Design, Print & Packaging Skillnet

www.dppskillnet.ie

Skillnets Enterprise-led learning networks

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Welcome

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The Irish PACKAGING SOCIETY Affiliated with I•M3

How are the projects going?

Project
Quick Review

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Design, Print & Packaging Skillnet

The Irish PACKAGING SOCIETY Affiliated with I-M3

Diploma in Packaging Technology

Unit 2a
Glass Packaging

David Little

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Glass packaging

- Uses for Glass Packaging
  - Bottles and jars used in the food, drink and pharmaceutical industries
  - Ampoules and vials used in the pharmaceutical industry

4

Quick Exercise

- Let's discuss some of the advantages and disadvantages of using glass as a packaging material

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5

Advantages of Glass	Disadvantages of Glass
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Glass Properties (Advantages)

- Thermally Resistant - Stable at high temp. and resistant to thermal shock. Suitable for hot filled and retortable products
- Good Thermal and Electrical Insulator
- Inert. Good barrier to moisture, gases and aggressive products (vinegar / oils)
- Strength (Isotropic) Same properties in all directions
- Can be decorated Sprayed, Sleeved (PE & PVC), Screen Print

Glass Disadvantages

High weight - 2.5g/cc

Breakability - Serious hazard with food etc.

Needs high energy supplies to make - therefore high cost

Noise - High noise levels on glass filling lines

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Glass

- Definition
  - An inorganic substance, fused at high temperatures and cooled quickly to solidify in a vitreous or non crystaline condition

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Glass Containers from Ancient Egypt

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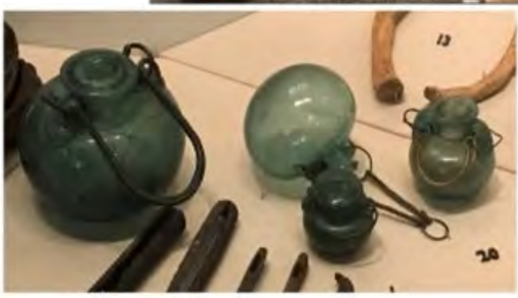
Containers from 1st & 2nd century Roman London



Roman containers (including Glass)

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Medieval Glass Manufacture

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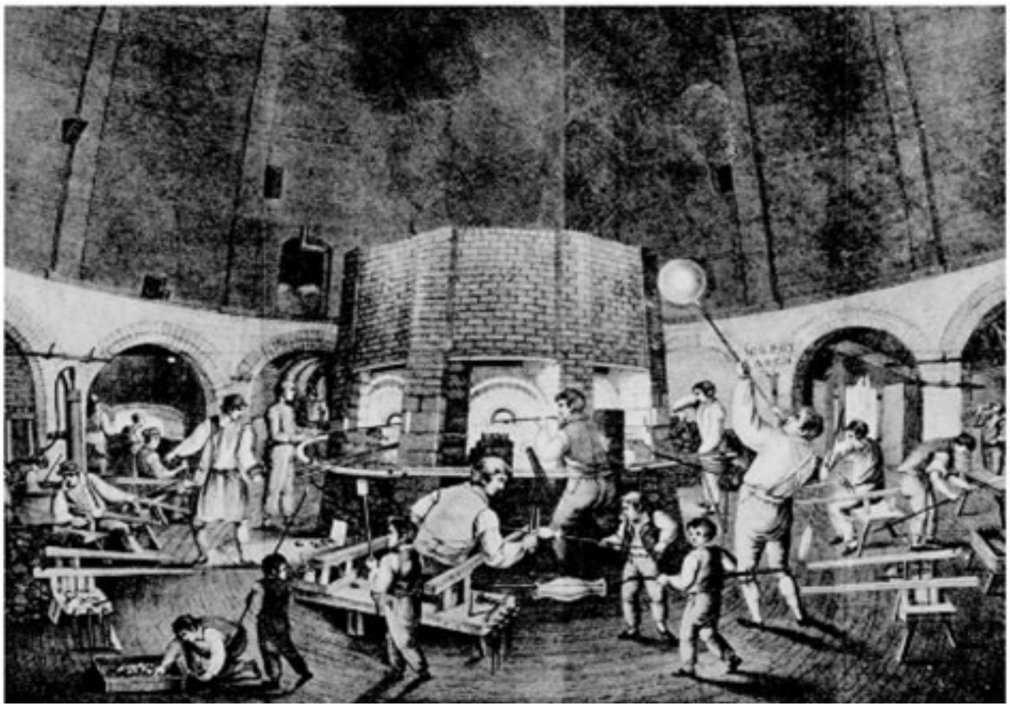
Glass Making in the 17th/18th century



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Making Glass containers in 1908

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Types of Glass

“Water glass” as a sealant. (Silica Sand & Sodium Carbonate) – Water soluble
is sold as solid lumps or powders or as a clear, syrupy liquid. It is used as a convenient source of sodium for many industrial products, as a filler in laundry detergents, as a binder and adhesive, as a flocculant in water-treatment plants, and in many other applications.

Soda Lime Glass
Silica, otherwise known as industrial sand, provides the most important ingredient **for glass production**. Silica sand provides the essential Silicon Dioxide (SiO_2) required for glass formulation, which makes silica the primary component in all types of standard and specialty glass. (Type III & Type II)

Borosilicate glass is a type of glass that contains boric oxide which allows for a very low coefficient of thermal expansion.
In 1915, Corning Glass Works brought it to the U.S. market under the name Pyrex. Since then, **borosilicate glass and Pyrex have been used interchangeably in the English-speaking language**. (Type I)

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EFES
MALT
Kozel
1874
Miller
GENUINE

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nutella
Çokokrem
Golden
Sarelle

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Nothing to hide

http://www.friendsofglass.com/health/nothing-is-good-for-you/

Glass packaging

- **Type III Glass**
  - Soda lime or standard alkaline glass
  - Used mainly for food and drink
  - Limited hydrolytic resistance
  - Not suitable for injectables

    (because of its limited hydrotytlc resistance)

Glass packaging

- **Type II Glass**
  - **Normal soda lime** (Type III glass) with inner surface treated (SO_2 or NH_4SO_3)
  - Higher hydrolytic resistance through surface treatment
  - Wash before use
  - Eye drop (surface treated)10 - 30ml

Glass packaging

- **Type I Glass**
  - Borosilicate or neutral glass
  - High hydrolytic & heat resistance
  - Suitable for repeated use
  - Ampoules and vials used for pharmaceuticals
    - standard (narrow neck) 1 - 50ml
    - standard (wide neck) 1 - 20ml
    - Vials (narrow neck) 5 - 50ml

Raw materials (Soda/ Lime glass)

- Readily-available materials:
  - o high purity silica sand ~ 68 -72%
  - oSoda ash (sodium carbonate)~ 14-15%
  - o Limestone (calcium carbonate) ~ 10-11 %
  - o Alumina (aluminium oxide) ~ 1-2%

    improves glass durability
  - o cullet - recycled glass, which lowers the melting temperature and saves energy - each 10% cullet added lowers the energy requirement by 2.5%

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Raw materials {Borosilicate glass)

- o high purity Silica sand ~ 80%
- o Soda ash (sodium carbonate)~ 4%
- o Limestone (calcium~carbonate) ~ 0%
- o Alumina (aluminium oxide) ~1-2%
- o Boron (Boric Oxide) ~ 13%

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Raw materials

(Soda / Lime glass compared to Borosilicate glass)

Soda /Lime Glass	Type III & Type II		Borosilicate Glass Lab ware / Pyrex	Type I
Silica Sand (Silicon Dioxide)	70%		Silica Sand	80%
Sodium Carbonate (Soda Ash)	15%		Sodium Carbonate	4%
Calcium Carbonate (Limestone)	10%		Calcium Carbonate	0%
Aluminium Oxide (Alumina)	2%		Aluminium Oxide	2%
Boric Oxide (Boran)	0%		Boric Oxide	13%

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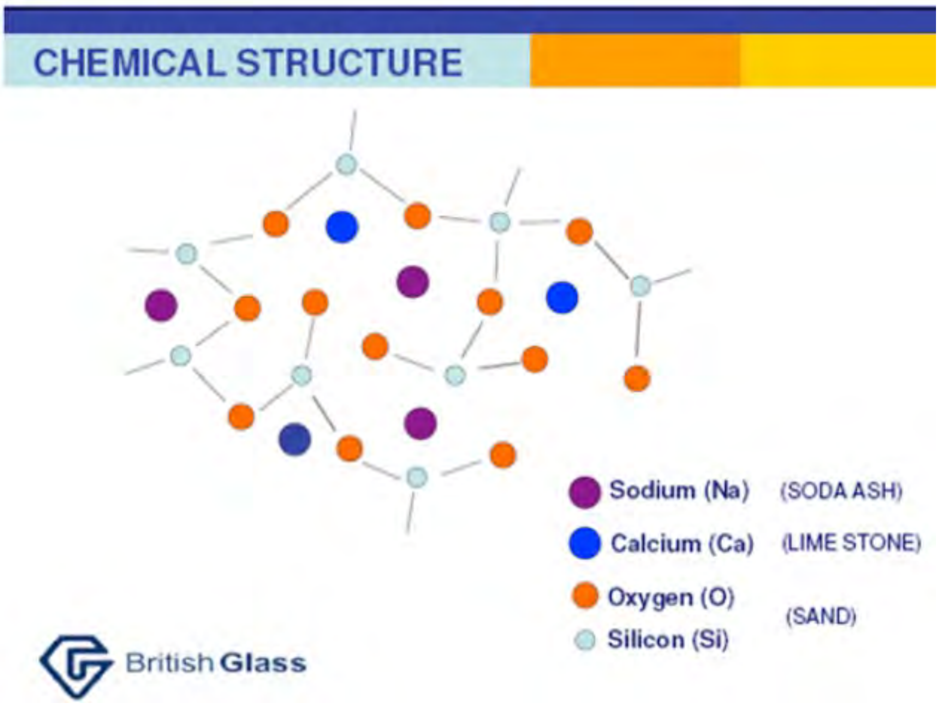
Glass Structure



Glass Manufacturing

Furnace holds up to 500 tonnes of glass

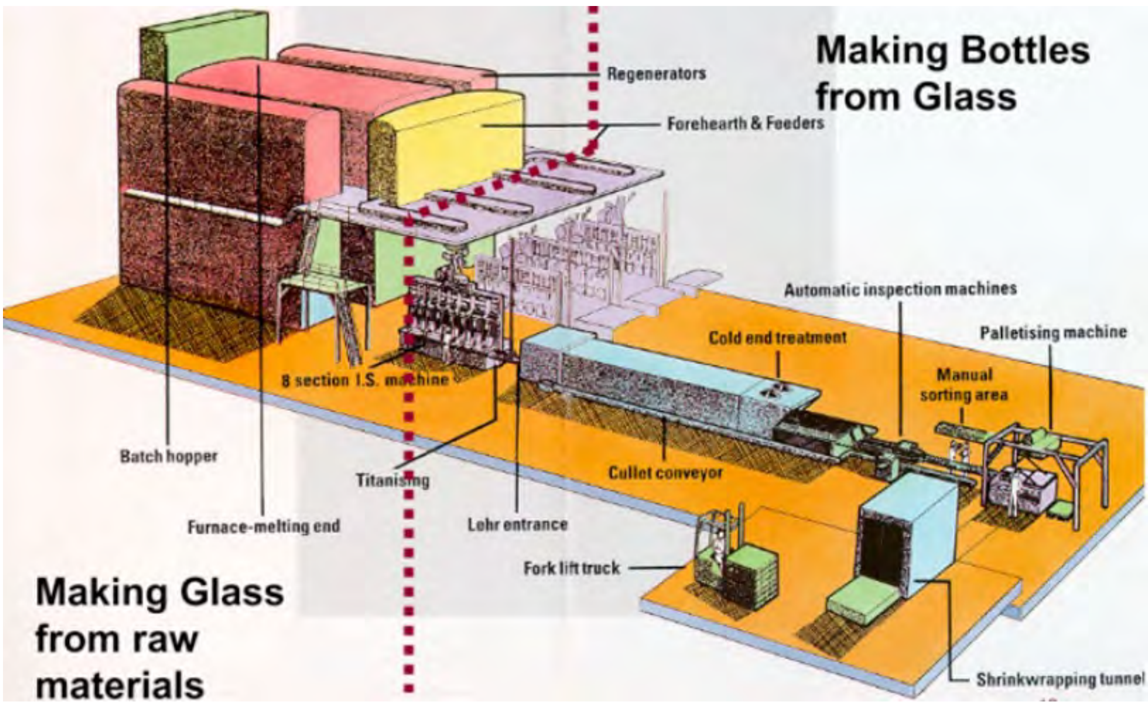
Glass is made in gas fired furnaces at about 1500oC

Average furnace produces 200-400 tonnes in 24 hours

Operates non-stop for 10 years+ between shutdowns

Can cost > £25 million to set up glass making facility

Process Overview



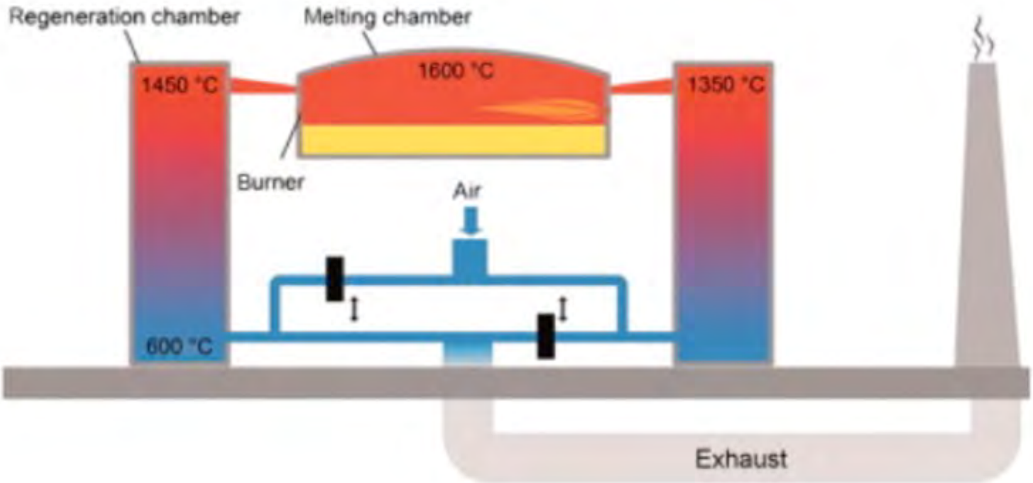
Air and Fuel mix

10:1 volumes of air are required to natural gas
High temperatures in a glass furnace can cause environmentally objectionable Nitrous Oxides to form.

Newer furnaces are using oxygen instead of air.
This eliminates possible pollution source and reduces energy requirement by up to one third.

Hot flue gasses are passed through a heat exchanger.
Heat exchanger used to heat incoming cold air or oxygen
Firing direction is changed every 20 minutes, alternatively heating and cooling each exchanger (see image)

Heat (Energy) Regeneration

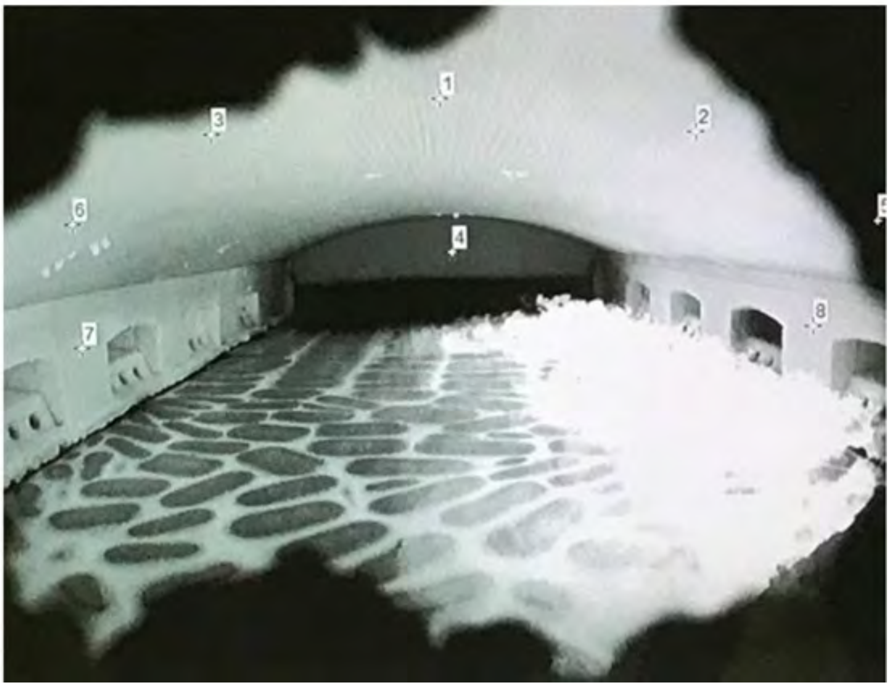


Furnace

- Raw materials weighed in batches and mixed
- Mix is added continuously to the furnace
- Each furnace is dedicated to one colour:
  - White flint (clear)
  - Amber, for UV sensitive products or for decoration
  - Green, for UV sensitive products or for decoration
  - Other colours can be added at the special forehearth

Furnace -United Glass, Alloa

Inside Working Furnace



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Standard Glass Colours

Due to large size of furnace, 3 basic colours used:

- Flint: Basic clear glass. Used for majority of packaging applications
- Green: A bright green glass used mostly in the beverage industry (wine, beer, vegetable oil)
- Amber: Familiar brown glass for beer and pharmaceuticals (see slide on UV light)
- Amber is the only standard glass that will filter out light in the critical ultraviolet (UV) region (300 to 400 nm)
- Total block at 3mm thickness
- Primarily used for UV-sensitive products
- e.g. Beer, and some pharmaceuticals

Raw materials

COLOUR

- Specialised Colourants:

Green - Chomium Oxides

Amber - Iron, Sulphur, Carbon

  - Cuts out light in UV range of the spectrum
  - Total block at 3mm thickness

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Raw materials

COLOUR

- Specialised Colourants:
  - o **Blue** - Cobalt Oxides
  - o **Red** - Selenium, Cadmium, Antimony Sulphides
  - o **Purple** - Manganese compounds
  - o *Opal* - Fluorides, Phosphates

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Cullet

- Cullet - broken glass recovered from:
  - Production operations
  - Post Consumer Waste (Bottle Bank Systems)
- Cullet added to furnace to:
  - Enhance melting rate
  - Significantly reduce energy requirements of glass production
- Cullet reduces energy requirements of glass production
- Every 10% cullet means 2.5% less energy requirements
- Typically 40-50% cullet in a glass batch
- Can be 80% (or more!) cullet in a glass batch

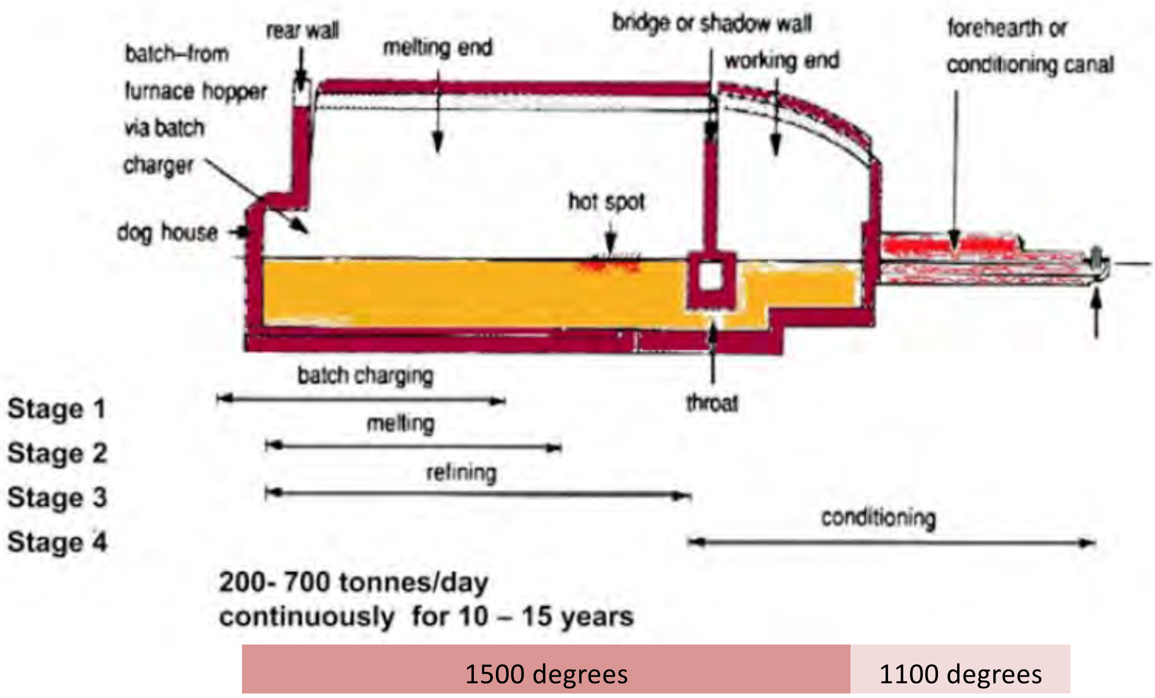
Peter Scheid Glass bottle production - Vietnam
https://www.youtube.com/watch?v=HwoMDBM4Mq4

Glass Furnace

- Ingredients and cullet weighed & mixed in rotary mixer
- Typically 1 tonne sand, with appropriate amount of soda, lime, mineral compounds, conditioning materials and cullet
- Colouring agents (frit) can be added to the melt furnace but more common to add them to the forehearth
- Ingredients melt in melt furnace at 1500 C
- Molten glass passes through throat into refiner
- Bridgewall holds back scum floating on surface
- At forehearth glass temp reduces to about 1100 C

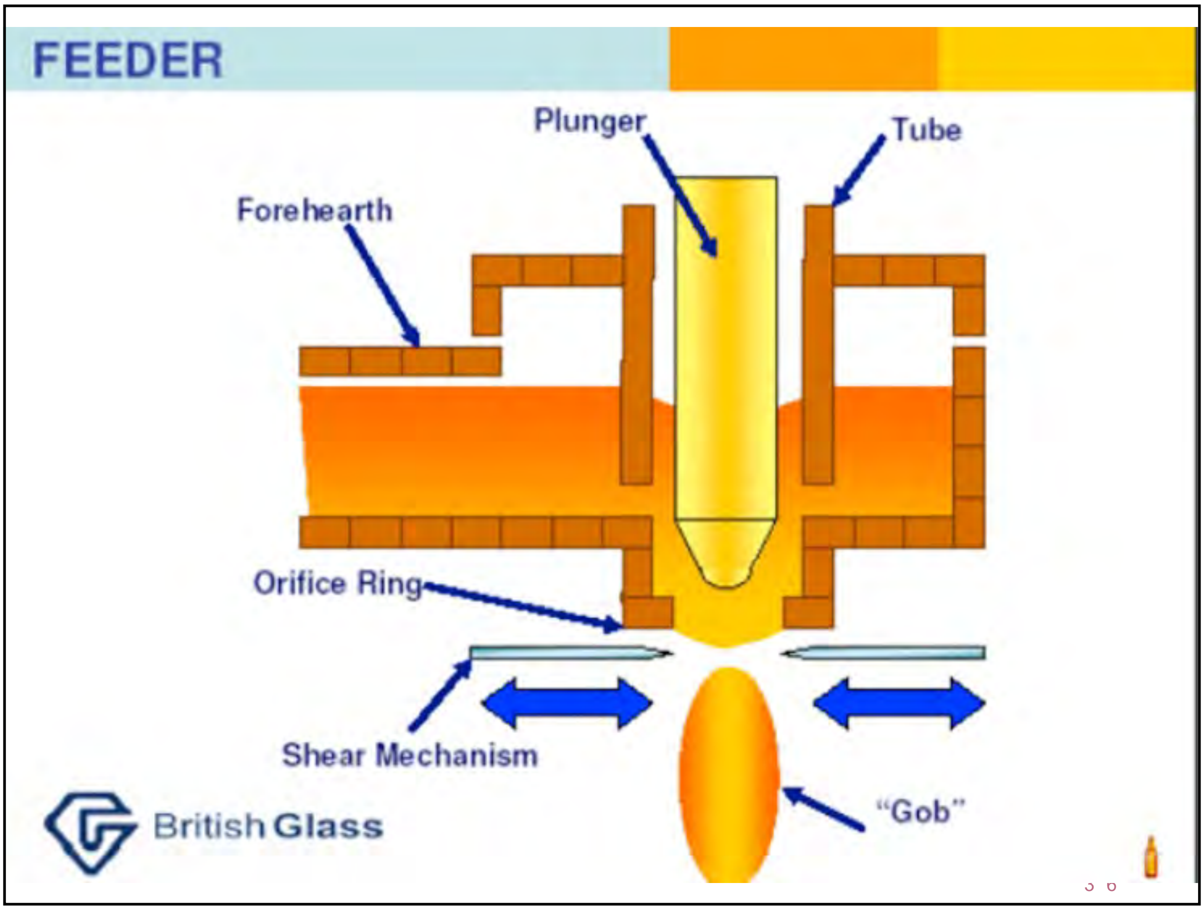
Furnace -United Glass, Alloa

Cross-section of furnace



Forming the gob

- Plunger forces molten glass through measured orifice
- Water-cooled mechanical shears cut off precise amounts of glass, known as 'gobs'
- One gob will form one container
- Control of gob weight controls container weight and resultant capacity
- Production capacity is increased by use of double, triple, quadruple gobs


FEEDER
Plunger
Tube
Forehearth
Orifice Ring
Shear Mechanism
British Glass
"Gob"

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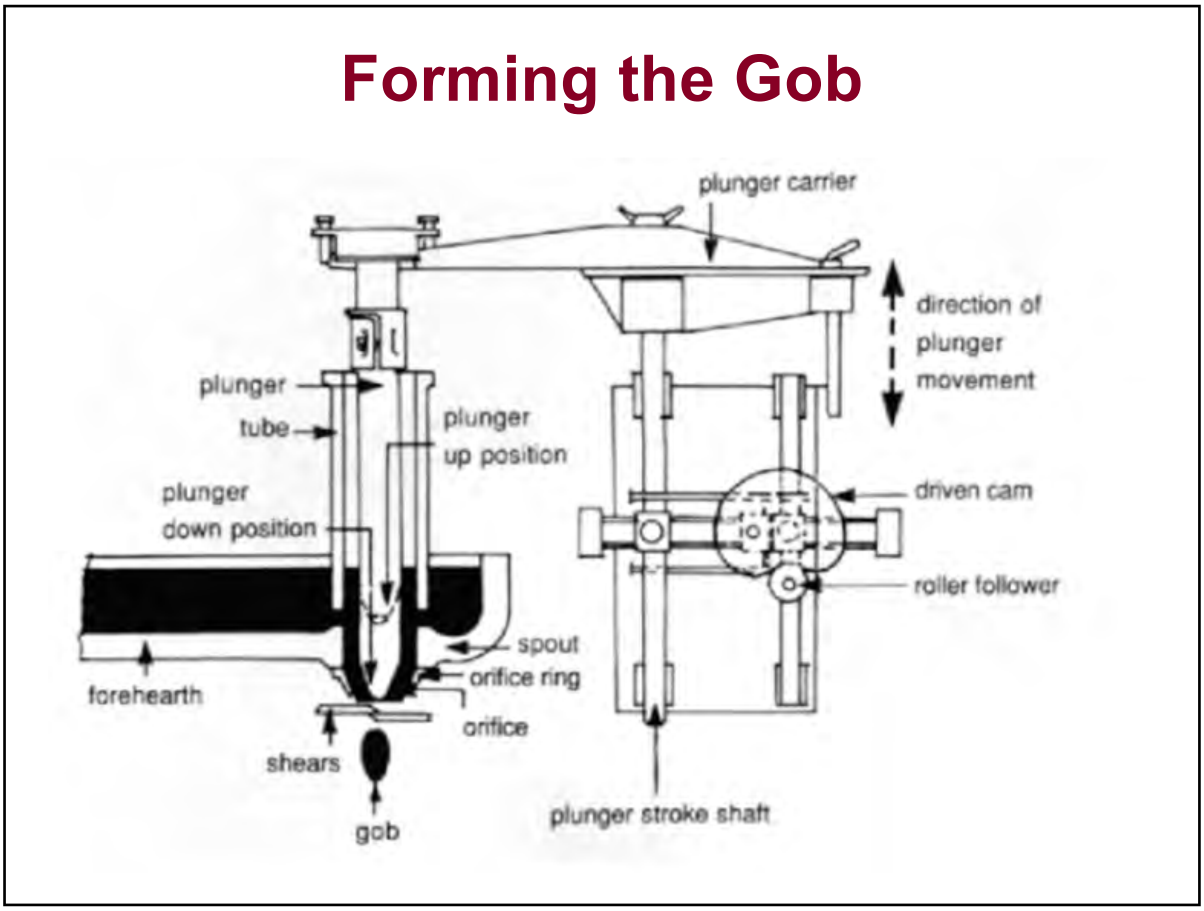
Forming the Gob
plunger carrier
direction of
plunger
movement
plunger
tube
plunger
up position
plunger
down position
driven cam
roller follower
spout
orifice ring
forehearth
orifice
shears
gob
plunger stroke shaft

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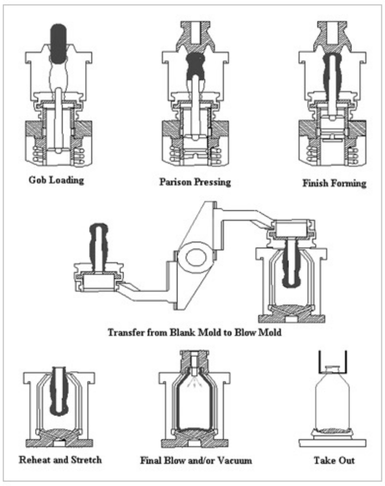
Mersin Factory

Mould Equipment

- Each container requires three sets of specific tooling - similar to manufacture of plastic containers
  - A "Blank" Mould, "Final" Mould and "Finish equipment
    - these components are accurately manufactured from various materials.
  - Independent section (I.S.) machines use sets of identical moulds designed for each specific container.
  - Moulds are identified by numbers engraved into the cavity - for traceability



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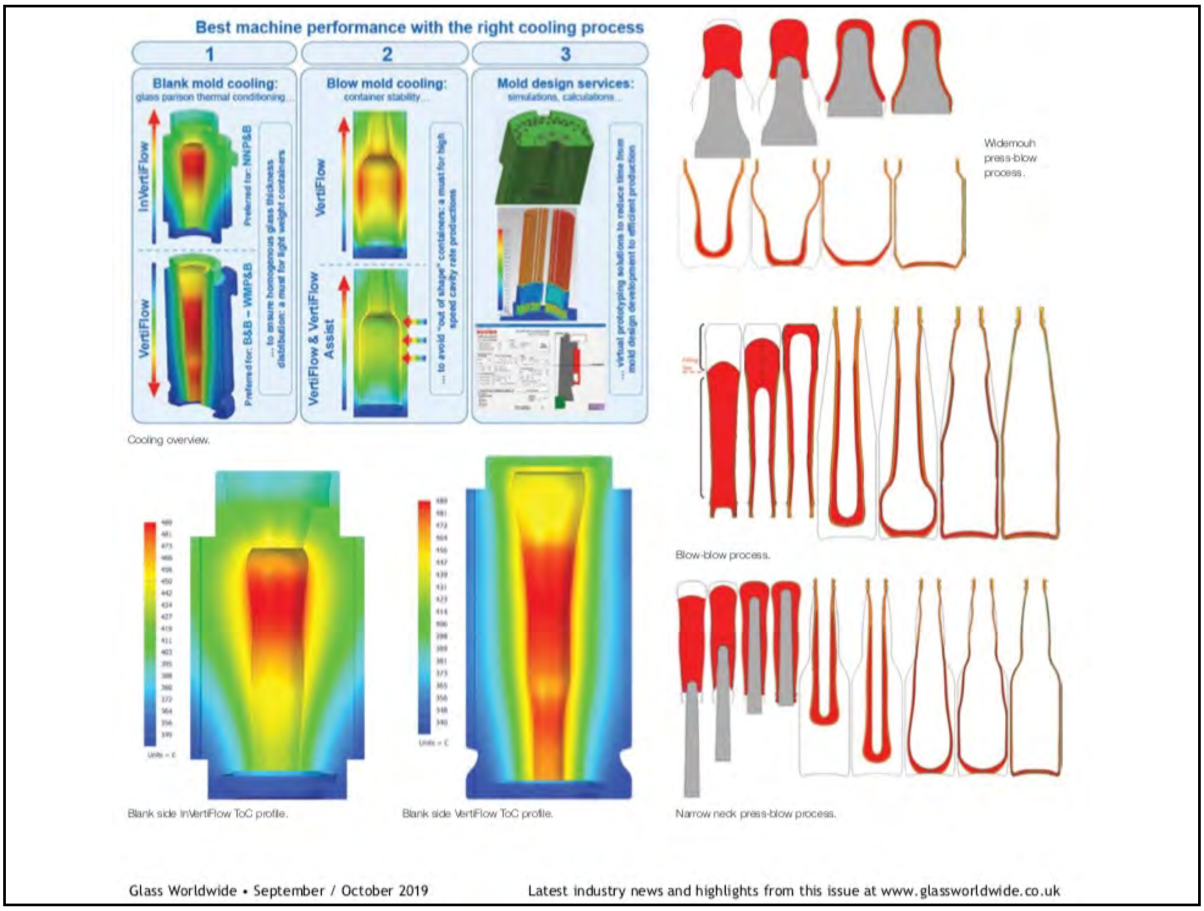

Cooling overview.

Blank side InVertiFlow ToC profile.

Blank side VertiFlow ToC profile.

Widemouh press-blow process.

Blow-blow process.

Narrow neck press-blow process.

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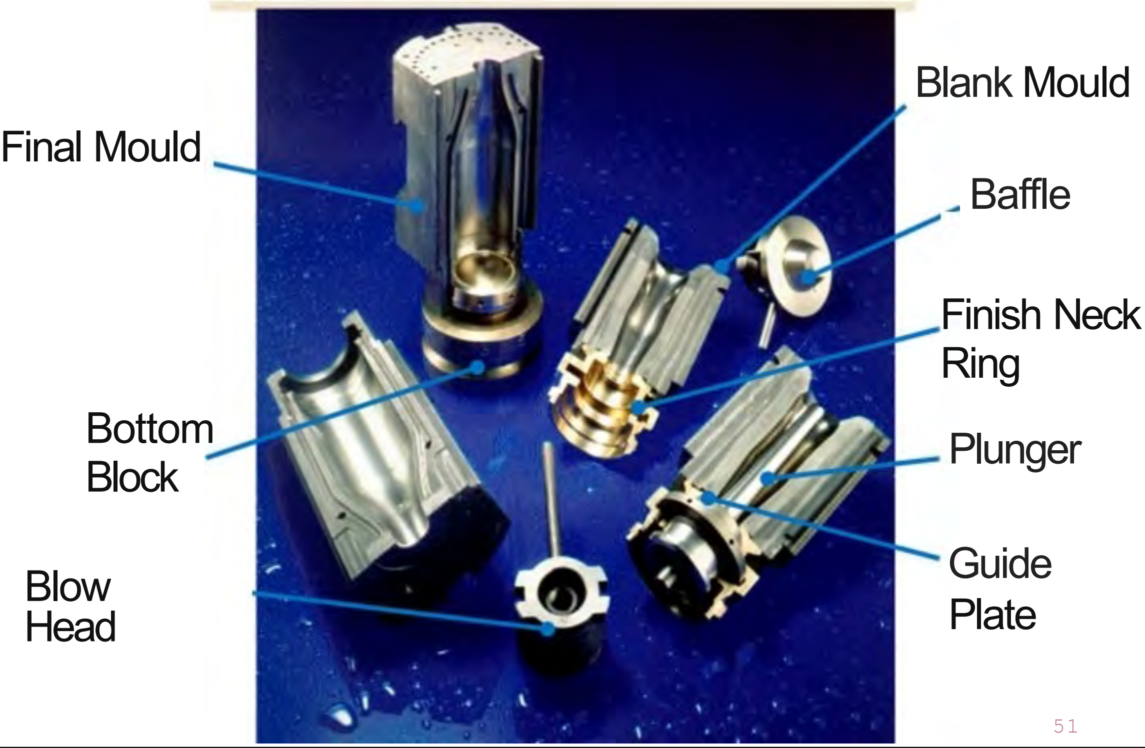
Mould Equipment



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I.S. Machine -UnitedGlass,Alloa

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I.S. Machine -United Glass, Alloa

- IS Machine
- Single / Dual / Triple/ Quad
- Different number of machine Sections

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Glass container manufacture

- Three main processes:
  - o Blow and Blow
    - commonly (traditionally) used for narrow neck containers
  - o Press and Blow
    - used for wide neck containers
  - o Narrow Neck Press and Blow (NNPB)
    - developed for narrow neck containers, allows better control and further light-weighting
  - o In a separate process tubular glass forming

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Manufacture of Bottles

(Blow & Blow Process)

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Manufacturing process of a glass bottle

https://youtu.be/A_M8WBJMcM0

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Blow and Blow process

- Narrow Neck Containers
- Standard (heavy) Weight

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Manufacture of Jars

(Press & Blow process)

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Press and Blow process

- Wide Mouth Containers

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Manufacture of Light Weight Bottles

(Narrow Neck Press & Blow process)

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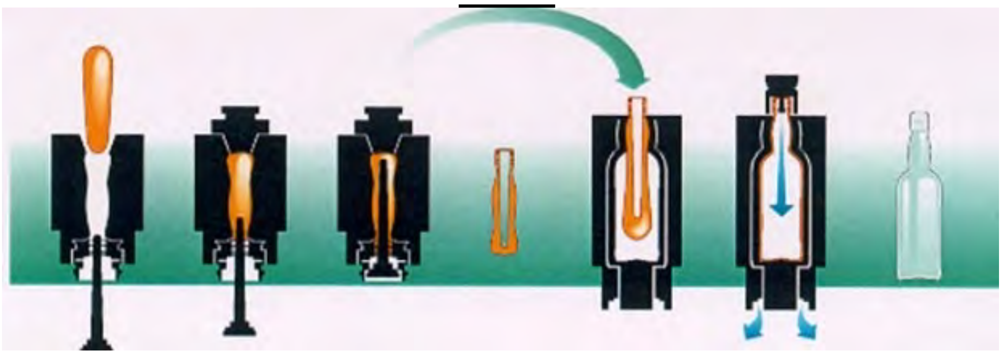
Narrow Neck Press and Blow process



- Narrow neck containers
- **Lightweight** (20% or more lighter than Blow and Blow)

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LIGHT WEIGHTING

547g ——— 227g

British **Glass**

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Light Weighting

- Compared with blow and blow, press and blow offers:
  - o Improved glass distribution
- But:
  - o the mechanical plunger and accuracy required means the tooling cost is higher
  - o Higher glass temperature, tighter tolerances and improved weight control essential and costly

LIGHT WEIGHTING

Benefits of NNPB
Weight savings = Distribution cost savings

British Glass

LIGHT WEIGHTING

Benefits of NNPB
Better visual quality

No reduction in strength because of less variation in wall thickness and no "settle wave"

British Glass

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LIGHT WEIGHTING

Benefits of NNPB
Clear crisp embossing

British Glass

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Completing the process

- Annealing to reduce internal stresses
- Coating to strengthen surface and lower the coefficient of friction
- On-line and off-line inspection
- Packing to meet customer requirements

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Annealing

- Rapid cooling during forming leads to stress
- Annealing carried out in the **LEHR** relieves internal stress
- Temperature control
  - o Reheat glass
  - o Hold temperature to release stress
  - o Slow cool

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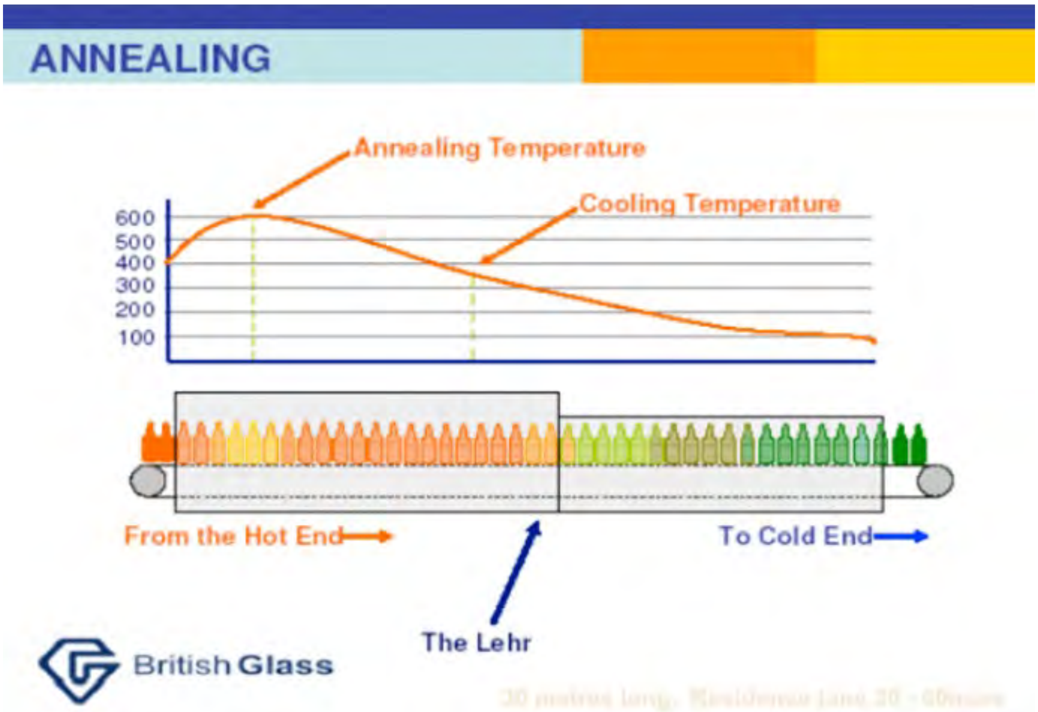
Annealing



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Surface Coating

- Coatings to strengthen surface and lower the coefficient of friction (scratched glass will be significantly more prone to breakage)
  - o Hot end - primer or bonding agent coat
    - eg tin or titanium tetrachloride
  - o Cold end - friction reducing coat
    - eg oleic acid, monostearates, waxes, silicones and polyethylene's

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Inspection

- High degree of 100% on line inspection, usually after annealing:
  - o Squeeze test - weak points, cracks
  - o Bore gauge - neck dimensions
  - o Crack detector
  - o Wall thickness
  - o Pressure - for carbonated drinks bottles

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Parts of a bottle

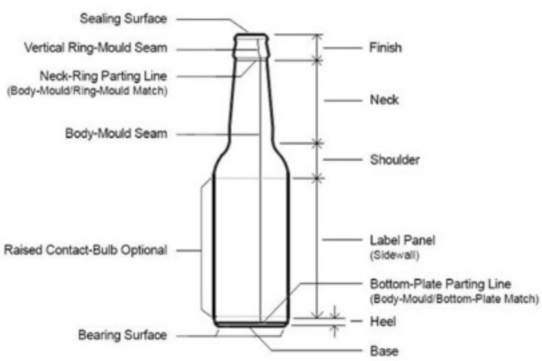
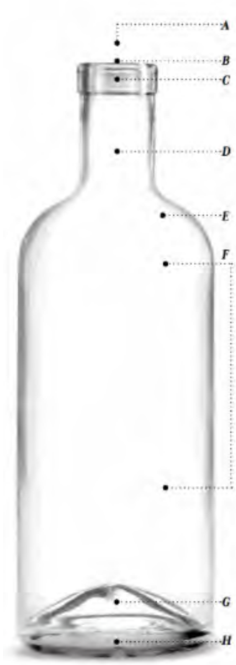


Image Glassplant GPC



A. Through Bore – This refers to the minimum neck diameter for ease in bottling. A fill tube must typically be at least 1 mm narrower than the through bore. For example, if a through bore is 16.5 mm, then the fill tube is recommended to be 15.5 mm. Normal filling tubes are 15 mm or larger.

B. Bore – This term refers to the dimension at the very top opening of the bottle and tells the bottler what size cork should be used for the best seal. Standard bore for the U.S. is 18.5 mm (0.728 inch). Many larger-necked spirits bottles use 21.5 mm (0.846 inch) or larger. The length of the bore inside of the neck is important for ensuring proper cork sealing.

C. Bottle Ring – Sometimes called the bead, this is the flared top section of the bottle. A seam on the lower edge of the ring shows where this part of the mold is joined to the body mold. The bottle ring can be interchanged with a compatible body mold.

D. Bottle Neck – This part of the bottle takes on a difficult task when air is blown into the bottle. It must be straight inside and out, creating a controlled cylinder for the cork to fit in. A thin neck takes a smaller diameter cork, while a fat neck will require a larger cork.

E. Shoulder – The widest part at the top of the body, just below the neck. If embossing is used, it is usually applied here because this area has no bottle-to-bottle contact point when bottles stand side-by-side.

F. Label Panel – The bottle blueprint shows the location and size of the label panel. Designers should use this reference to ensure the label fits on this flat area.

G. Punt – This pushed-up area is a traditional addition to the bottle. It has no real use in current glassmaking, but some consider a deep punt to be an indication of quality. The punt can add height to a bottle by taking up volume in the base, and can be customized.

H. Base – The bottom of the bottle has a base plate where the base attaches to the body mold. This area can be customized.

Inspection

- Inspection equipment requires adjustment for each bottle design
- Rejected containers recycled as cullet
- Feedback of information to forming end
- Statistical process control
- Visual inspection and off-line laboratory testing also carried out

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Packaging

- Glass shipped on standard pallets.
- Normally layer packed and shrink wrapped
- Can be case-packed for small quantities
- Date coding for traceability
- Encourage use of returnable transit packaging
- Pack stability and pallet utilisation influence total cost

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Decoration of glass containers

- Variation from standard colours
  - o Coloured frit added to white flint glass on specialised forehearth
  - o Ideally 3-day minimum production run
- Embossing of surface design, especially logos for branding

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Decoration of glass containers

- Surface colouring:
  - o Opaque or transparent
- Surface printing (screen)
- Ceramic decals
- Labels - spot, wraparound and sleeve

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Economics of Glass Making

- Capital-intensive process:
  - o Furnace
  - o Bottle forming equipment
  - o Storage facilities
- High energy usage - melting temperature of 1500°C
- Continuous operation 365 days per year

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Economics of Glass Making

- For each tonne of glass melted you need
  - o 1.2 tonnes of virgin raw materials and
  - o 1.1 MWh energy (c.107 cu meters of natural gas)
- and from this
  - o approx 374kg of CO_2 is produced

    (206 kg from the gas and 168 kg from the decomposition of the raw materials.)
- However, if you add 40% cullet, you need
  - o approx 1.0 MWh of energy and
  - o approx 320kg of CO_2 is produced

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Design considerations

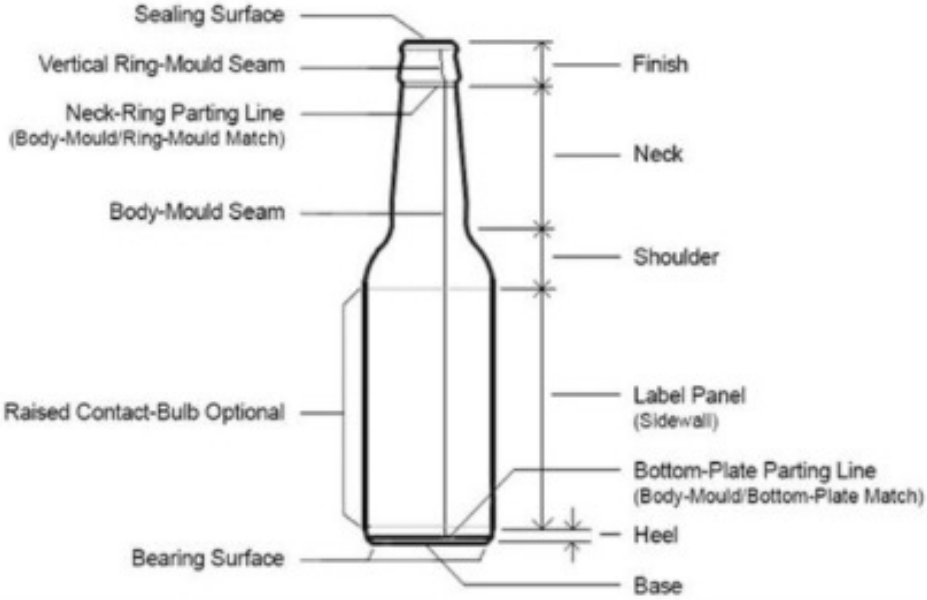
- Standard vs. custom tooling:
  - Cost and lead time
- Can incorporate anti-counterfeit measures
- Unique shape for selling function

Specification

Exercise

- Glass specification
  - List the key criteria required for a glass container specification and for quality checks.

Key spec details



Design considerations

- Iconic Product Shapes

Design considerations

- Iconic Brand Shapes

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Design considerations

- Container capacity:
  - o Legislation re contents declaration
  - o Allow for expansion of product e.g. alcohol

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Design considerations

- Closure:
  - o Standard neck finishes
  - o Think about consumer convenience in opening and resealing
- Colour and decoration:
  - o Wide range of options

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Design considerations

- Consumer use - think about:
  - o Shape for ease of holding
  - o Neck finish for easy access to the product:
    - Spooning out solids such as jam
    - Shaking out solids such as tablets
    - Pouring out syrups
  - o Avoid undercuts to trap product

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Design considerations

- Filling line:
  - o Low Centre of Gravity
  - o 'Shingling' on conveyors
  - o Neck finish for closure application
- Display and storage:
  - o Secure stacking - interlock with closure

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Industry developments

- Use of CAD/CAM 3-dimensional visualization for rapid development and accuracy
- Further light-weighting via more use of narrow neck press and blow etc.
- Surface strengthening using coatings
- Fragility improvement via formulation
- More on-line 100% inspection

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Quality Checks

Automatic on-line
- wall thickness inspection,
- squeeze testing,
- sealing surface inspection,
- side wall scanning and base scanning.

Off-line dimensional checks,
- capacity checks and
- pressure testing.

Hot end
Weight, Verticality, Height, Diameter

Cold End
Automatic Inspection
Routine Checks Visual defects, gauge checks

Quality Assurance
- Pressure tests, annealing, coating levels, thermal shock
- Laboratory Testing
- Colour, density, seeds/bubbles

Finished Goods
- AQL Inspection

Quality

•Data from on-line and off-line quality checks is fed continuously back to the ‘hot-end’ forming machine operators who can then make adjustments to remove the problem at source, rather than relying on inspecting the problem out.

•Each container has a series of dots moulded into the in-sweep which create a coded number when read by the on-line inspection machines. This quickly highlights any bottle faults being seen and faults in the mould which created it.

•Also identifies if a particular mould in a set is at fault.

Quality

Critical
Hazardous to the user and those that make the container completely unusable.

Major
Materially reduce the usability of the container or its contents

Minor
Does not affect the usability of the container, but it detract from its appearance or acceptability to the customer.

Quality Issues - CRITICAL

1. Stuck Plug. A piece of glass, usually very sharp, projecting inwards just inside the neck bore

2. Overpress. Is a defect where a small ridge of glass has been formed on the sealing surface of the finish

3. Split. An open crack starting at the top of the finish and extending downward.

4. Check. A small, shallow surface crack, usually at the bore of the container

5. Freaks. Odd shapes and conditions that render the container completely unusable. Bent or cocked necks are a common defect of this type.

6. Poor Distribution. Thin shoulder, slug neck, choke neck, heavy bottom are terms used to describe the uneven distribution of glass.

7. Soft Blister. A thin blister, usually found on or near the sealing surface. It can however show up anywhere on the glass container.

Quality Issues - Critical contd.

8. Choked Bore. Here excess of glass has been distributed to the inside of the finish or opening

9. Cracks. Partial fractures, usually found in the heel area.

10. Pinhole. Any opening causing leakage. It occurs most often in bottles with pointed corners.

11. Filament. A hair-like string inside the bottle.

12. Spike. Spikes are glass projections inside the bottle.

13. Bird Swing. Is a glass thread joining the two walls of the container

Quality Issues - Major.

Chipped Finish.
- Pieces broken out of the top edge in the manufacturing process.

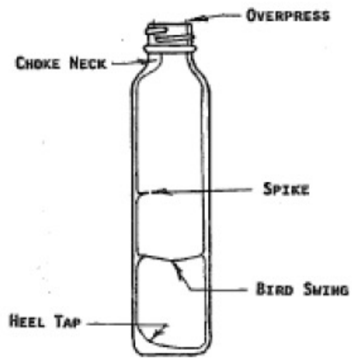
Stone.
- Small inclusion of any non-glass material
- Ceramic, earthenware – from cullet
- Metal – bottle caps apron rings and from cullet
- Refractory materials from furnace bricks (alumina, zirconium, silicates)

Rocker Bottom.
- A sunken centre portion on or in base of the container

Flanged Bottom.
- A rim of glass around the bottom at the parting line

Quality Issues - Minor

- **Sunken Shoulder**. Not fully blown, or sagged after blowing
- **Tear.** Similar to a check, but opened up. A tear will not break when tapped, a check will.
- **Washboard.** A wavy condition of horizontal lines in the body of the bottle.
- **Hard Blister.** A deeply embedded blister that is not easily broken.
- **Dirt.** Scaly or granular nonglass material.
- **Heel Tap.** A manufacturing defect where excess glass has been distributed into the heel
- **Mark.** A brush mark is composed of fine vertical laps, e.g. oil marks from moulds.
- **Wavy bottle.** A wavy surface on the inside of the bottle.
- **Seeds.** Small bubbles in the glass (from furnace)
- **Neck ring seam.** A bulge at the parting line between the neck and the body.



Tubular Glass

- Two other glass manufacturing processes

Tubular Glass

- Used for ampoules and vials
- Special raw materials
- Excellent control over wall thickness

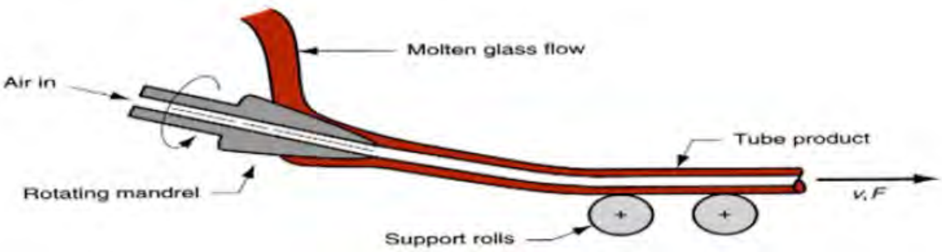
Tubular Glass

- Two processes to manufacture glass tubing:
  - o Danner
  - o Vella - faster, but higher capital investment
- Glass tubing is annealed
- Tubing cut and shaped using mechanical forming and heat

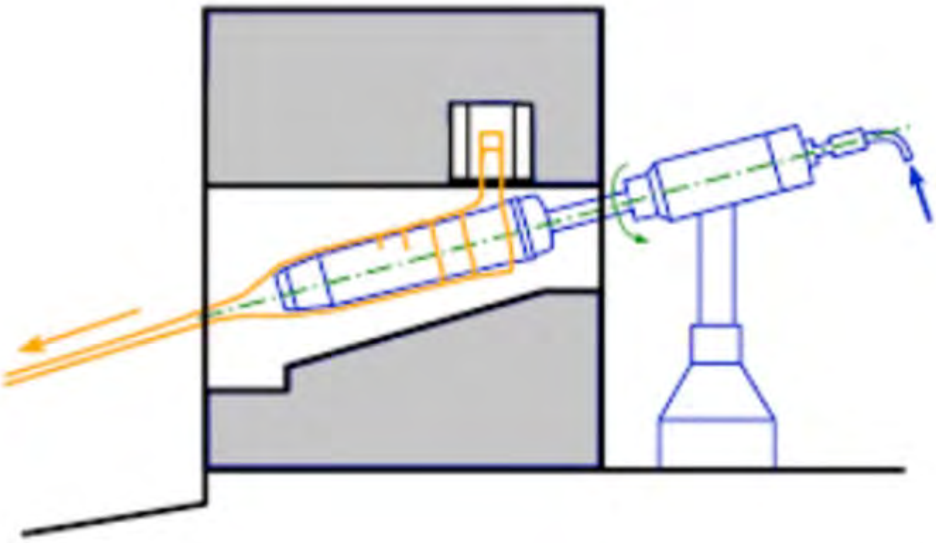
s

Danner Process

- Used to form tubing 1.5mm to 70mm diameters
- Produced at speeds of up to 400m/min for small diameters
- Glass leaves the furnace as a ribbon
- Wrapped around a sleeve and over the tip of a tube
- Hollow tip for tubing
- Solid tip for rod glass



Danner Process



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Danner Process

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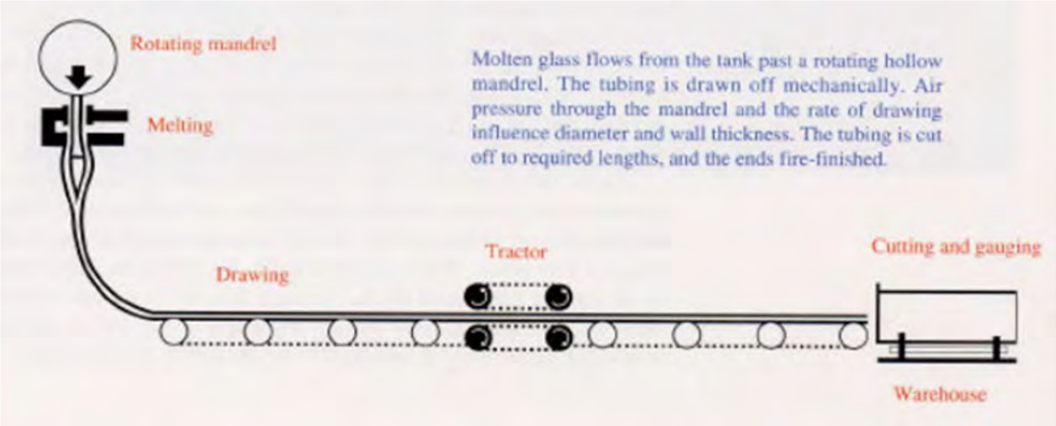
Vello Process

- Faster production than Danner process
- Glass flows through space between mandrel and orifice ring
- Rate of draw effects diameter and wall thickness



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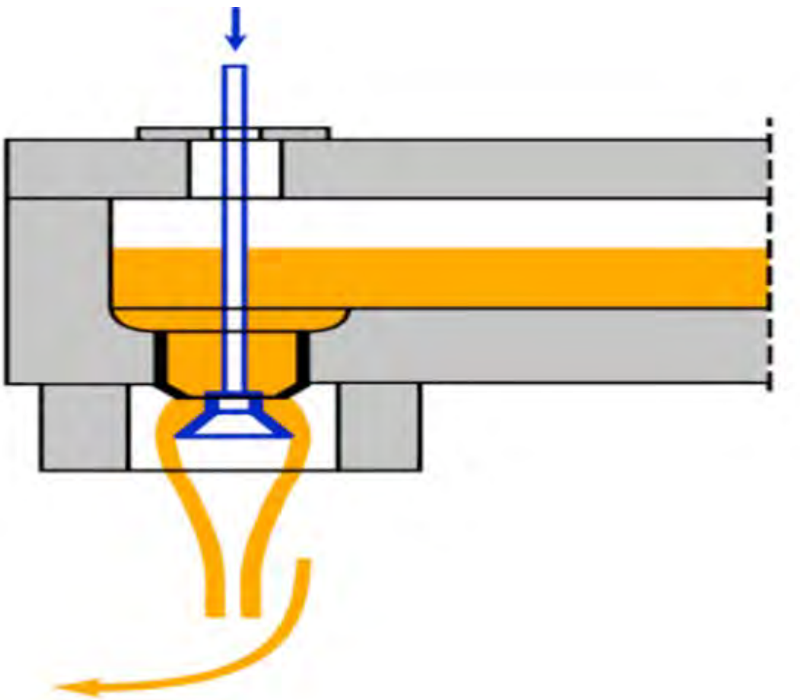
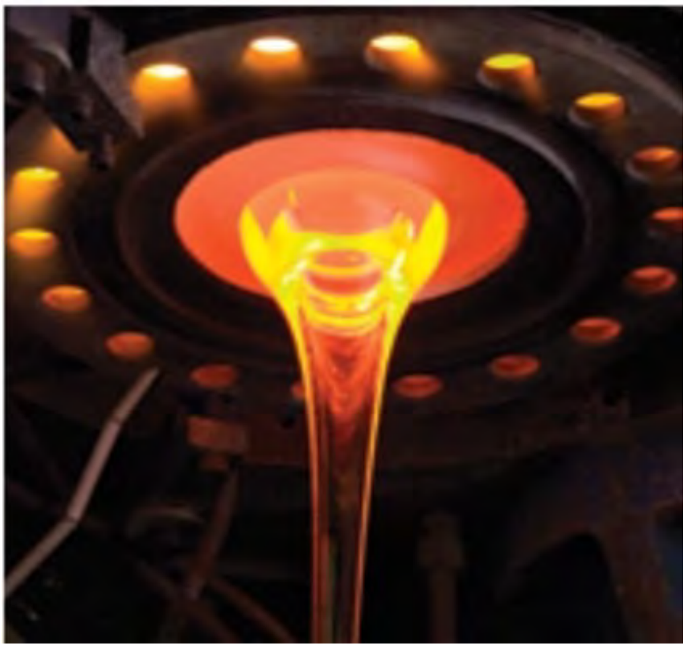
Vello Process



Vello Process



Tubular Glass

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Any Questions?

Thanks for
your time.

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