

$P_1 v_1$ $P_2 v_2$

$A_2 < A_1$
$v_2 > v_1$
$P_2 < P_1$

A_2

A_1

Increase in fluid speed results in decrease in internal pressure

Fire Protection & Safety Technology
Oklahoma State University

Application of Venturi Meter

Flow

Pressure Differential

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Variations

Orifice D_1 D_t Flow

Flow Nozzle D_1 D_2 Flow

Venturi D_1 D_2 Flow

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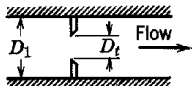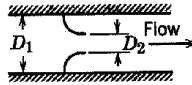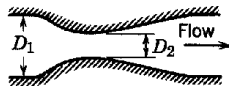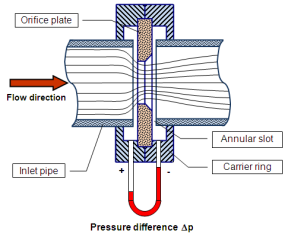
Orifice plate meter

$$V_2 = \sqrt{\dfrac{2g\Delta h}{1 - \left(\dfrac{A_2}{A_1}\right)^2}}$$

$$V_2 = C_d \sqrt{\dfrac{2g\Delta h}{1 - C_d^2\left(\dfrac{A_2}{A_1}\right)^2}}$$

Orifice Plate Meter
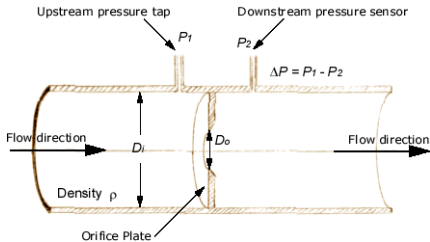

Upstream pressure tap   Downstream pressure sensor

P_1 P_2

$\Delta P = P_1 - P_2$

Flow direction D_i D_o Flow direction

Density ρ

Orifice Plate

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Flowmeters

- Indicate water volume through pump instead of pressure
- Typically a digital readout
- Allowed by NFPA 1901 instead of pressure gauges on all discharges 1 ½ to 3 inches in diameter
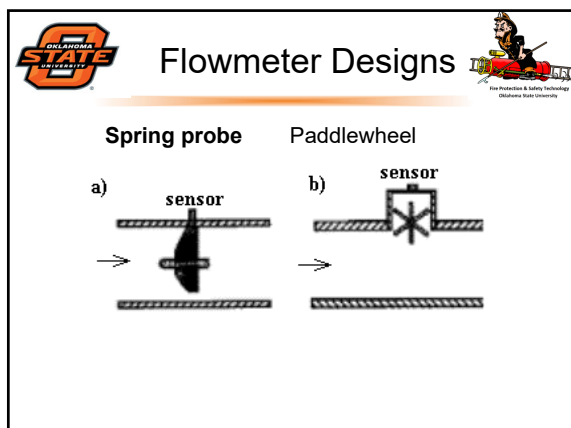- Pressure gauge also required on all 3 ½-inch or larger discharges equipped with flowmeters

Flowmeter Designs

Spring probe   Paddlewheel

Flowmeters

Spring Probe Flowmeter

Paddlewheel Flowmeter
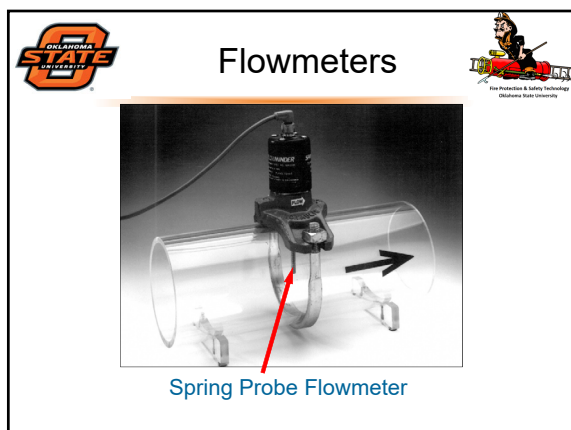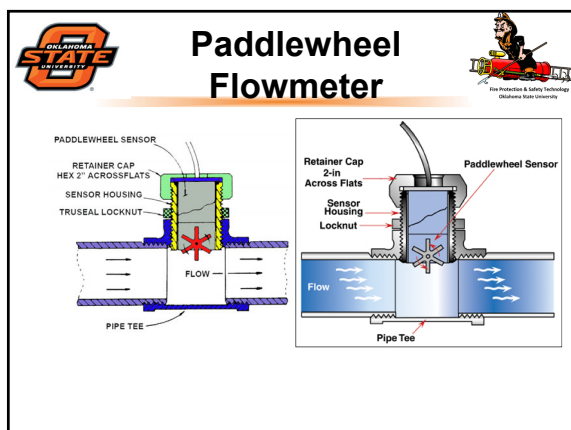
Equipment in your lab: Hose Monster

Equipment in your lab: Annubar

Fischer-Porter Intelligent annubar flow meter
Annubar flow meter is used to measure liquids, gases and steam. The flow meter structure is relatively simple, small pressure loss, installation and demolition convenient, and small amount of maintenance. It will be very widely used. Especially because of its small pressure loss, it has been greatly reduced power consumption, significant energy saving effect.

Summary

- We have reviewed flow measurement instruments, which are based on the principles of hydrokinetics, or specifically, the Bernoulli equation.
  - The pitot tube & orifice flow
  - Venturi meter
  - Orifice plate meter
  - others