

# Wind-tunnel techniques – 3

## Pressure, velocity Measurement

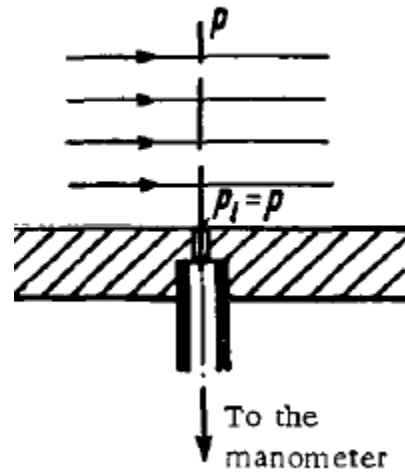
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# Pressure Measurement

Pressure measurement in experimental aerodynamics is important. From the pressure distribution on a body we can determine the forces acting on it also we can determine the local velocity.

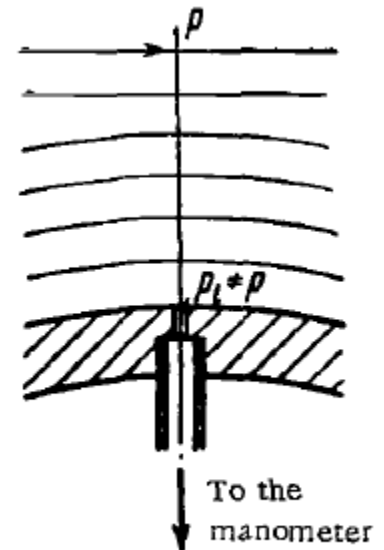
## Measurement of static pressure

A common technique is to connect a stationary probe to an orifice drilled perpendicularly to the wall of the test model at a point where the streamlines are undisturbed and parallel to the streamlines in the undisturbed flow. Neglecting minor disturbances caused by the orifice the pressure sensed by the manometer is equal to the static pressure in the flow.



a

Measurement of static pressure. a — at a flat wall;

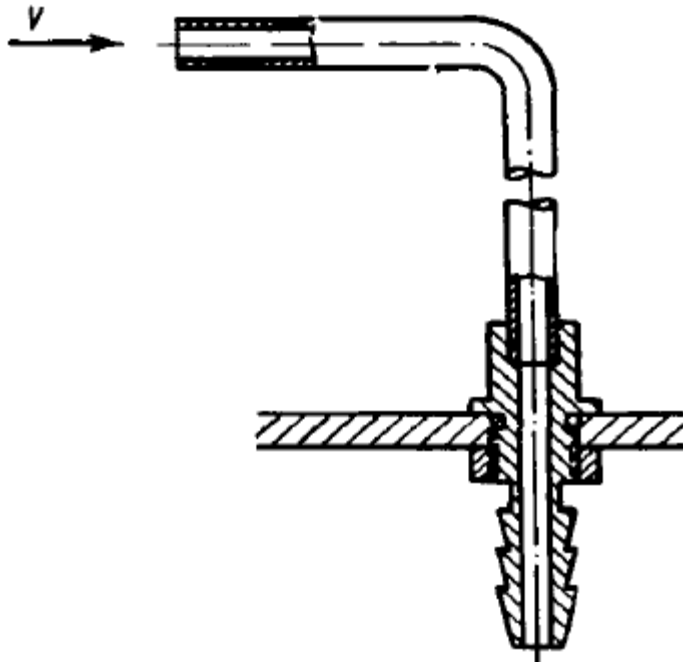


b

b — at a curved wall.

## Measurement of total pressure

- At stagnation point velocity is zero. The heat transfer is negligible in subsonic flow
- The total pressure at the stagnation point is almost exactly equal to the initial stagnation pressure in the settling chamber of the tunnel.
- Total pressure is measured with a cylindrical tube having an orifice pointing toward the flow. The shape of the nose and the ratio of the orifice diameter to the external diameter of the tube do not influence the total-pressure measurements over a wide range of velocities, provided that the axis of the tube coincides with the flow direction.



Total- pressure tube .

# Pressure measuring Device

- The instruments used for measuring pressures in aerodynamic research can be divided into the following groups:
  - 1) liquid-column manometers,
  - 2) pressure gages with elastic sensing elements (mechanical),
  - 3) pressure transducers,

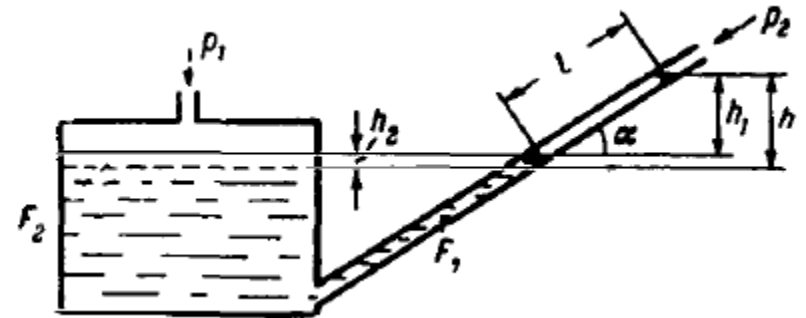
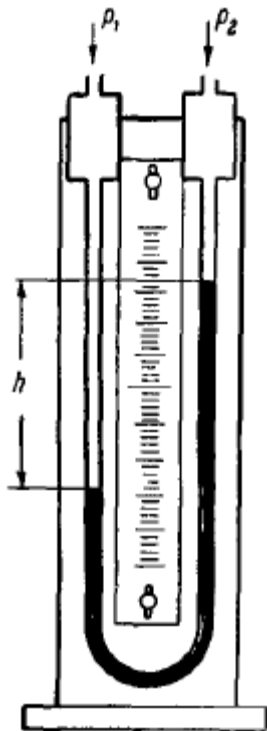
## Liquid-column manometers

- Basic principle of manometer is the pressure applied is balance the weight of a liquid column
- The medium used in liquid-column manometers is most often alcohol, water, **or mercury;**
- The main requirements for manometric fluids are: high chemical stability, low viscosity, low capillary constant, low coefficient of thermal expansion

- **U-tube manometers**

- The U-tube manometer consists of two communicating vertical glass tube. The pressure difference to be measured is related to the level difference  $h$  in the tubes (legs) of the manometer by the equation

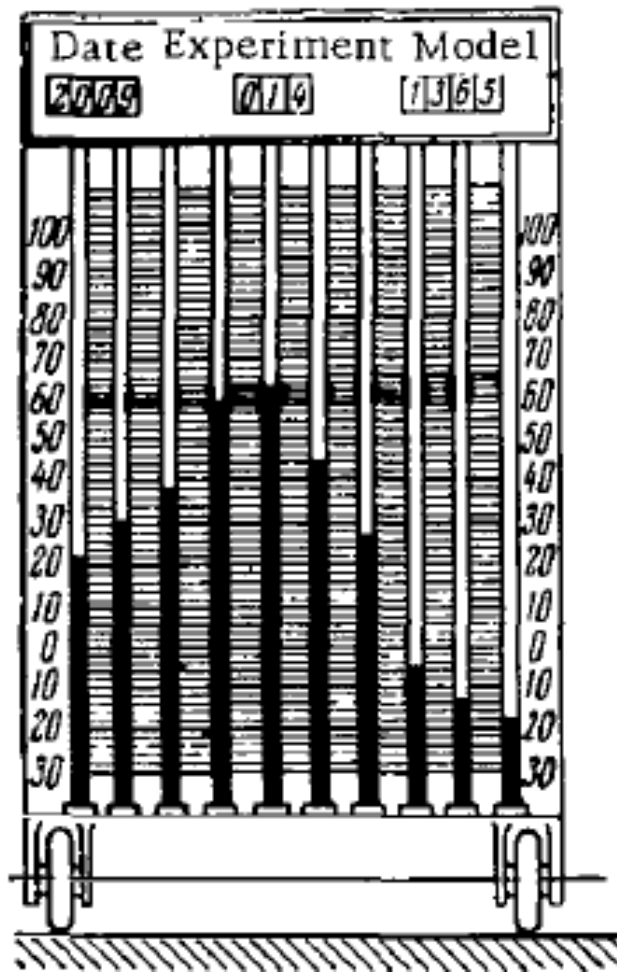
$$P_1 - P_2 = \rho gh$$



Inclined micromanometer.

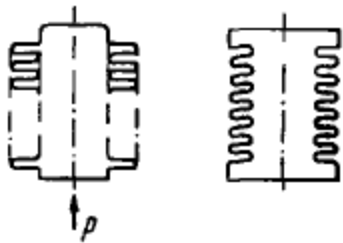
# MULTIPLE MANOMETERS

- The most widely used instrument for measuring pressure distributions is a liquid-column multiple manometer. This is used to measure large number of pressure at a same time
- U-tube manometers are used only when the measured pressure differences may have different signs.

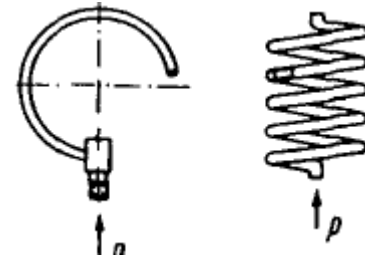


## MECHANICAL MANOMETERS

- When large pressure of the order of MEGA Pascal have to measure the liquid column required extremely large and measure in liquid manometer became unmanageable.
- For such high pressure measurement dial type of pressure gauge is appropriate. Due to change in pressure the mechanical device will expand or compress. This motion can be read on the dial type or on screen.
- Bellows are most widely used in the design of manometers employed for measuring steady pressures in wind tunnels. A bellows is a cylindrical thin-walled tube with uniform folds. The presence of a large number of folds makes possible large deformations of the moving bottom of the bellows under the action of pressure differences.



bellows.



## ELECTRICAL PRESSURE TRANSDUCERS

- Pressure transducers can be designed and built for almost any pressure generally encountered in fluid flow measurement and they can also be used for remote indication
- Pressure transducers are instruments which convert pressure into an electric signal.
- These transducer is classified as mechanical, electrical and optical type.
- Commonly used transducer employ an elastic diaphragm which is subjected to a displacement whenever pressure is applied. This movement is small and kept within the linear range and amplified using a mechanical, electrical, electronic or optical system

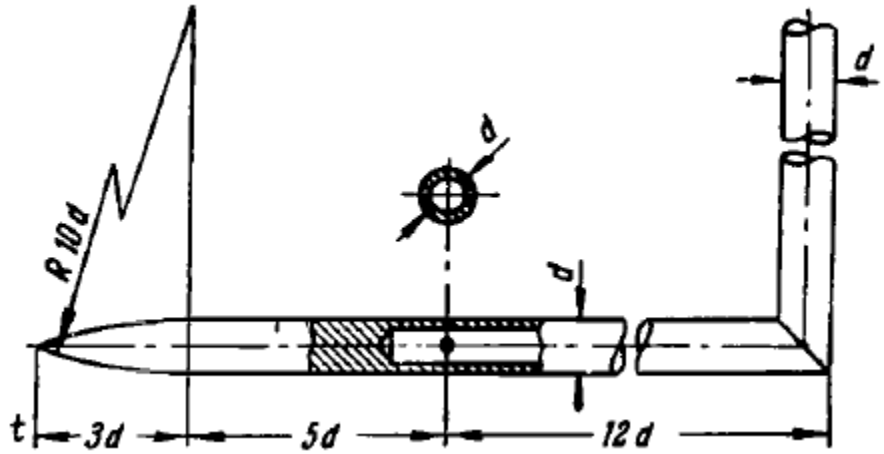
### Static Probe

- Static pressure measurements are very sensitive to the inclination of the tube to the flow direction
- It is common practice the probe should have four holes in mutually perpendicular directions
- The static probe hole should be located such a location that the effect of flow separation and boundary layer should be very less



- For correct measurement of static pressure, the pressure tap must be located in the zone where the pressure acting at probe surface should be equal to the free stream static pressure. Hence appropriate location of static hole will depend on the probe nose. The appropriate location found by experimental research is about  $8D$  from the probe nose for Conical or ogival tubes

Sub sonic static probe:



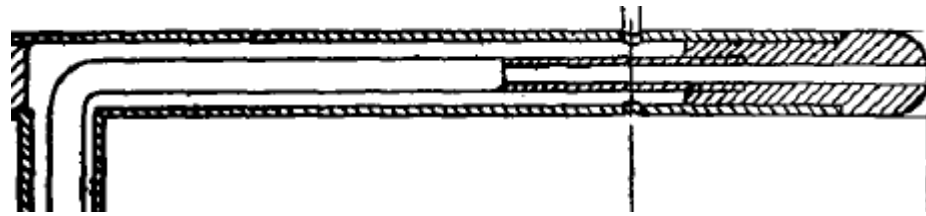
- For measurement of static pressure in supersonic flow, the static pressure hole should be located beyond  $18D$  from the nose . It should have very sharp nose (angle less than  $10^\circ$ ) to avoid velocity changes near to the hole
- Special care should be taken when drilling these holes since at supersonic velocities the smallest roughness at the edges may cause large errors in the pressure measurement.
- Also it is usual practice to use straight probe (without vertical stem) in supersonic flow

### **Pitot Tube**

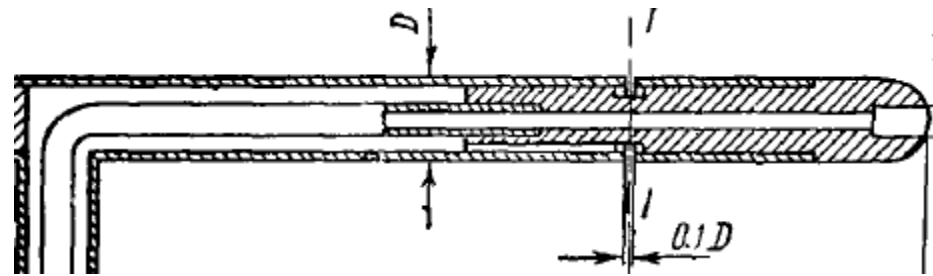
- Pitot tube is used to measure the total pressure of fluid
- This will have hole perpendicular to flow direction

### **Pitot-static tube**

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NPL tubes



Pitot-Prandtl tube

### NPL – National Physical Laboratory

- The NPL tube has circular orifices to sense the static pressure, while the Pitot-Prandtl tube has slots.
- Slots are less liable to clogging, but the measured static pressure is more sensitive to the geometry of the slot. Circular orifices are therefore generally used in hemispherical-nose tubes
- NPL pitot-static tube is treated as standard for many years.

- The pitot-static tube measure both pitot and static pressure in a fluid flow
- **Limitation of Pitot-Static Tube**
- It is very difficult to measurement of small differential pressure experience at very low speed.
- **Factor influencing Pitot-Static tube Performance**
- Major factor influence the pitot-static tube are
  - Turbulence
  - Velocity Gradient
  - Viscosity
  - Vibration effect (within vortex shedding)
  - Misalignment

## The measurement of the Mach number and flow velocity

- Velocity can be measured directly or indirectly as follows:
- The velocity of flow can be directly measure by the photograph technique. Small light particle (aluminum foil) can be kept in water surface and the photograph can be taken at different time interval. Distance can be measured and velocity can be calculated (distance / time)
- Usually the velocity measured in wind tunnel is always indirect method. Velocity or mach no can be calculated from other parameter which are more easily measured in wind tunnel. The parameters  $P_o$ ,  $T_o$ ,  $P$  and  $T$  can easily be measured directly inside the wind tunnel. To find out these parameter, pressure transducer or pitot-static or hot-wire anemometer are used
- In isentropic flow (super sonic) the Mach number can be found using the relation

$$\frac{T_o}{T} = 1 + \frac{\gamma - 1}{2} M^2. \quad \frac{P}{P_o} = \left( \frac{\rho}{\rho_o} \right)^\gamma = \left( \frac{T}{T_o} \right)^{\frac{\gamma}{\gamma - 1}},$$

$$\frac{P_o}{P} = \left( 1 + \frac{\gamma - 1}{2} M^2 \right)^{\frac{\gamma}{\gamma - 1}}.$$

- *PI look (calibration of supersonic w/t) section for other method to find out the mach no in super sonic flow*

- For subsonic(incompressible) flow following relation can be used after finding out  $\Delta p$

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$$V = \sqrt{\frac{2(p_0 - p)}{\rho}} = \sqrt{\frac{2\Delta p}{\rho}};$$

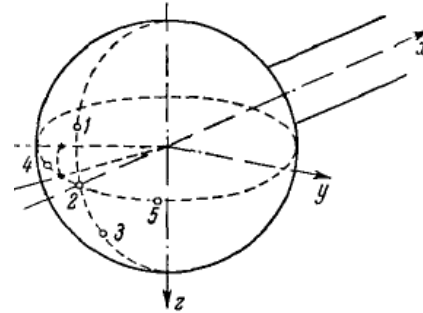
## THE MEASUREMENT OF FLOW DIRECTION

The stream line of the flow inside the test section should be parallel to the tunnel axis, when the tunnel is run without any model in the test section. The measurement of angularity inside the test section can be done using Yaw sphere or Claw yaw meter.

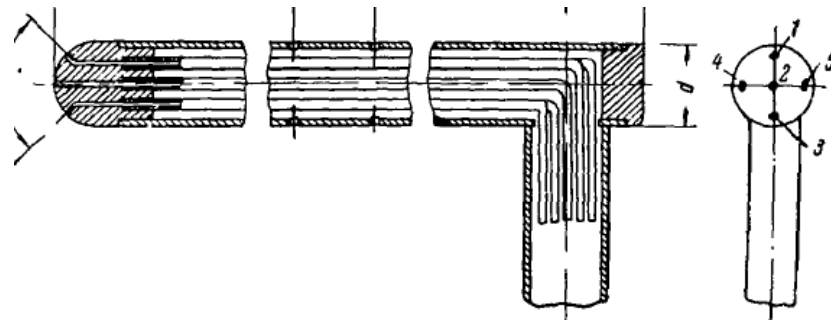
### Yaw sphere

- for measuring the angularity of 2-D flow we need two-hole yaw sphere, however a yaw meter with four holes is required for 3-D flow because the yaw and pitch of the stream need to be measure at same time.
- A sphere with the two orifices located 90 deg apart on the forward port
- The yaw sphere (instrument) axis has to be adjusted in the vertical plan until both the pressure taps measure equal pressure by two pressure tap. Now the angle between the tunnel axis and yaw speher axis gives the angle between the flow axis and tunnel axis.
- Claw yaw mwter
- Claw yaw meter work same principle as yaw sphere

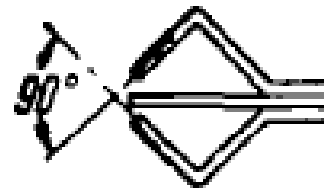
Spherical yawmeter



Hemispherical yawmeters



Claw yaw meter





## MEASUREMENT OF TEMPERATURE IN FLOW

The measurement of the temperature of a flowing gas is important in investigations of the aerodynamic heating of the surfaces of aircraft and rockets. Temperature can be found out measuring following changes in a thermometers

1. The expansion or contraction
2. Increase or decrease in pressure if it is enclosed
3. Change in color
4. Change of state
5. Change of electrical resistance
6. Generation of electromotive force
7. Change of degree of surface radiation

Following are different types of thermometers are used to measure the temperature

Following are different types of thermometers are used to measure the temperature

1. Mercury in glass Thermometer
2. Beckmann Thermometer
3. Gas Thermometer
4. Bimetallic Thermometer
5. Thermocouple Thermometer