



Processing Glass

MATR 4350

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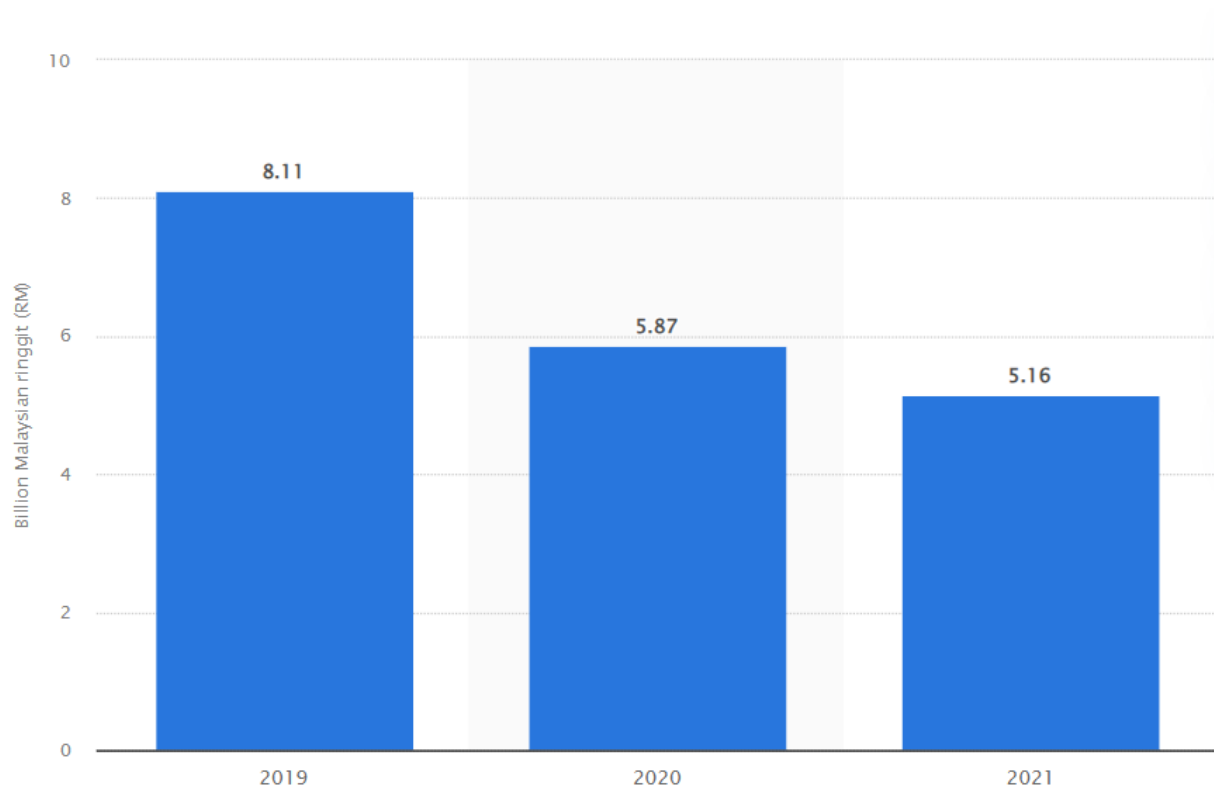
Market For Glass And Glass Products

- More than half of the total worldwide ceramics market is glass products, accounting for over \$50 billion/year.
- The market for manufactured glass products emphasizes 3 main types of glass:
 - Hollow glass (bottles, drinking glasses, lamp bulbs, glass containers), 35%
 - Flat glass (mirrors, windows), 30%
 - Fiberglass (includes glass fiber), 17% Hollow glass includes most of the container glass and tableware we use (consumer glassware).

TABLE 26.1 Glass Product Types and Applications

<i>Glass product type</i>	<i>Applications</i>
Flat glass	Automotive: cars and trucks Architectural: commercial buildings, storefronts Residential: windows, doors, sunrooms, skylights Patterned glass: shower doors, privacy glass Blanks for microscopes and telescopes
Containers/ tableware	Beverage Liquor, beer, wine Food Pharmaceutical, drugs Glasses, plates, cups, bowls, serving dishes
Fiberglass and glass fiber	Wool: insulation, filters Textile: plastic or rubber tire reinforcements, fabrics, roof shingles, roll goods reinforcement Optical communications
Specialty glass	Artware, stained glass, lead and lead crystal, lighting TV picture tubes and flat-panel displays, ovenware and stovetops Ophthalmics, aviation, tubing, foamed glass, marbles

Sales value of manufactured glass products in Malaysia from 2019 to 2021



- Glass production starts with a mixture of raw materials, which for glass manufacture often contain a high proportion of naturally occurring minerals (sand & limestone).
- However, some industrial such as Na_2CO_3 & Al_2O_3 are also used.
- The mixture containing the raw materials in the appropriate amounts is known as the batch.
- The batch contains a mixture of glass formers, modifiers, & intermediates; the amount of each component depends on the application of the final glass product



GLASSWORKING

1. Raw Materials Preparation and Melting
2. Shaping Processes in Glassworking
3. Heat Treatment and Finishing
4. Product Design Considerations



Glass: Overview of the Material

- Glass is one of three basic types of ceramics
 - The others are traditional ceramics and new ceramics
- Glass is distinguished by its noncrystalline (vitreous) structure
 - The other ceramic materials have a crystalline structure



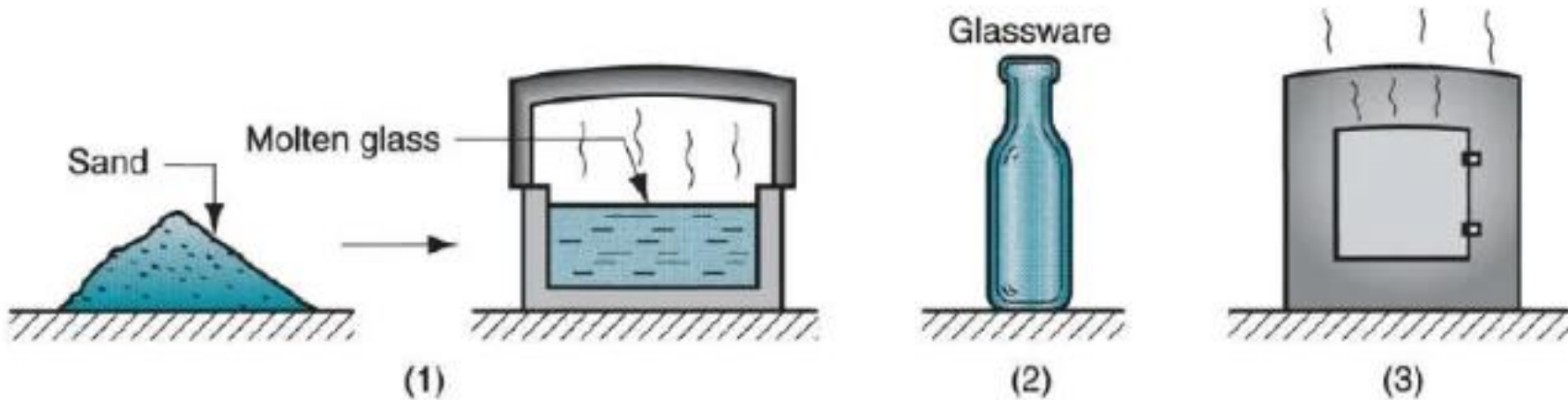
Glass Products

- Glass products are commercially produced in an almost unlimited variety of shapes
- Most products made in very large quantities
 - Light bulbs, beverage bottles, jars, light bulbs
 - Window glass
 - Glass tubing (e.g., for fluorescent lighting)
 - Glass fibers
- Other products are made individually
 - Giant telescope lenses



Process Sequence in Glassworking

- Typical process sequence in glassworking: (1) preparation of raw materials and melting, (2) shaping, and (3) heat treatment





Raw Materials Preparation and Melting

- Principal component in nearly all glasses is silica, SiO_2
 - Primary source is natural quartz in sand
- Other components are added in proportions to achieve the desired composition:
 - Soda ash (source of Na_2O), limestone (source of CaO), aluminum oxide (Al_2O_3), and potash (source of K_2O),
 - Recycled glass is usually added to the mixture too



Glass Melting

- The batch of starting materials is called a *charge*, and loading it into furnace is called *charging* the furnace
 - Melting temperatures for glass are around 1500°C to 1600°C (2700°F to 2900°F)
- Viscosity of molten glass is inversely related to temperature
 - Shaping immediately follows melting, so temperature at which the glass is tapped depends on the viscosity required for the shaping process



Shaping Processes in Glassworking

- Shaping processes to fabricate glass products can be grouped into three categories:
 1. Discrete processes for piece ware (bottles, jars, plates, light bulbs)
 2. Continuous processes for making flat glass (sheet and plate glass) and tubing (laboratory ware, fluorescent lights)
 3. Fiber-making processes to produce fibers (for insulation and fiber optics)



Shaping of Piece Ware

- Ancient methods of hand-working glass included glass blowing
- Handicraft methods are still used today for making glassware items of high value in small quantities
- However, most modern glass shaping processes are highly mechanized technologies for producing discrete pieces such as jars, bottles, and light bulbs in high quantities



Piece Ware Shaping Processes

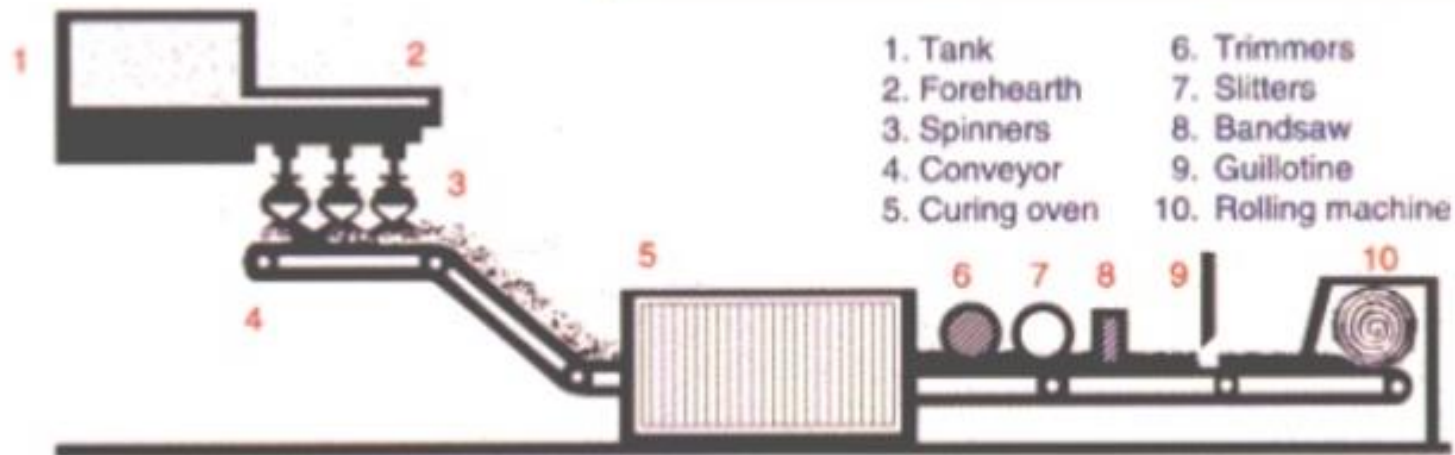
- Spinning – similar to centrifugal casting of metals
- Pressing – mass production of flat products such as dishes and TV tube faceplates
- Press-and-blow – production of wide-mouth containers such as jars
- Blow-and-blow - production of smaller-mouth containers such as beverage bottles and incandescent light bulbs
- Casting – large items such as astronomical lenses that must cool slowly to avoid cracking

Glass Forming

- 1) **Casting** : molding
- 2) **Pressing**: pressing second mold into molten glass
- 3) **Core-forming**: clay core dipped into molten mass
- 4) **Fusing** : fusing glass rods together around a mold
- 5) **Blowing**: blowing air into a glob

Flat glass – floating / rolling

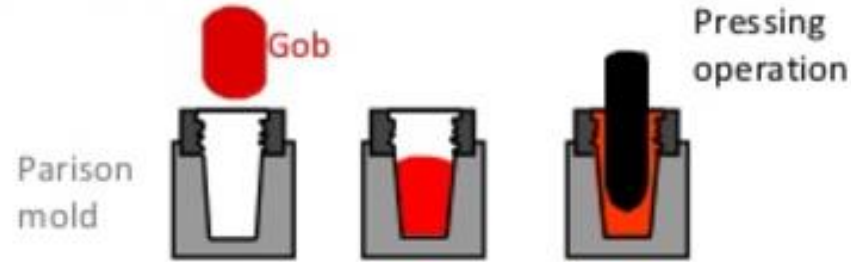
Glass fibre – continuous strands and Crown process for glass wool



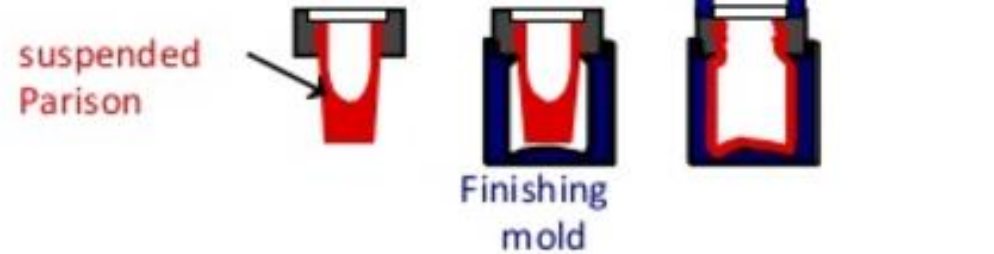
Glass Fabrication Methods

GLASS FORMING

- **Pressing:**



- **Blowing:**



PARTICULATE FORMING

CEMENTATION

plates, dishes, cheap glasses
-mold is steel with graphite lining

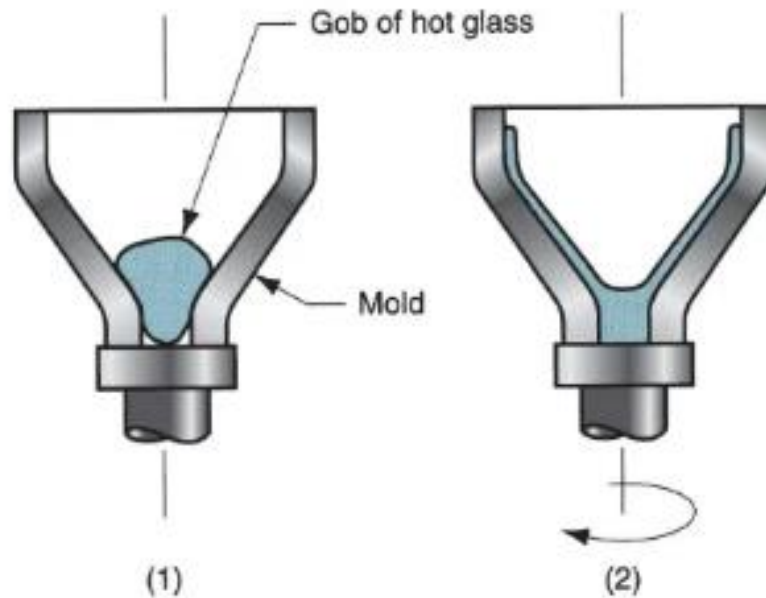
- **Fiber drawing:**





Spinning: Process Sequence

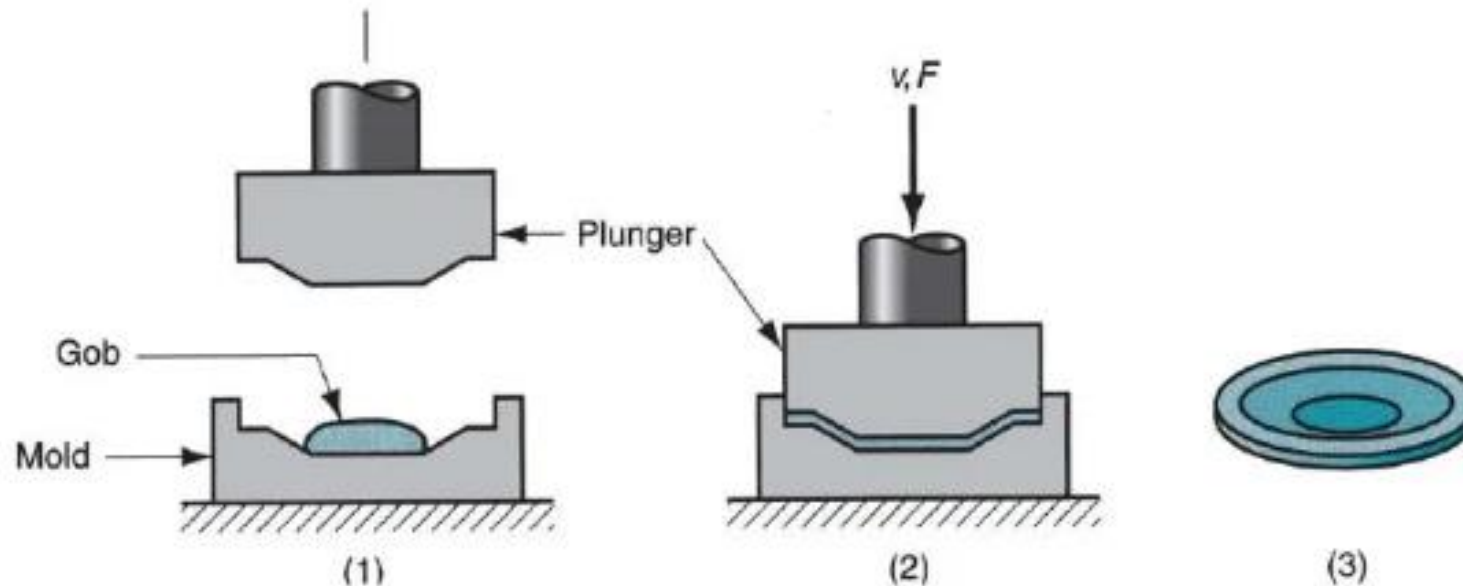
- Spinning of funnel-shaped glass parts such as cathode ray tubes for TVs: (1) gob of glass dropped into mold; and (2) rotating mold to spread molten glass on mold





Pressing of Flat Pieces: Process Sequence

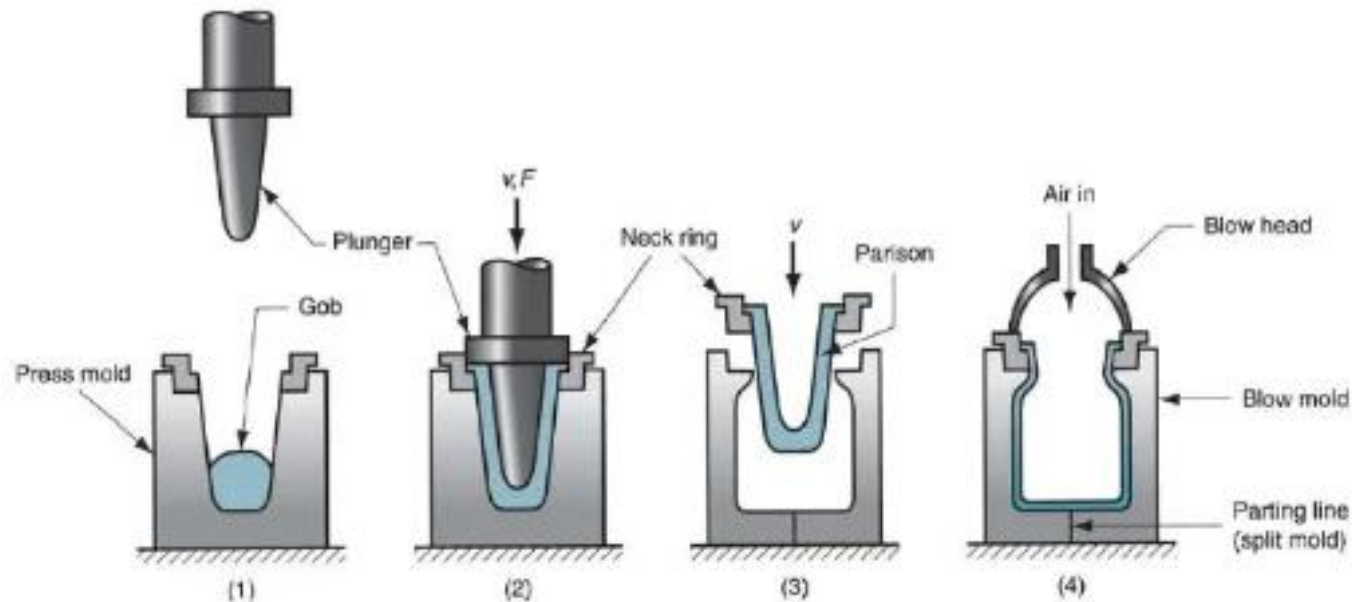
- (1) Glass gob is fed into mold; (2) pressing into shape by plunger; and (3) plunger is retracted and finished product is removed





Press-and-Blow: Process Sequence

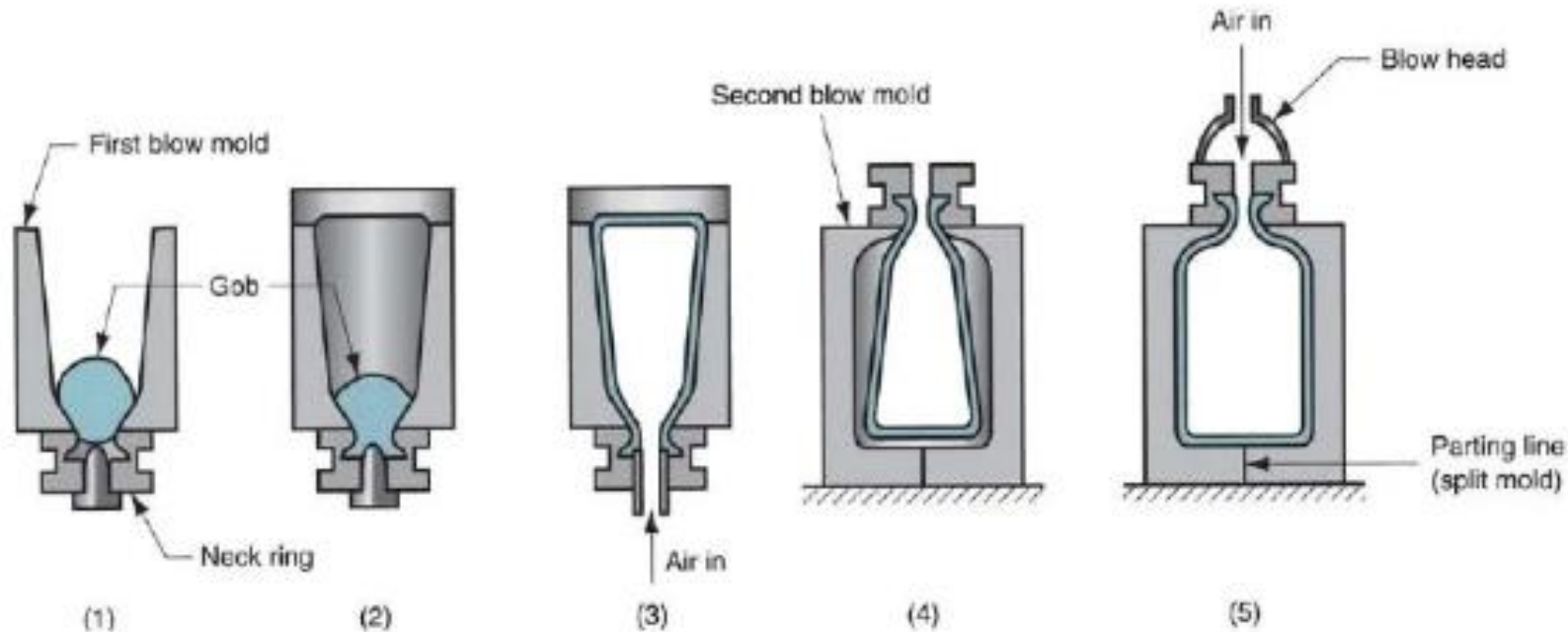
- (1) molten gob is fed into mold cavity; (2) pressing to form a *parison*; (3) parison is transferred to blow mold, and (4) blown to final shape





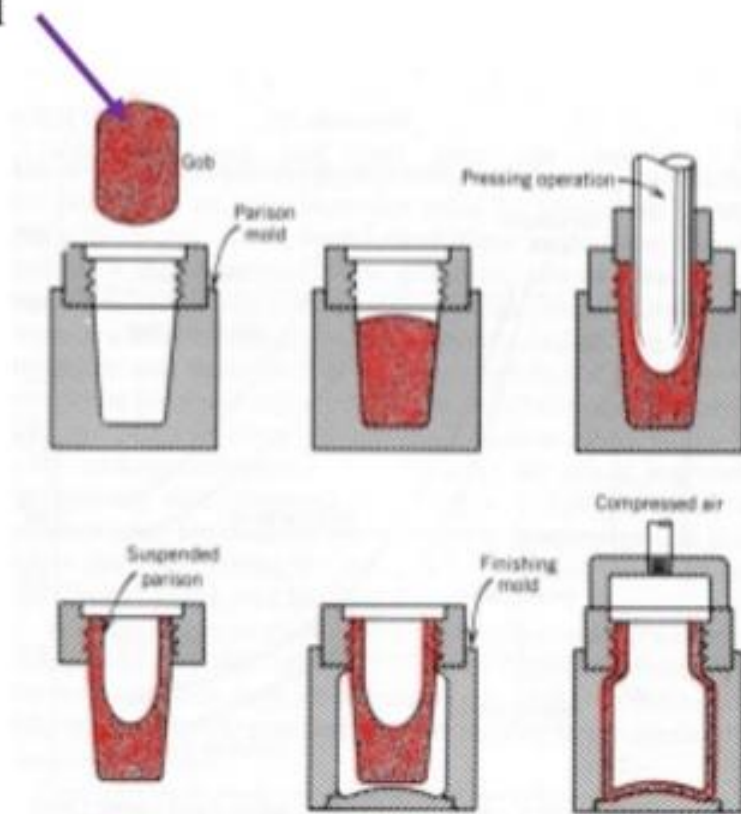
Blow-and-Blow: Process Sequence

- (1) gob is fed into mold cavity; (2) mold is covered; (3) first blow step; (4) partially formed piece is repositioned in second blow mold, and (5) blown to final shape



Blow Molding

Softened glass



Pressed Glass Processing

Softened glass





Casting

- If molten glass is sufficiently fluid, it can be poured into a mold
- Massive objects, such as astronomical lenses and mirrors, are made by this method
- After cooling and solidifying, the piece must be finished by lapping and polishing
- Casting is not often used except for special jobs
- Smaller lenses are usually made by pressing



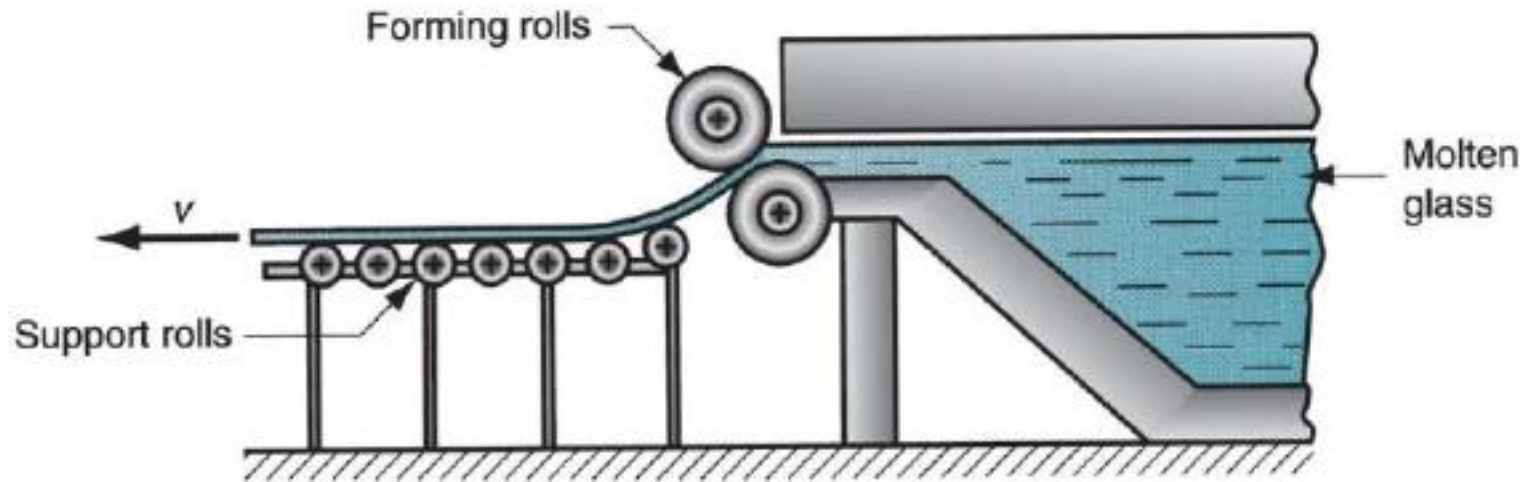
Shaping of Flat and Tubular Glass

- Processes for producing flat glass such as sheet and plate glass:
 - Rolling of flat plate
 - Float process
- Process for producing glass tubes
 - Danner process



Rolling of Flat Plate Glass

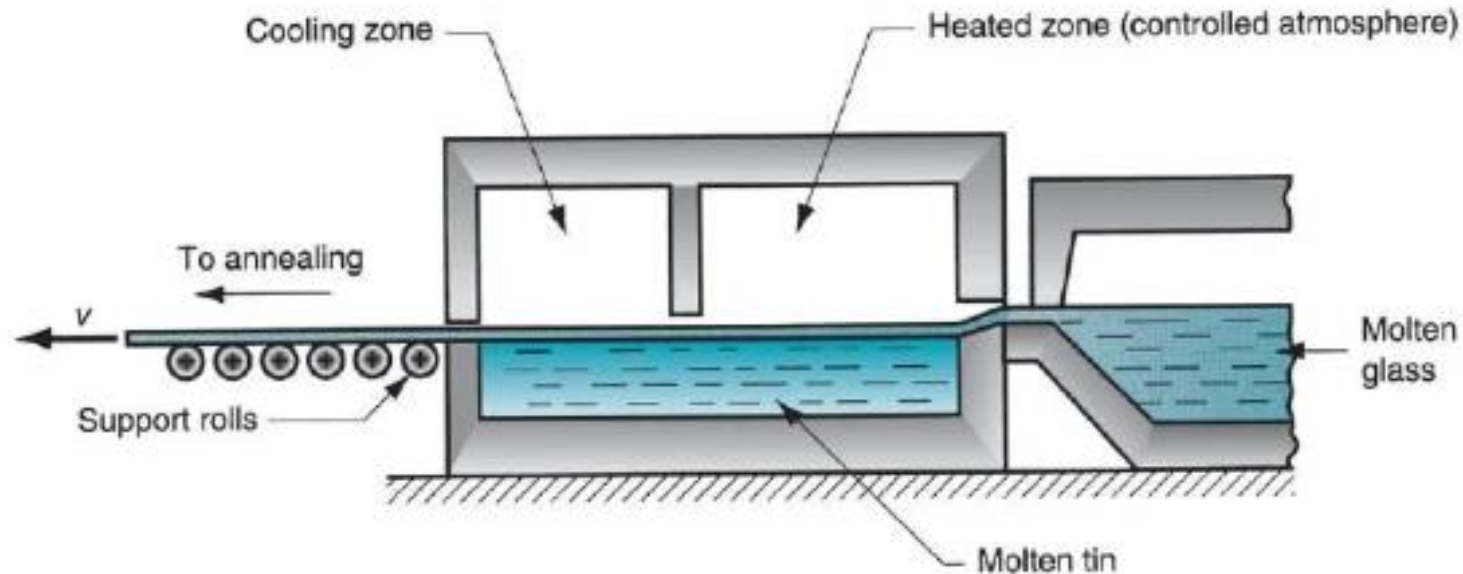
- Starting glass from furnace is squeezed through opposing rolls, followed by grinding and polishing for parallelism and smoothness





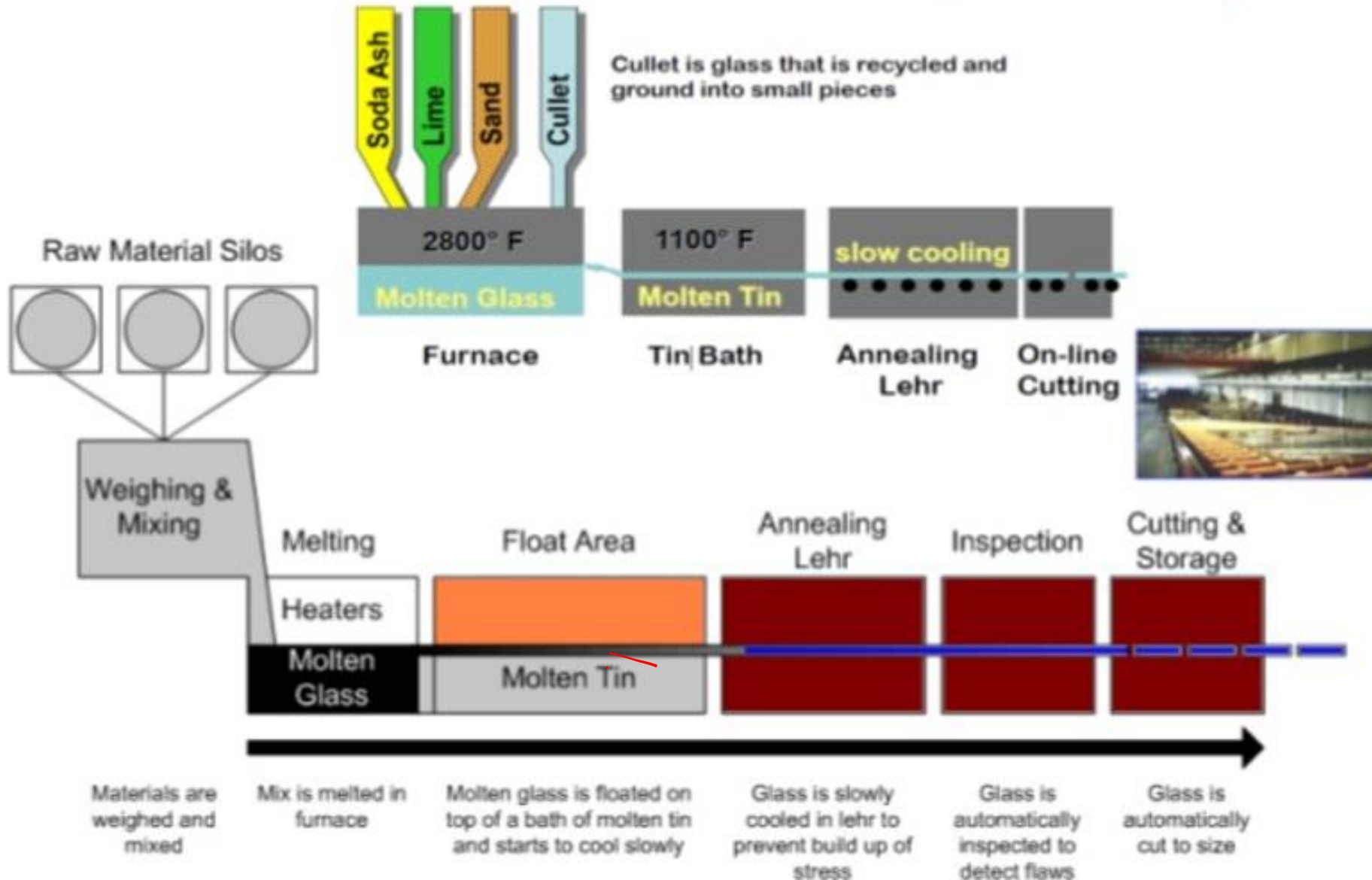
Float Process for Producing Sheet Glass

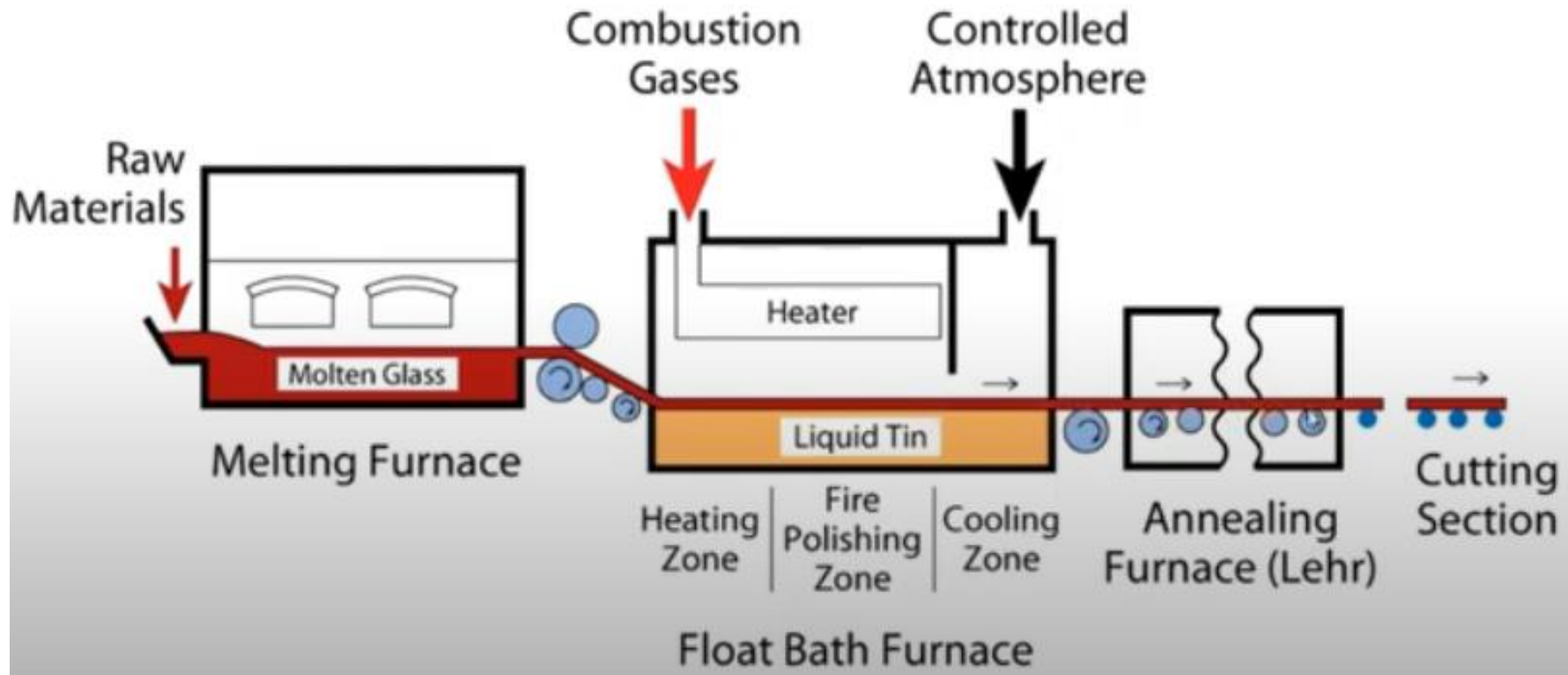
- Molten glass flows onto surface of a molten tin bath, achieving uniform thickness and smoothness - no grinding or polishing is needed



Float Glass: The Process

Modern Plate/Sheet Glass making:

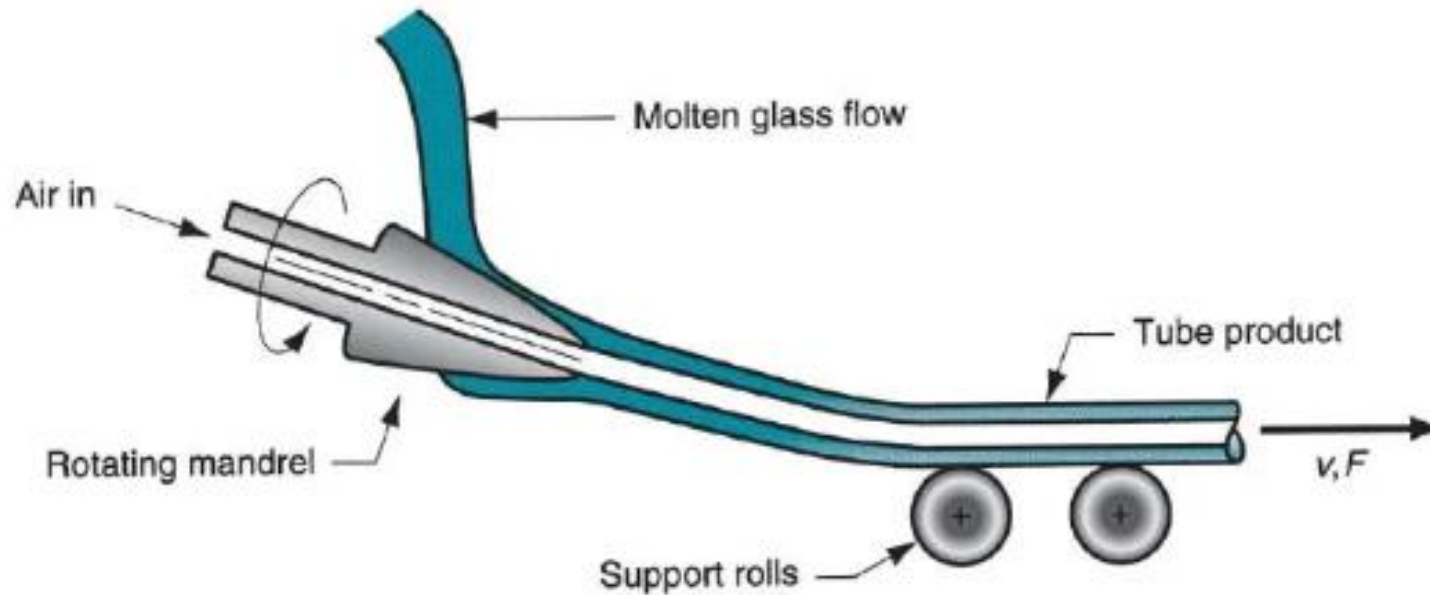






Danner Process for Drawing Glass Tubing

- Molten glass flows around a rotating hollow mandrel through which air is blown while glass is drawn





Forming of Glass Fibers

Glass fiber products fall into two categories, with different production methods for each:

2. Fibrous glass for thermal insulation, acoustical insulation, and air filtration, in which the fibers are in a random, wool-like condition
 - Produced by centrifugal spraying
3. Long continuous filaments suitable for fiber reinforced plastics, yarns, fabrics, and fiber optics
 - Produced by drawing



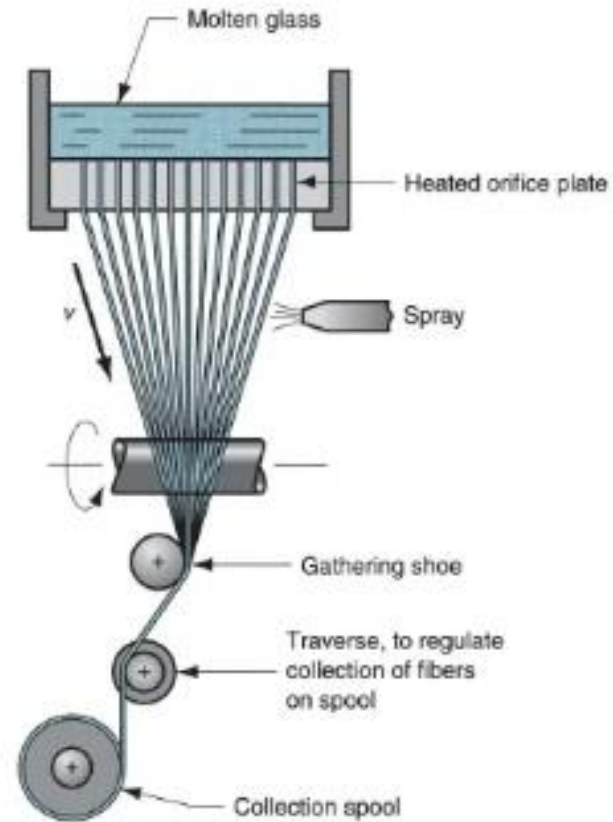
Centrifugal Spraying

- In a typical process for making glass wool, molten glass flows into a rotating bowl with many small orifices around its periphery
- Centrifugal force causes the glass to flow through the holes to become a fibrous mass suitable for thermal and acoustical insulation



Drawing of Continuous Glass Fibers

- Continuous glass fibers of small diameter are produced by pulling strands of molten glass through small orifices in a heated plate made of a platinum alloy





Heat Treatment: Annealing of Glass

Heating to elevated temperature and holding to eliminate stresses and temperature gradients; then slow cooling to suppress stress formation, then more rapid cooling to room temperature

- Annealing temperatures ~ 500°C (900°F)
- Same function as in metalworking – stress relief
- Annealing is performed in tunnel-like furnaces, called *lehrs*, in which products move slowly through the hot chamber on conveyors



Tempering of Glass

Heating to a temperature somewhat above annealing temperature into the plastic range, followed by quenching of surfaces, usually by air jets

- Surfaces cool and harden while interior is still plastic
- As the internal glass cools, it contracts, putting the hard surfaces in compression
- Tempered glass is more resistant to scratching and breaking due to compressive stresses on its surfaces
- Products: windows for tall buildings, all-glass doors, safety glasses



Finishing Operations on Glass

- Operations include grinding, polishing, and cutting
- Glass sheets often must be ground and polished to remove surface defects and scratch marks and to make opposite sides parallel
- In pressing and blowing with split dies, polishing is often used to remove seam marks from the product
- Cutting of continuous sections of tube and plate is done by first scoring the glass with a glass-cutting wheel and then breaking the section along the score line



Other Finishing Operations

- Decorative and surface processes performed on certain glassware products include:
 - Mechanical cutting and polishing operations
 - Sandblasting
 - Chemical etching (with hydrofluoric acid, often in combination with other chemicals)
 - Coating (e.g., coating of plate glass with aluminum or silver to produce mirrors)



Product Design Considerations - I

- Glass is transparent and has optical properties that are unusual if not unique among engineering materials
 - For applications requiring transparency, light transmittance, magnification, and similar optical properties, glass is likely to be the material of choice
 - Certain polymers are transparent and may be competitive, depending on design requirements





Product Design Considerations - II

- Glass is much stronger in compression than tension
 - Components should be designed to be subjected to compressive stresses, not tensile stresses
- Glass is brittle
 - Glass parts should not be used in applications that involve impact loading or high stresses that might cause fracture



Product Design Considerations - III

- Certain glass compositions have very low thermal expansion coefficients and can tolerate thermal shock
 - These glasses should be selected for applications where this characteristic is important
- Design outside edges and corners with large radii and inside corners with large radii, to avoid points of stress concentration
- Threads may be included in glass parts
 - However, the threads should be coarse

