

Wind-tunnel techniques – 4

Flow Visualization

By

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Flow visualization

Using flow visualization method, flow pattern can be found out. This helps to find out the flow(B/L) separation, wake region, turbulence region, flow distribution across the body. Also it is used to find out the change in density, shock wave in flow. Flow of fluid can be visualized by

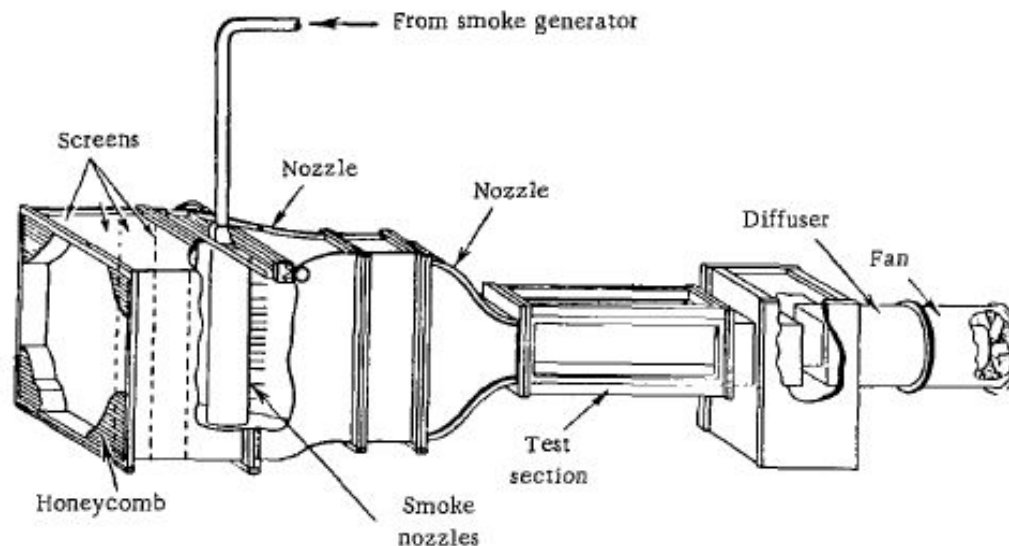
- observing the motion of foreign materials added to the flowing fluid. This is suitable for low speed
- using an optical pattern resulting from the variation of the optical properties of fluid, such as refractive index with variation of density. This technique is used for compressible (supersonic) flow
- Using visualization technique based on a combination of both the above for low-density gas (Helium) flow.

Following are popular techniques for flow visualization

- Smoke flow visualization
- The tuft grid method
- Dye injection technique
- Chemical coating
- The Schlieren method
- The Shadowgraph method

Smoke flow visualization Method

- This method is widely applied at low velocities (up to 40m/sec). This is used to demonstrate flow pattern around the bodies of various shapes and study the problems such as boundary layers, design of exhaust systems of locomotives etc.
- Smoke are injected along the free stream to visualize the flow pattern. White dense smoke is used for this purpose. Quality of flow pattern depend on the type of smoke
- The qualities of smoke should be
 - White and dense
 - Same density of the fluid (air) using in wind tunnel
 - Smoke particle should not deposit on the surface of wind tunnel
 - Production of smoke should be easy



Smoke Production Method

- There are many methods as well as materials used for producing smoke.

Wood Smoke

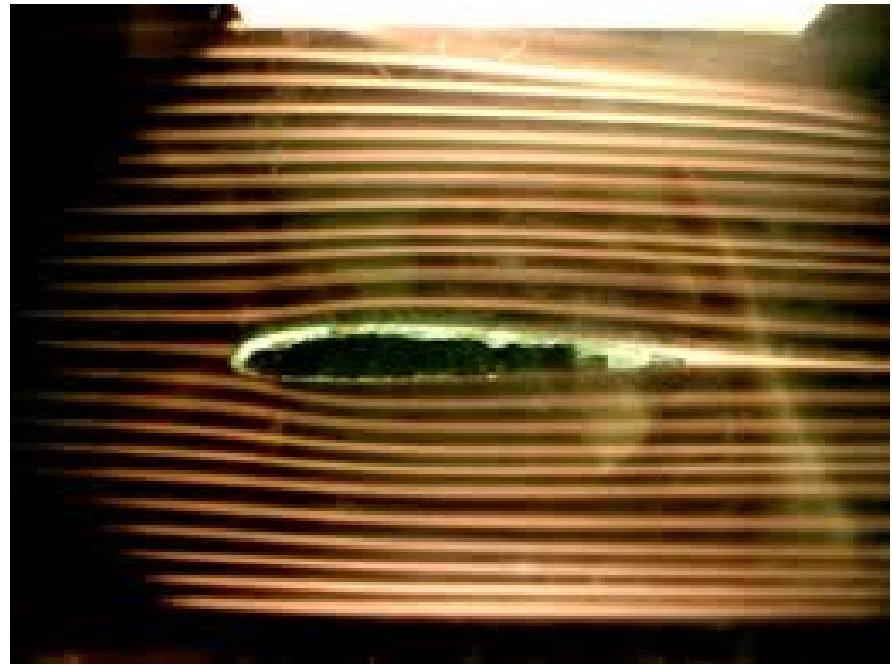
- Smoke can be produced by partial combination of damp wood, Some is rich in tar and water vapor. It has to be initially filtered by passing through a filter and water condenser.
- White and dense smoke can be produced by this method. By choosing proper quality of wood, better smoke can be produced. Small quantity of liquid paraffin will appreciably increase the optical density of the smoke.

Kerosene / Parfine Smoke Generator

- In this smoke is created evaporation of kerosene or parfine in an an air stream. The system is compact and electrically operated.
- Smoke can be generated within few minute. No solid deposits are formed.

Titanium Tetrachloride and ammonia hydrochloric acid smoke

- Also Titanium Tetrachloride or ammonia hydrochloric are used to create the smoke



Video



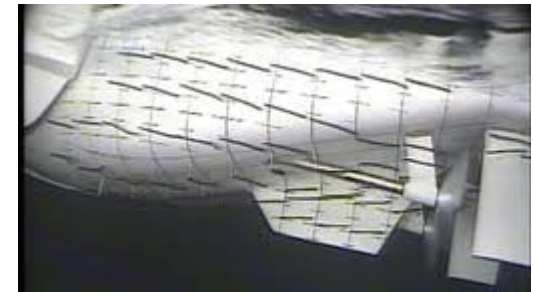
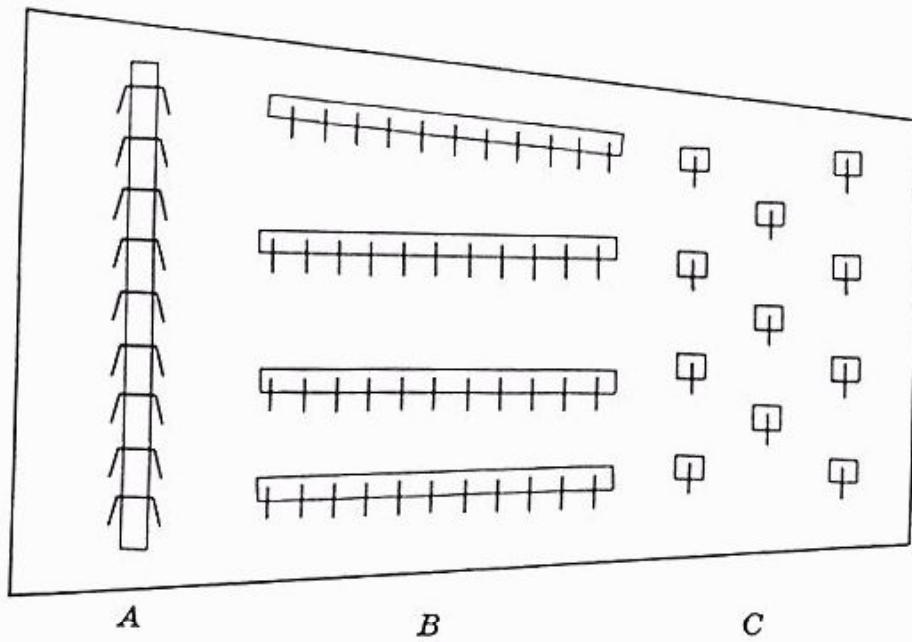
smoke airfoil.flv



smoke flap.flv

The tuft grid method

- This method consists in fixing light silk threads to thin wires inside the stream. The threads remain in a definite position in steady flow, but vibrate at points where the flow is non steady or turbulent. It is thus possible to establish the flow direction over the model.
- Behind the point of boundary-layer separation the vibrations of the threads become very intense. The tuft method is widely used in qualitative analyses of flow around models, since the motion and location of the tufts can be easily observed and photographed
- This method is used for the speed range from 40 to 150 m/s. This technique is used to study the B/L flow, wake flow, flow separation and stall
- Most rapid method of installing tufts is to attach the tuft about every 4 inches to the tape before application. Whole strip can then put on model at once.
- Wire grid method can be used to check the roll-up of the vertices of various wing platform



tuft - Airplane stall strip.flv



tuft -PA-28 Stall.flv



tuft Trailing Vortices.flv

Dye Injection

- Different dye(color) can be used for better flow visualization. Most of time this technique is used in water tunnel.



Delta Wing Airflow.mp4



C-5A Wing Vortice tests at NASA Langley Research Center.mov

Other methods (coating)

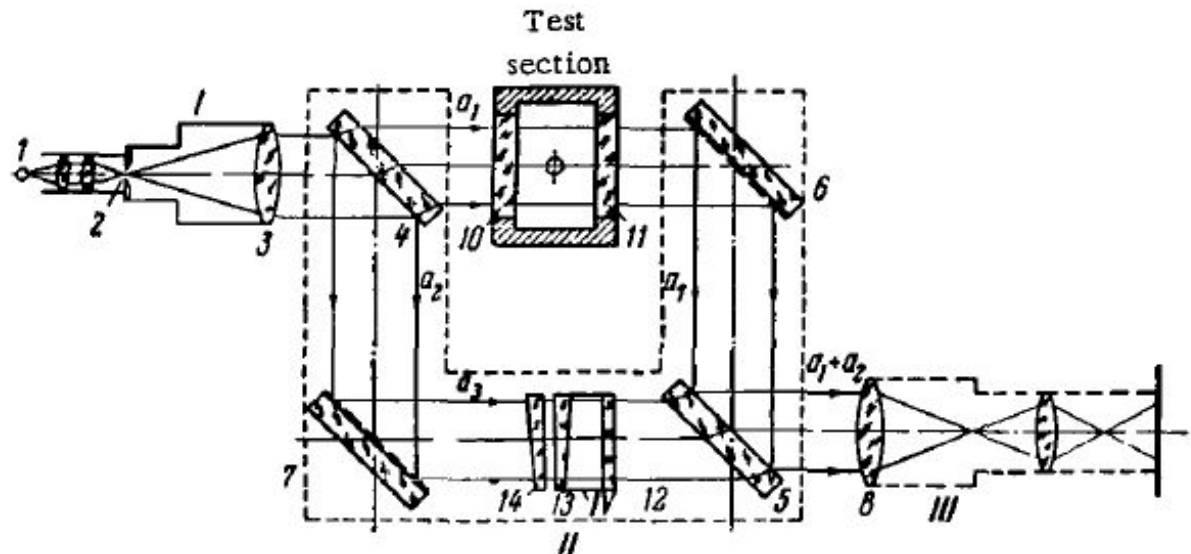
- Chemical coating methods are used now a days for higher velocities. In one of these the body is coated with a thin layer of material which reacts chemically with an active gas added to the wind-tunnel air or injected directly into the boundary layer. The rate of mixing, and the rate at which visible reaction products appear in the turbulent region is higher than in the laminar region, so that the transition between the two can be observed.
- Mixture of lampblack and kerosene can be used to see flow pattern over the model. The air flow spreads the mixture along the stream lines so that after the tunnel has been stopped the flow pattern remain on the model
- Also china clay can be used for flow visualization. This is similar to above method

Optical methods of flow visualization

- Optical methods have found wide application in high-velocity flow, where compressibility effects are considered. Optical methods of flow investigation are based on the dependence of the index of refraction on the density of a gas. Following are commonly used optical method to visualize shock and expansion wave in super-sonic flow.
 - Mach-Zender Interferometer
 - Schlieren System
 - Shadowgraph System

Mach-Zender Interferometer

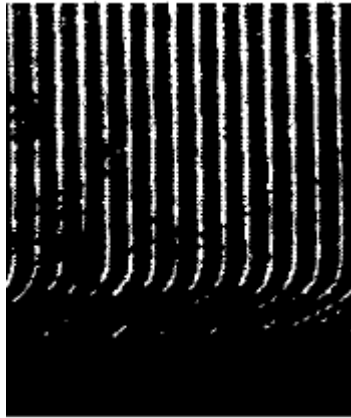
- This is an optical method most suitable for qualitative determination of density field of high speed flows.



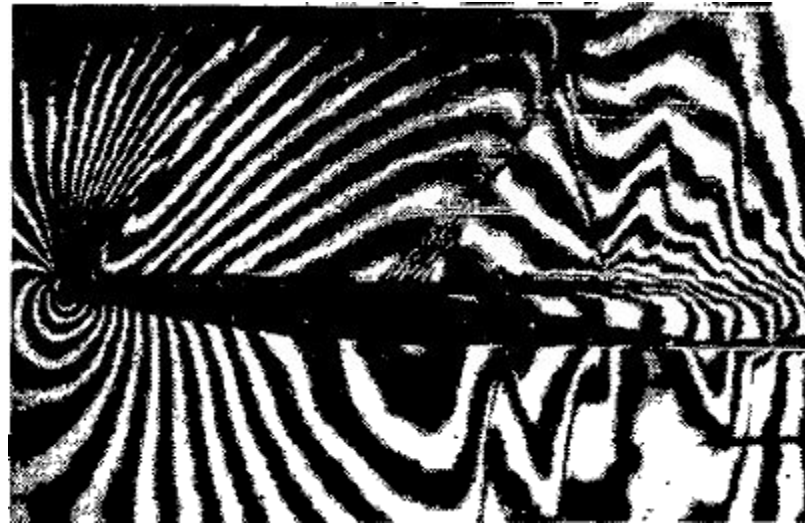
Arrangement and working procedure of Mach-Zender Interferometer

- Light from the source is made pass through lens L1 which became parallel after passing the lens
- The light ray are divided into two beams by the half-silvered mirror M1 and pass through two different path (1-2-3) and (1-5-6) but equal length of path is equal
- One ray (1-2-3) pass through the test section. Other one(1-5-6) pass through outside the test section
- When there is no flow in test section, the two rays having passed through identical paths and re-combined into a single ray. Thus a uniform patch of light will be seen on the screen
- When there is flow in test section then density of medium will change for path (1-5-6)
- If the density of one medium of one path is changed, then the light beam passing through will be retarded and there will be a phase difference between the two beams.
- If there is appreciable difference in the density the picture on the screen will consist of dark and white bands

Fig of Mach-Zender Interferometer and screen



laminar boundary layer

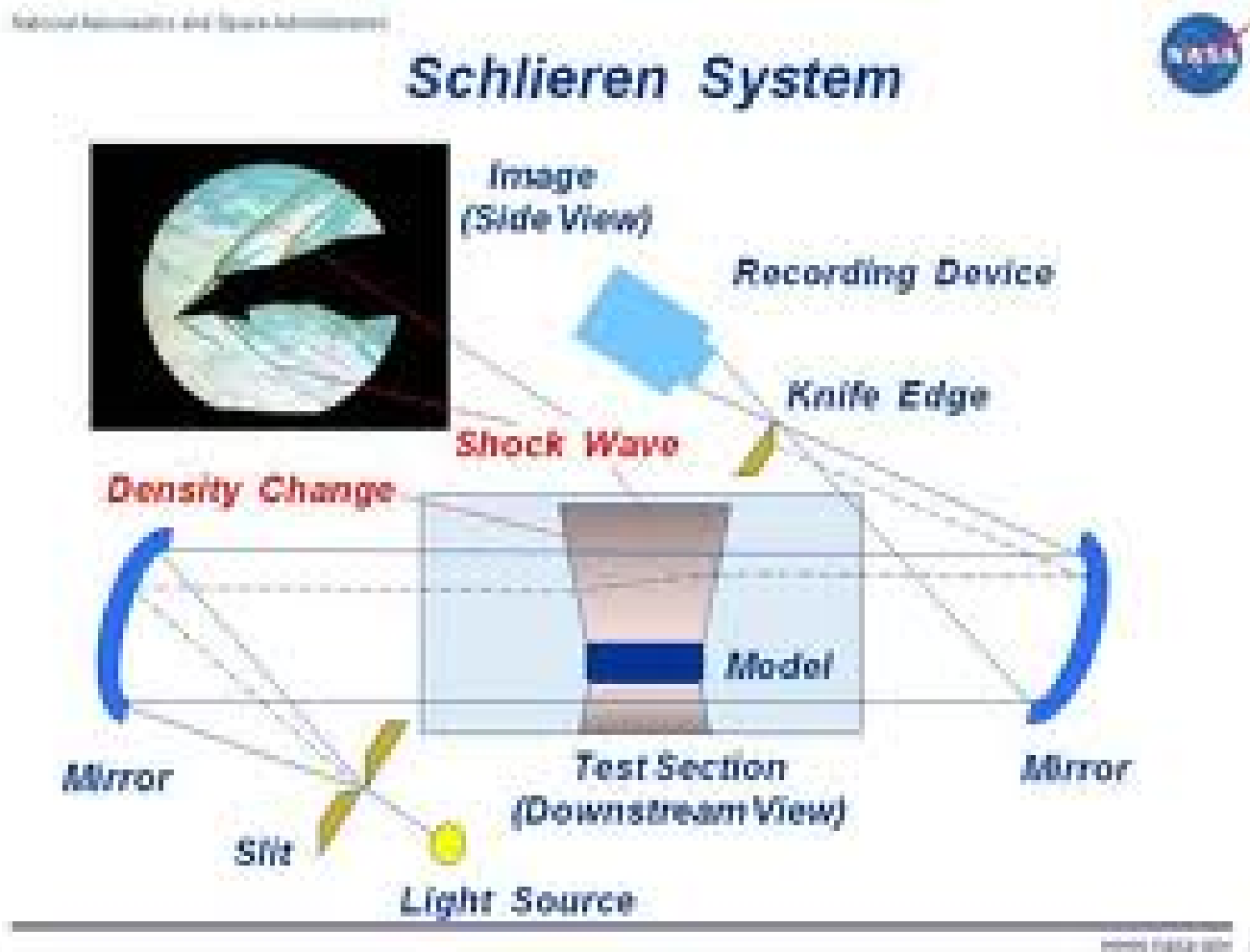


flow around airfoil ($M = 0.95$; $\alpha = 6^\circ$)

Schlieren System

The schlieren method is a technique for visualizing the density gradients in a transparent medium for supersonic flow. This is based on the refraction of light by a refractive index gradient. The index gradient is directly related to flow density gradient

Diagram of schlieren system



Arrangement and working procedure of schlieren system

- Light from a source kept at the focal distance of a concave mirror (M1), so that reflected rays from mirror are parallel
- The source light reflected from mirror (M1) and pass through the test section(glass window)
- Then rays are reflected from second concave mirror (M2) and converged on knife edge which is kept at focal point of second mirror (M2).
- Finally rays reach at screen or camera and shock and expansion wave can be seen or recorded
- When the tunnel is not running all the rays through the test section will go through same order of refraction as they are traveling same medium. The image will be uniform.
- When the tunnel is running, different density exist due to shock and expansion wave
- Then the ray will undergo different order of refraction due to different density
- Some of the ray bent due to density change will not pass through the focal length, but are stopped by the knife edge. The resulting image recorded by camera has darkened lines occur where the density gradient are present

- The model completely blocks the passing of light rays, so we can see black image of the model.



NCSU Supersonic Wind Tunnel.mp4

The Shadowgraph System

- The shadowgraph system is the most simple and least expensive of the three optical system. The system includes a point source, a lens and viewing screen as shown in fig

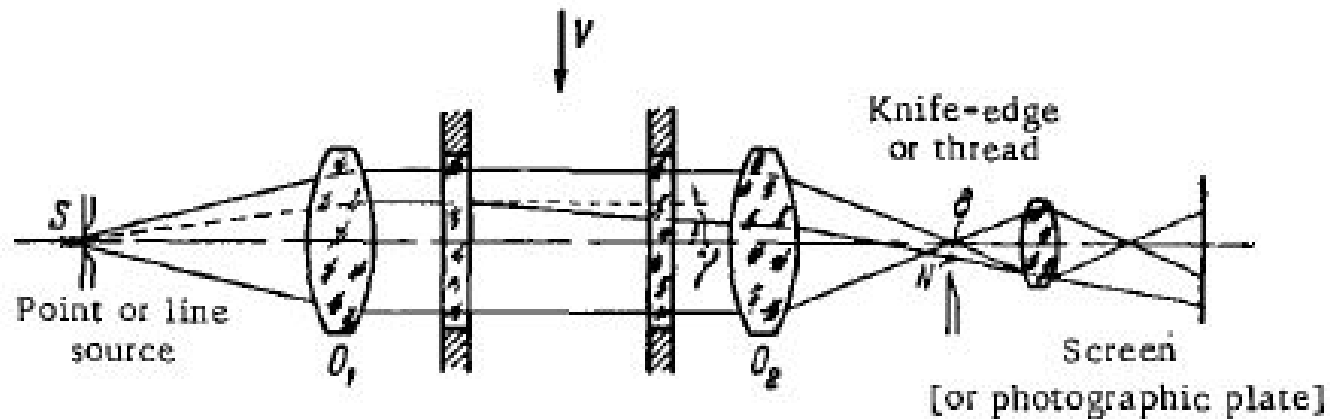
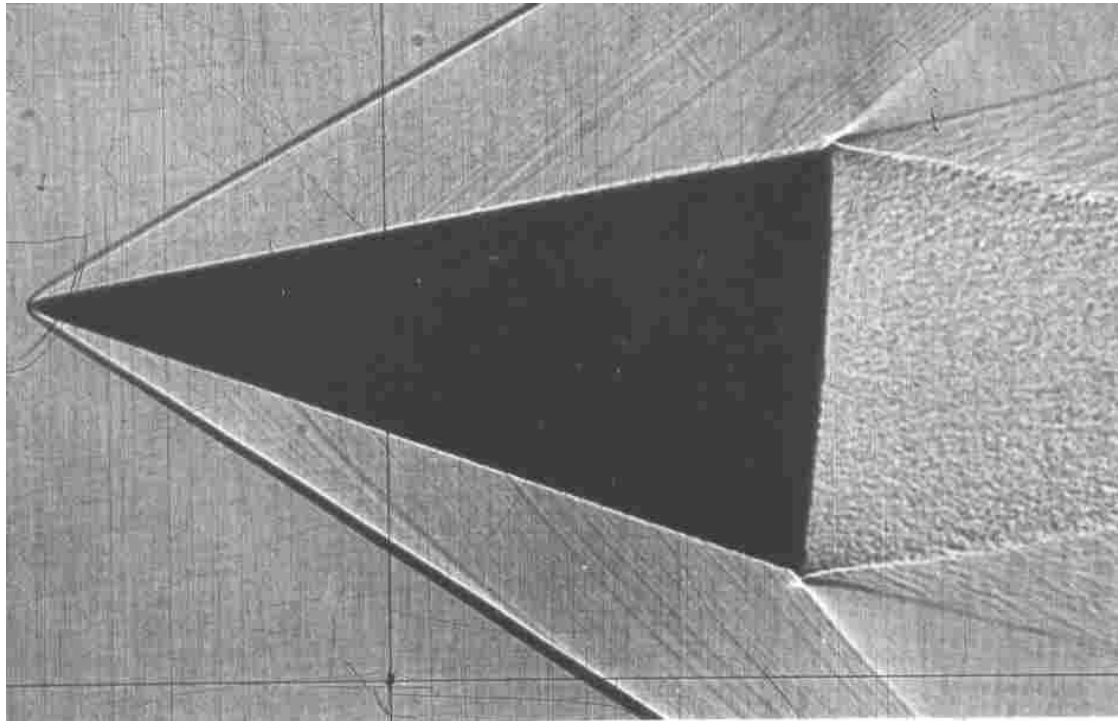
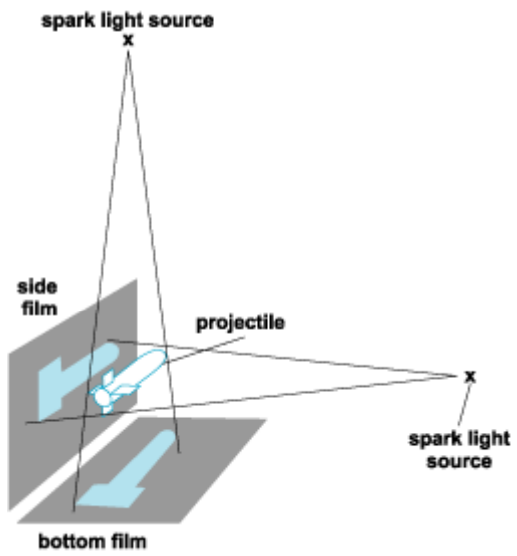


FIGURE 4. 86. Schlieren system .



- When the tunnel is not running the illumination on the screen is of uniform intensity. When flow take place through the test section the light beam will be refracted wherever there is density gradient
- When the density gradient is constant in test section then all the light rays would deflect by the same amount (in case of not running of tunnel) and there would be no change in the illumination of the picture on the screen
- Only when there is a gradient in density there be a tendency for light rays to converge or diverge. In other ward the variation of illumination of picture on the screen appears
- The shadowgraph is best suited only for flow fields with rapidly varying density gradient