

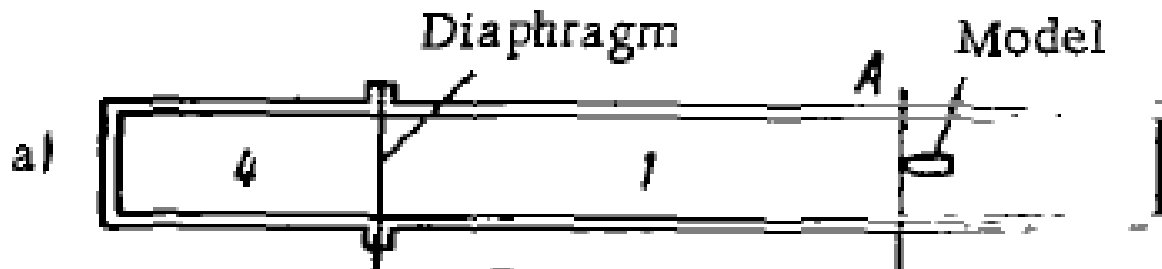
# High Speed Wind-tunnel

By

Sangram Samal

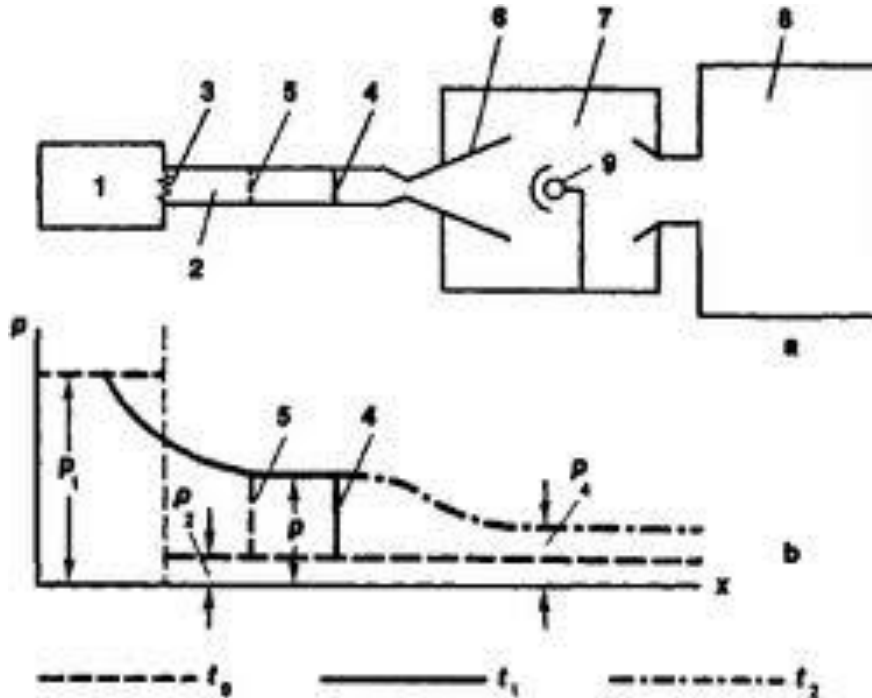
# The Shock Tube

- Shock tube is device to produce the flow at very high Mach No for a very short time
- This device is a long tube, in which the diaphragm separates a region in which the air is compressed to a very high pressure from an evacuated region
- When the pressure crosses a limit the diaphragm burst
- The air rushes at very high speeds into the vacuum region
- The front of the air body is mixed region created a shock wave
- Behind of this have a high mach no and uniform flow
- This flow passes over a model which is placed at initially in vacuum region
- The time for which the uniform flow is achive is for a very short time (micro seconds)
- The measurement of forces is very difficult as it run for vey sort time



# Shock Tunnel

- Shock tunnel are wind tunnel that operate at Mach number 25 or higher for a few milliseconds by using air heated and compressed in shock tube.
- The function of shock tunnel is similar to shock tube



Graph of the variation of pressure in a shock tube: (1) high-pressure section, (2) low-pressure section, (3) membrane, (4) shock wave, (5) contact surface, (6) nozzle, (7) working section, (8) tank, (9) model.

## Gun Tunnel

- The gun tunnel is quite similar to the shock tunnel in operation
- It has a high pressure driver and low pressure driven section with diaphragm separating two section
- A piston is placed in driven section
- When the diaphragm ruptures the piston travel inside the driven tube compressing the gas ahead of this.
- This will cause to produce a shock wave inside driven tube
- Gun tunnel is having limitation of temperature depending on piston design
- Run time can be higher than the shock tunnels

## Helium tunnel

# THE DESIGN OF MODELS

- It is very difficult to reproduce flight conditions exactly in aerodynamic experiments
- We consider following two type of similarity in wind tunnel testing
  - Geometric similarity
  - Dynamic similarity
- Geometric similarity
  - If we consider to different bodies of identical shapes (different size) placed in each case same attitude (may be different fluid, condition and speed) then we say two flow are geometrically similar
  - geometric similarity is fully maintained only when testing full-scale prototype
  - In most cases reduced scale model is created to test inside the tunnel
  - it is difficult to reproduce faithfully the shape of small projections and the surface finish of the smaller model
  - Small variance in shape will case large change the result
  - The Reynolds number can be reproduced in a small-scale model by increasing the velocity in inverse proportion to the geometric scale factor, or by increasing the density of the test medium

- Dynamic similarity
  - With geometric similarity when the ratio of local velocity to free stream velocity will be the same as for corresponding point on both the bodies then we can say flow are dynamically similar. If this is the case the aerodynamic force coefficient will be same for the two bodies.
  - Condition for Dynamic similarity is Geometric similarity plus the identical Reynolds number.

# Calibration

- The **calibration of** wind tunnel test section is to ensure flow characteristic everywhere in the test section

## Low speed wind tunnel

- Calibration of low speed W/T involves the determination of the following
  1. Speed setting – Calibration of true air speed at test section
  2. Flow direction – Angularity of flow if any (pitch and yaw)
  3. Turbulence level
  4. Velocity distribution
  5. Wake survey
- **Speed setting**
- Difference in static pressure between inlet and outlet of contraction cone can be measured and velocity can be found out using Bernoulli equation considering the losses in contraction cone as follows:
- **Flow Direction**
- Flow (stream line) inside the test section should be parallel to W/T axis. So ensuring the flow direction inside tunnel is essential before using the tunnel

- A yaw head probes (sphere-type or claw type) is used to measure the flow angularity of the flow
- **Turbulence**
- The turbulence is created inside the test section due to propeller, Guide vanes, screen, honey comb, and vibration of the tunnel
- The turbulence can be measured with
  - Turbulence sphere
  - Pressure Sphere
  - Hot-wire anemometer
- **Hot-wire anemometer**
- Hot-wire is commonly used instrument to find out the turbulence level inside the w/t. This can be used at very low speed also
- The turbulence is defined as 'Turbulence = Deviation from mean speed / Mean speed'
- The hot-wire anemometer works on the principle of the rate of heat loss from wire heated electrically and placed in side air stream is proportional to the stream velocity
- The wire used is platinum or tungsten of about 0.015 mm dia and about 10 mm long.



- **Velocity distribution**
- Velocity distribution need to find out and plotted for the test section of the tunnel (from lower to upper wall and both the side wall)
- This can be find out using pitot-static tube at different location
- **Wake survey**
- Determine the flow field in the wake of any model. This can be measured by large number of total head reading behind the model
- Rake is commonly used to survey the wake

## supersonic wind tunnel

The **calibration of supersonic** wind tunnel includes determining the test section flow mach no, flow angularity and turbulence level

### MACH NO

- Following method can be used to find out the Mach number of test section
  1. Mach no can be obtained by measuring the static pressure(P) in test section and the total pressure ( $P_o$ ) at settling chamber using formula
  2. Obtaining the static pressure(P) and total pressure ( $P_o2$ ) at test section and using following formula
  3. Measurement of shock wave angle  $\beta$  from schlieren and shadowgraph photograph of flow past a wedge or cone of angle  $\theta$ . Use the  $\theta - \beta - M$  relation
  4. Mach angle  $\mu$  measured from schlieren system.
  5. Measuring total pressure at settling chamber and test section

## **Flow Angularity**

- Flow angularity in supersonic w/t is measured using either cone or wedge meter
- The cone yaw meter is more extensively used than the wedge yaw meter because it is easier to fabricate

## **Turbulence level**

- Hot-wire anemometer is used to measure the turbulence level of W/T
- It shows high fluctuation in the air stream of test section compare to the free air
- This fluctuation due to small oscillations in velocity, stream temperature, and static pressure inside the W/T test section
- The pressure regulator valve, test section boundary layer are the meyor causes for the fluctuation
- Velocity fluctuation at upstream can be reduce by additional screen at settling chamber

## **Calibration of Hypersonic Tunnel**

- Calibration procedure is generally the same as the calibration of supersonic tunnel
- In Hypersonic tunnel it is important to calibrate over the complete range of conditions through which the tunnel will operate

