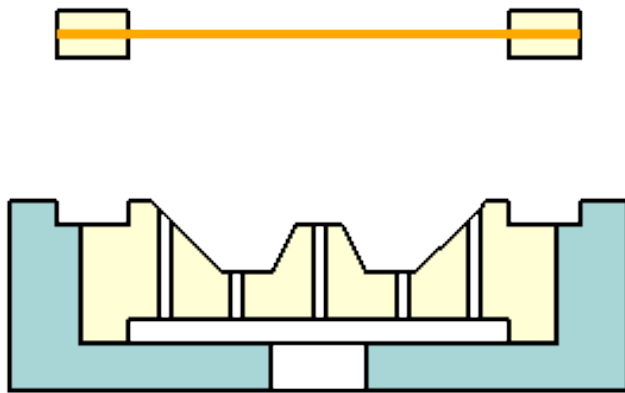


# 2.008 Design & Manufacturing II

Fall 2005

**Thermoforming  
Blowmolding  
Etc.**

# Vacuum (Thermo) forming



- Soften a sheet of thermoplastics molding material with a heater.
- Suck the air out of the mold through the vent hole to form a vacuum, causing the molding material to conform to the mold and assume its shape.
- Allow air in again to remove the part.

- Sheet
- Heat
- Form
- Cool
- Trim

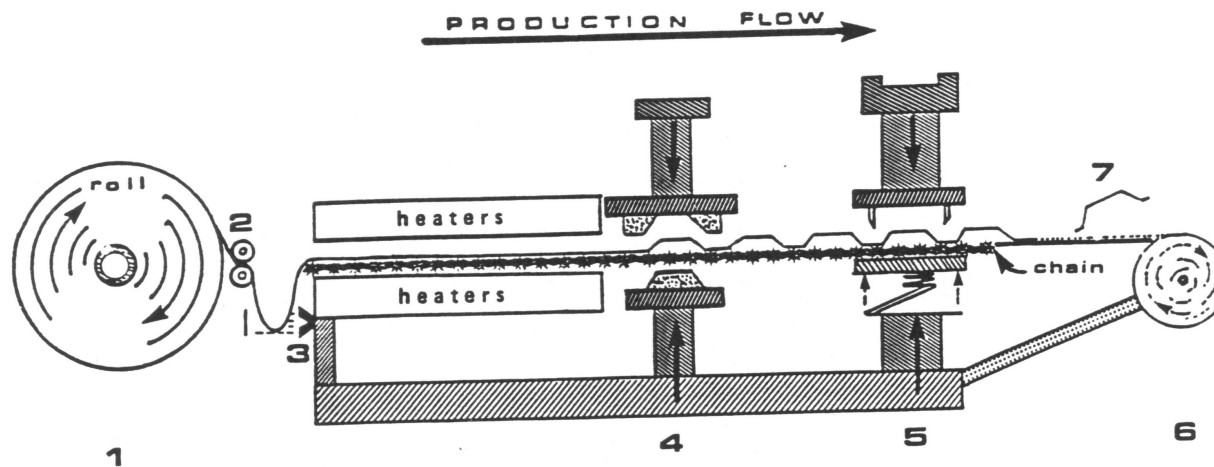
## Advantages

- Low temperature, pressure requirement
- Low mold cost, machine cost
- Large parts
- Fast mold cycles

## Disadvantages

- High cost of raw materials (sheets), scraps
- Limited part shapes
- Only one side of part defined by mold
- Inherent wall thickness nonuniformity
- Residual stresses

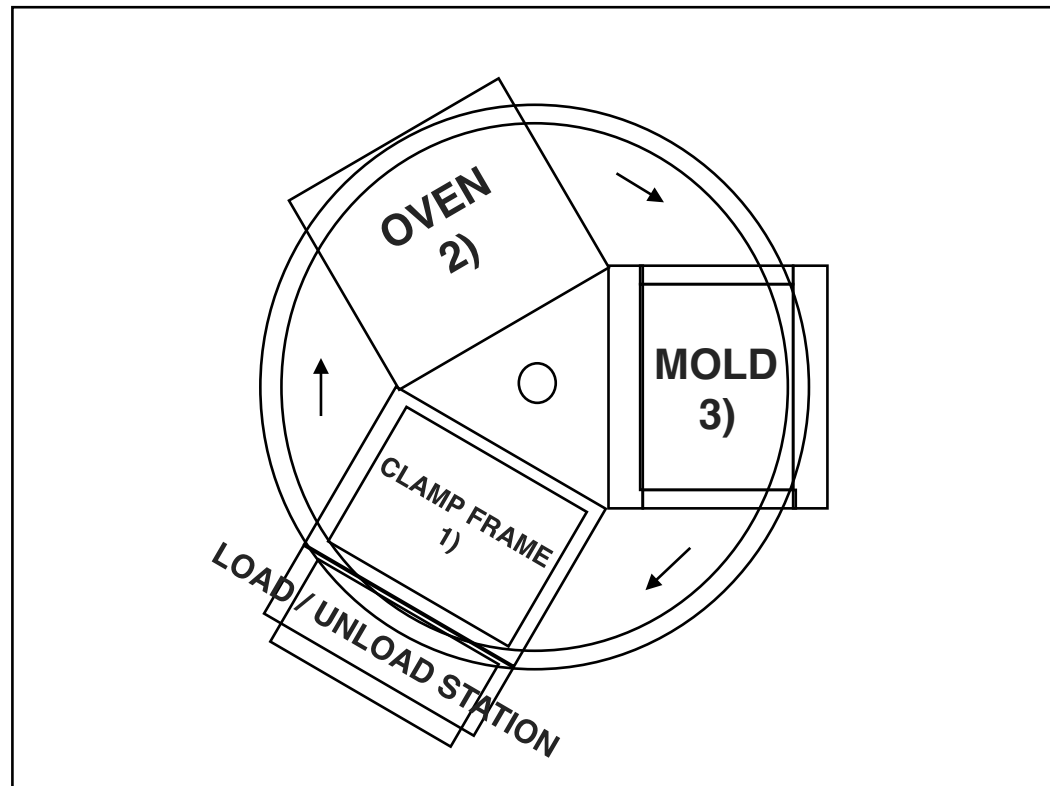
# Typical Mass Production Flow: In-line Arrangement



1. roll stock, 2. nip rollers, 3. electric eye,
4. forming station, 5. trimming station,
6. scrap wind, 7. part stacking

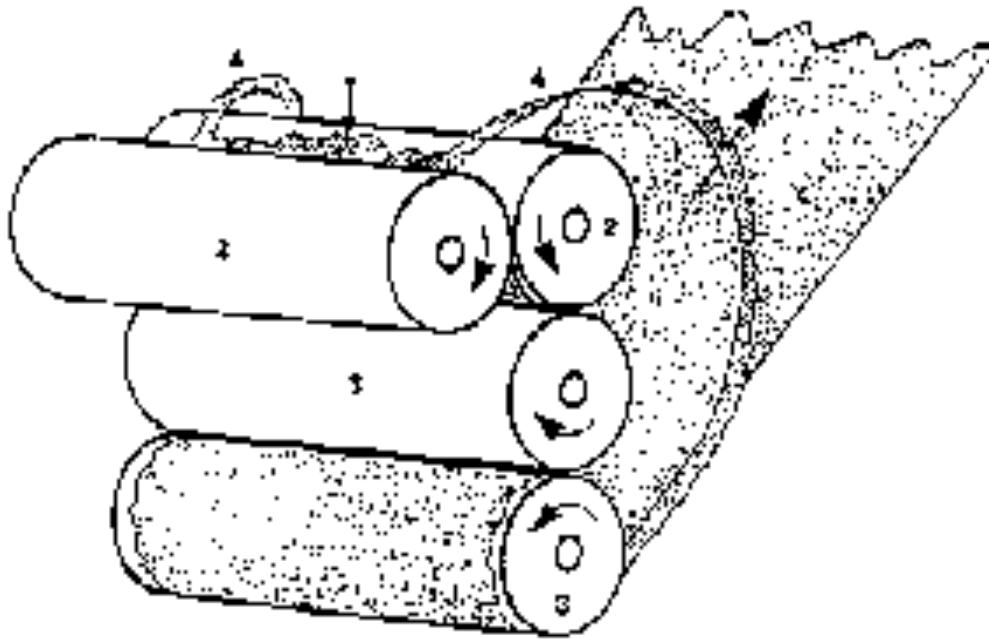
Blister pack  
Skin pack

# Three-station thermoforming machine



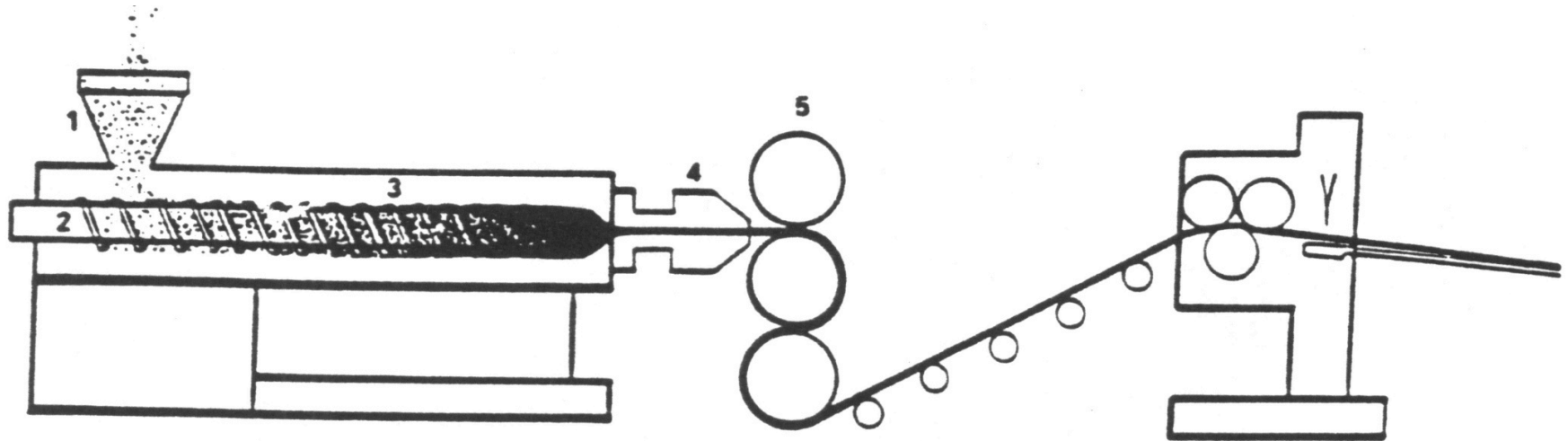
1. loading and unloading station, 2. heating station,  
3. forming station

# Plastic Sheet Making: Calendering



1. thermoplastic material,
2. feed rollers,
3. sizing and surfacing rollers,
4. edge trim

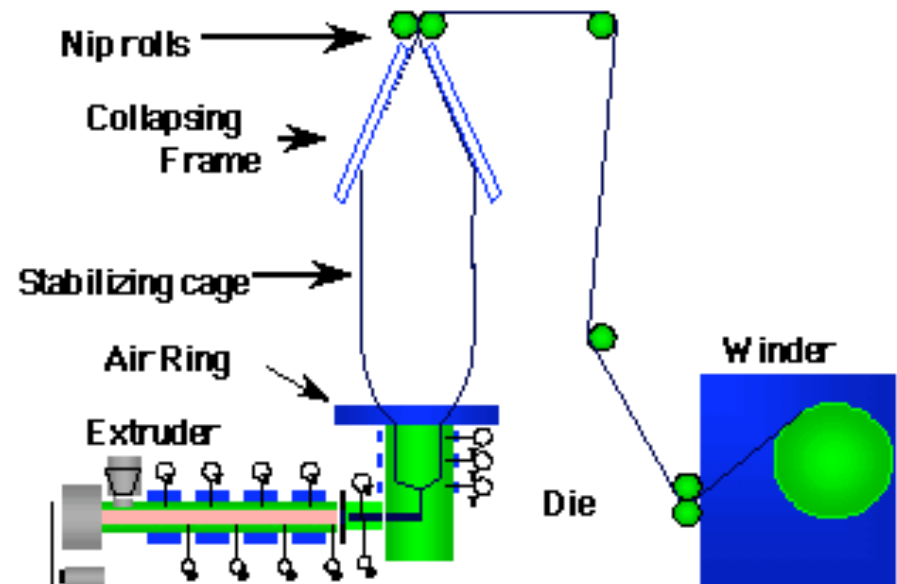
# Plastic Sheet Making: Extrusion



- 1. feed hopper, 2. extruder screw,
- 3. extruder barrel, 4. die, 5. roller stack

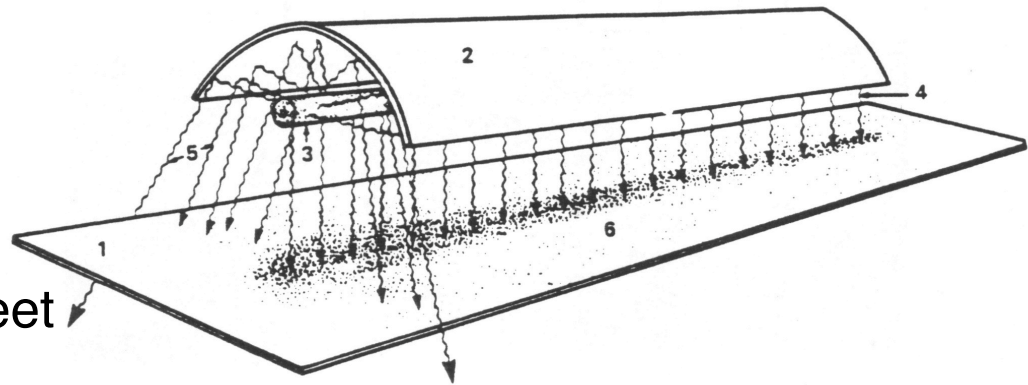
# Blow Film Extrusion

- Products
  - Heavy duty films (0.1 to 0.2 mm) used for covers for agriculture
  - Packaging: wrap, can lining, garbage bags, T-shirt bags, garment
  - Multilayer: (3 to 11 layers) for barrier film
- Process
  - Melting resin in extruder
  - Form molten resin into cylinder or tube.
  - Blow air inside the resin bubble.
  - Pull film into nip rollers through guide rolls.
  - Pull film through a series of rollers.
  - Wind-up film in take-up rolls
  - Bi-axial stretching



# Heating Methods: Radiant Heating

1. thermoplastic sheet, 2. reflector, 3. tubular heater element, 4. direct heat, 5. reflected heat, 6. actual heat distribution on the plastic sheet

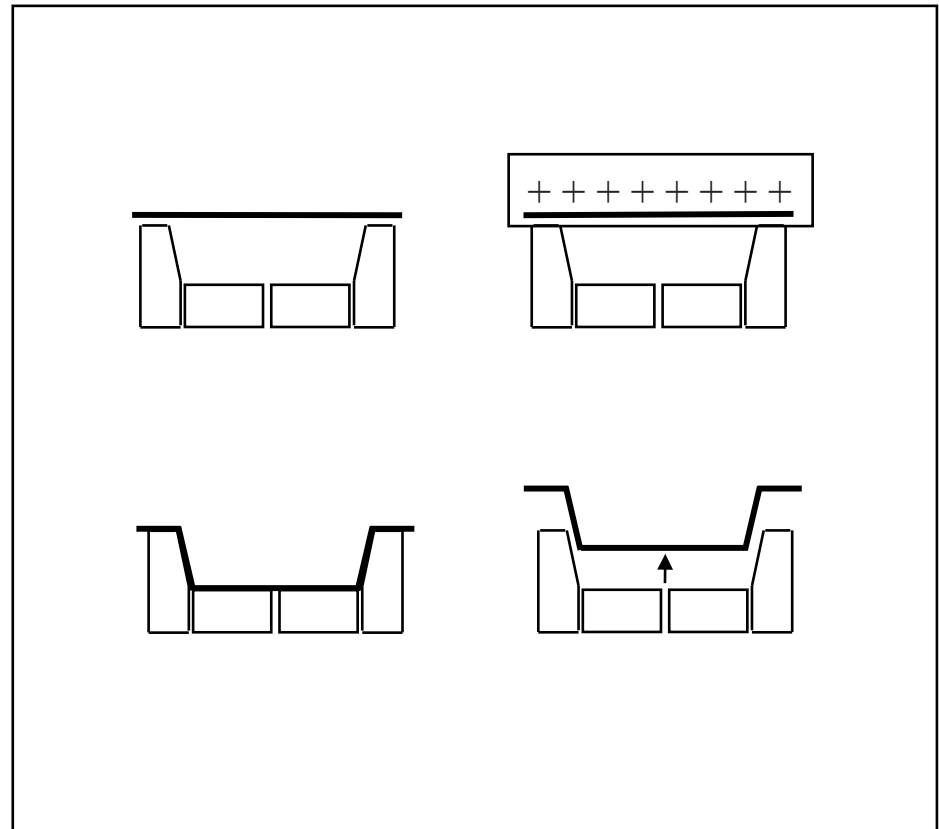


## Other methods

- Convection Heating
- Contact Heating

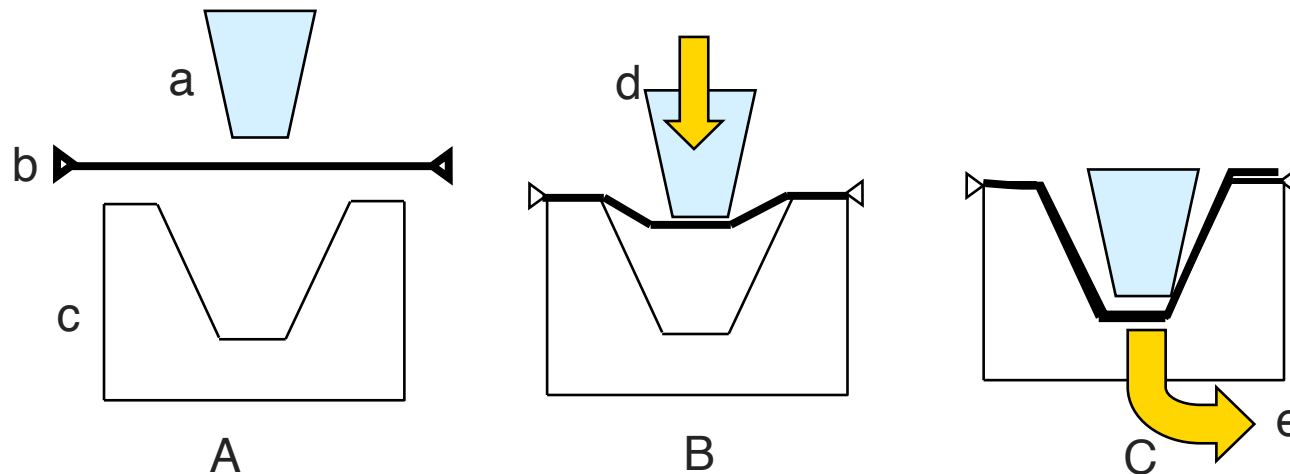
# Pressure Forming: Vacuum or Pressure

- Positive air pressure  
(14.5 to 300 psi)
- faster mold cycles
- lower temperatures  
with higher forming  
pressure

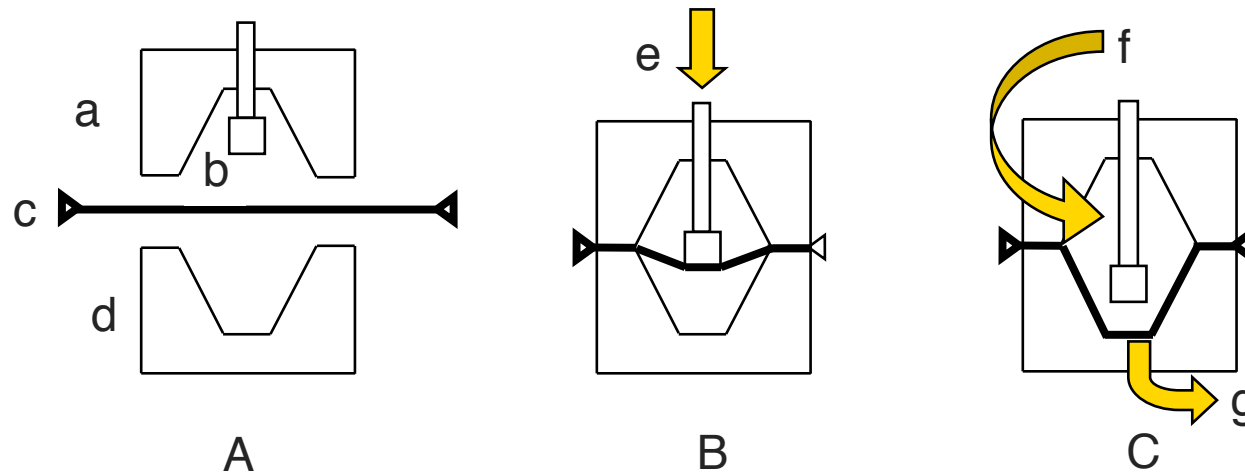


# Plug-assisted vacuum forming

- Better wall thickness uniformity especially for cup or box shapes
- Materials of plug include wood, metal, thermoset polymers.
- Plug is 10% - 20 % smaller than cavity.
- Temperature of plug

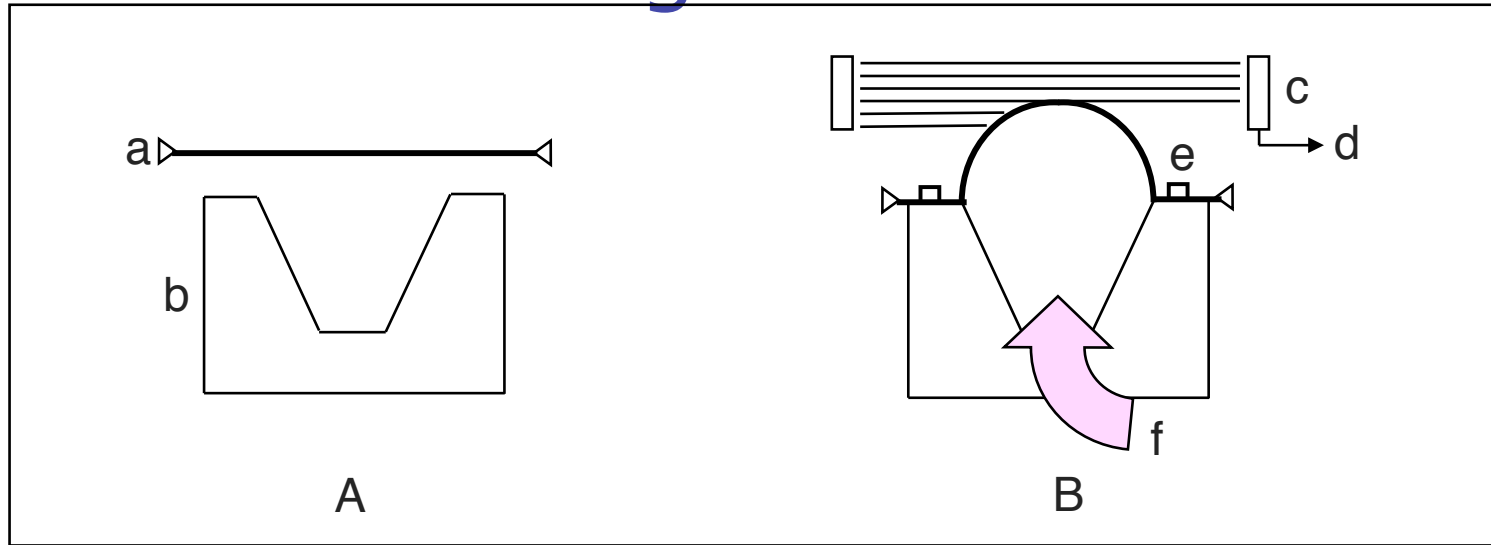


# Plug-assisted pressure forming



“a” pressure box “b” plug “c” preheated, clamped sheet “d” female mold with vent holes “e” moving plug “f” applied air pressure “g” venting air

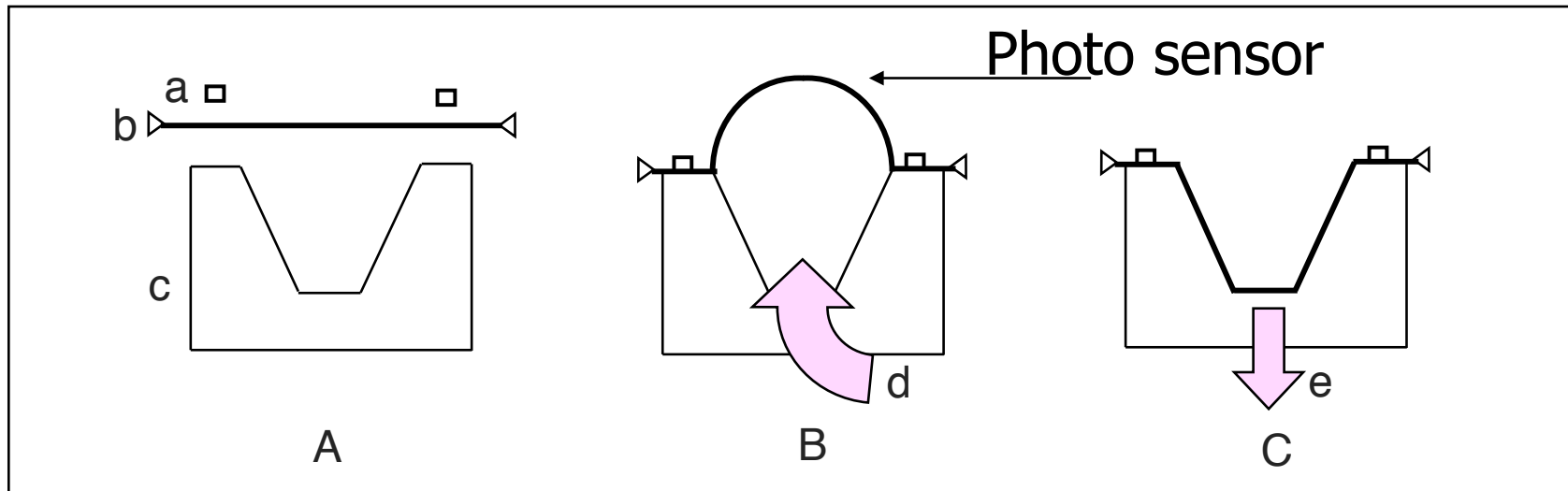
# Free Blowing



a - preheated clamped sheet, b - pressure box,  
c - proportional photocell monitor, d - signal to air pressure, e - hold-down  
ring, f - air pressure

- Clamping ring designs can result in controlling shape to hemisphere (circle ring) and elongated (tear drop ring).
- Canopies for racing vehicles.
- Size of bubble not to exceed 50% to 75% of the shorter dimension of clamped sheet.

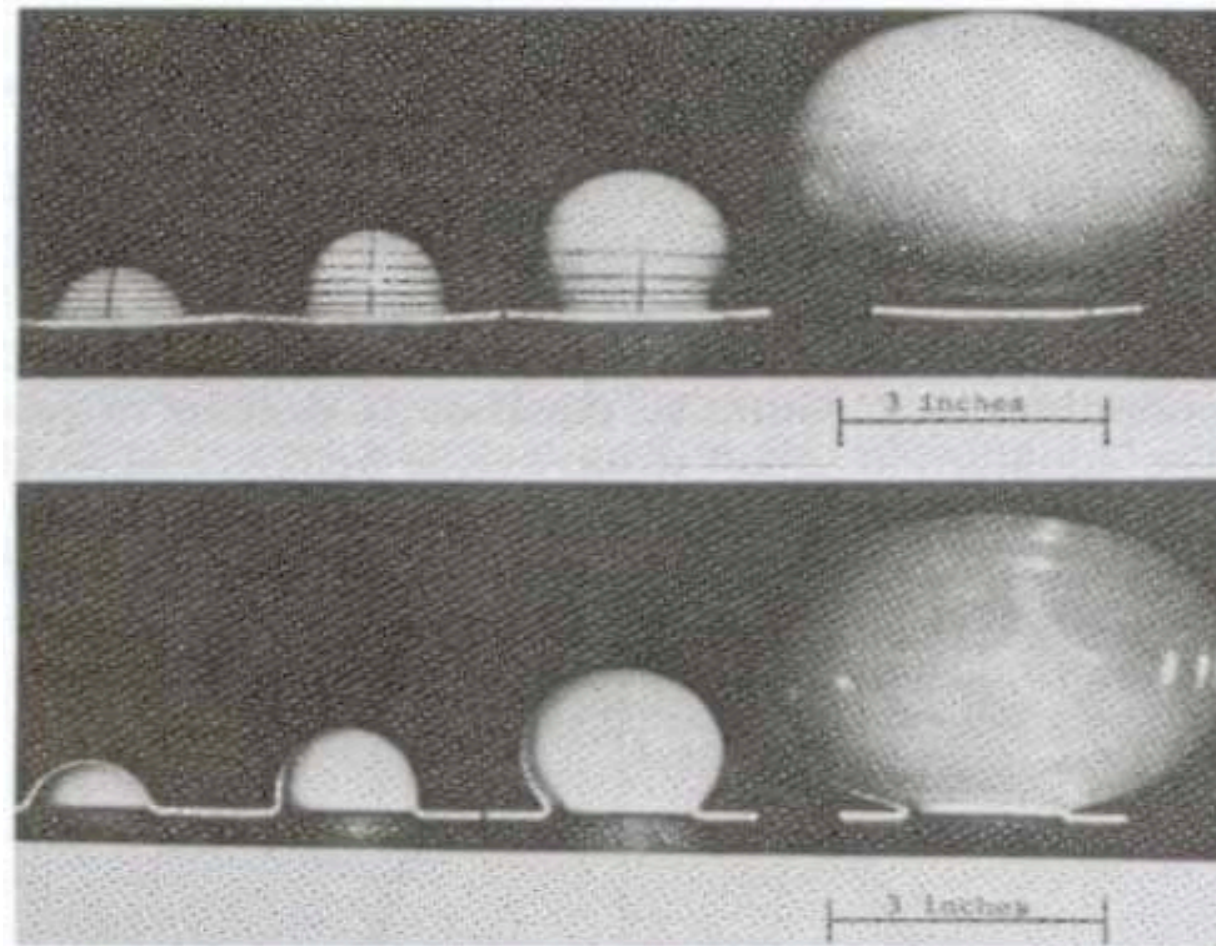
# Reverse Draw Forming



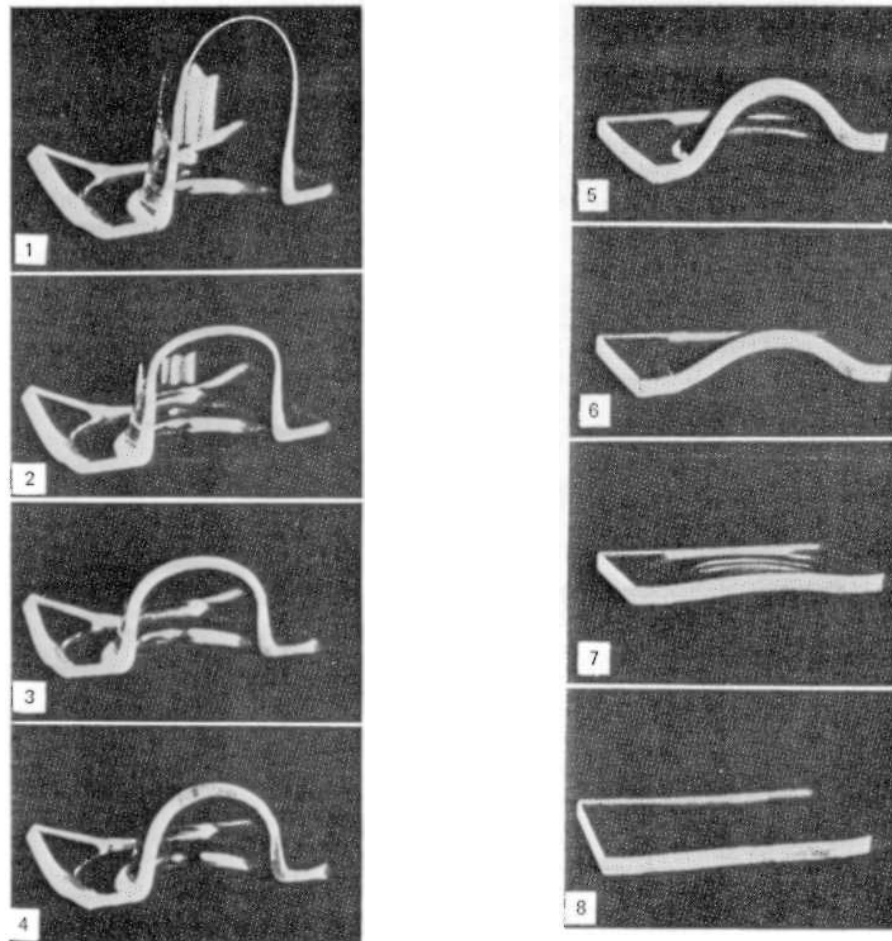
a - hold down ring, b - preheated clamped sheet,  
c - female mold with pressure/vacuum holes,  
d - applied pressure, e - vacuum

- Better thickness uniformity
- Deep draw
- Longer cycle time

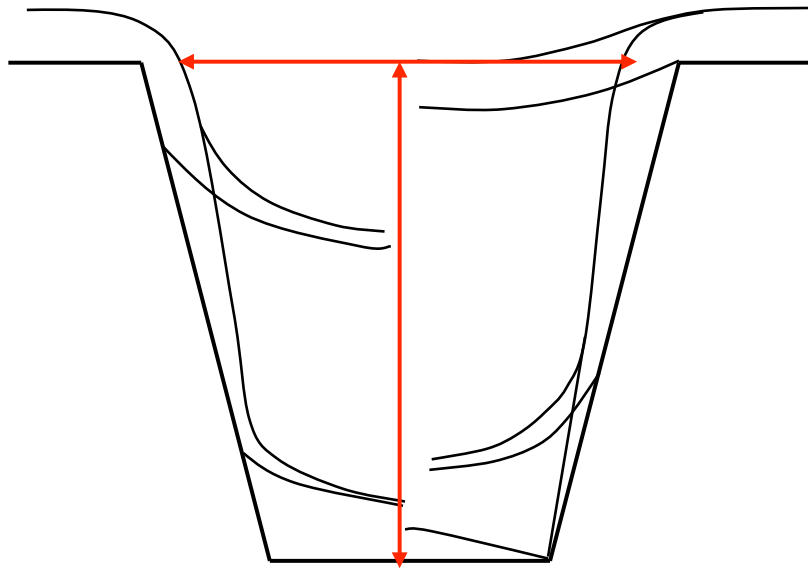
# Thickness Uniformity



# Forming Mechanism

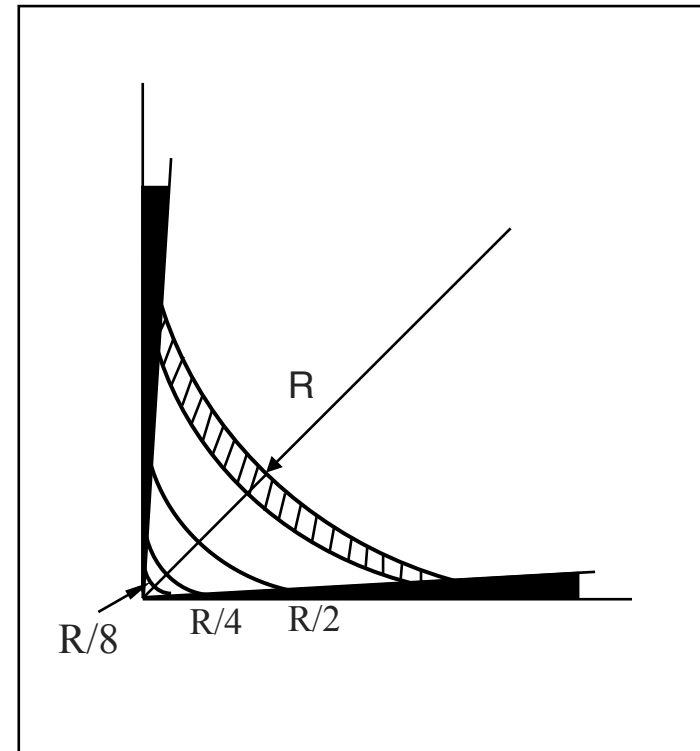
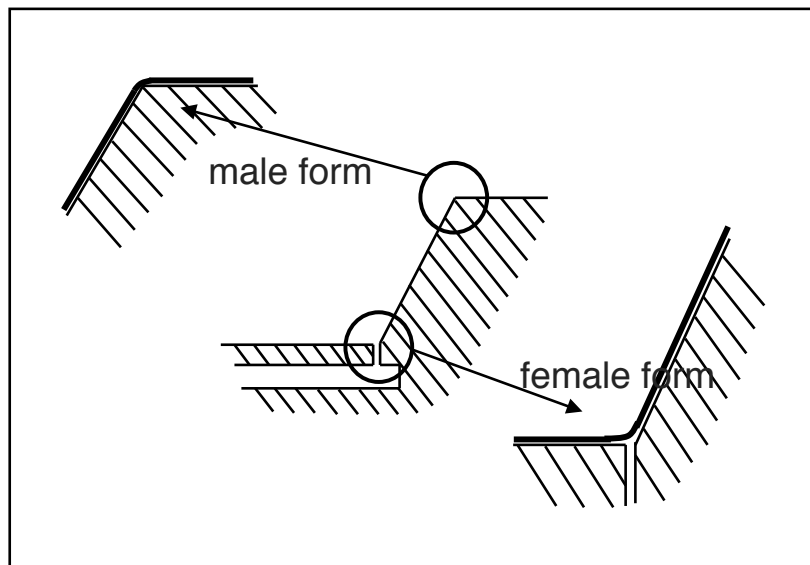


# Forming Considerations: Part Thickness

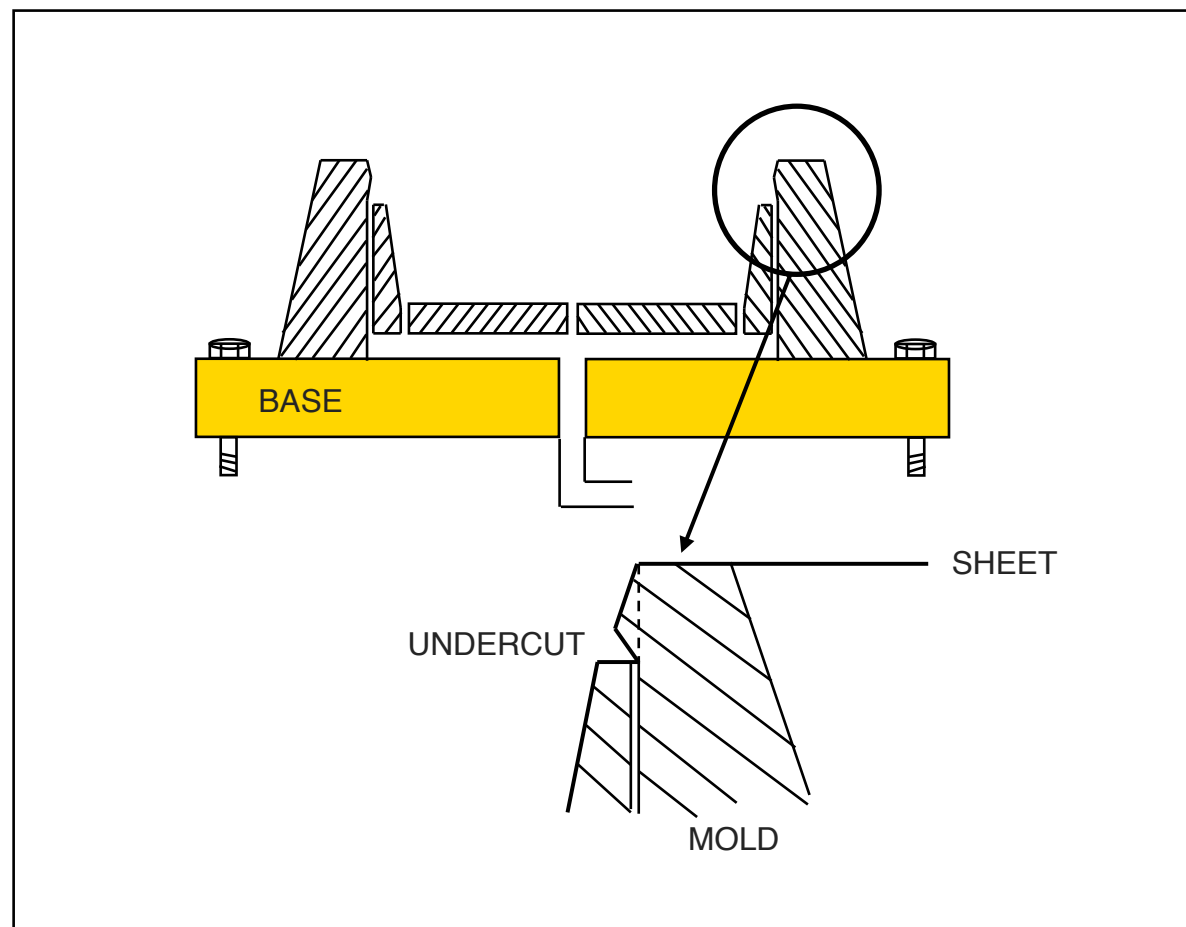


- Draw ratio = depth of part / width of part.
- Draw ratio should be less than
  - 2:1 for female molds
  - 7:1 for male molds
- Draft angle; 2 to 7 degrees

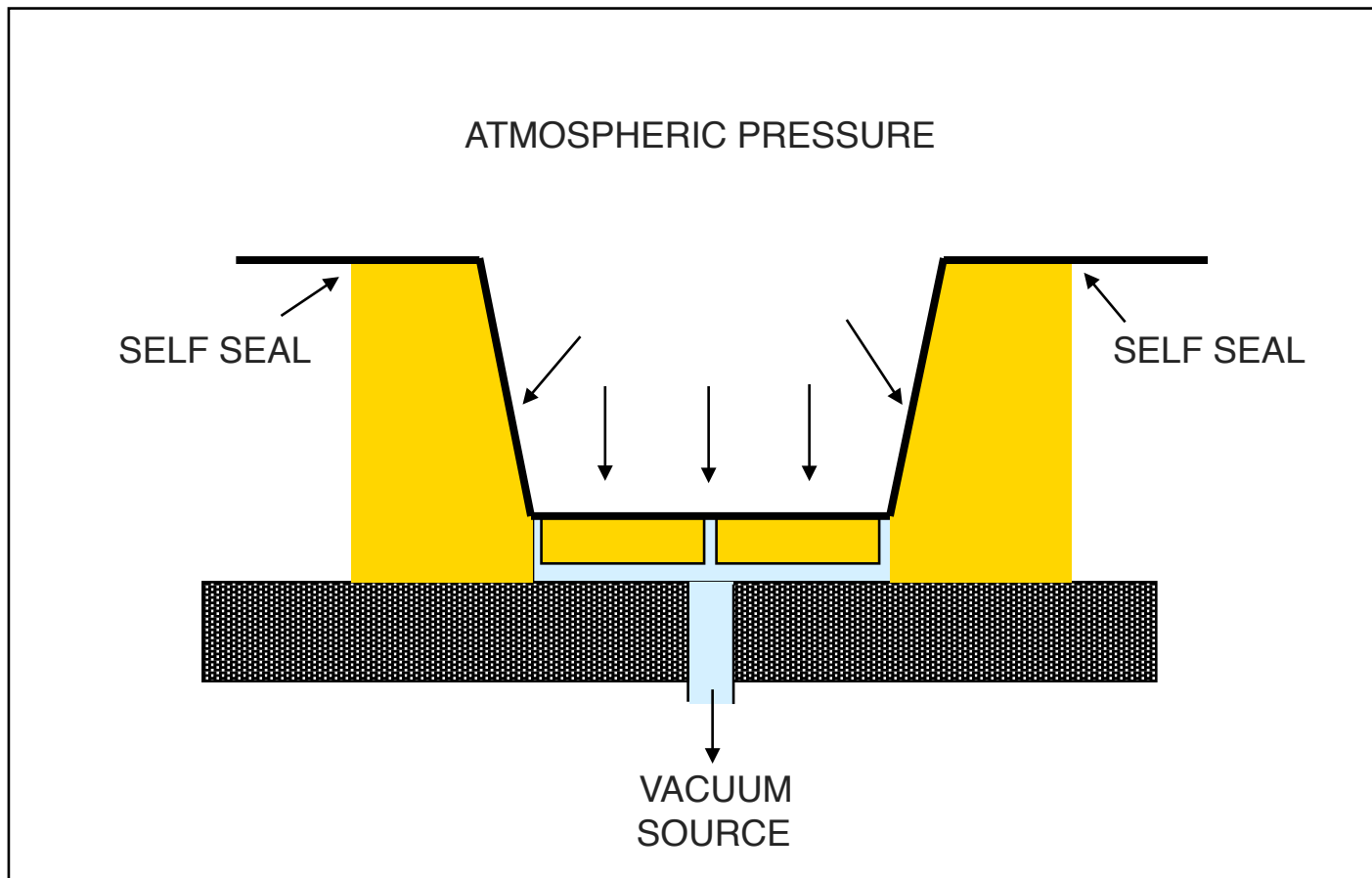
# Forming Considerations: Detail Loss, Progressive Draw-Down



# Forming Considerations: Undercut



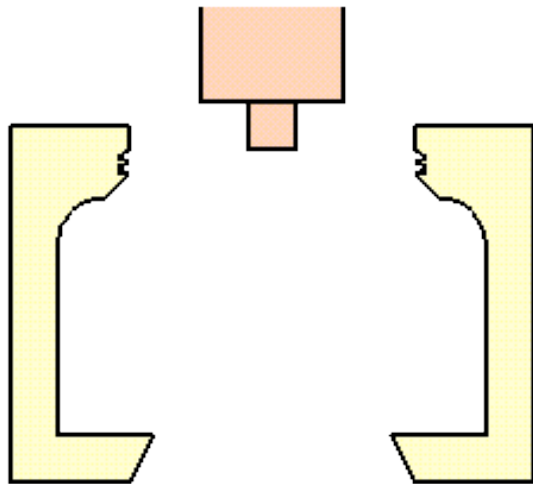
# Forming Considerations: Vacuum holes



# Design for Thermoforming

- Uniform thickness ( $\sim 10\%$ )
- Simpler shapes (avoid under cuts, etc.)
- Rounded corners (1t min, 4t ideal)
- Draft angle for removal ( 2 – 7 degree)
- Draw ratio ( $< 1:1$ , max 2:1)
- Shrinkage
- Design for holes and trim lines

# Blow molding



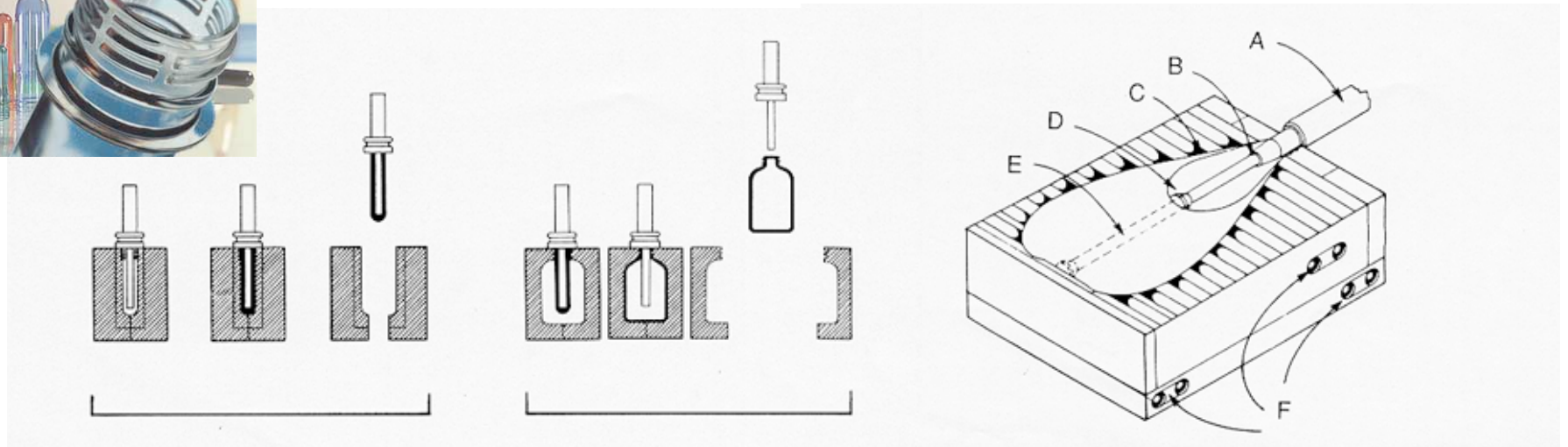
- Pinch a part of a molding material that has been molded into a tube shape with a separate mold.
- Blow compressed air into the molding material, causing it to expand until it conforms to the shape mold to mold the part.

Injection blow molding  
Extrusion blow molding

# Blow Molding

- Packaging, bottles for drinks, containers for cosmetics and toiletries, automotive containers and bumpers.
- Coextrusion products for chemical resistance and structural
- HDPE is the most widely used for high volume packaging
- PP used in processes that promote orientation
- PVC is used for bottles in Europe (homopolymer can be crystal clear) –but temperature, HCl
- PET is primarily used for injection blow molding.

# Injection blow molding



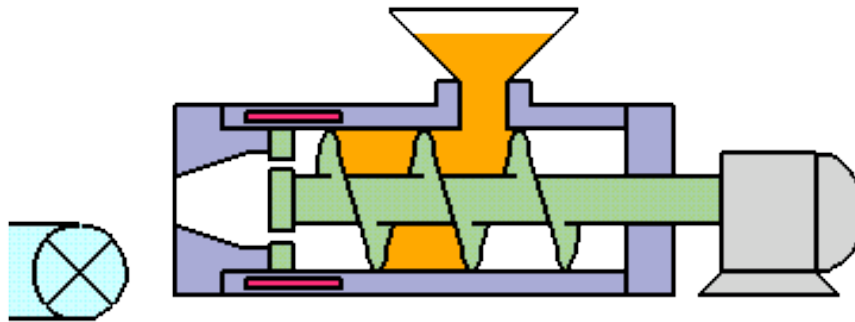
- A **parison** can have a non-constant cross-section resulting in better wall thickness uniformity than from extrusion blow molding.
- Parisons can be made by injection and then either stored until the finished blow molded parts are needed or shipped to a satellite location where they can be blown. → shipping cost
- Just oven and a blowing station at the bottling site.
- Stretch blow molding for bi-axial orientation

# PET bottles



- Performance requirement (after 120 days)
  - less than 15% loss of CO<sub>2</sub>
  - no off-taste, no change of shape (swelling), no fall in liquid level
  - drop test of 6 feet with no cracks or leakage, burst test for CO<sub>2</sub>
  - PET had excellent barrier properties versus PVC (2x), HDPE (52x), PP (57x), and LDPE (114x).
- Stretch blowing development improved properties of PET.
  - PET is injected at 480F-540F and then quenched. (resin is dried)
  - PET parison is heated to 200F (60F higher than T<sub>g</sub>)

# Extrusion



- Put a molding material in a hopper (material feed container).
- Plasticate it by stirring and mixing it with a screw while heating it up.
- Push the molding material out by the screw through a small hole of the apex mold (a die used to give the material a desired shape).
- Finish molding by cold solidification.
- Continuous and high productivity
- Constant cross-sections

# Advantages & Disadvantages Extrusion

- Advantages
  - Continuous
  - High production volumes
  - Low cost per pound
  - Efficient melting
  - Many types of raw materials
  - Good mixing (compounding)
- Disadvantages
  - Limited complexity of parts
  - Uniform cross-sectional shape only

## Injection vs. Extrusion BM

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- Scrap free.
  - Better suited for smaller bottles.
  - Higher accuracy in the final part.
  - Uniform wall thickness
  - No seam lines or pinch marks
  - Transparencies
  - Improved mechanical properties from improved parison design and from stretch blowing.
- Best suited for bottles over 1/2 pound.
  - Tooling costs are 50% to 75% less than injection blow molding.
  - Generates 20% to 30% scrap due to sprue and head trimming.
  - Regrind scrap and reuse.
  - Total cycle time is shorter.
  - Wider choice of resins with higher viscosities.

# Additives

- Antistatic Agents
  - Compounded into plastic attract water to surface and thus making it more conductive to dissipate charges
- Antioxidants
  - oxygen breaks the bonds of the polymer and reducing the molecular weight down into a powder. (PP and PE)
  - To stop or terminate oxidation reactions, to neutralize reactive materials that cause oxidation
- Flame Retardants
  - Emit a fire-extinguishing gas (halogen) or water when heated,
- UV Stabilizers
  - Plastics susceptible to UV degradation are polyethylene, polystyrene, PVC, ABS, polyesters, and polyurethanes
  - Polymer absorbs light energy and causes crazing, cracking, chalking, color changes, or loss of mechanical properties

# Additives

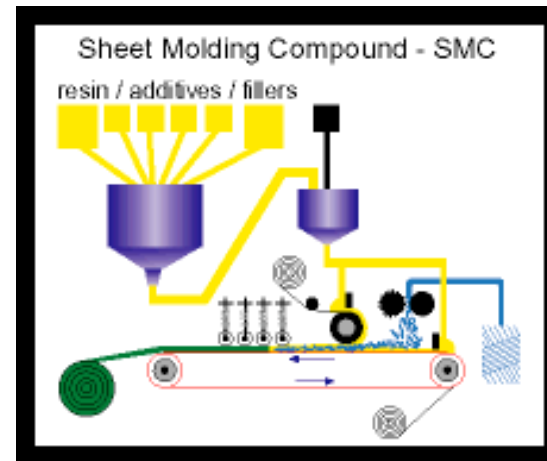
- Heat Stabilizers
  - Retard thermal decomposition for PVC
- Impact Modifiers
  - Elastomers added to polymers
  - PVC is toughened with ABS, EVA, etc.
- Lubricants
  - Reduce friction between resin and equipment
  - Mold release for the mold
  - Causes surface blemishes and poor bonding
- Plasticizers
  - Chemical agent added to increase flexibility, reduce melt temperature, and lower viscosity
  - Neutralize Van der Waals' forces
  - Results in leaching for food contamination, reduced flexibility PVC hoses

# Thermosets

- Epoxy: bisphenol A (resin)+ Diethylenetriamine(curing agent)
  - Excellent chemical and corrosion resistance
  - Excellent thermal properties and low creep
  - High stiffness and adhesion properties
- Polyester(terephthalic acid + ethylene glycol)
  - Rigid, resilient to chemical and environmental exposures, corrosion resistant, and flame retardant
  - Recreation vehicles, automotive body panels, floor pans; SMC
  - Cultured marble, buttons, corrosion resistant tanks and parts,
  - Corrugated and flat paneling, simulated wood furniture, bowling balls, polymer concrete, and coatings

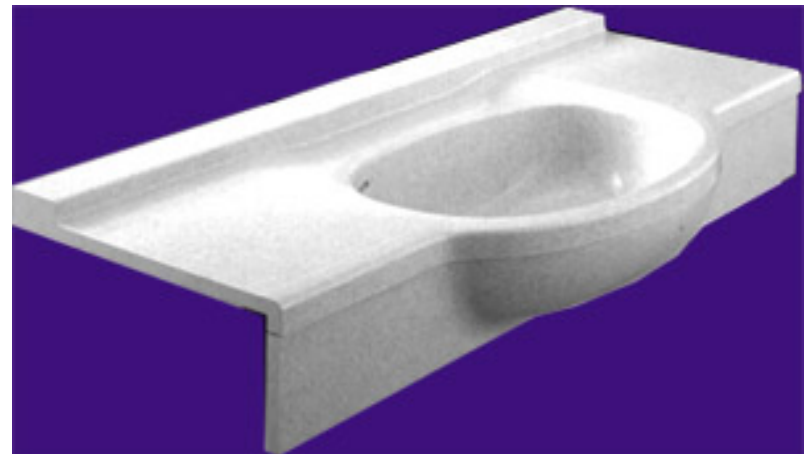
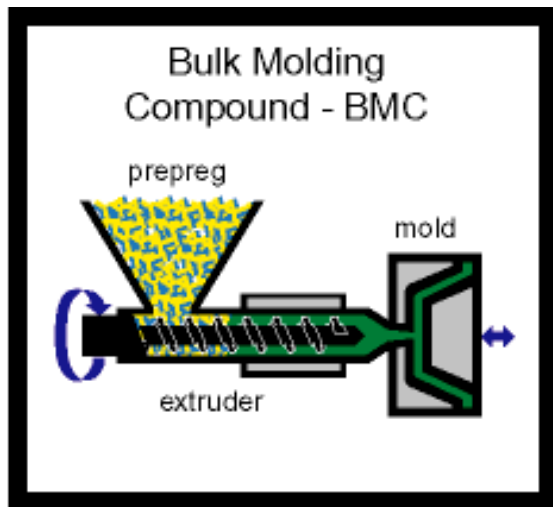
# SMC (Sheet Molding Compound)

- SMC is a paste that is to be compression molded.
  - 33% polyester resin and styrene, which polymerizes and crosslinks
  - 33% glass fibers (1" fibers)
  - 33% Calcium Carbonate



# Bulk Molding Compound

- BMC- Resin, chopped fiber, and filler
- Compression Molding

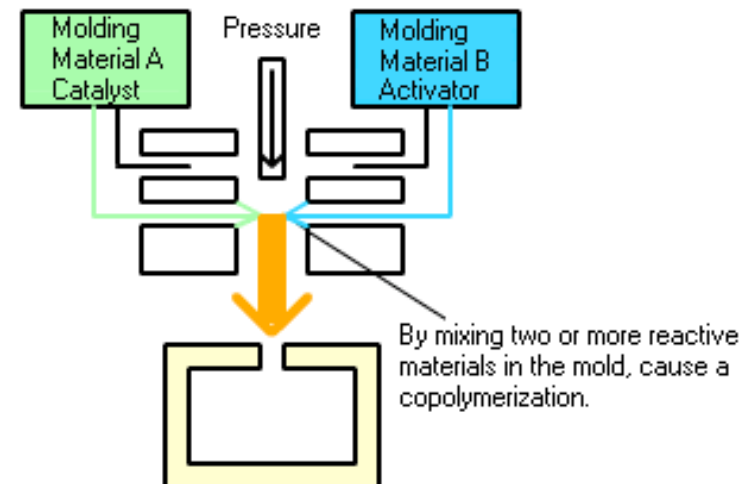


# Polyurethane

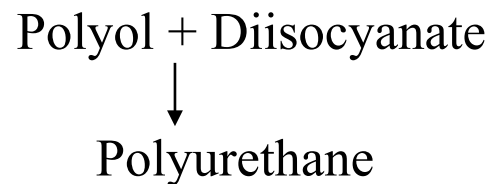
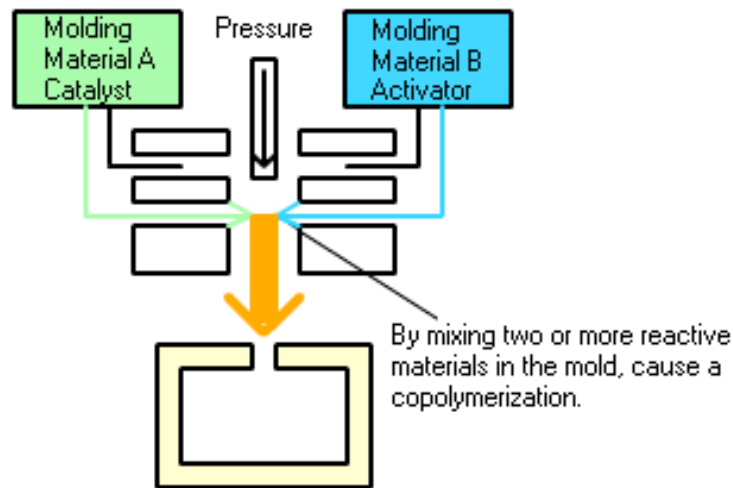
- Flexible foam, less crosslinking
  - Chemical blowing agent, microcellular
- Rigid urethane, high crosslinking
- Polyurethane can be processed by
  - Casting, painting, foaming
  - Reaction Injection Molding (RIM)

Polyol + Diisocyanate

Polyurethane



# Reaction Injection Molding (RIM)



## Advantages

- As this molding requires lower pressure than regular injection molding, an aluminum or fiber mold can be used.

## (RRIM)

- Molding large sizes and complicated shapes is possible.

## Disadvantages

- A copolymerization generates gas, which compresses the air left in the mold and is likely to cause burns.
- Molding cycle is extended.

# RIMed automotive parts

