

INTRODUCTION TO GLASS EVIDENCE-SURBHI MATHUR

WHAT IS GLASS?

A product of fusion of sand (SiO_2), soda (Na_2CO_3) and lime (CaO) that produces a transparent solid when cooled. Glass is amorphous in nature. It is a 3D network of atoms which lacks the repeated, orderly arrangement typical of crystalline materials.

It consists of: SiO_2 (sand): Basic component required for formation of glass. SiO_2 starts degrading at 1713 degree centigrade; Na_2CO_3 (soda) : it is called as fluxing agent which makes the glass soft and fragile. It brings down the melting point to 1500-1650 degree centigrade; CaO (lime): is called as modifiers used for hardening of glass.

1713°C 500°C 600°C

Coloring components of glass includes: Cobalt: produces blue, pink and green; Copper: blue, red and green; Nickel: Blue, violet, black; Titanium: Yellow and brown; Manganese: Purple; Chromium: Green, yellow, pink; Iron: Green, brown and blue

PROPERTIES OF GLASS

- It is solid, hard and durable material.
- Disordered and amorphous.
- Fragile and easily breakable in sharp pieces under tension.
- Transparent to visible light.
- Inert and biologically inactive material.
- Electrical and thermal resistance.
- Range of thermal expansion
- High rigidity and stability
- 100% recyclable

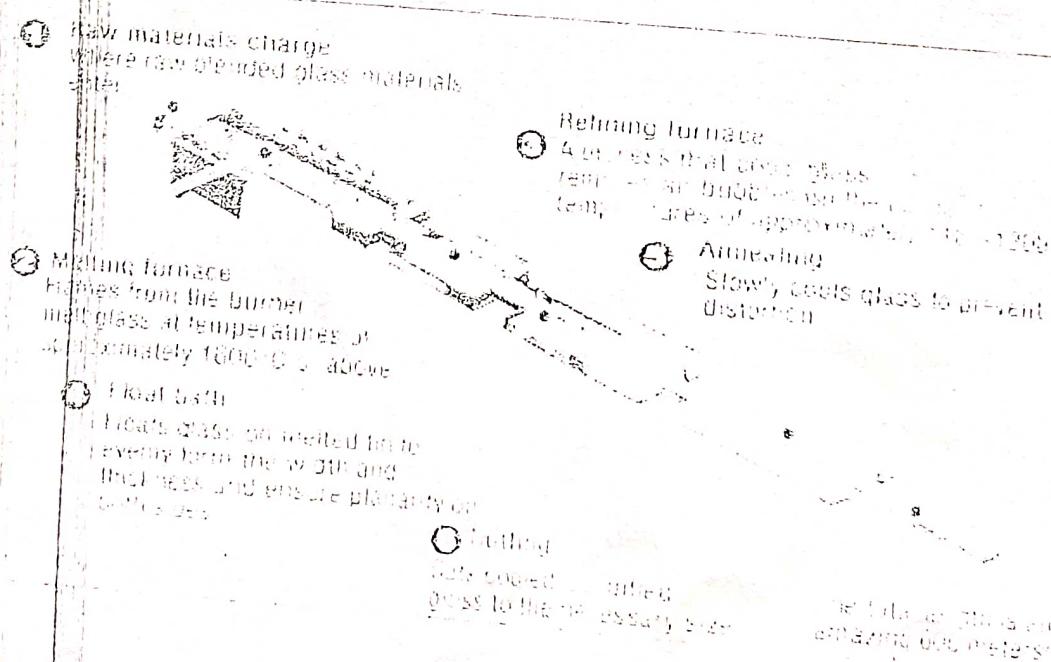
TYPES OF GLASS

- **Fused Silica:** Contains 100% silica, e.g. fused quartz containing silica in amorphous form. Quartz is crystalline form of silica. Such type of glass is used to prepare optical fibers used for telecommunication, as an envelope in high intensity discharge lamps, halogen lamps (as it has high strength and melting point) and cover lid to protect internal circuits of computer hardware.
- **Soda lime glass:** contains Silica- 60-70%, Soda- 12-18%, Lime- 5-12%. Other type of glass are used for windows, panes, and glass containers (bottles and jars) for beverages, food, and some cosmetic items.

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- Boro-silicate glass: also known as pyrex. Contains Silica- 70-80%; Boric acid- 7-13%; Alkali oxide (Na_2O & K_2O)-4-8%; Aluminium Oxide (Alumina)- 2-7%. Borosilicate glass has a wide variety of uses ranging from cookware, lab equipment, microwave utensils to high quality products like implantable medical devices and devices used in space exploration.
- Lead Glass: contains Silica-54-65%; Lead Oxide (PbO)- 18-38%; Soda/Potash- 13-15%. Lead increases the refractive index and brilliance of glass. Lead is very good absorbent of radiations such as X-rays, gamma rays. Protection windows in laboratories, radioactive storage stations, nuclear fuel development plants and reprocessing plants, lenses for safety goggles and protective screens for radiation testing equipments.
- Alumino-silicate glass: contains Silica-6.2%; Alumina- 17%; CaO - 8%; MgO - 7%. It is able to withstand high temperatures and thermal shock and is typically used in combustion tubes, in high-pressure steam boilers, and in halogen-tungsten lamps capable of operating at temperature as high as 750°C .
- Borate glass: Contains little or no silica. Used for soldering purpose.
- Phosphate glass: Composed of Phosphorous pentoxide (P_2O_5). Used in semiconductor devices.
- Chalcogenide glass: these are non-oxide glasses, containing group 16 elements like sulphur and selenium combined with arsenic and halides. These are used in switching devices of computers.

MANUFACTURING OF GLASS



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Step 1: All the ingredients like silica, soda, lime or other minerals along with Cullet/waste glass are first allowed to melt in melting furnace at about 1500 deg C.

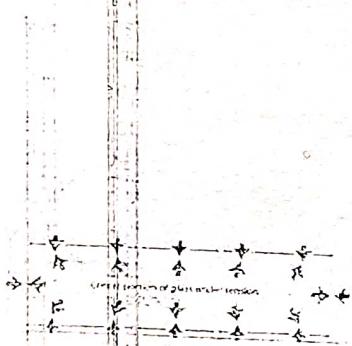
Step 2: the mixture is then allowed to undergo refining and homogenizing process in order to control or regulate the viscosity of the molten mixture. Thermal and mechanical stirring is done.

Step 3: The molten material is given a particular shape.

Step 4: The formed glass has to undergo annealing process i.e. slow and controlled cooling in range of 700-1000 deg C in order to prevent crystallization and to relieve internal stress. The glasses which are not annealed are liable to crack and shatter under mechanical stress or shock.

Step 5: Secondary processing of the molded glass like tampering or toughening process. It is disannealing process of thermally stabilizing the glass by inducing compressive stress at its outer surface, while bringing its inner surface in tension. Any damage to the surface will expose the centre which is in tension and thus, the glass will break. In this process in which the glass is heated above its transformation temperature (at 598 deg C), maintained at this temperature for 10 minutes and then cooled strongly (at 4.5 deg C per minute). These type glasses are called as safety glass or tampered glass which will break into blunt pieces (less harmful).

TEMPERED GLASS

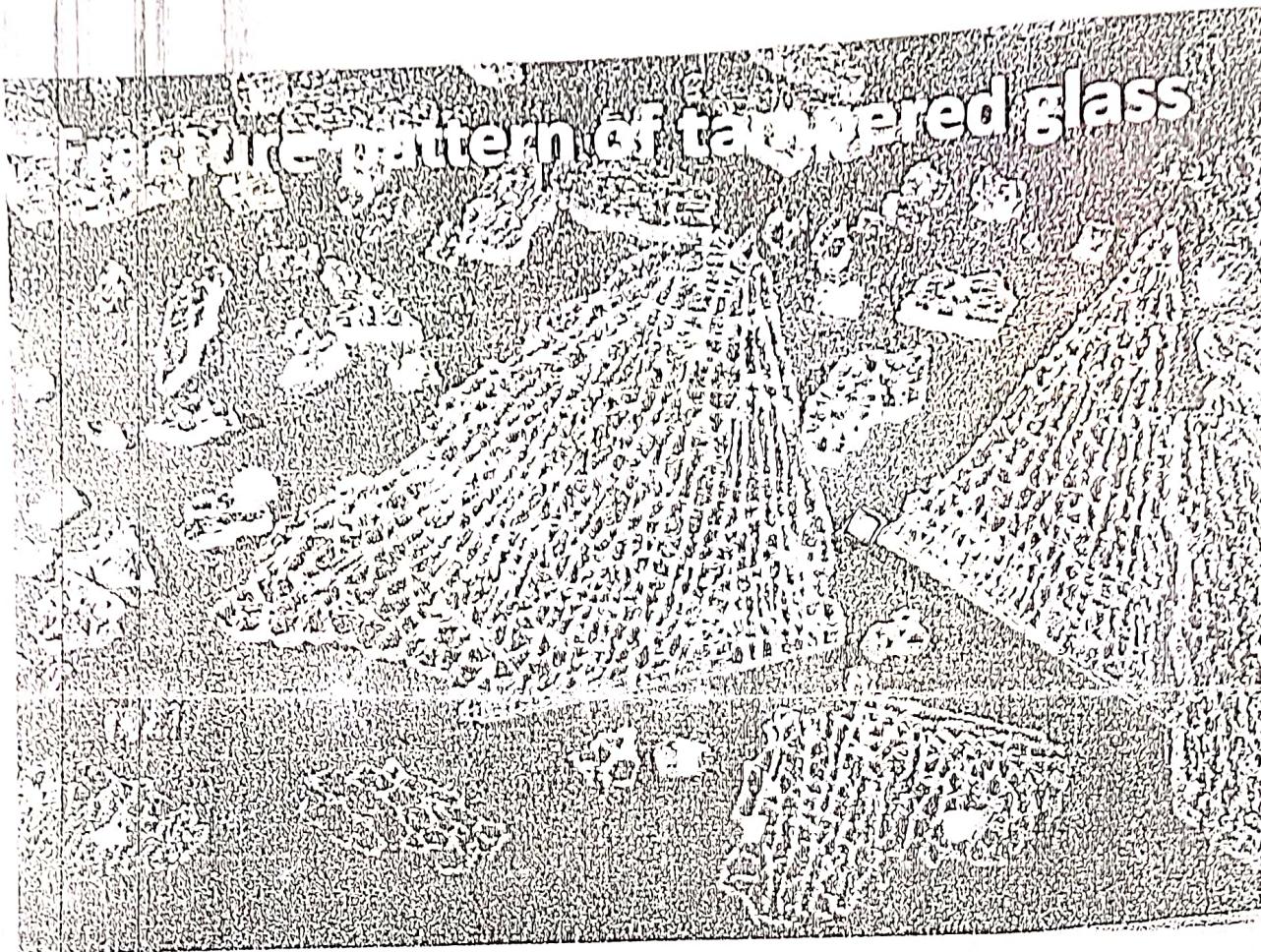


6) Design no

- 1) Melting - 1500°C
- 2) Homogenization
- 3) Casting
- 4) Annealing -
to prevent
crystallization
- 5) Cooling
- tampering
toughening
(+) +
Disannealing
heat - 598°C
- (cooling rate)
tampered
breaking in blunt
pieces

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Step 6: secondary process also include decoration, polishing, frosting (etching with acid to change optical characteristics), coloring.



FORENSIC IMPORTANCE OF GLASS

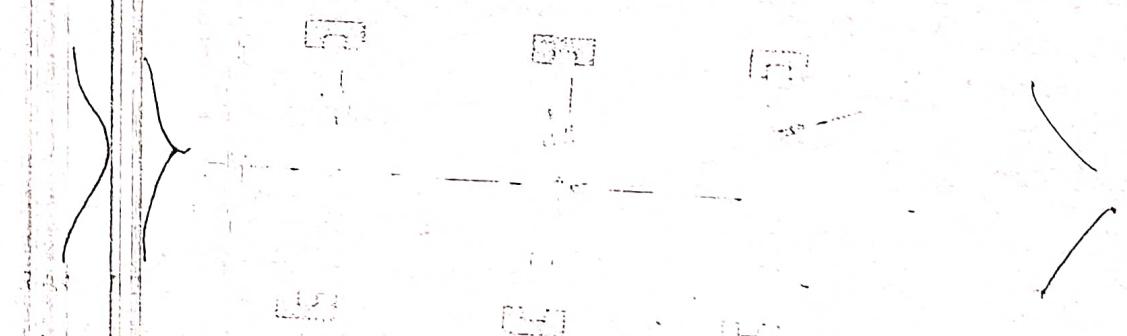
Glass, as a physical clue, is frequently encountered in various crimes, such as burglary, road accidents, murder, sexual assault, shooting incidents, arson and vandalism. The chips of broken glass from a window may be lodged in suspect's shoes or garments during the act of burglary or particles of headlight glass found at the scene of hit and run accident may offer clues that confirm the identity of a suspected vehicle or glass may also be found on the clothing of an alleged assailant, where a bottle is used as weapon. Further, anytime, there is violence, bottles, window pane glass, mirrors, eyeglasses and other glass objects can be accidentally scattered and fragments of these can adhere to the criminal's clothing or shoes. Thus, glass forms one of the crucial materials in many criminal investigations. Forensic analysis of glass includes:

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- Determination of the types of glass at the scene
- Determination of how the glass was fractured
- The site where the fracture originated
- Sequence of shots
- Direction of applied force
- Use of physical characteristics to classify it
- Individualizing the glass to a source

FRACTURE PATTERNS OF GLASS

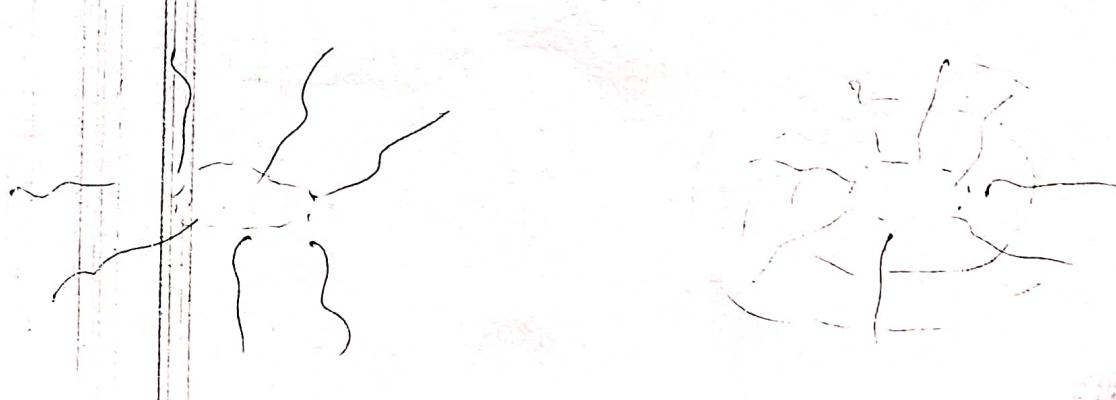
Whenever the force is applied on glass, it causes a deformation that may leave a visible mark or fracture on it. Compressive strength of glass is more than its tensile strength that is why glass breaks under tension not due to compression. Glass acts initially as an elastic surface and bends away when a force is applied. When the force increases beyond its tensile strength, it cracks.



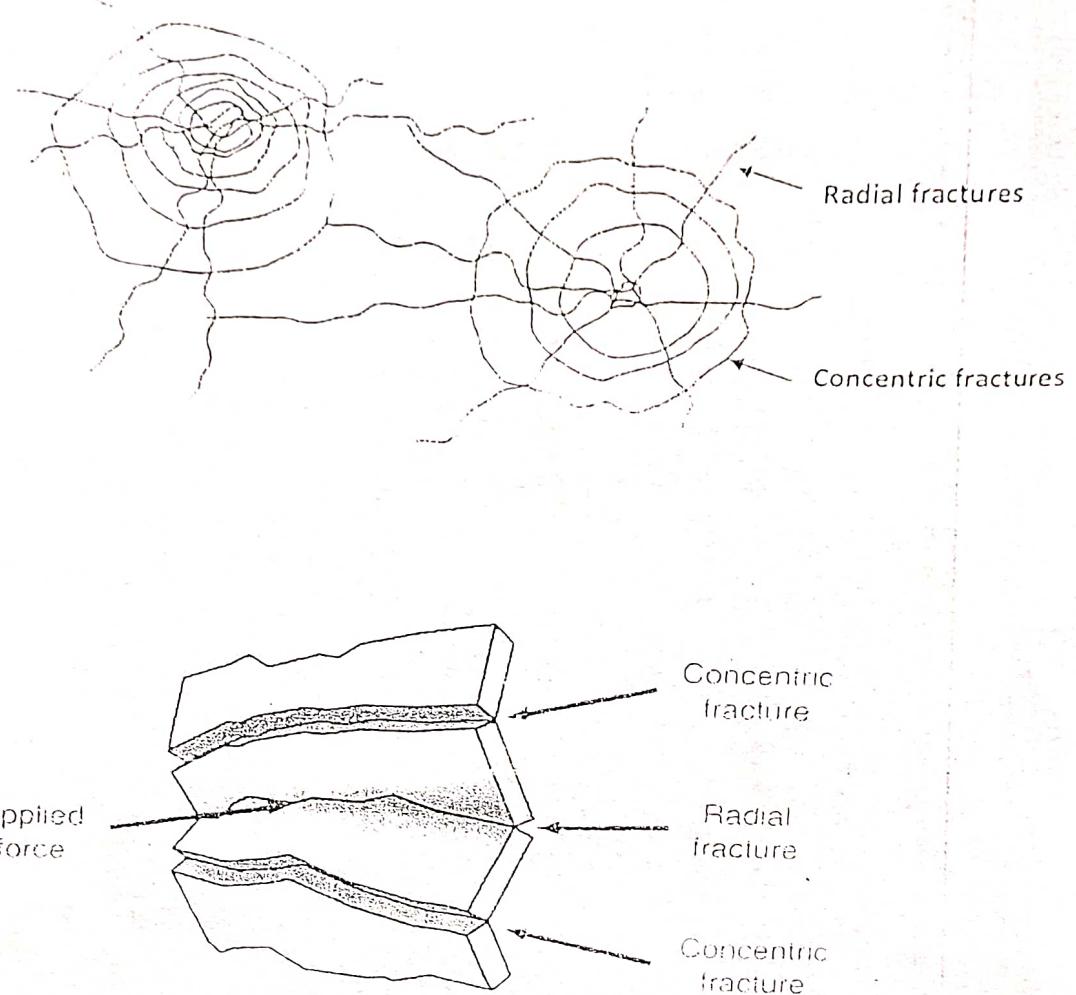
Cracks travel in two directions: along the length and along the thickness.

Radial/primary fractures: as soon as the glass breaks, the fracture proceeds towards near surface and at the same time radiate outwards from the centre point of origin.

2. **Concentric/secondary fractures:** if the stress is still not relieved, the continued stress on the segment between radial fractures places tension on the near surface. The segments between radiating fractures break



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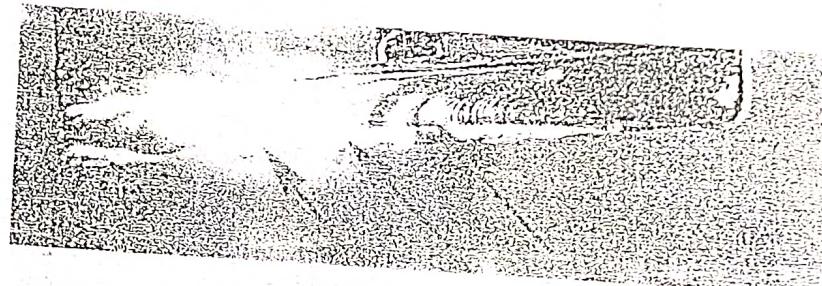
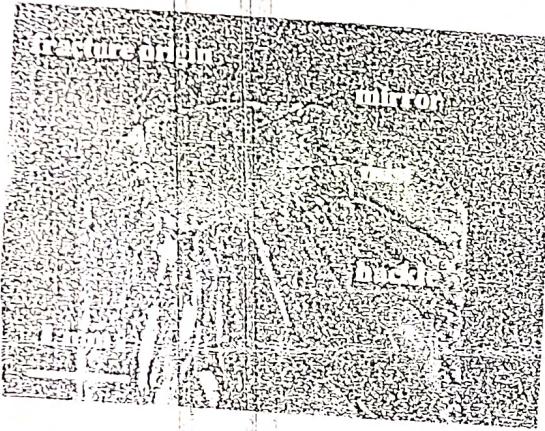
Fracture patterns are unique. Fracture features in a piece of glass reflect the nature of the glass, and velocity of the breaking object. Glass fracture examinations can provide information as to the direction of the breaking force and the sequence of multiple impacts. A physical match of two pieces of glass establishes that they came from the same source to the exclusion of all other sources.

Features of fractured surface

Mirror: near the fracture origin, the flat or featureless surface. It indicates relatively slow fracture propagation.

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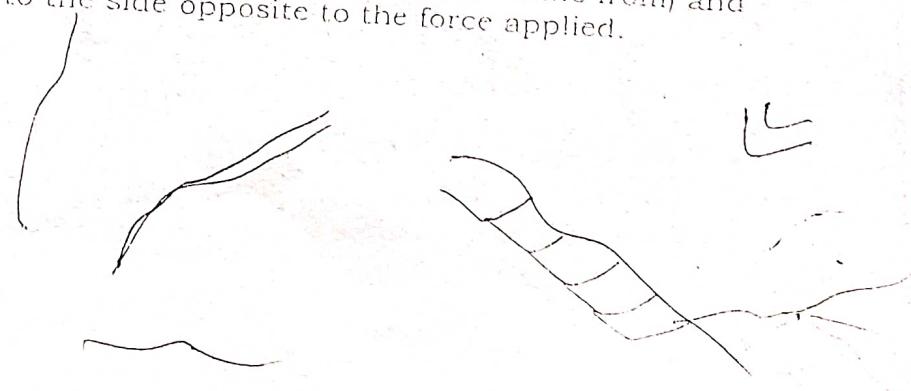
2. **Mist:** A multitude of exceedingly minute cracks formed at the crack tip.
3. **Hackle marks or striations:** marks caused due to branching of cracks. These are parallel to one another and also to the direction of propagation of fractures.
4. **Wallner lines/Conchoidal lines/ridge lines/rib marks:** fracture surface markings which are usually curved in nature, caused by interaction between a propagating crack front and elastic waves released when pre-existing flaws or cracks are unloaded as the crack passes them.



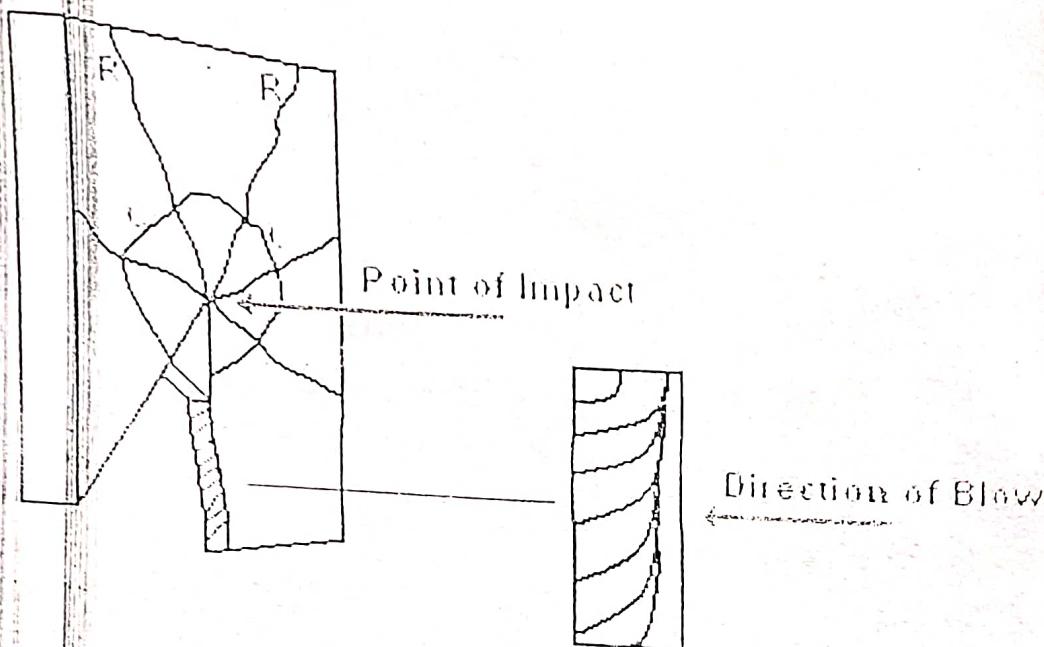
Wallner line/rib lines

4 R RULE

- This method determines the direction of the applied force. This technique aids the investigator in evaluating the side on which impact is made.
- It states that "*Ridge lines on Radial fractures are at Right angles to the Rear*".
- When the projectile strikes the glass, it creates ridges called conchoidal fractures along the edge that are visible in profile.
- These conchoidal fractures are nearly parallel to the side in which force was applied (the direction which the projectile came from) and perpendicular to the side opposite to the force applied.

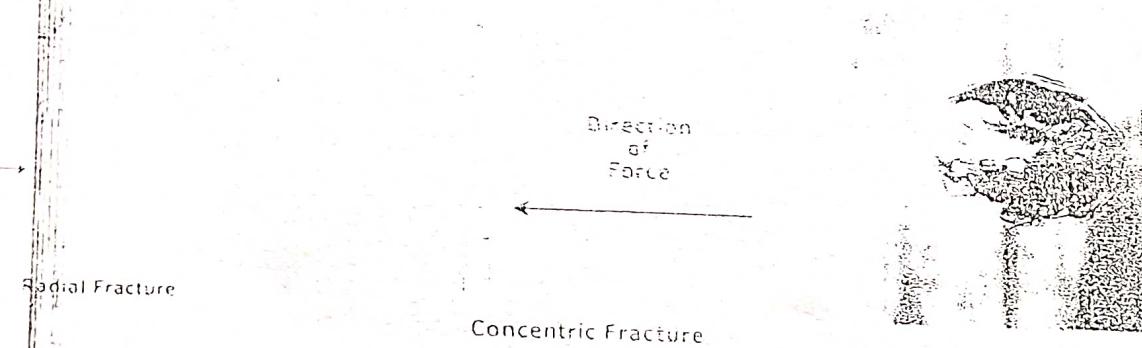


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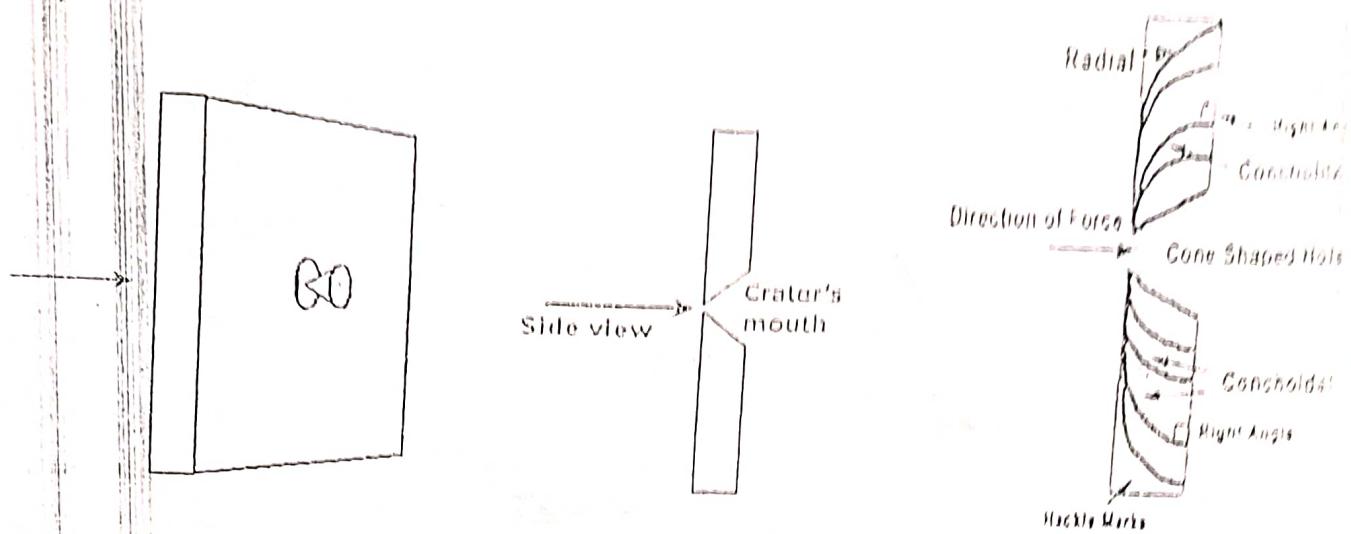
PATTERN OF BULLET FRACTURES ON GLASS

1. **Low velocity impact:** Low-velocity projectiles produce cracks in the glass, which radiate outward from the point of impact (radial cracks). If a pane is firmly held on all sides, concentric cracks can form around the point of impact. Wallner lines can be clearly seen on the cracks produced which will help in identification of direction of impact.



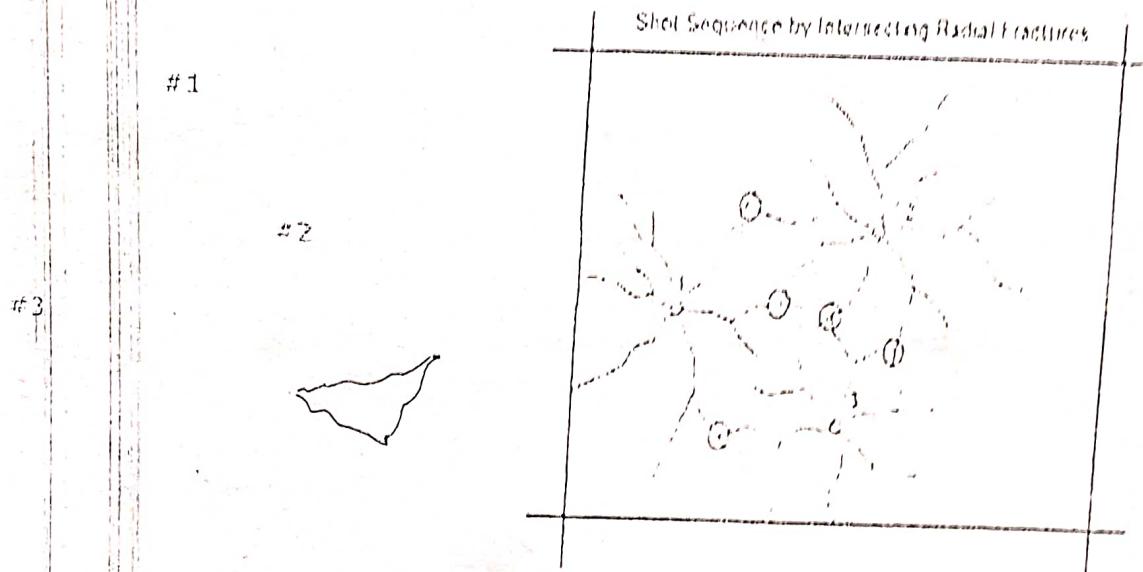
2. **High velocity impact:** If the projectile passes through the glass, the opening on the exit side will be larger than the opening on the entry side. A high-speed projectile striking a piece of glass will produce a cone or crater, the mouth of which opens on the opposite side of applied force. These types of fractures are also called as hertzian fractures.

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DETERMINATION OF SEQUENCE OF SHOTS FROM FRACTURE PATTERNS

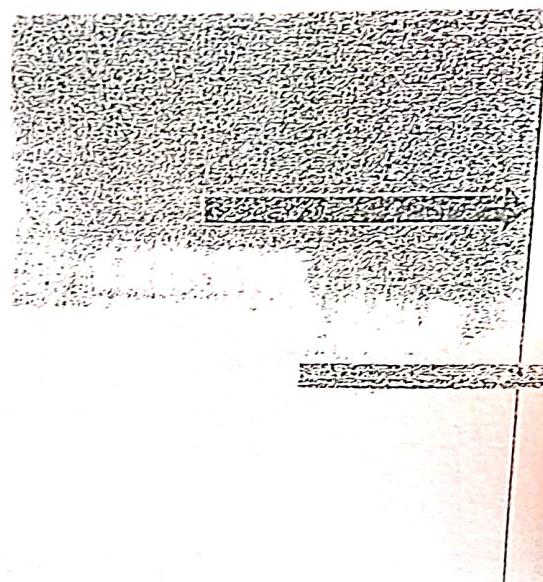
- An examiner can establish the sequence of the shots by considering the radial fracture's termination points.
- The first shot's radial fractures will extend completely while the subsequent shot's radial fractures will be stopped or cut off as they come into contact with prior fractures.



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THERMAL FRACTURES

Thermal fracture of glass may occur when the glass is heated creating temperature differences across the surface of the glass. The difference in temperature can be created by solar radiations, space heating devices, fire, hot and cold liquids. If the temperature of part of a glass pane is raised, that area will expand relative to the cooler areas of the pane. The cooler area of glass attempts to restrain the expansion and thermal tensile stresses develop in the cooler area. If the temperature difference is sufficiently great the glass can fracture. (In non-tempered glass a typical heat crack is curved, has a smooth edge, and has no indication of the point of origin of the crack.)



Factors influencing thermal stress in glass

- a. **Solar absorption and heat traps:** The amount of heat which is absorbed by the glass has a direct effect on the temperature of the glass, so is an important factor in the development of thermal stress.
- b. **Shadows:** Shadow creates cooler areas as compared to exposed areas, thus raising temperature differences within the glass and makes it more prone to fractures
- c. **Edge strength:** A clean cut edge is the strongest to fight stress as the cutting produces the least amount of damage. A polished edge is the next strongest. The non-uniform or deformed edges makes them more prone to break.
- d. **Frame type and color:** The frame in which the glass is captured affects the temperature of the edge of the glass. An insulating material such as timber or vinyl will keep the glass edge cool while a conductive material such as aluminum is influenced by the frame color. A dark color is more absorptive than white so will enable the frame to absorb more heat
- e. **Glass type:** The type of glass will also have an influence on the risk of thermal fracture. This is influenced by the capacity of the glass to absorb and release heat, and the characteristic edge strength of the glass. E.g. sun absorption glass, lead glass, borosilicate glass.

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BACKSCATTERING/FRAGMENTATION OF GLASS

- When glass objects are broken, glass flies backward from all parts of the object where cracks appear not just from point of impact.
- This creates a shower of minute glass particles and evidences can be transferred to the garments of suspects/victims (Locard's principle of exchange).
- Collection of such glass evidences from the suspect or victim helps in linking them with the crime scene.

Factors affecting recovery of glass fragments

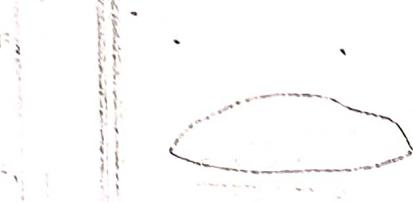
- Distance between the glass and person.
- Size of fragment.
- Composition and weave of the fabric.
- Time interval between breaking and recovery.
- Degree of fragmentation.
- Type and thickness of the glass.
- Weather conditions.

BECKE LINE CONCEPT

Becke line is a bright halo of light that appears around the perimeter of an object when the indices of refraction of the object & surrounding medium are different. The Becke line moves towards the region with higher index of refraction, when the microscope is defocused or when the focus is raised by increasing the distance between objective and sample.

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Divergent Cone

For the case where $n_{\text{oil}} > n_{\text{min}}$, the cone of light diverges above the mineral grain. If the stage is lowered so that the focal plane changes from F_1 to F_2 , the Becke line will appear to move out of the grain and into the oil, i.e. into the material with the higher refractive index.

$$n_{\text{oil}} > n_{\text{min}}$$



Convergent Cone

For the case where $n_{\text{oil}} < n_{\text{min}}$, the cone of light converges above the mineral grain. If the stage is lowered so that the focal plane changes from F_1 to F_2 , the Becke line will appear to move into the mineral grain.

$$n_{\text{oil}} < n_{\text{min}}$$

(Top)
Ans