Lecture #9

Basic Intent

To gain knowledge of flowsensors.

Flow Sensors

There are three basic approaches to the measurement of flow. The first of these categories involves the use of thermal effects to measure fluid motion. In general, this approach uses a heat source to deposit heat into the fluid, and a thermometer to measure the temperature of the fluid. If the heat source is upstream of the sensor, flow increases heat transport and causes the sensor temperature to increase. Another possible arrangement is to heat a thermistor with a fixed power, and measure its temperature. In this case, fluid flow acts to cool the thermometer.

These approaches can be analyzed to predict the sensitivity of such a system. In general, the fluid flow around a real physical system is very difficult to model, and the resulting performance generally needs to be calibrated. In addition, non-linear effects in turbulent flow can cause severe nonlinearities. Nevertheless, such an arrangement is easy to assemble, and inexpensive thermistors enable such systems to be produced at low cost. properly calibrated, such systems are capable of excellent performance, and are in wide use in industry.

A slightly more complicated approach relies on Bernoulli's Equation, which is:

$$P_1 + \frac{\rho v_1^2}{2} + \rho g h_1 = P_2 + \frac{\rho v_2^2}{2} + \rho g h_2$$

This roughly states that the Pressure + the kinetic energy density + the gravitational potential energy density is a constant throughout a fluid. This principle is applied by measuring pressure at a pair of points in a fluid. When water flows through a pipe with a varying diameter, the total flow rate in each region is a constant (since the fluid must all get through the tube). Therefore, changes in tube diameter are compensated for by changes in fluid velocity. By measuring the pressure in regions with different diameter, it is possible to measure fluid velocity.

Now, the textbook section (P. 394) which describes this technique is not completely accurate. Whereas the drawings and the text discuss measuring pressure drop across a flow impedance (much like a resistor - relies on dissipation in the impedance to produce a pressure drop), the equations all describe a Bernoulli principle, in which a velocity change is being measured. It is important to understand this distinction:

Bernoulli's equation techniques only work if the flow is not turbulent (non-dissipative). Then the pressure difference is between the wide and narrow regions (see equations in text).

Pressure drop techniques only work if the flow is turbulent (dissipative). Then the pressure difference is across the dissipative region (see figures and words in text).

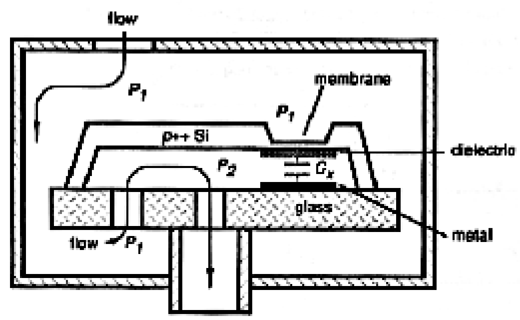

Fig. 1: Capacitive Pressure Sensor

Fig. 1 (Fig. 10-16 in the text) does show a proper configuration for a Bernoulli flow sensor. Here, flow induces a pressure difference across a silicon diaphragm which separates a wide channel from a narrow channel.

The last technique for flow measurement is based on measurement of Doppler effects in sound transport. Since sound is carried by pressure waves in a medium (the fluid), its transport laterally across a channel is affected by the motion of the fluid. It is possible to measure the change in sound frequency due to fluid motion (direct Doppler effect), or listen for changes in the travel time from transmitter to receiver. High sensitivity techniques generally measure frequency shifts, since excellent accuracy may be obtained by use of analog or digital signal processing techniques to measure small frequency shifts.

To review, flow may be measured by thermal, Bernoulli, or Doppler techniques. Thermal techniques are generally least accurate and least expensive, Bernoulli techniques can work well, but are accurate only for non-turbulent flow, and Doppler techniques are potentially most accurate, but are also generally most expensive.

Some possible pictures to be used in the development of these pages:

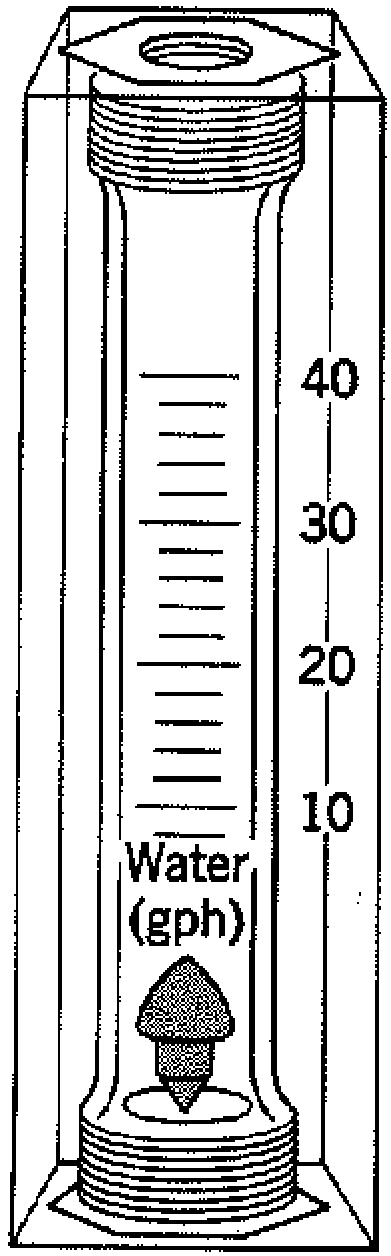

Fig. : Float-type flow meter.

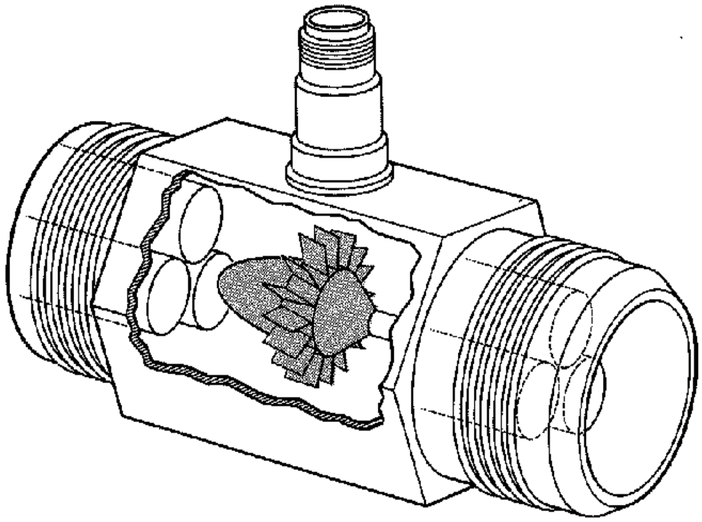

Fig. : Turbine flow meter.

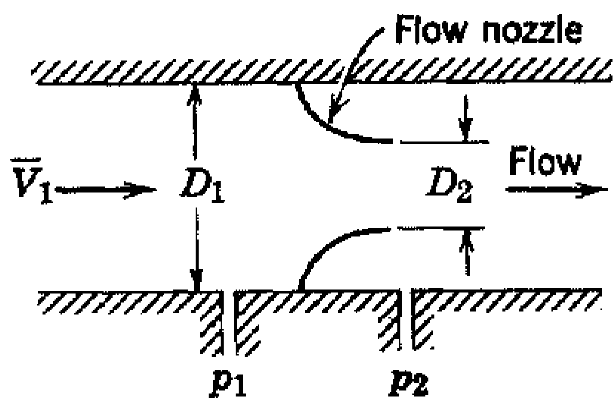

Fig. : Nozzle flow meter in duct.

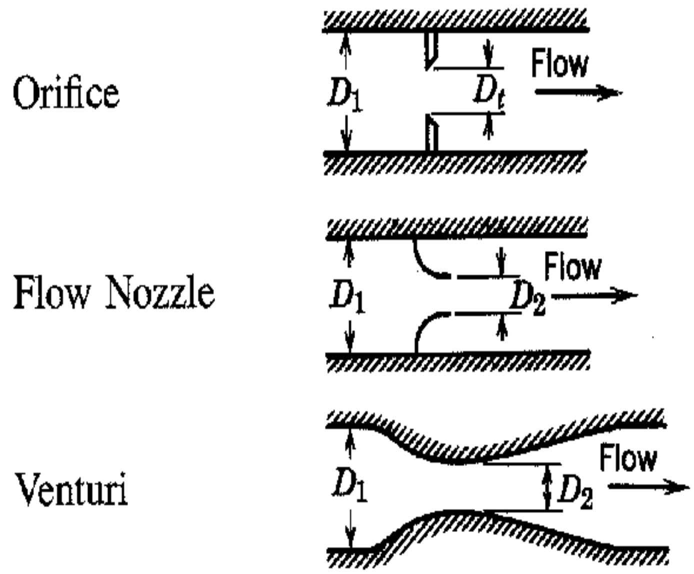

Fig. : Orifice, flow nozzle, and venturi flow meters.

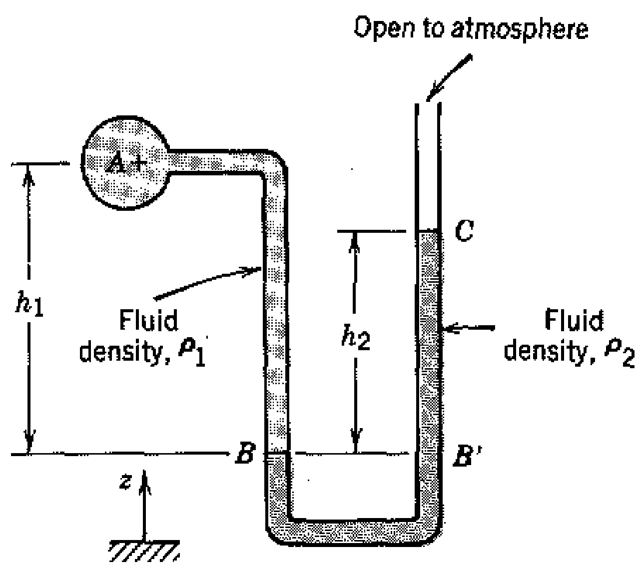

Fig. : U-tube manometer.

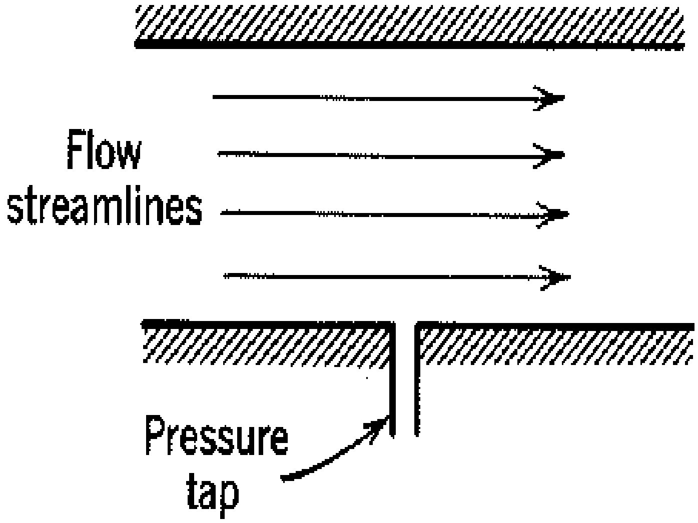

Fig. : Wall pressure tap for static pressure measurement.

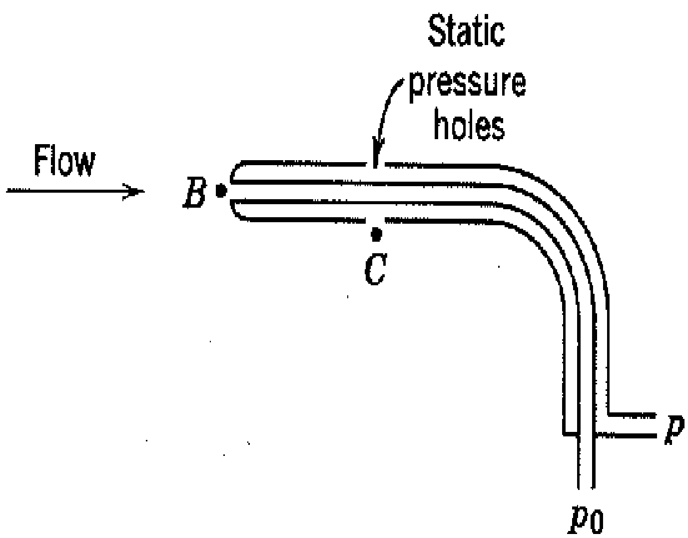

Fig. 1: Static pressure probe.

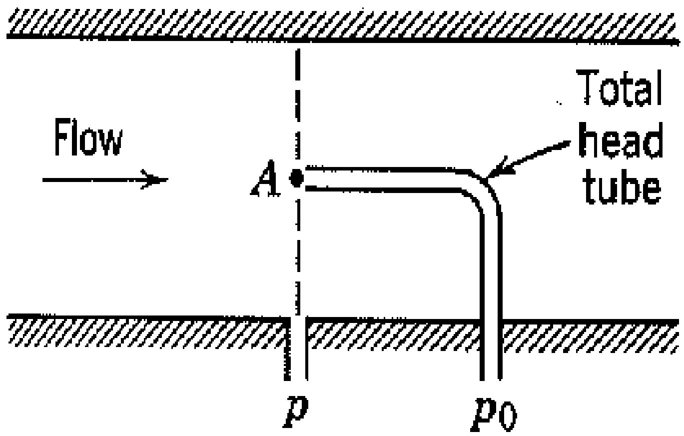

Fig. :Simultaneous measurement of stagnation and static pressures.