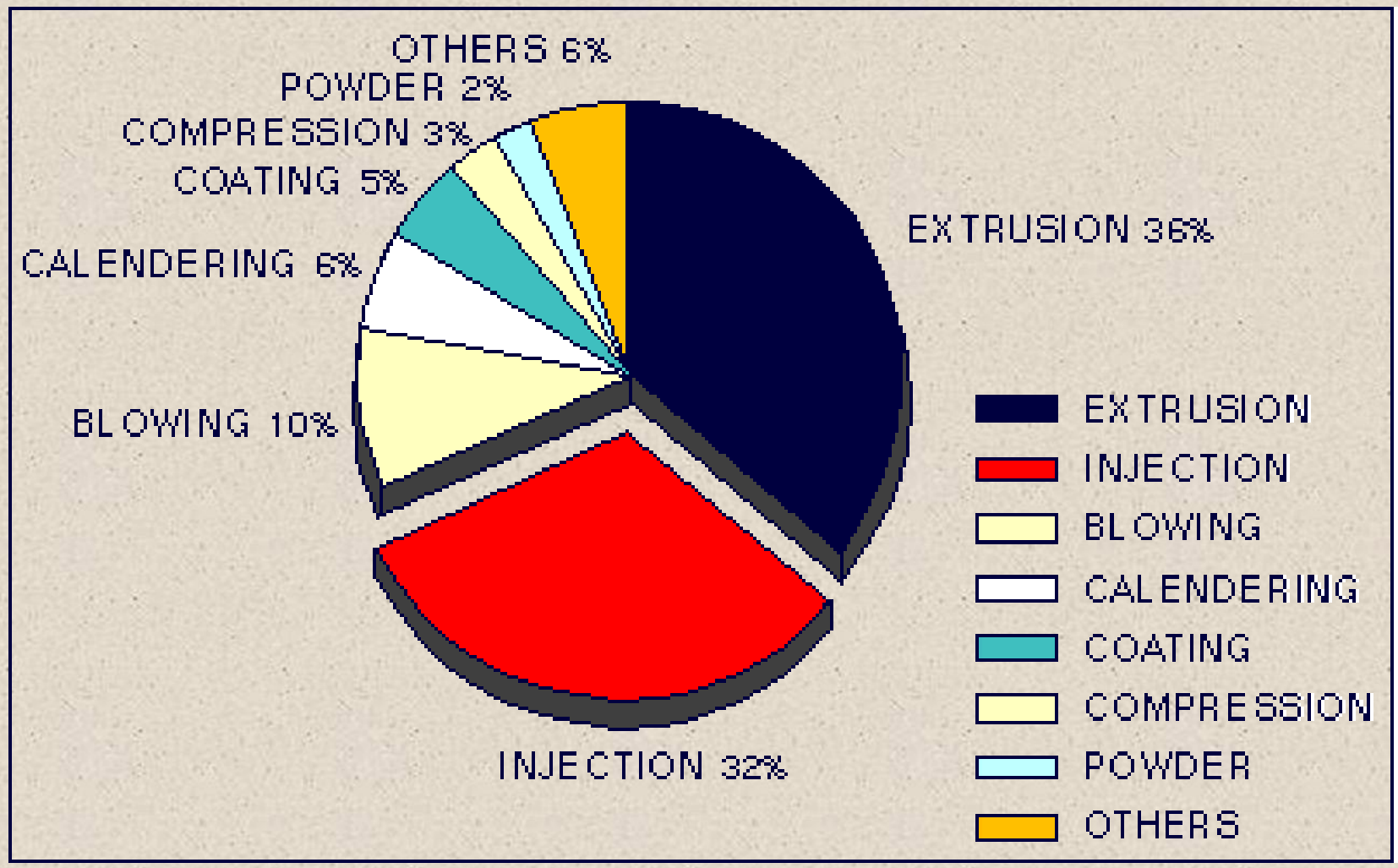
SME 2713
Processing of Polymers - 2

Outline

1. Introduction
2. Extrusion process
3. Injection molding process
4. Blow molding process
5. Rotational molding
6. Thermoforming
7. Compression molding
8. Transfer molding
9. Casting, potting, encapsulation
10. Blow film molding
11. Calendaring

Introduction

Introduction



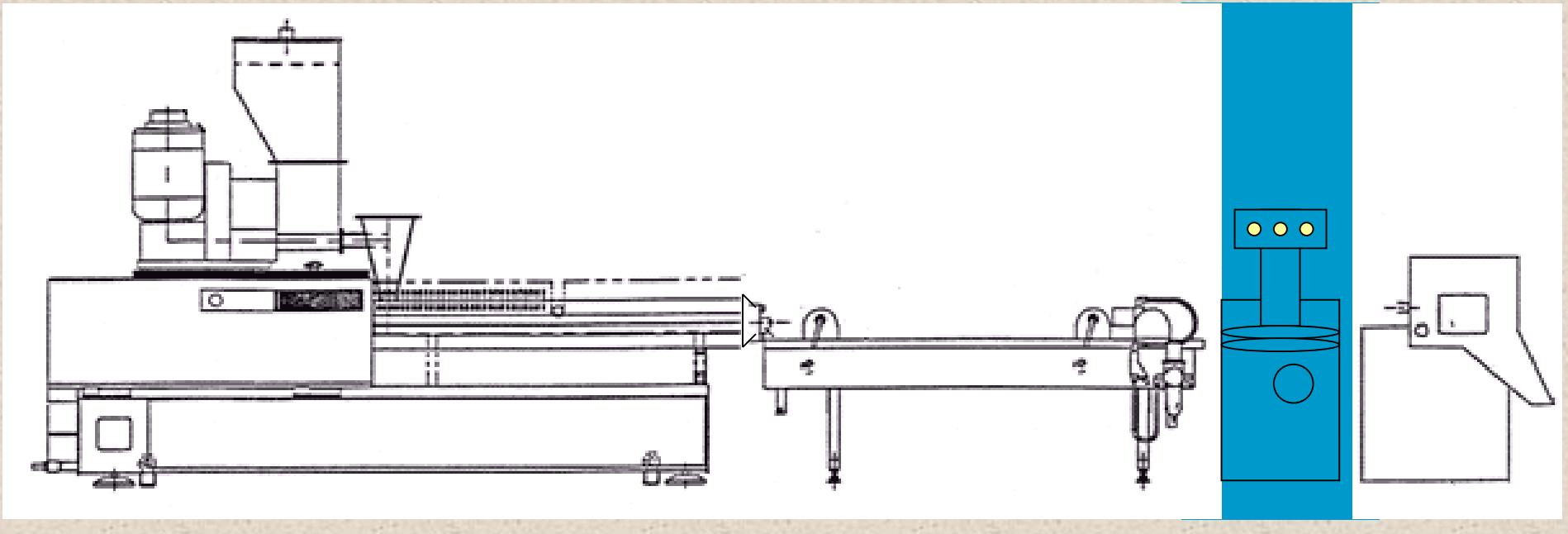
Introduction - Manufacturing with Polymers

- Plastic (polymer) materials are increasingly being used to replace traditional metal artefacts.
- A wide choice of manufacturing techniques are available for polymers.
- Manufacturing processes for polymers are cheaper than that for most metals.
- Polymers also enables greater flexibility in the design of components.
- However, polymer components are not as strong or stiff or resistant to heat as that of metals.

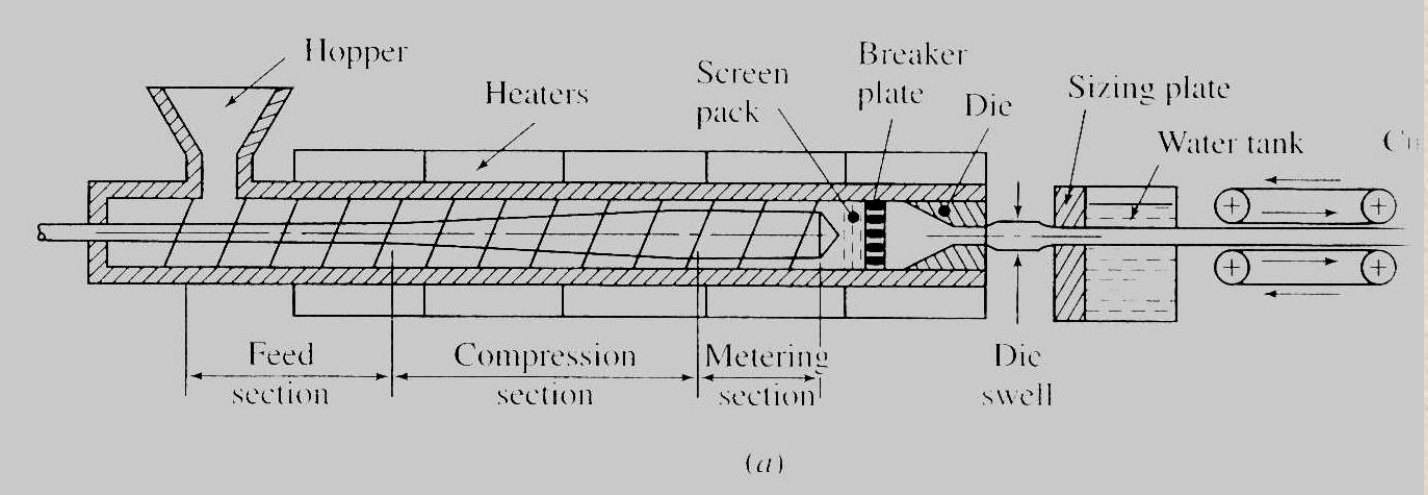
Introduction - Advantages over Metals

- Polymer manufacture energy requirements are small compared with that of metal manufacture.
- The amount of polymer used can be accurately determined - negligible amounts of waste.
- Shrinkage voids are less of a problem in casting -
  - low thermal conductivity hence no large thermal gradients leading to uneven cooling.
- Polymers do not, in general, react with the air:
  - this means that incorporating features in the mould to reduce oxidation problems are not required.

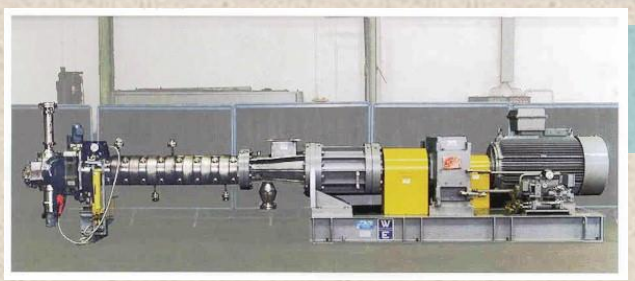
2. Extrusion Process



2. Extrusion Process



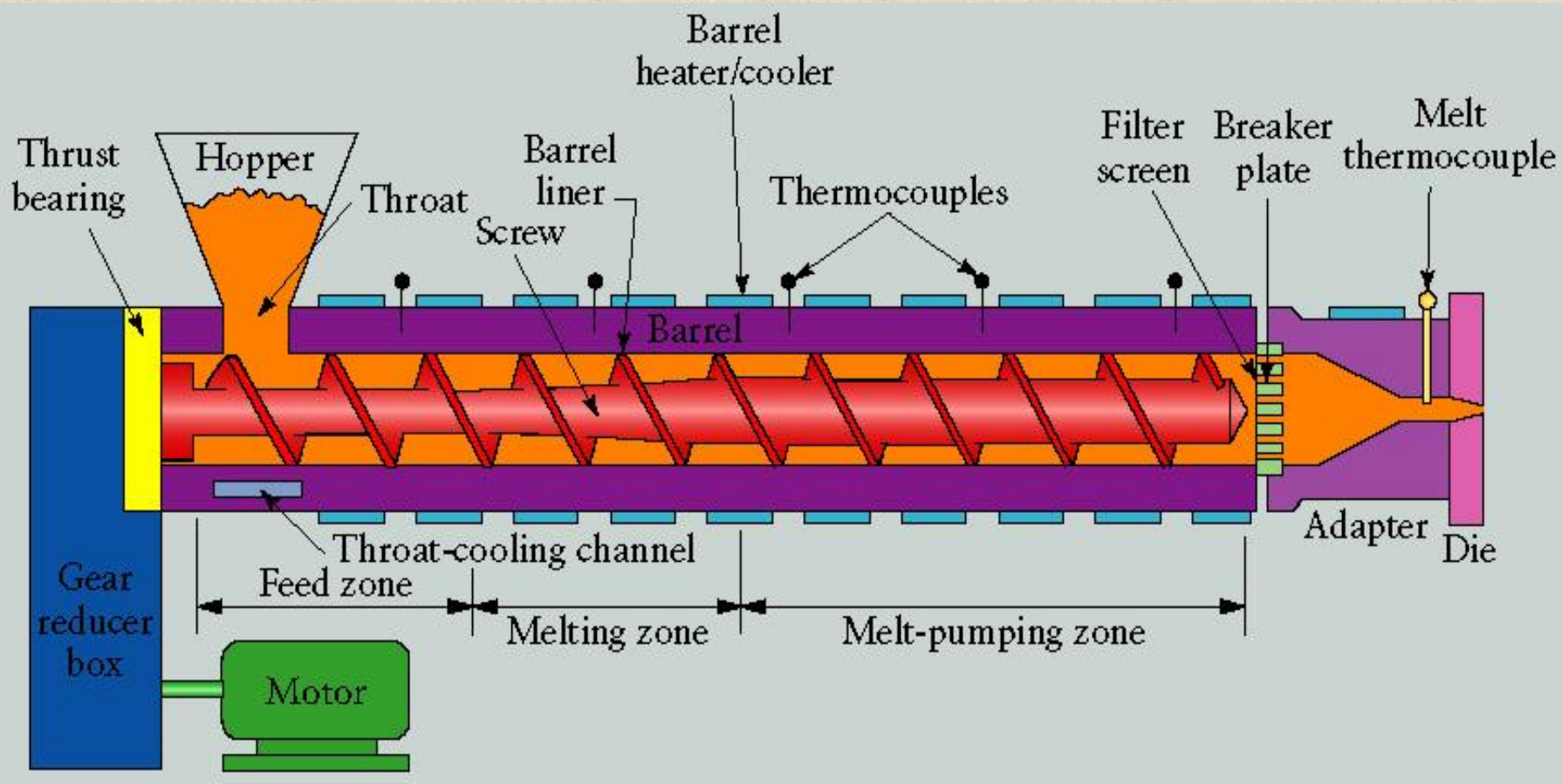
Extruder



2. Extrusion Process

- The extrusion machine forms the basis of nearly all other polymer processes.
- Basically involves melting polymer pellets and extruding them out through a two dimensional die.
- Produces long, uniform solid or hollow, simple or complex cross-section, wide range of dimensional tolerances, high production rates, low tooling cost
  - Coating for electrical wire
  - Fishing Line
  - Tubes, etc.

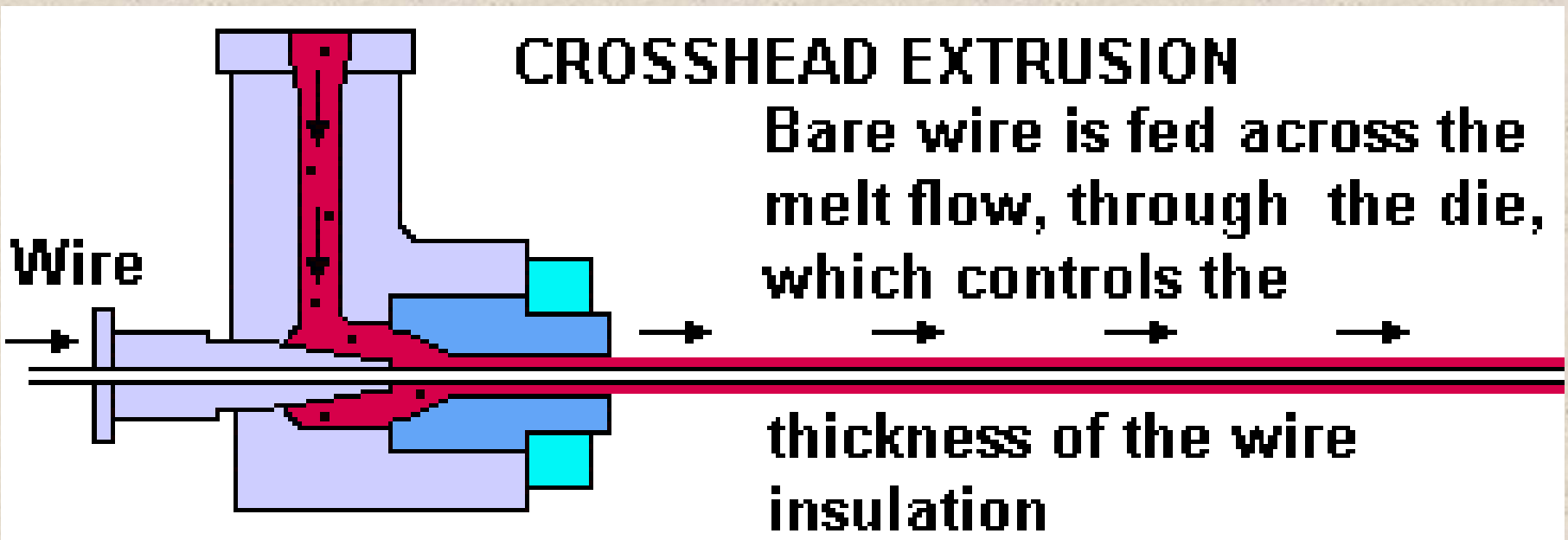
Extruder Schematic



Schematic illustration of a typical extruder. *Source: Encyclopedia of Polymer Science and Technology*, 2nd ed

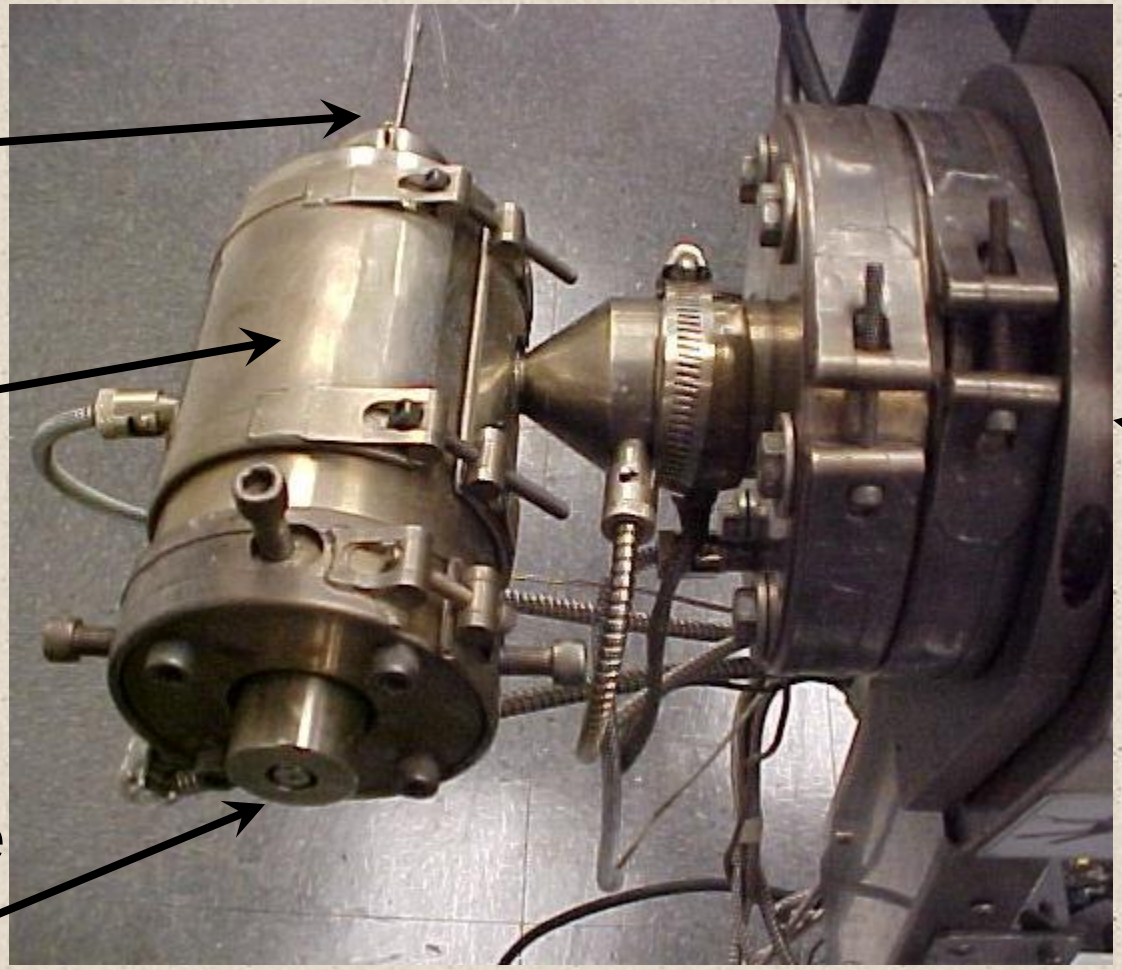
2. Extrusion Process

Wire Coating

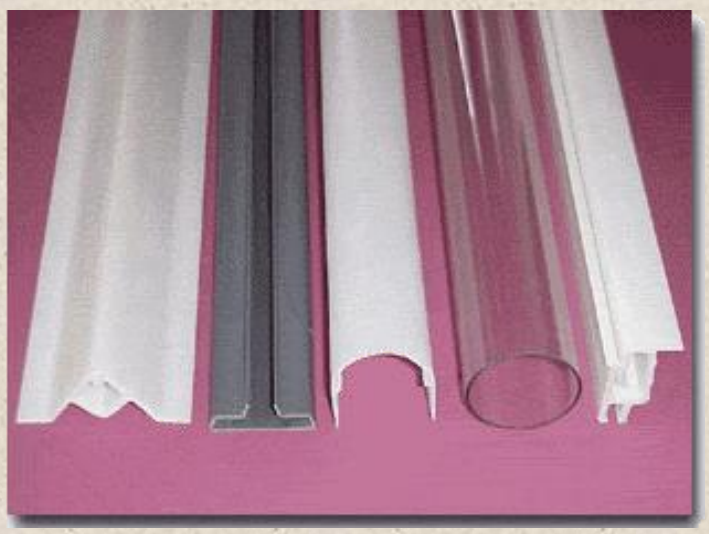


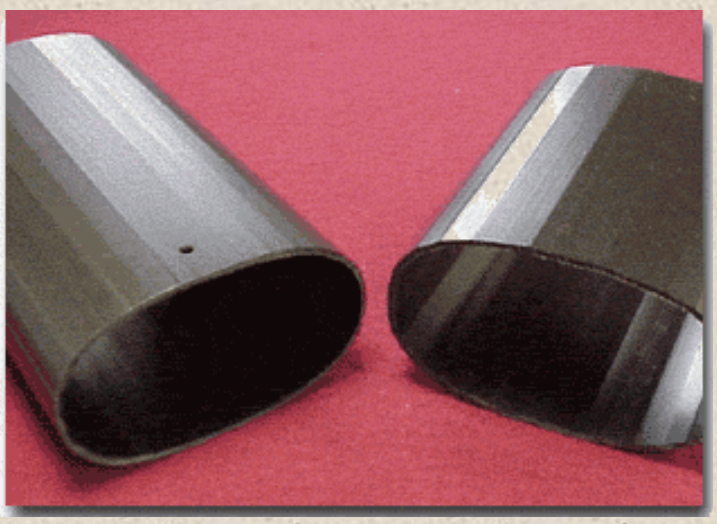
2. Extrusion Process

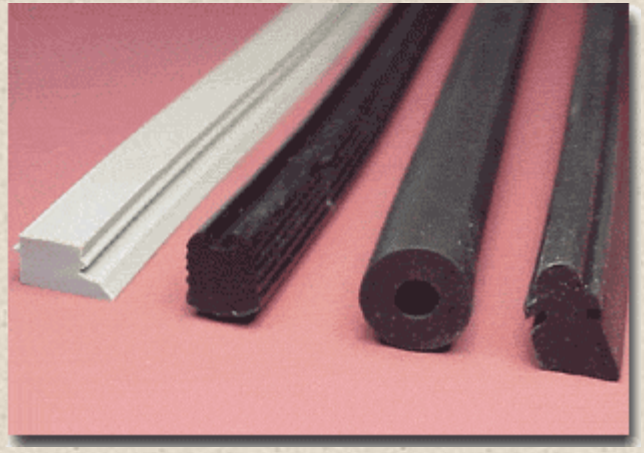
Wire Coating



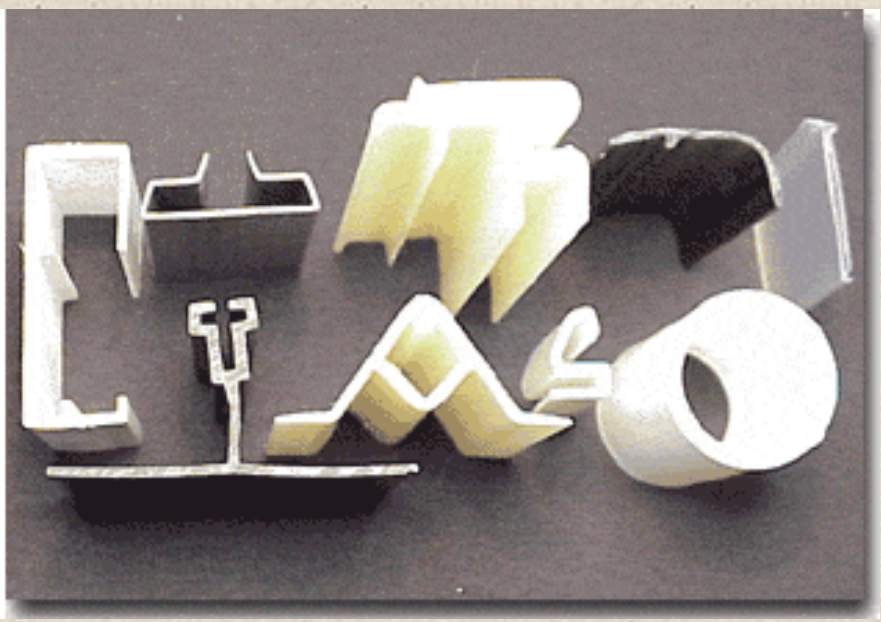
Extrusion Product Examples



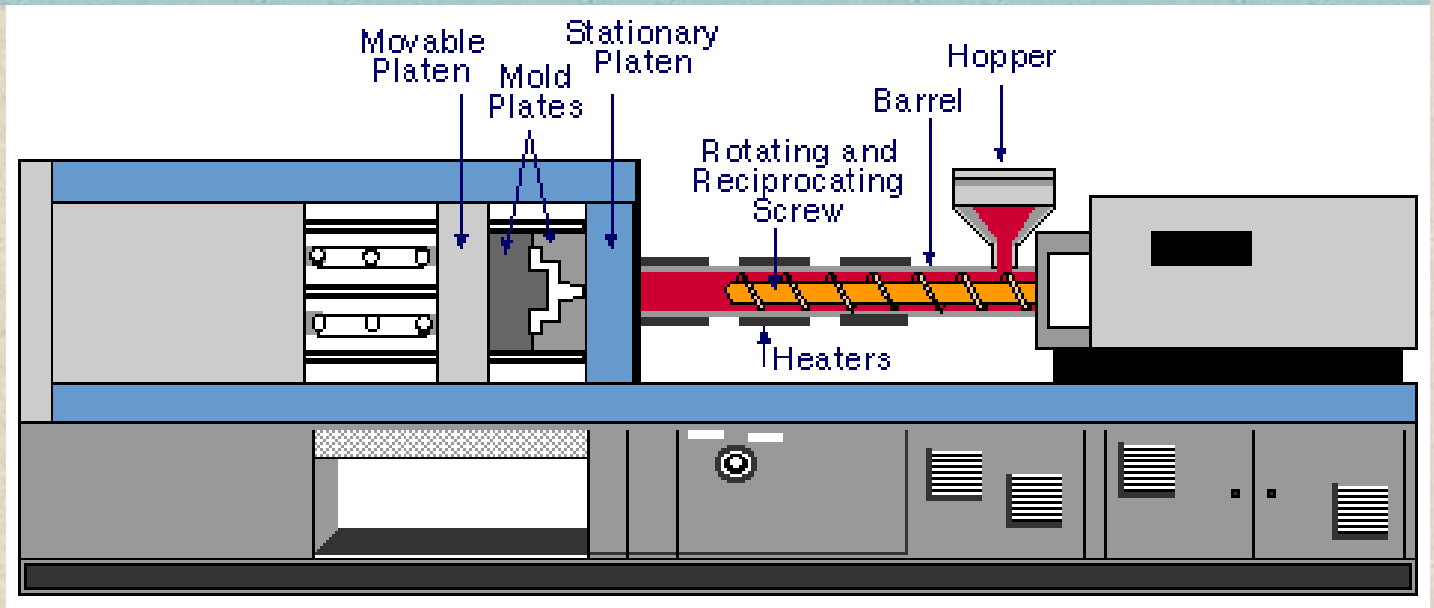




Extrusion Product Examples



3. Injection Molding Process

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3. Injection Molding Process

Injection molding is accomplished by forcing molten plastic under pressure into a cavity formed between two matched metal mold halves. Once the plastic cools, the molds are opened and the part is removed.

Process Characteristics

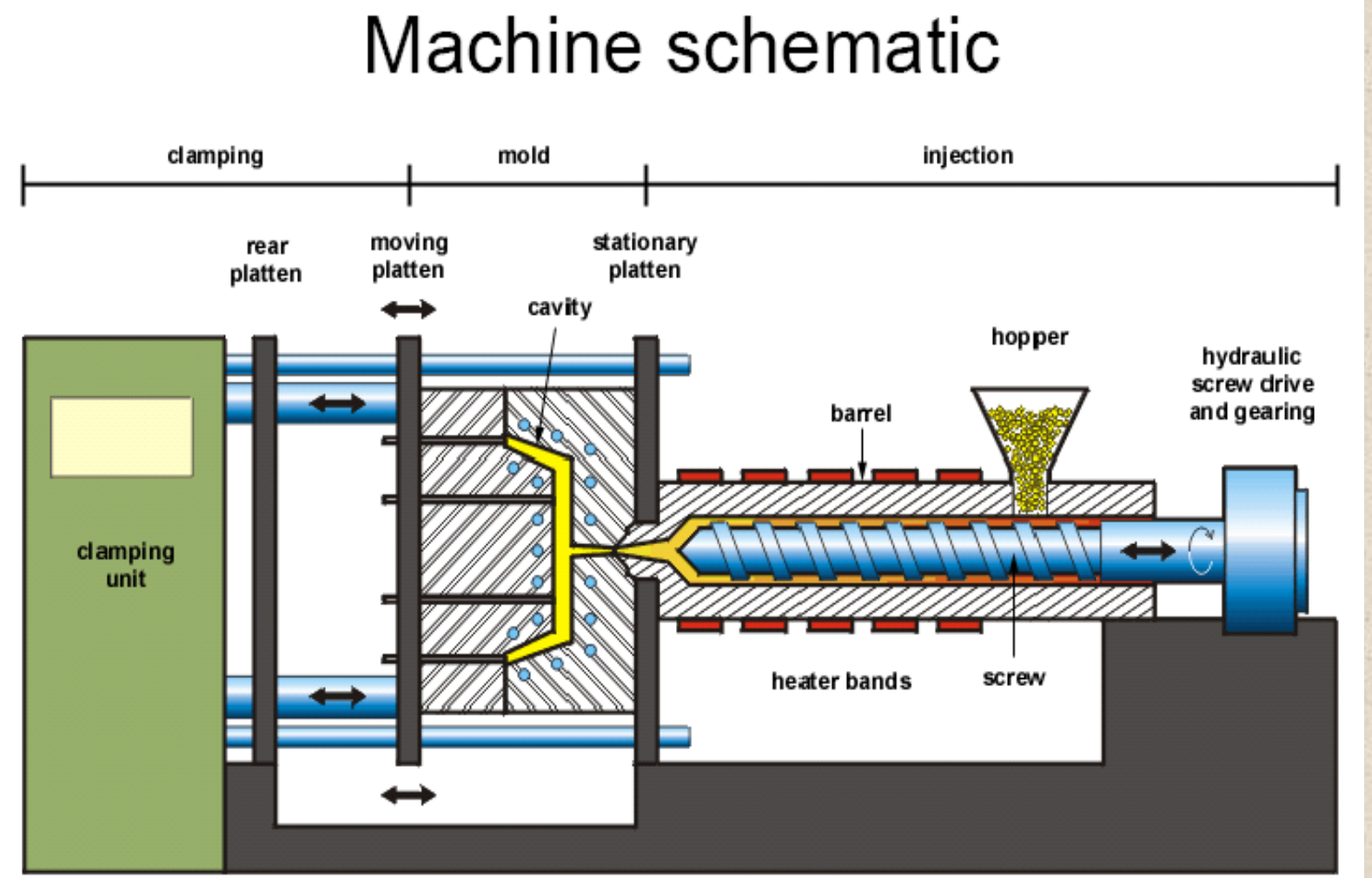
Part cost - low Tooling cost - high

Production Rate - high Can produce intricate parts

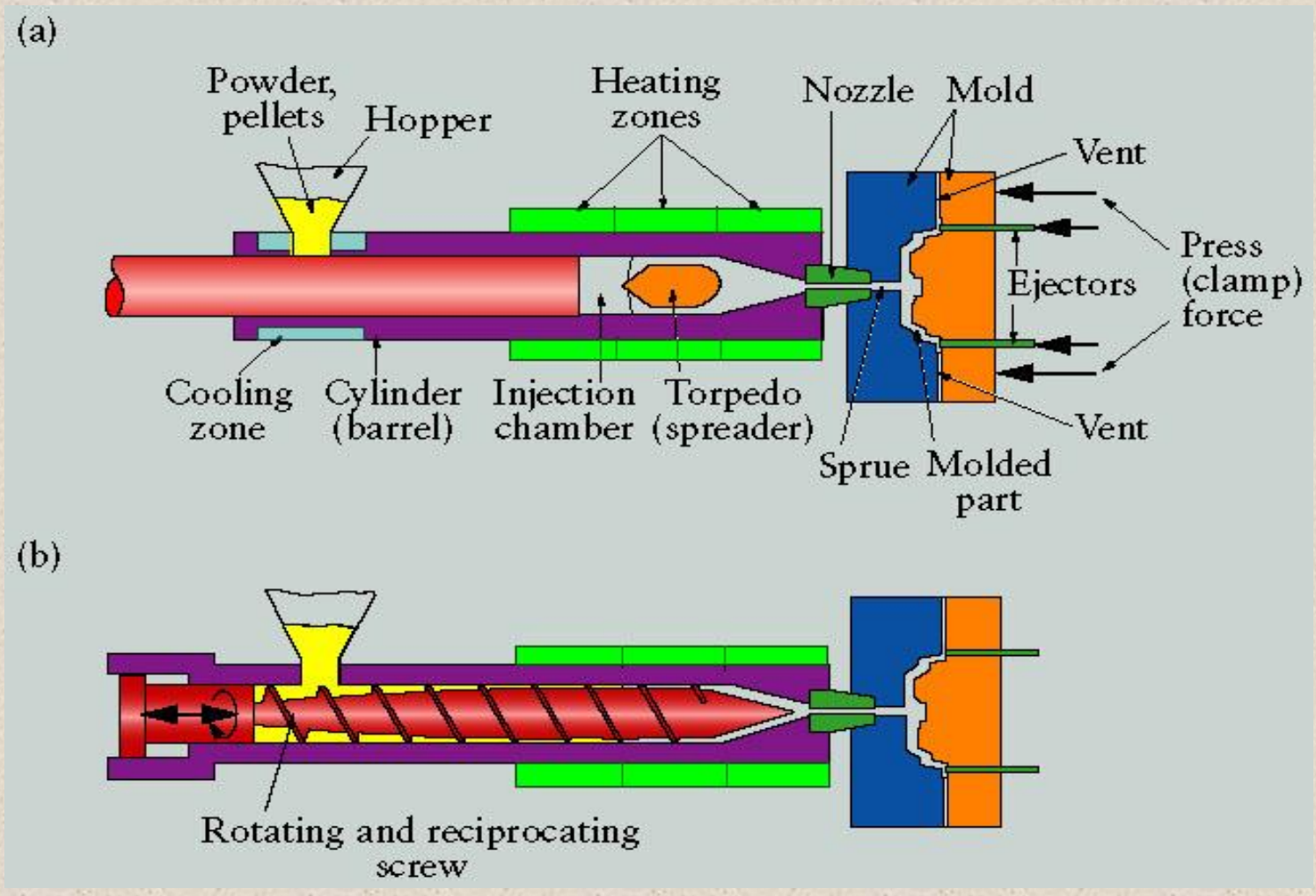
Large variety of polymers gives wide range of properties.

Can produce a wide range of part sizes with different press sizes.

3. Injection Molding Process



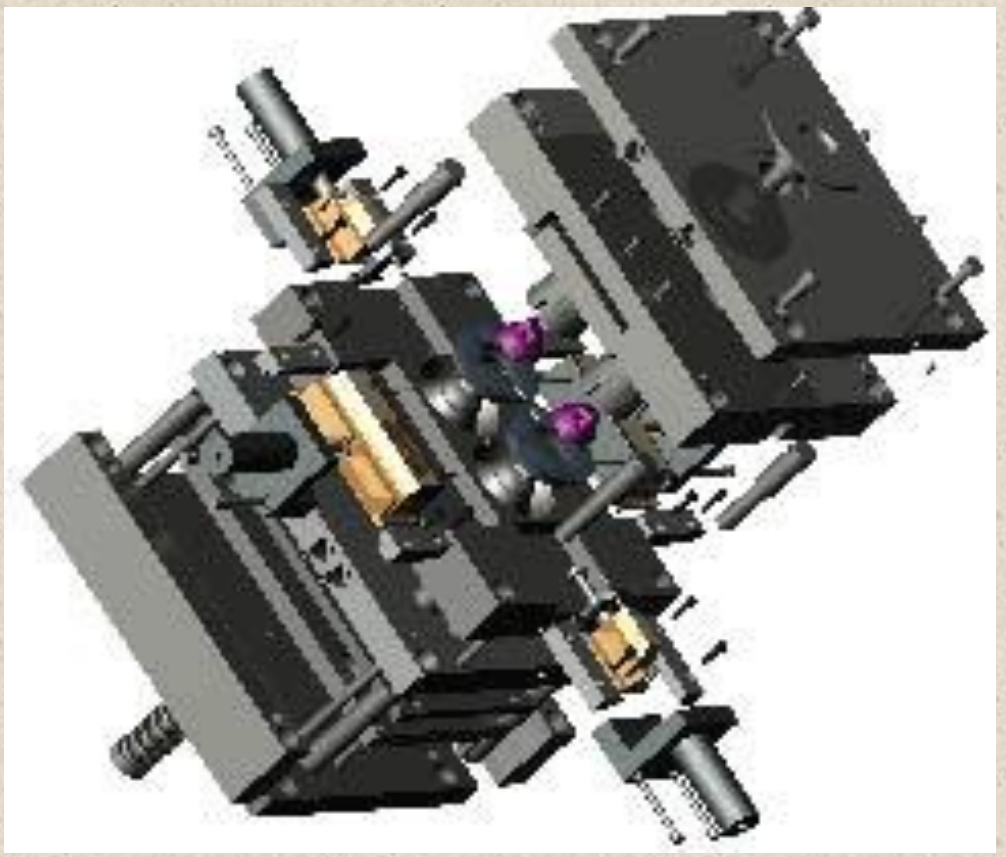
3. Injection Molding Schematic



Injection molding with (a) a plunger and (b) a reciprocating rotating screw. Telephone receivers, plumbing fittings, tool handles, and housings are made by injection molding.

3. Injection Molding Mold

3. Injection Molding Mold



3. Injection Molding Process

Mold Materials

- *Aluminium*
- *Tool Steel*
- *Stainless Steel*
- *Hot work die steel*
- *Berylluim-* copper

Choice based on critical properties:

- *Machinability*
- *Coeff. of thermal expansion*
- *Specific heat capacity*
- *Thermal conductivity*
- *Density*
- *Hardness (abrasion resistance)*
- *Yield strength*
- *Weldability*

3. Injection Molding Process

- Complex shapes of various sizes and fine details, good dimensional accuracy, high production rate, high tooling cost.
- Shapes
  - Possible to do very complex shapes
    - Structural features
      - Pins, ribs, bosses, threads, holes
  - Deep parts are possible
  - Internal or external threads
  - Undercuts require sliding mold sections

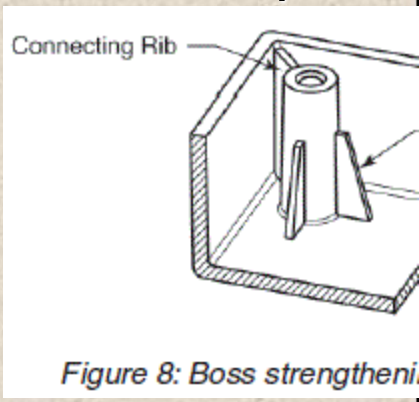
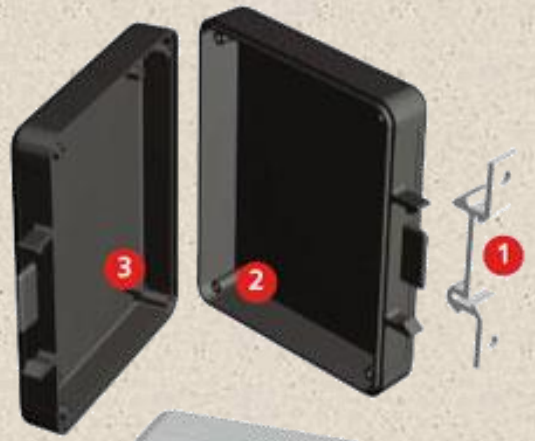


Figure 8: Boss strengtheni

Injection Molding Product Examples



Insert Injection Molding Example

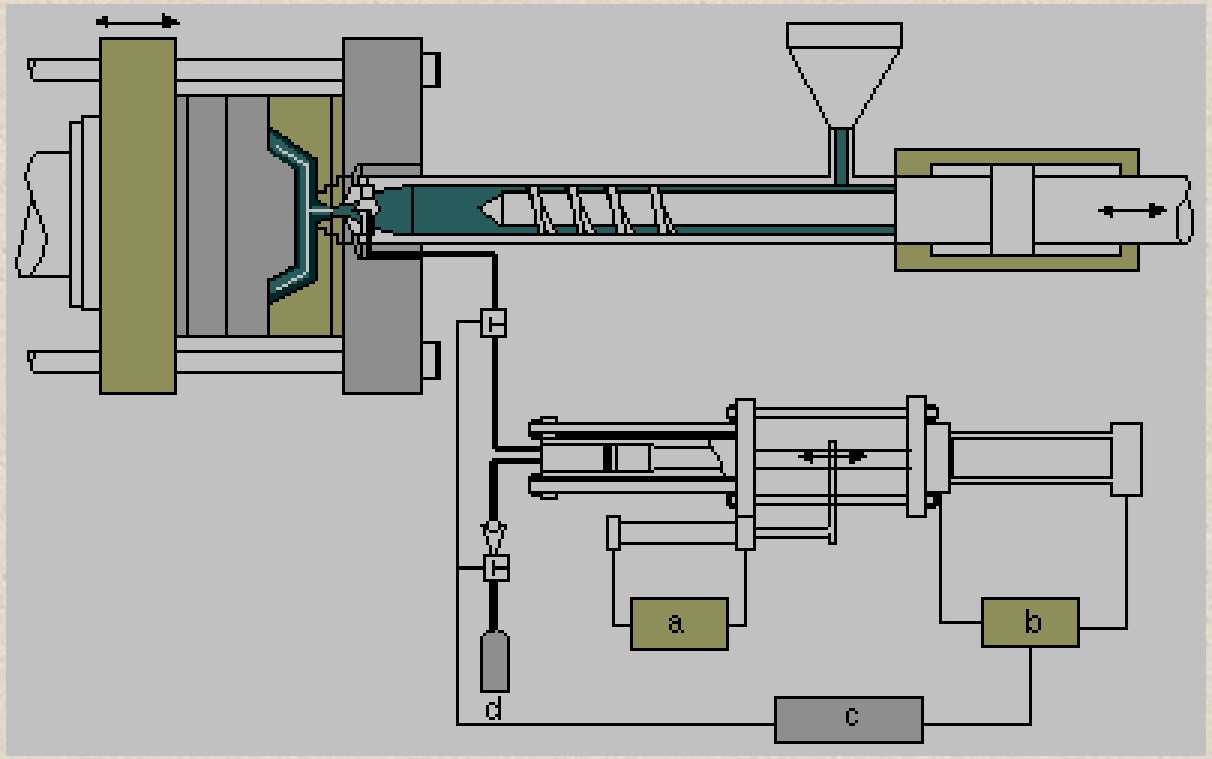
Products made by insert injection molding. Metallic components are embedded in these parts during molding. Source: Rayco Mold and Mfg.

Injection Molding of Thermosets

- Plastics "set" when they cool
  - Mold temperature will be set to allow full cavity fill, while increasing production rate
- Thermosets undergo a chemical cross-linking that produces the solid structure
  - Mold temperature will be hotter usually – set to allow full cavity fill, while accelerating the chemical reaction to cure.
  - Often called "Reaction Injection Molding" (RIM)
  - Injection Molding of thermosets is basically identical to that of thermoplastics, with the exception that the thermoset material is injected cool into a heated mold. The heated mold causes a cross-linking reaction in the material and a hard part is removed from the tool.

Thermoset Products

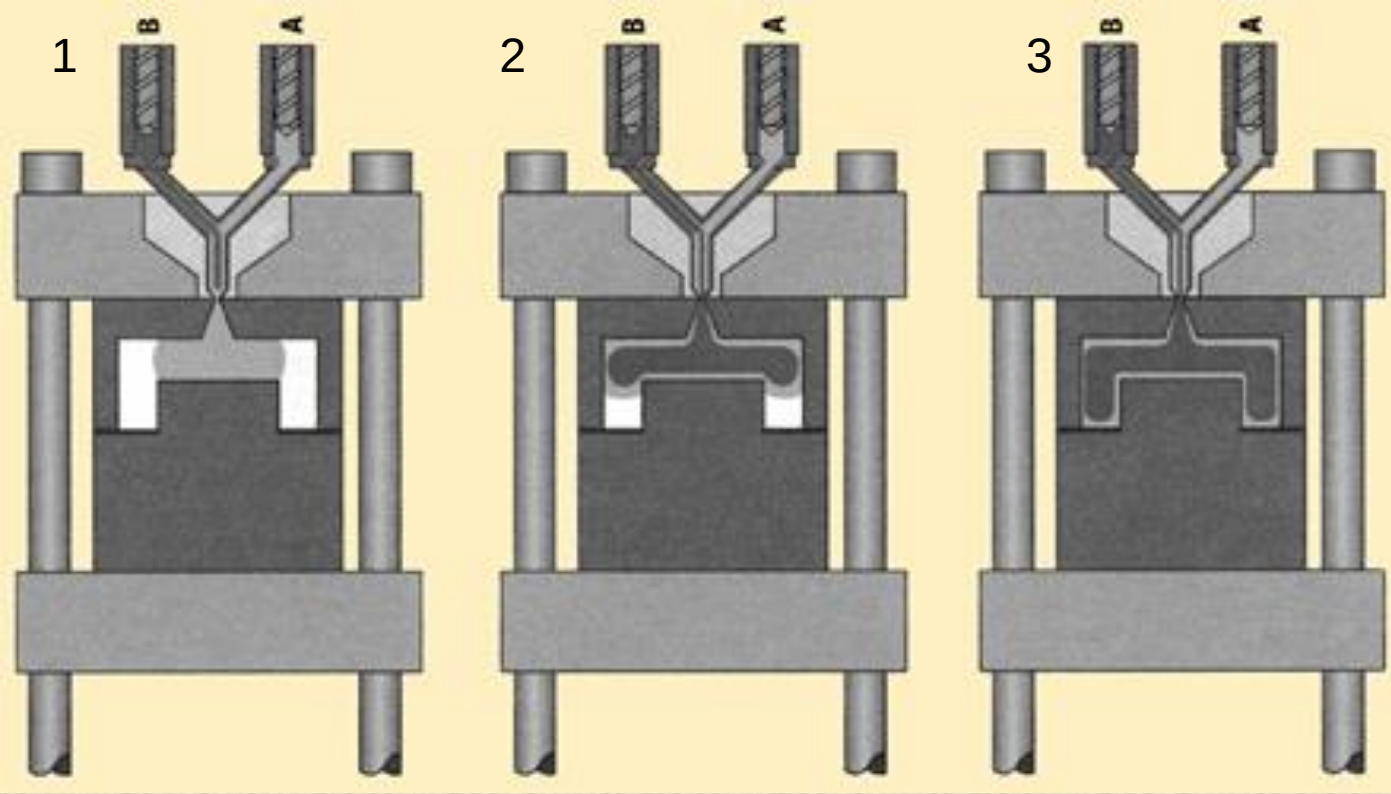
Gas Assist Injection Molding



Applicable to hollow parts without interior control.

Special Injection Molding Processes

- Coinjection molding

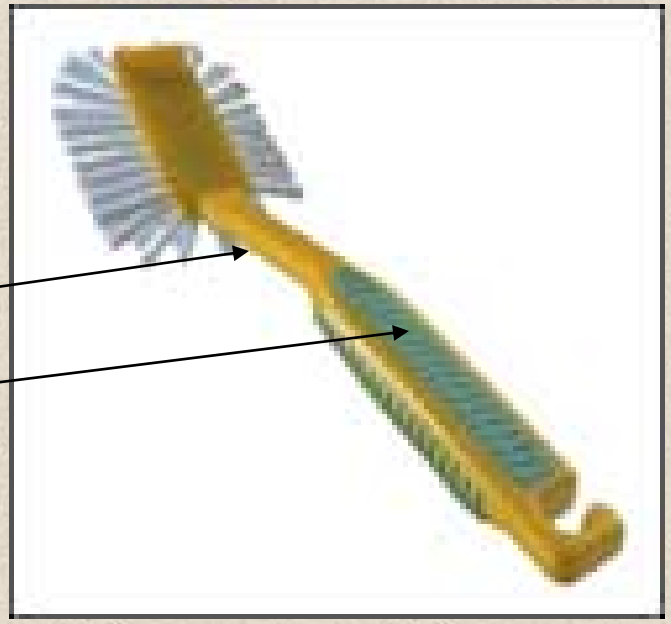


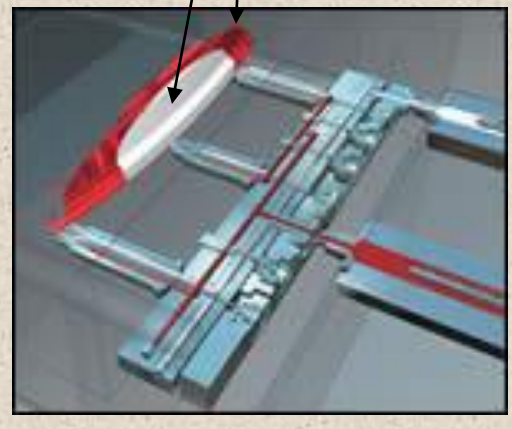
Special Injection Molding Processes

- Coinjection molding

Part 1

Part 2





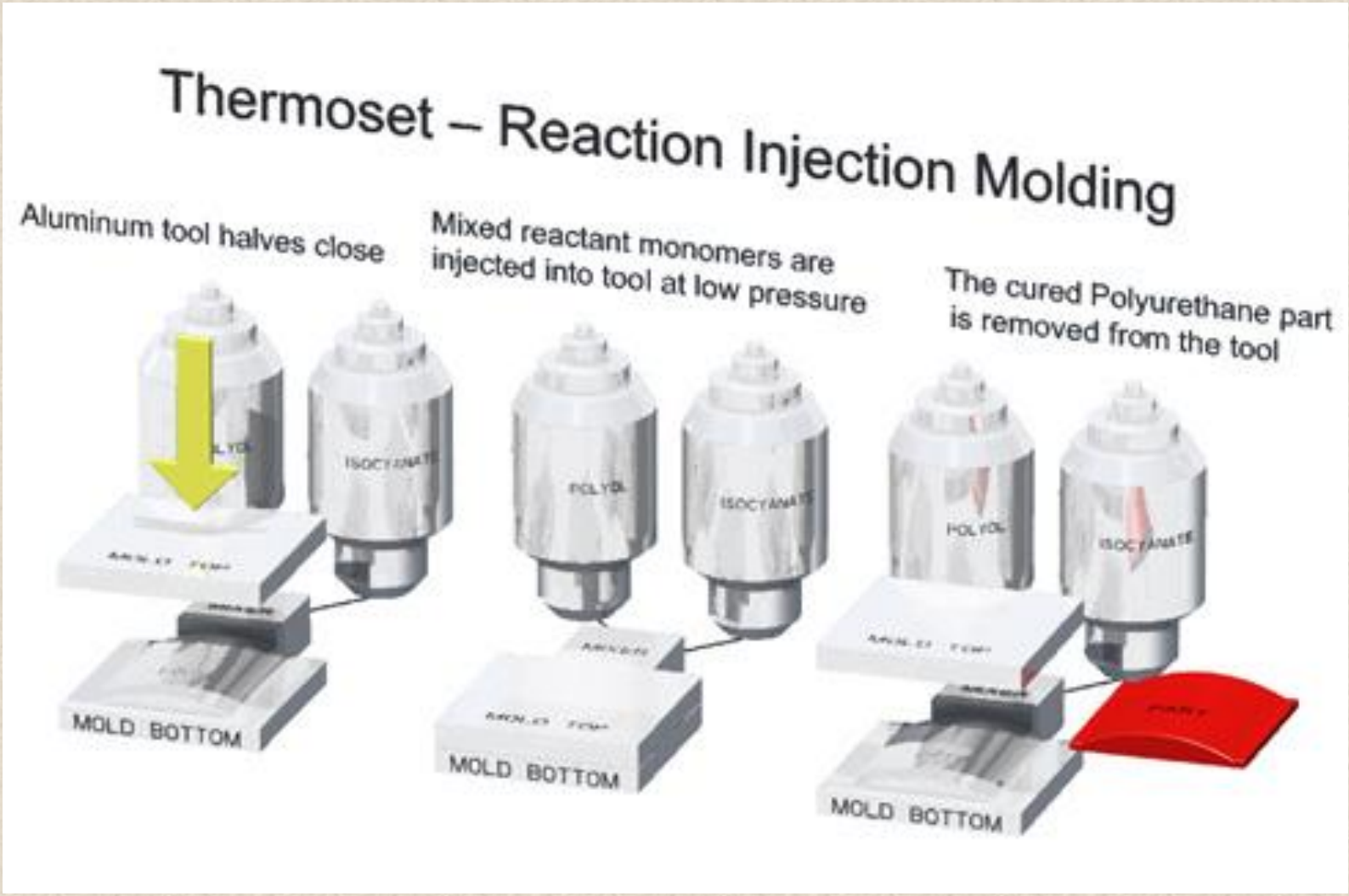
Reaction Injection Molding

- Reaction Injection Molding (or RIM) is a process in which two reactive liquid components -- a polyol and an isocyante - are metered, blended together, and injected into a closed mold at low pressure. The two materials fill the mold easily because they have a viscosity similar to that of water. The chemical reaction between the two components forms a polyurethane structural foam part with a dense, durable skin and a low density cellular core.

Reaction Injection Molding

- Process Characteristics
- Part Cost - moderate to high
- Tooling Cost - low
- Production Rate - moderate
- Parts can be molded in color with good surface finish
- Material can be reinforced
- Material is very impact resistant

Reaction Injection Molding

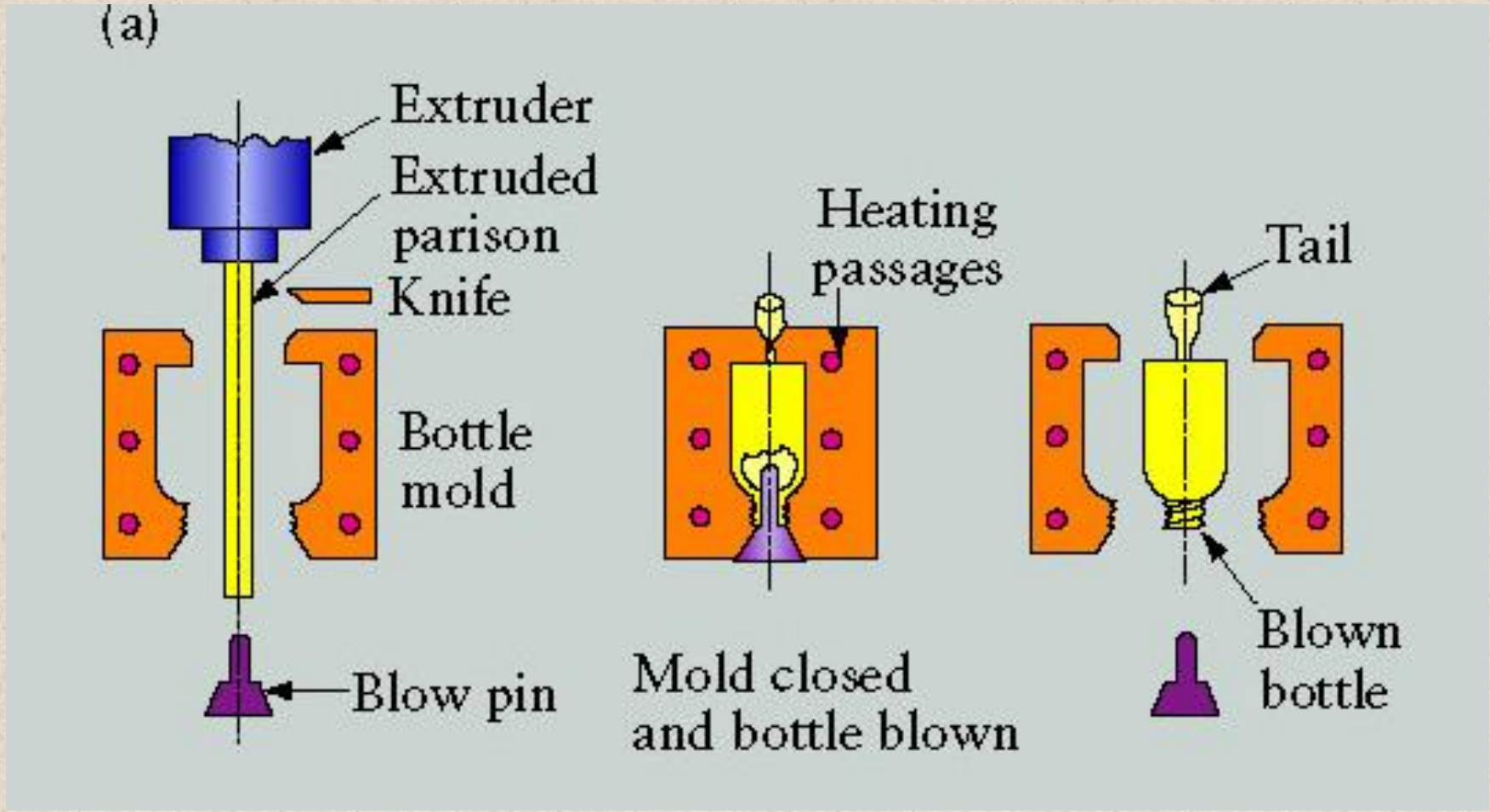


Reaction Injection Molding

Operation and control

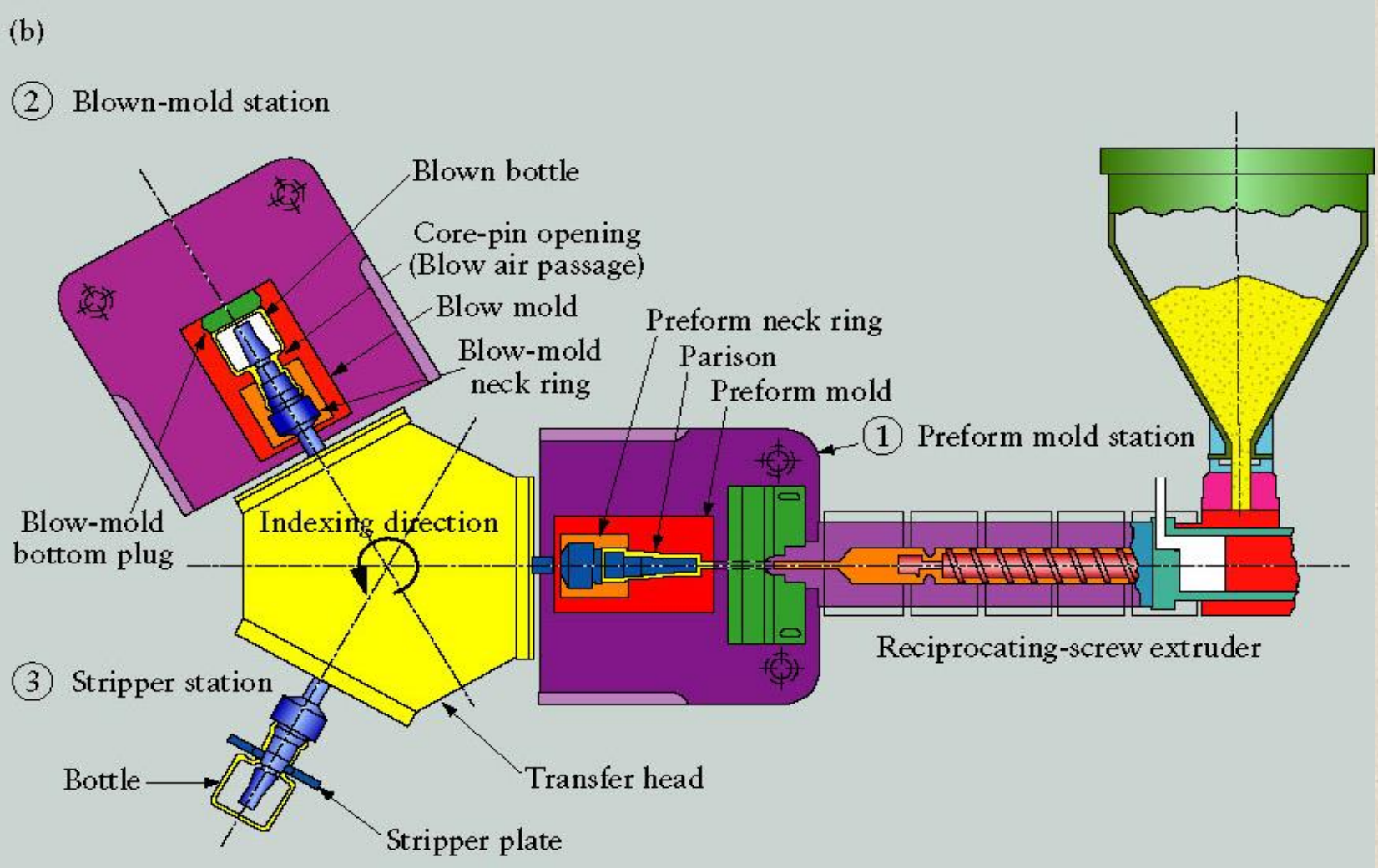
- Temperature of melt
- Temperature of mold
- Pressure of injection and hold
- Injection or fill rate and time
- Dwell time
- Freeze time
- Ejection

4. Blow Molding



Schematic illustrations of (a) the blow-molding process for making plastic beverage bottles

4. Blow Molding



Schematic illustrations of (b) a three-station injection-blow-molding machine.

4. Blow Molding

Blow Molding is accomplished by vertically extruding a hollow tube of molten plastic. This tube is called a "parison" in blow molding terms. The parison is then clamped between two mold halves and expanded into the desired shape by inflating it with compressed air. After cooling, a hollow part emerges.

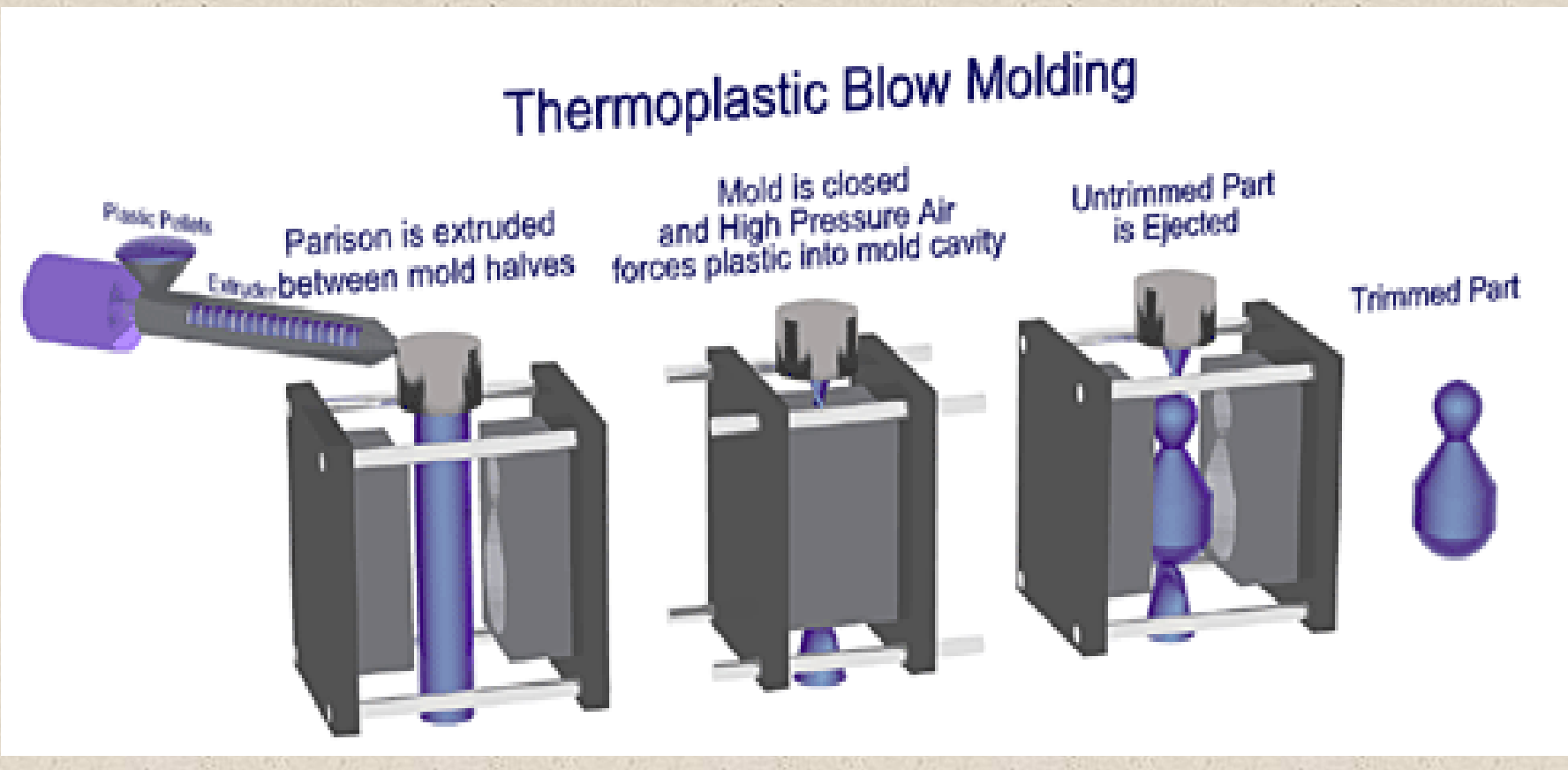
Process Characteristics

Part cost - moderate Tooling Cost - moderate

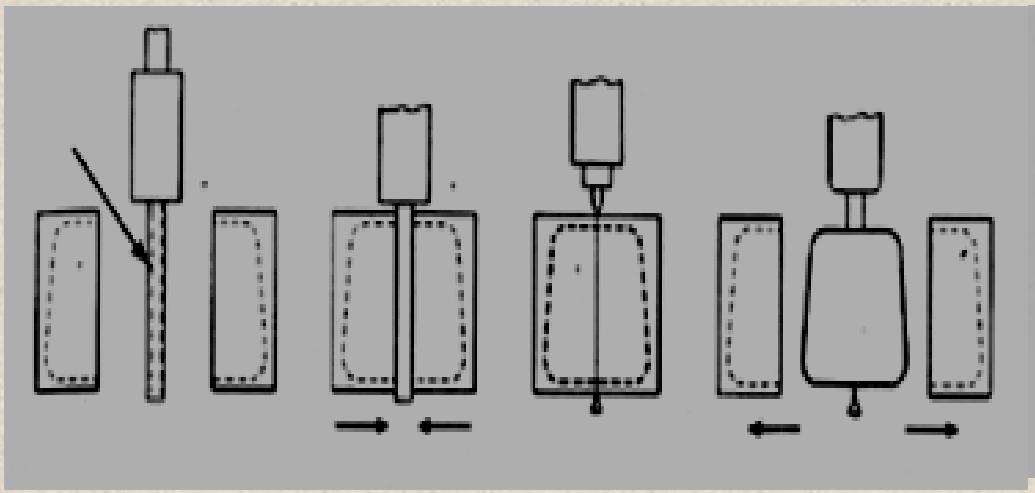
Production rate - moderate to high

Blow molding produces parts with the highest strength to weight ratio of any plastic process. Complex, hollow parts are formed with no internal stresses. Parts as large as 12 ft. x 4 ft. x 4 ft. can be formed

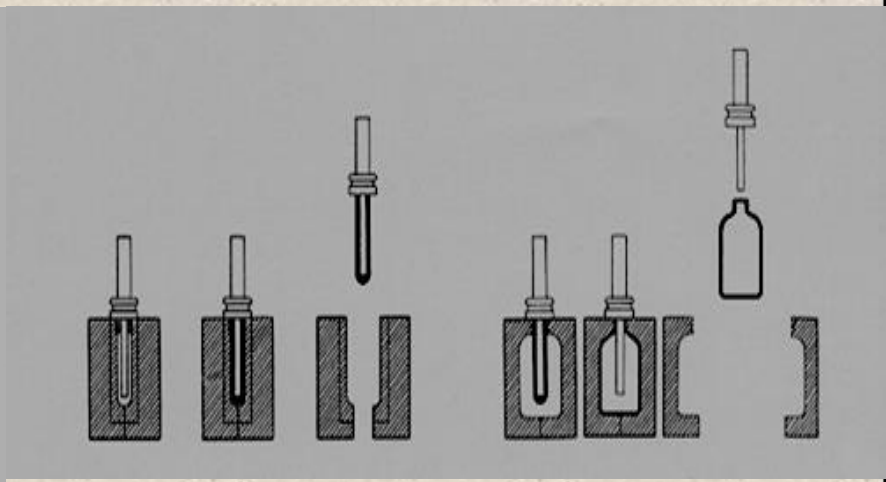
4. Blow Molding



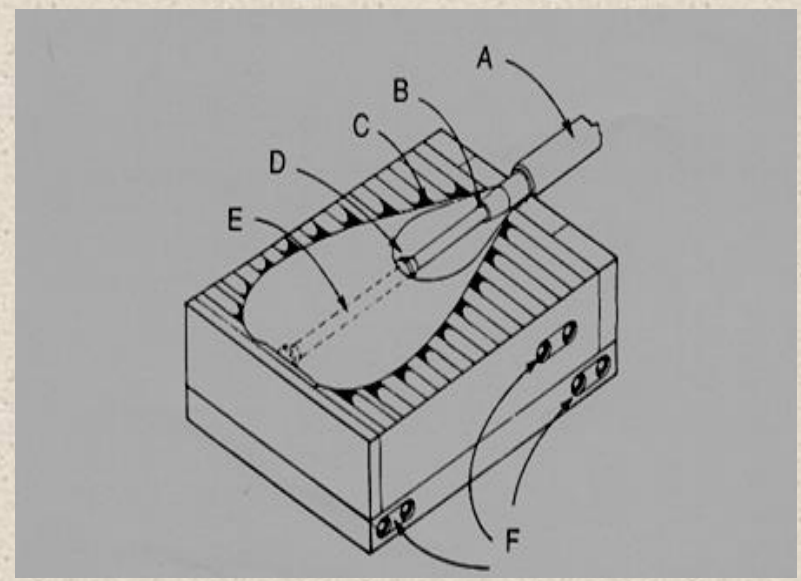
4. Blow Molding Processes



Extrusion Blow Molding



Injection Blow Molding

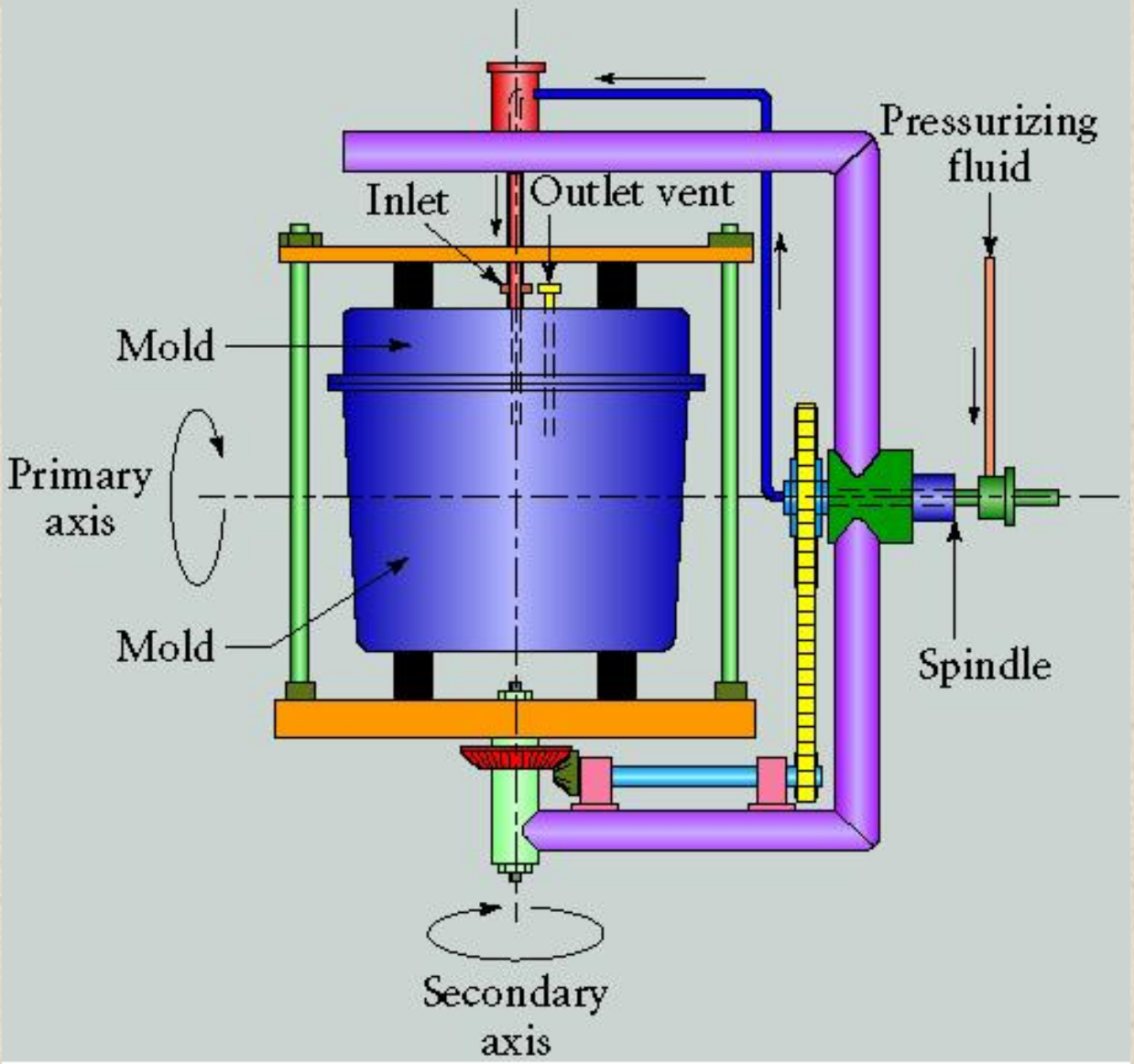


Stretch Blow Molding

Blow Molding Example Products

Blow Molding Example Products

5. Rotational Molding



The rotational molding (rotomolding or rotocasting) process. Trash cans, buckets, and plastic footballs can be made by this process.

5. Rotational Molding

Rotational Molding is a method of casting hollow plastic parts with few restrictions regarding size or complexity. Plastic powder is fused in a hollow female mold by rotating it simultaneously in two directions while heating it in an oven. Once the plastic is fused, the mold is cooled to solidify the plastic and the part is removed by splitting the mold.

Process Characteristics

Very stable parts - no molded in stresses

Low tooling cost for large parts

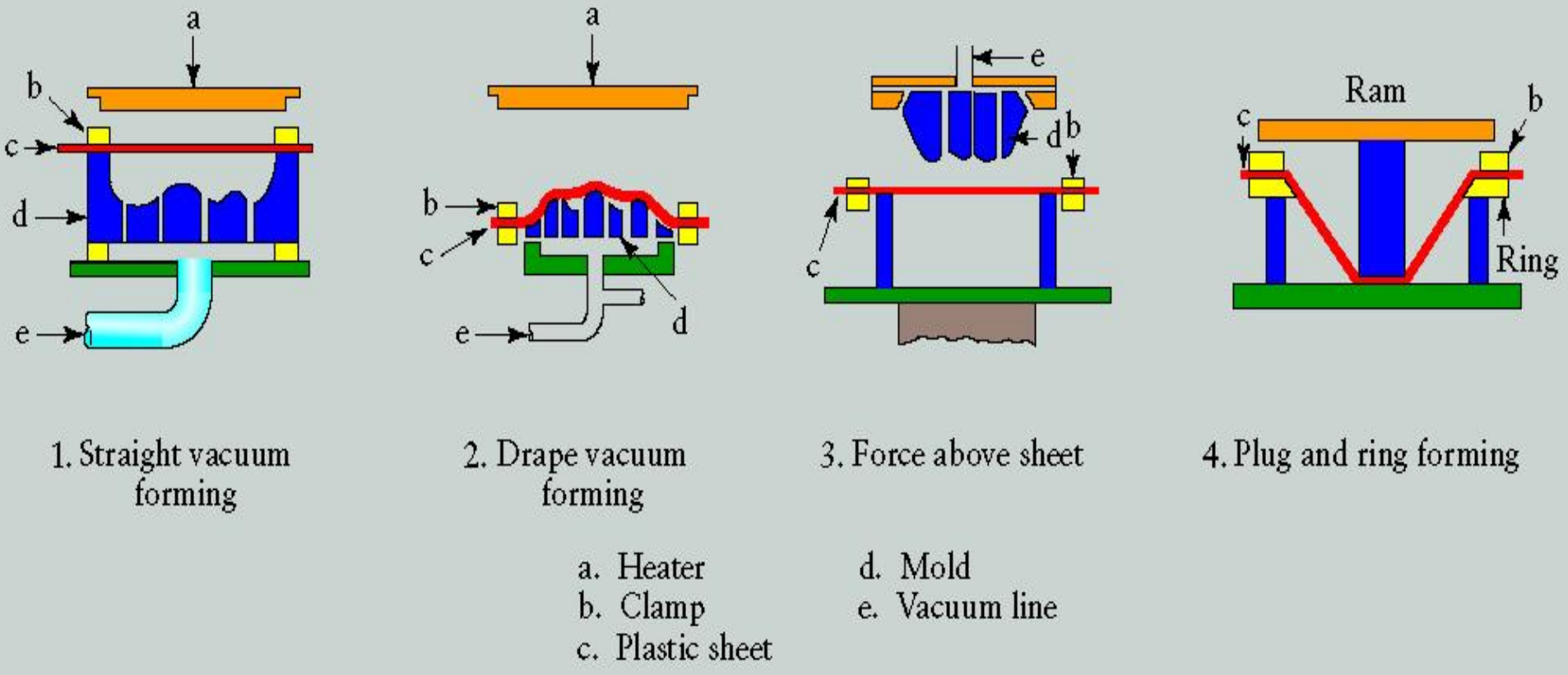
Suited for low volume production

Can produce complex part geometries

Can mold in metal inserts and graphics

5. Rotational Molding

6. Thermoforming



Various thermoforming processes for thermoplastic sheet. These processes are commonly used in making advertising signs, cookie and candy trays, panels for shower stalls, and packaging.

6. Thermoforming

Vacuum forming is accomplished by taking a flat piece of plastic, heating it until it softens, then using a vacuum to pull it onto a contoured surface where it is held until it cools and hardens. Tooling costs for this process are the lowest of any plastic molding process.

Pressure forming is vacuum forming that uses air pressure to assist the vacuum. This results in much better definition on the part surface.

Twin sheet forming is two pressure or vacuum forming operations occurring simultaneously, which are joined to produce an integrally welded hollow part.

6. Thermoforming

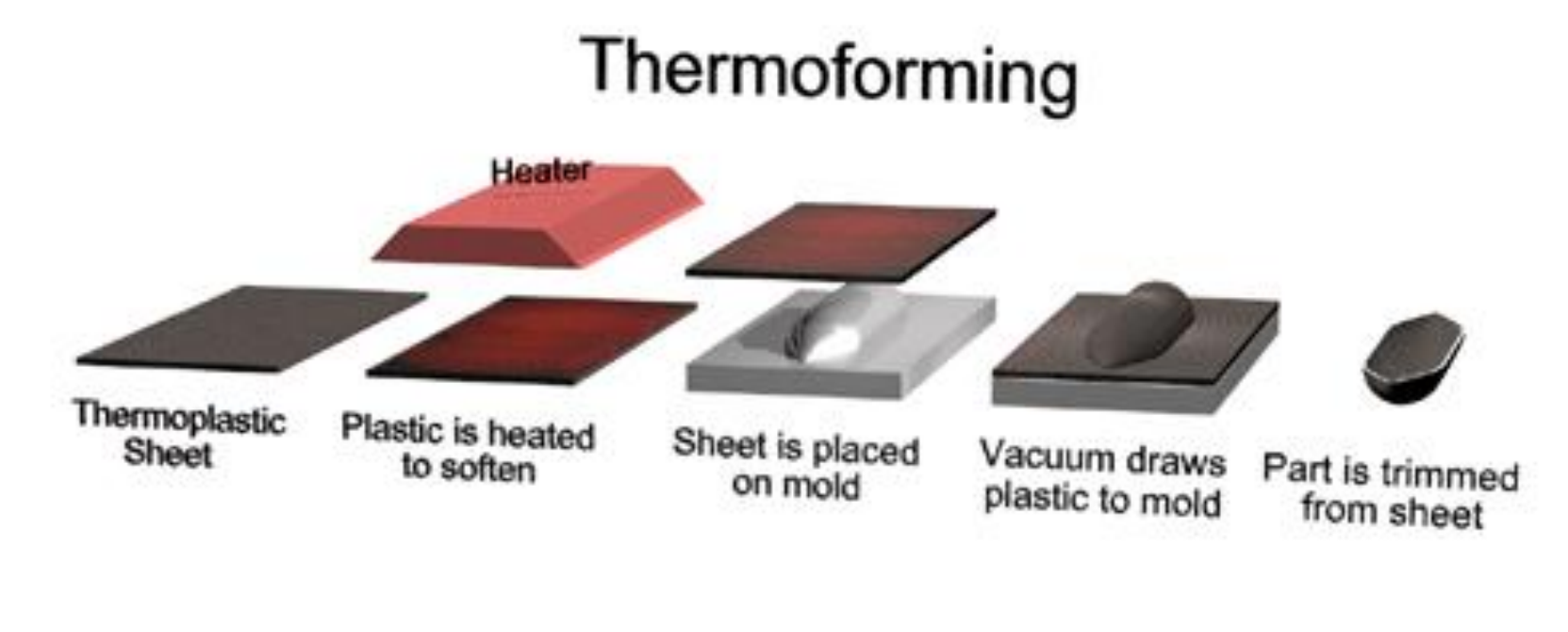
Process Characteristics

Part Cost - moderate to high

Tool Cost - low Production Rate - low

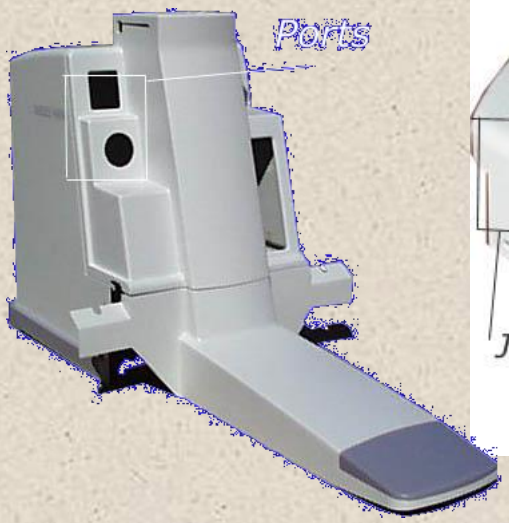
Capable of producing very large parts

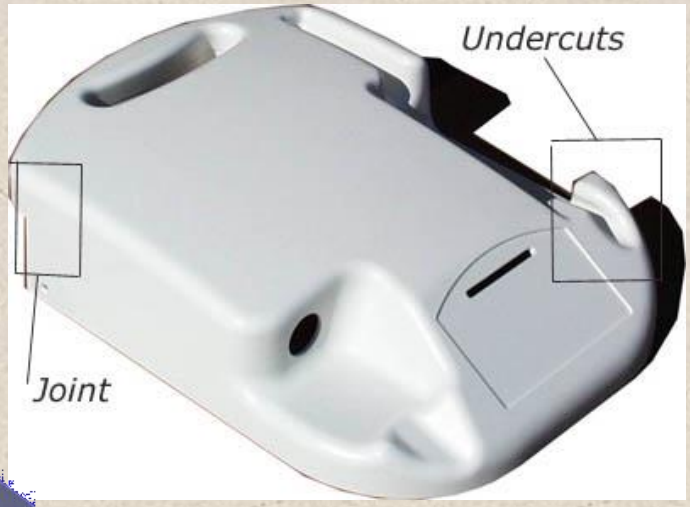
Parts are molded without stress, so they are very stable

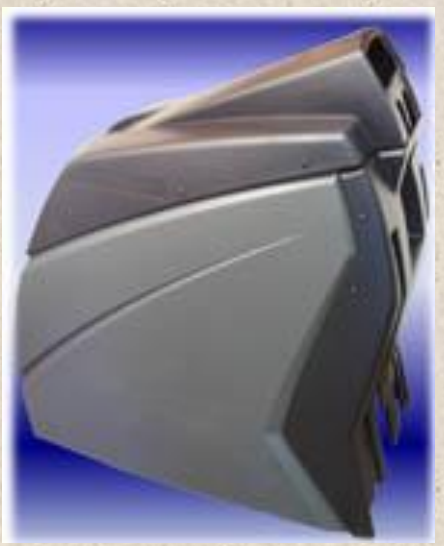


6. Thermoforming

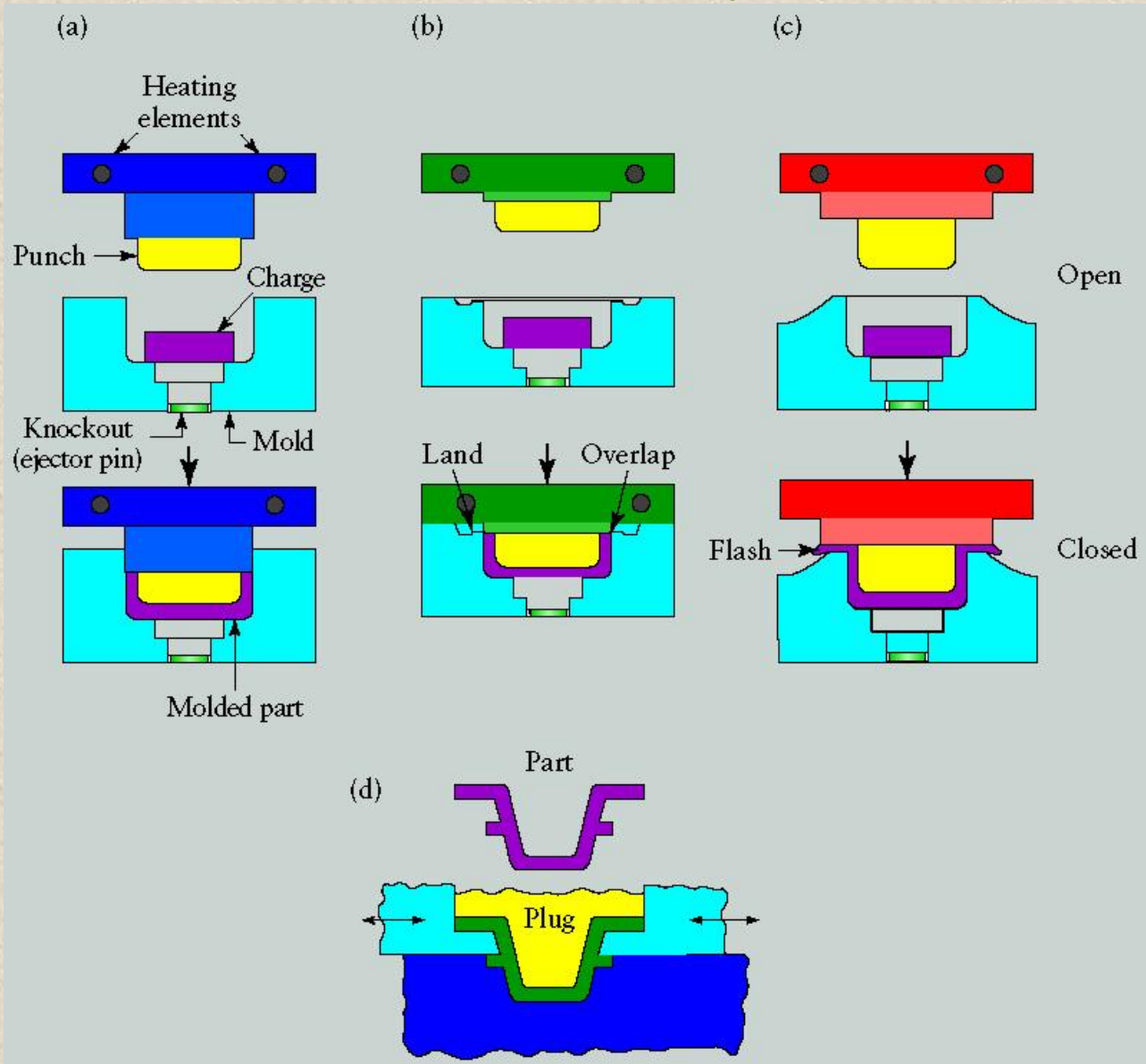
Thermoforming Products







7. Compression Molding



Types of compression molding, a process similar to forging: (a) positive, (b) semipositive, and (c) flash. The flash in part (c) has to be trimmed off. (d) Die design for making a compression molded part with undercuts. Such designs are also used in other molding and shaping operations.

7. Compression Molding

Compression and Transfer Molding is accomplished by placing a pre-weighed amount of material in a matched metal mold and closing the mold. The heat and pressure cause the material to liquify and flow into the voids in the tool where it chemically reacts and hardens into the final shape. Very large shapes can be molded in compression presses.

Process Characteristics

Part Cost - moderate Tooling Cost - high

Production Rate - moderate

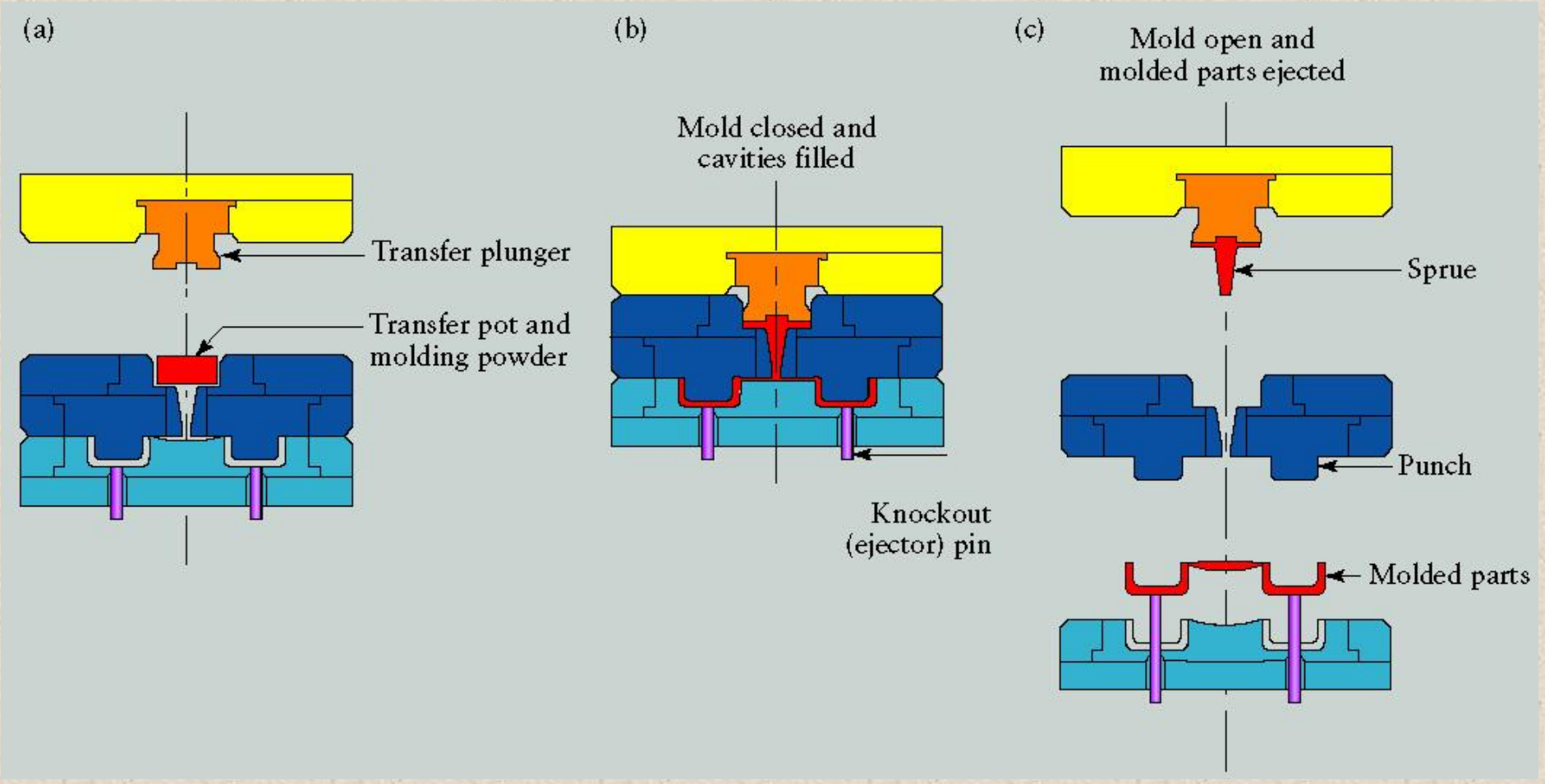
Thermoset materials are very strong

Thermosets are very heat resistant at a moderate cost

Greatly reduced shrinkage eliminates design limitations.

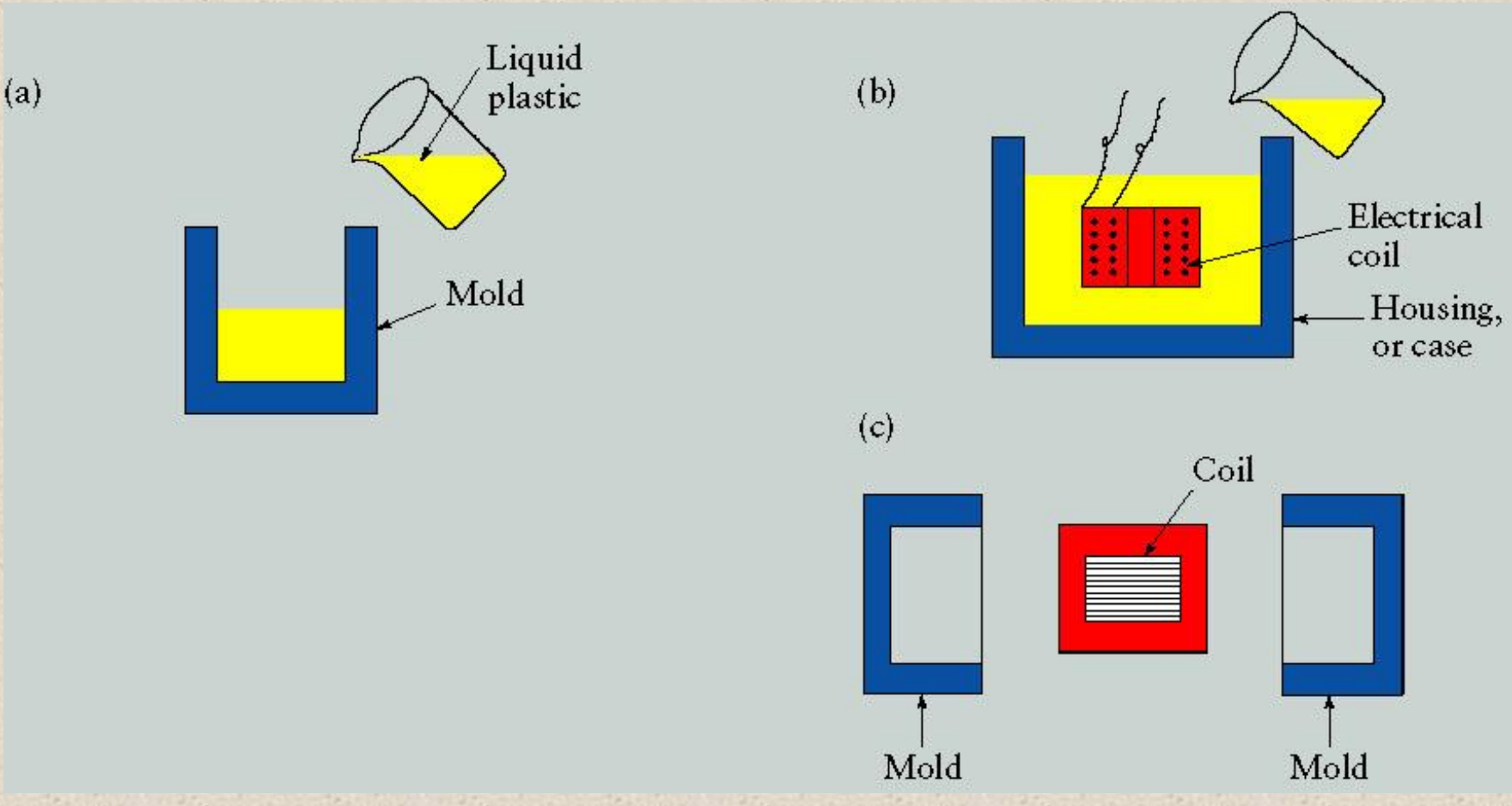
7. Compression Molding

8. Transfer Molding

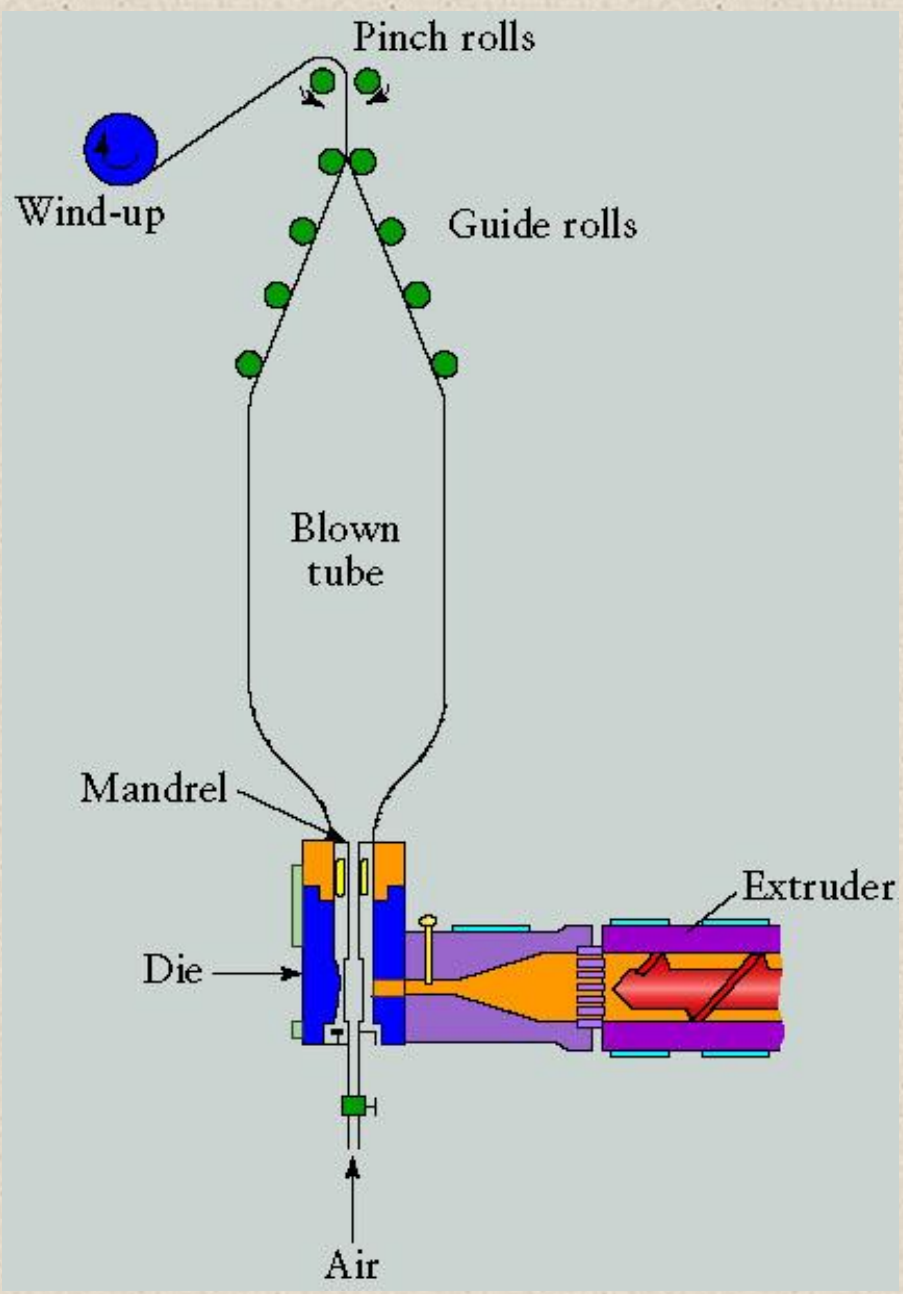


Sequence of operations in transfer molding for the thermosetting plastics. This process is particularly suitable for intricate parts with varying wall thickness

9. Casting, Potting and Encapsulation



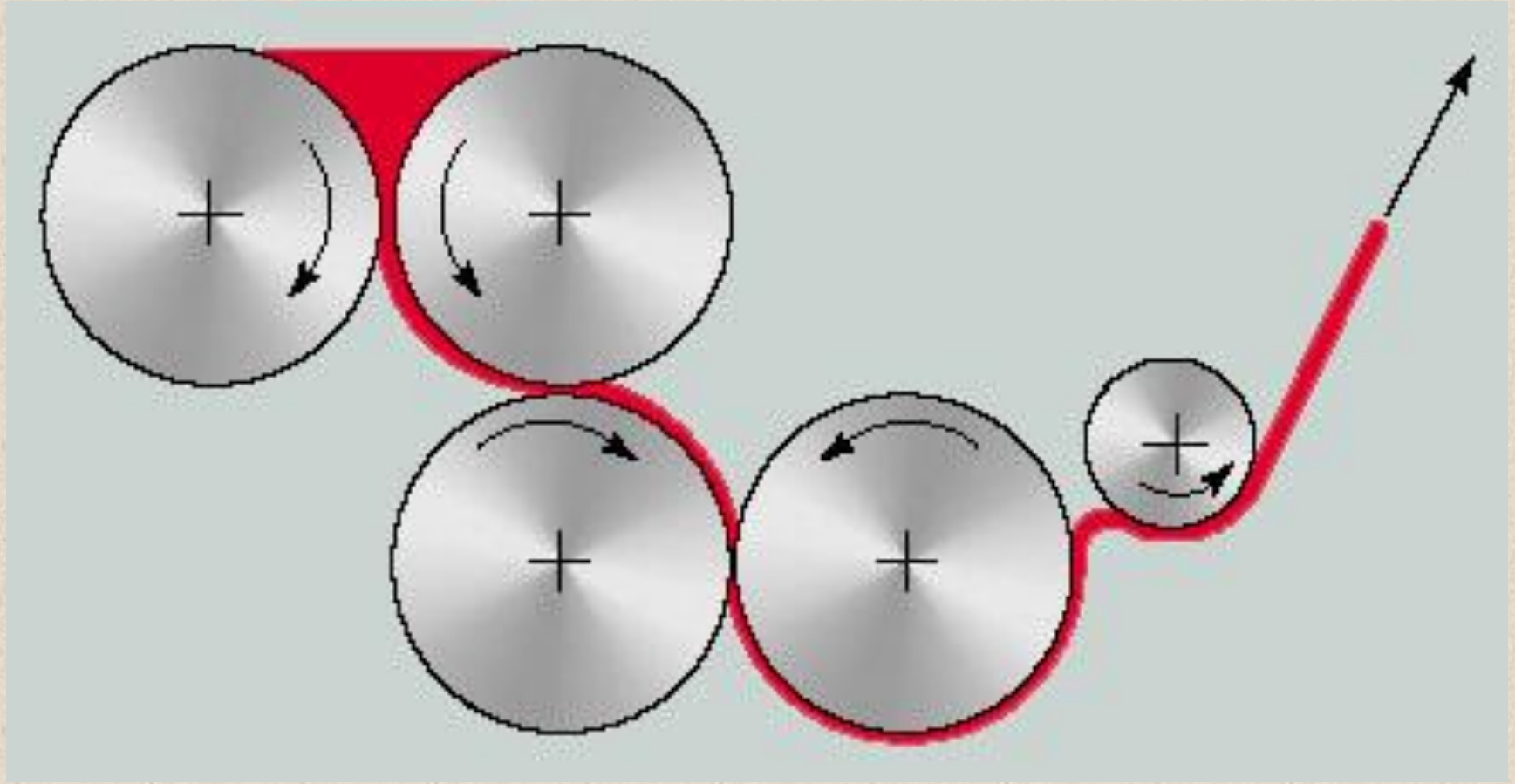
Schematic illustration of (a) casting, (b) potting, and (c) encapsulation of plastics



10. Production of Blown Film

Schematic illustration of production of thin film and plastic bags from a tube produced by an extruder, and then blown by air. *Source*: D. C. Miles and J. H. Briston, *Polymer Technology*, Chemical Publishing Co., 1979.

11. Calendering



12. Reinforced Plastic Components

Reinforced-plastic components for a Honda motorcycle. The parts shown are front and rear forks, a rear swing arm, a wheel, and brake disks

13. Costs in Processing of Plastics

Comparative costs and production volumes for processing of plastics.

	EQUIPMENT CAPITAL COST	PRODUCTION RATE	TOOLING COST	TYPICAL PRODUCTION VOLUME, NUMBER OF PARTS						
				10	10^2	10^3	10^4	10^5	10^6	10^7
Machining	Med	Med	Low	■	■					
Compression molding	High	Med	High			■	■	■	■	
Transfer molding	High	Med	High			■	■	■	■	
Injection molding	High	High	High				■	■	■	■
Extrusion	Med	High	Low	*						
Rotational molding	Low	Low	Low		■	■				
Blow molding	Med	Med	Med			■	■	■	■	■
Thermoforming	Low	Low	Low		■	■				
Casting	Low	Very low	Low	■	■					
Forging	High	Low	Med	■	■					
Foam molding	High	Med	Med				■	■	■	■

Source: After R.L.E. Brown, Design and Manufacture of Plastic Parts. Copyright © 1980 by John Wiley & Sons, Inc. Reprinted by permission of John Wiley & Sons, Inc.

* Continuous process.