Plastics Processing

Plastics Processing

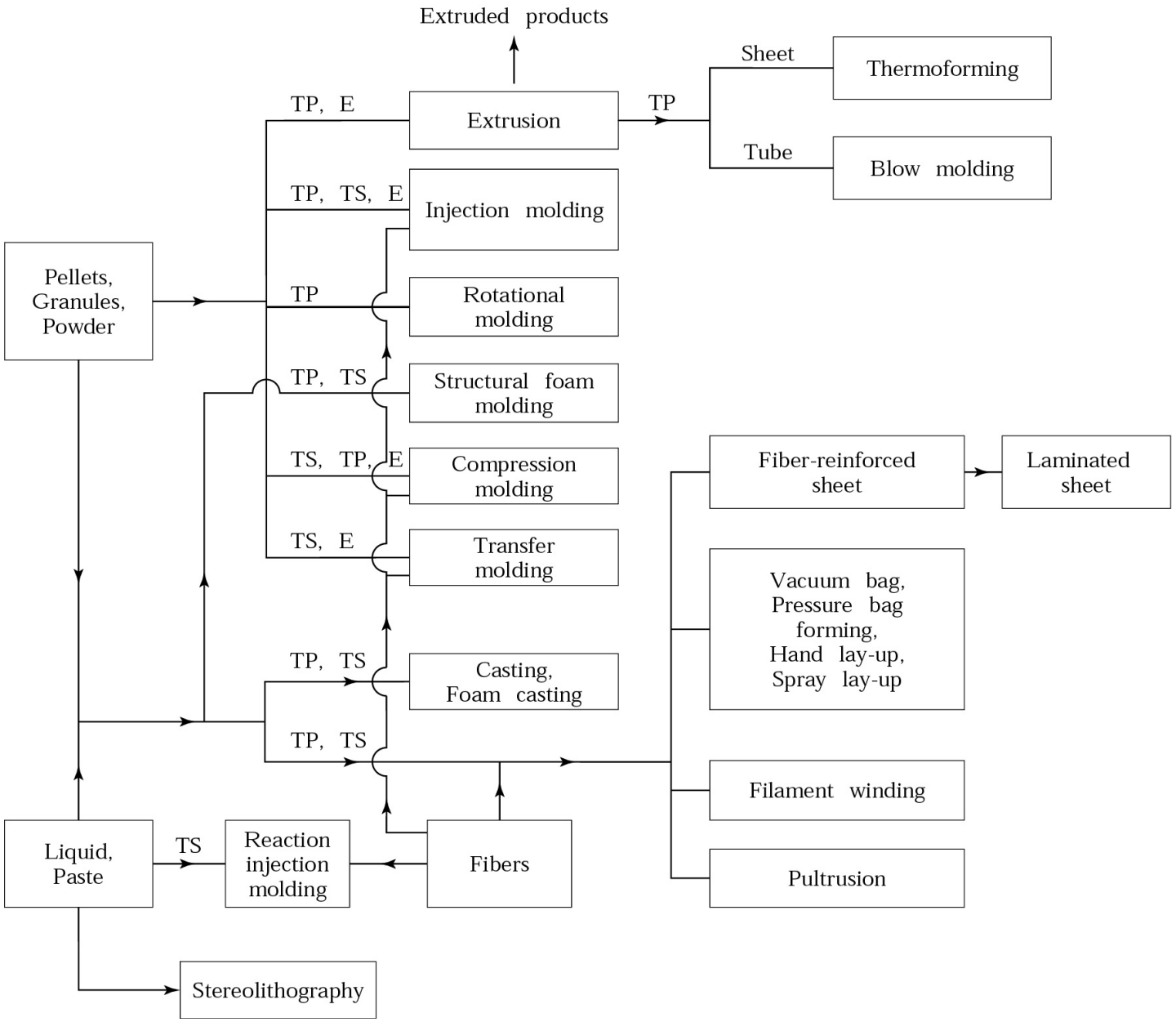
- Plastics can be machined, cast, formed, and joined with relative ease requiring little post-processing or surface-finish operations
- Plastics melt or cure at relative low temperatures
- Plastics require less energy to process than metals
- Raw materials most commonly are pellets, powders
- Also available as sheet, plate, rod, and tubing (produced by extrusion, etc.)
- Liquid plastics used to make reinforced plastic parts (composite materials)

Plastics Processes

TABLE 18.1

Process	Characteristics
Extrusion	Long, uniform, solid or hollow complex cross-sections; high production rates; low tooling costs; wide tolerances.
Injection molding	Complex shapes of various sizes, eliminating assembly; high production rates; costly tooling; good dimensional accuracy.
Structural foam molding	Large parts with high stiffness-to-weight ratio; less expensive tooling than in injection molding; low production rates.
Blow molding	Hollow thin-walled parts of various sizes; high production rates and low cost for making containers.
Rotational molding	Large hollow shapes of relatively simple shape; low tooling cost; low production rates.
Thermoforming	Shallow or relatively deep cavities; low tooling costs; medium production rates.
Compression molding	Parts similar to impression-die forging; relatively inexpensive tooling; medium production rates.
Transfer molding	More complex parts than compression molding and higher production rates; some scrap loss; medium tooling cost.
Casting	Simple or intricate shapes made with flexible molds; low production rates.
Processing of composite materials	Long cycle times; tolerances and tooling cost depend on process.

Plastics Processes

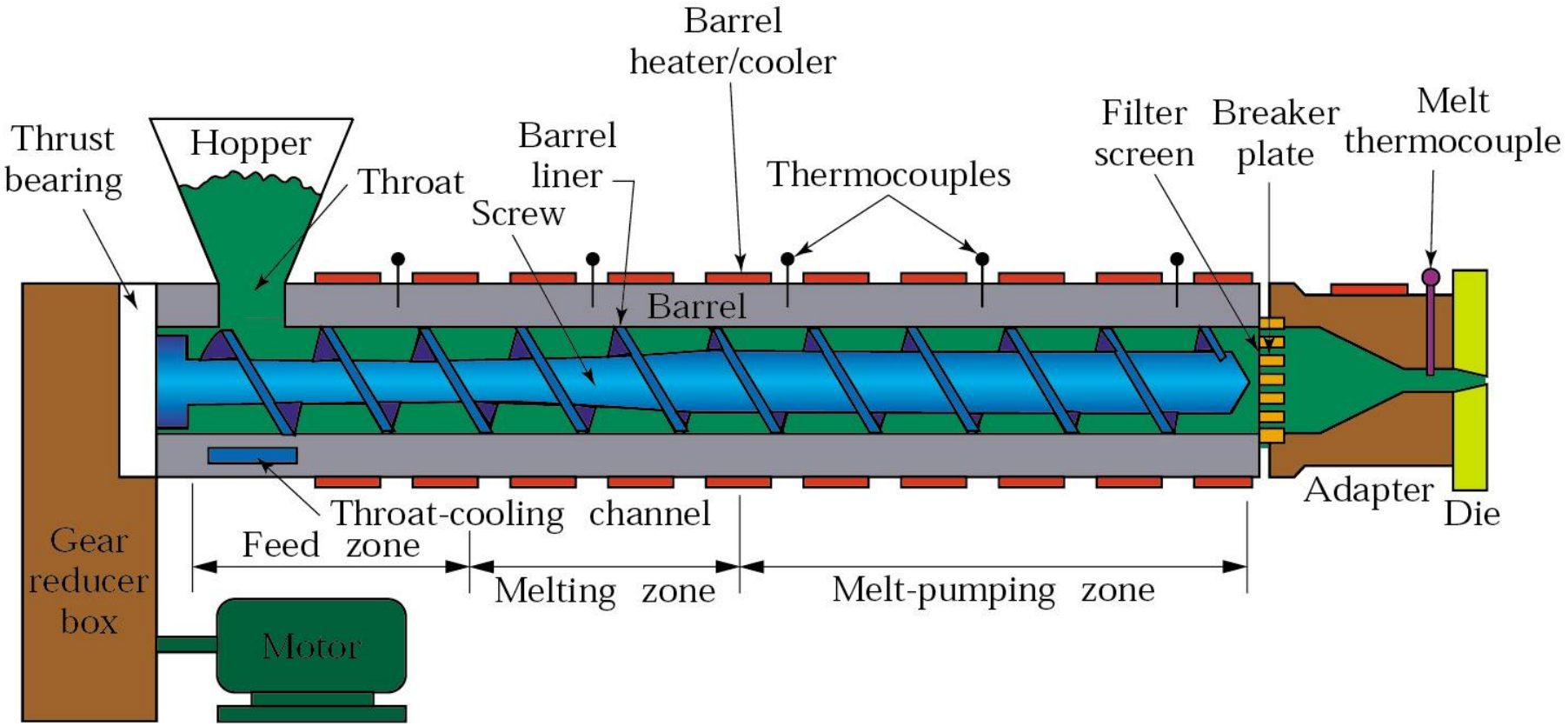


Extrusion

- Raw materials are thermoplastic pellets, granules, or powder
- Placed in hopper and fed into extruder barrel
- Screw blends pellets and pushes them down the barrel – through the feed, transition/melt, and pumping sections
- Barrel is heated from outside, and by friction
- Plastic (or elastomer) is liquefied and forced through a die under pressure
- Pellets for other plastics processes are made by extruding small-diameter rod and chopping into short segments
- Equipment costs on the order of $300,000
    - Rated by barrel diameter (D, 1-8 inch) and L/D ratio (5 to 30)

Extruded Products

Extrusion


Barrel
heater/cooler
Thrust
bearing
Hopper
Throat
Barrel
liner
Screw
Thermocouples
Filter
screen
Breaker
plate
Melt
thermocouple
Barrel
Adapter
Die
Throat-cooling channel
Gear
reducer
box
Feed zone
Melting zone
Melt-pumping zone
Motor

Polymer Melts

- Viscosity reduces with temperature
- Polymer melts have viscoelastic properties
- This causes die swell during extrusion

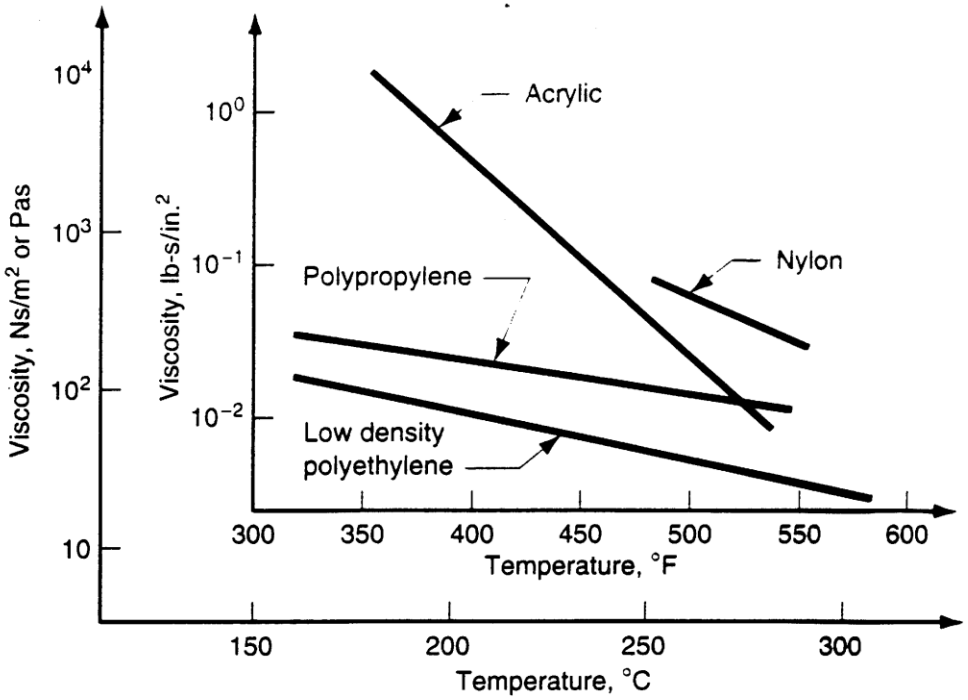


FIGURE 15.2 Viscosity as a function of temperatures for selected polymers at a shear rate of 10^3 sec^{-1}. Data compiled from [11].

Extrusion Die Swell

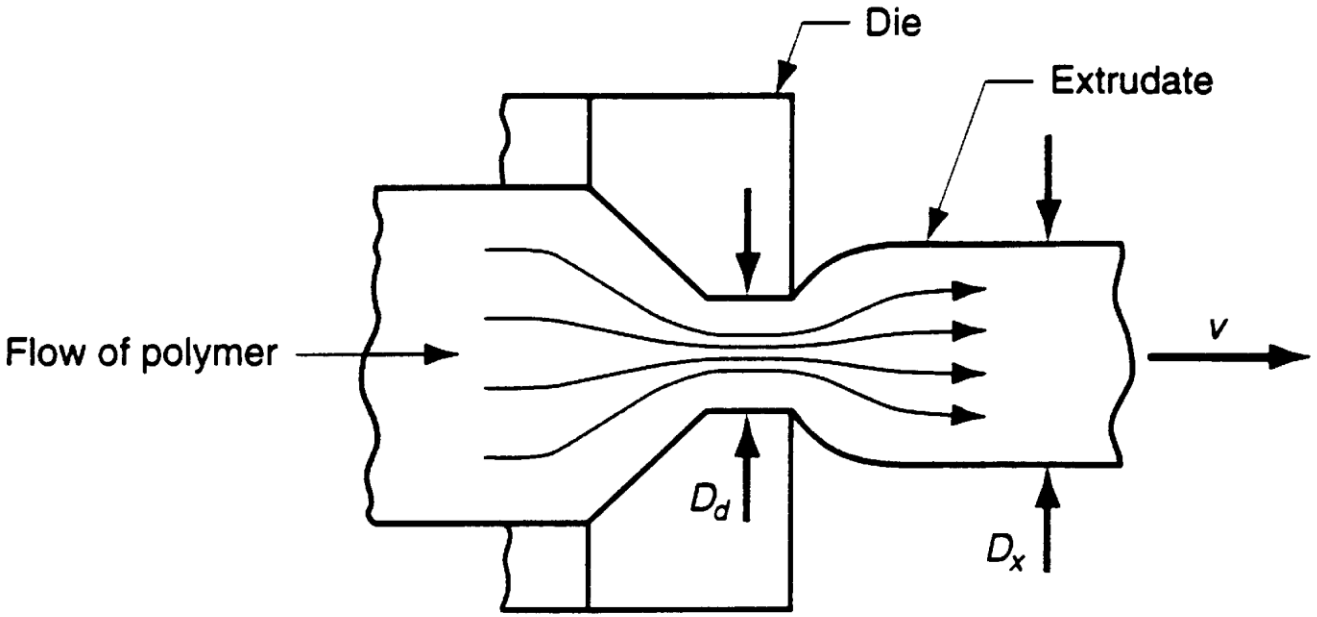
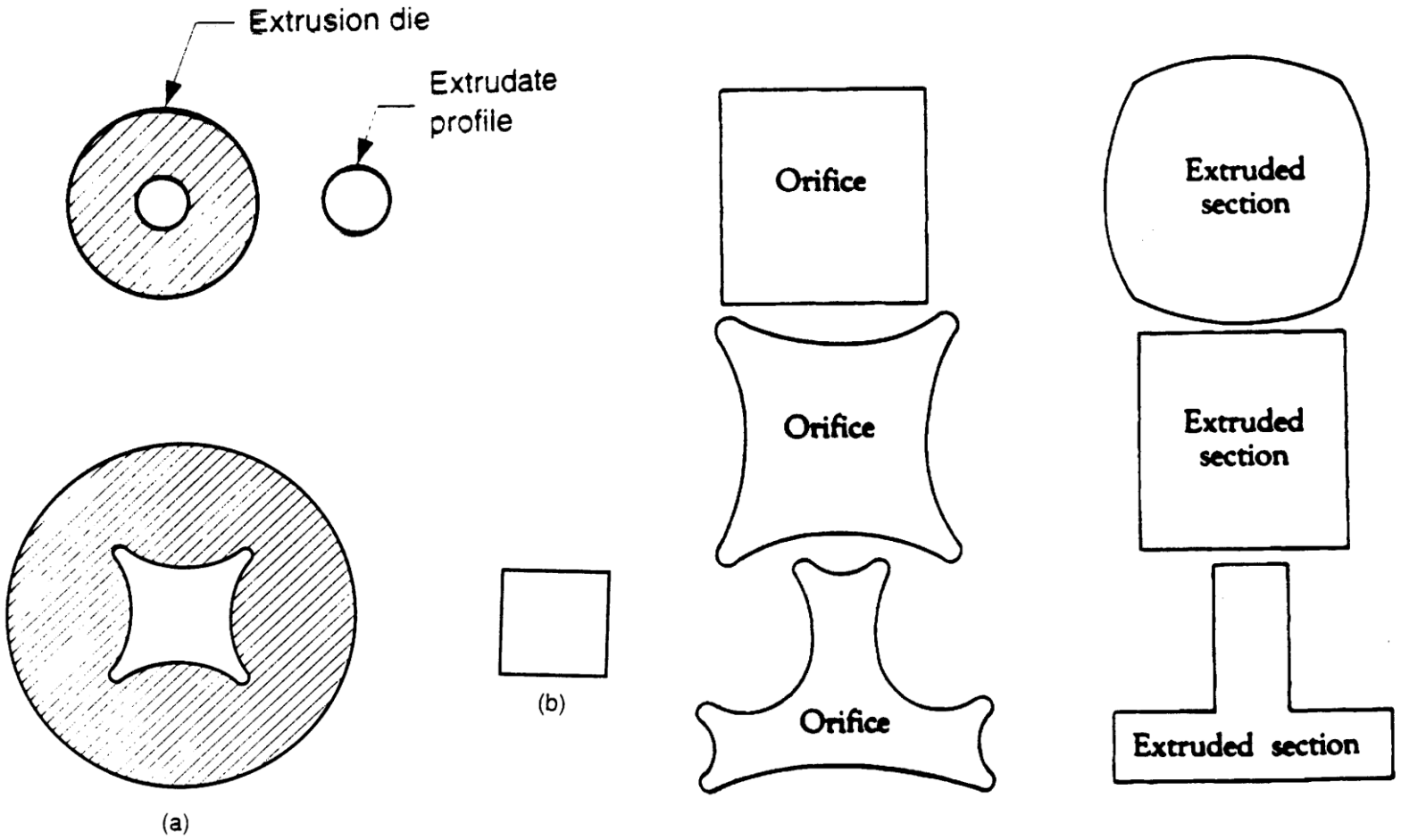


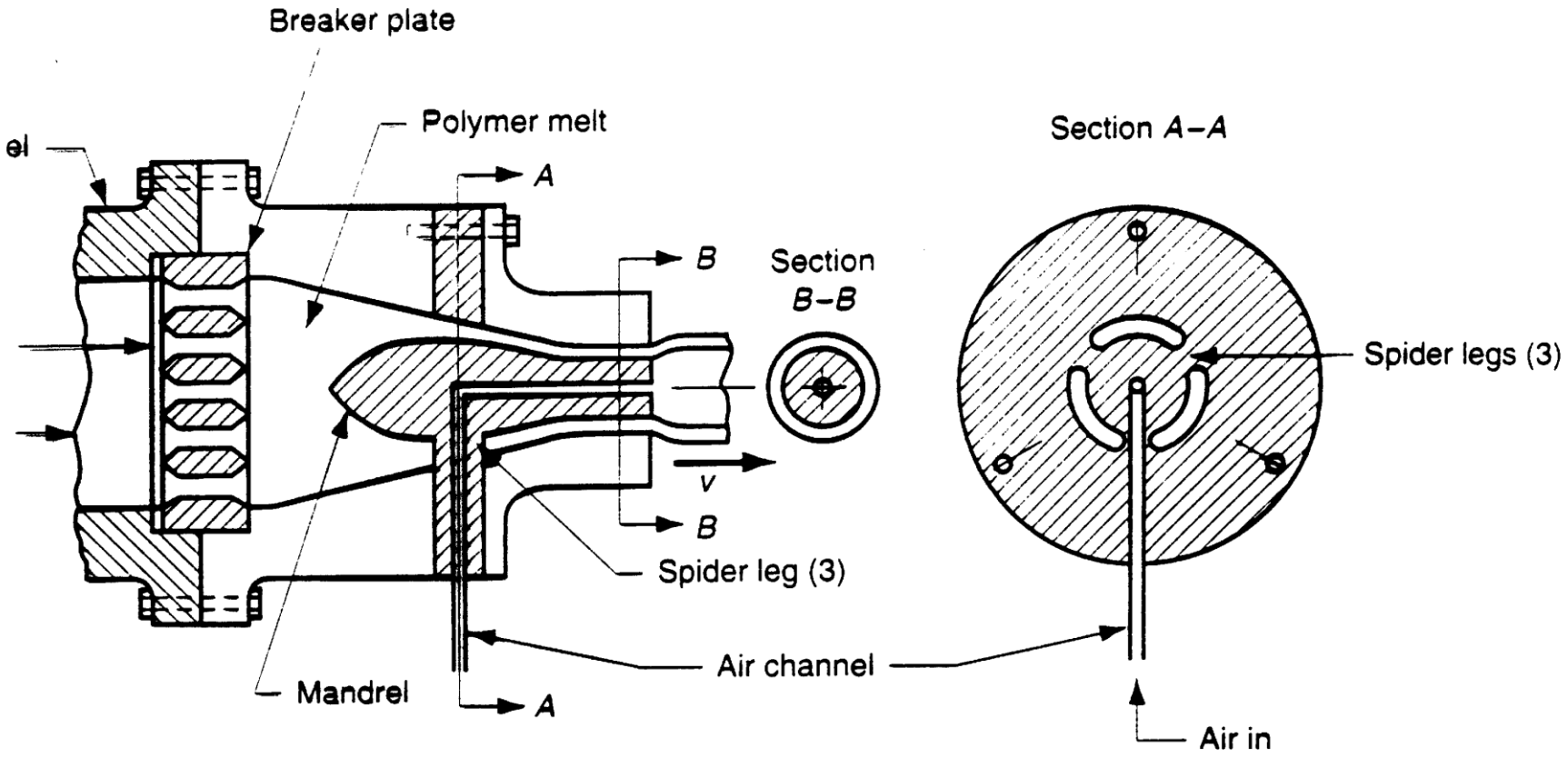
FIGURE 15.3 Die swell, a manifestation of viscoelasticity in polymer melts, as depicted here on exiting an extrusion die.

Swell ratio: $$r_s = \frac{D_x}{D_d}$$

Extrusion – Effects of Die Swell



Extrusion of Hollow Shapes



de view cross section of extrusion die for shaping hollow cross sections such as ction *A–A* is a front view cross section showing how the mandrel is held in place; the tubular cross section just prior to exiting the die; die swell causes an enlarger. (Some die construction details are simplified.)

Extrusion Coating of Wires

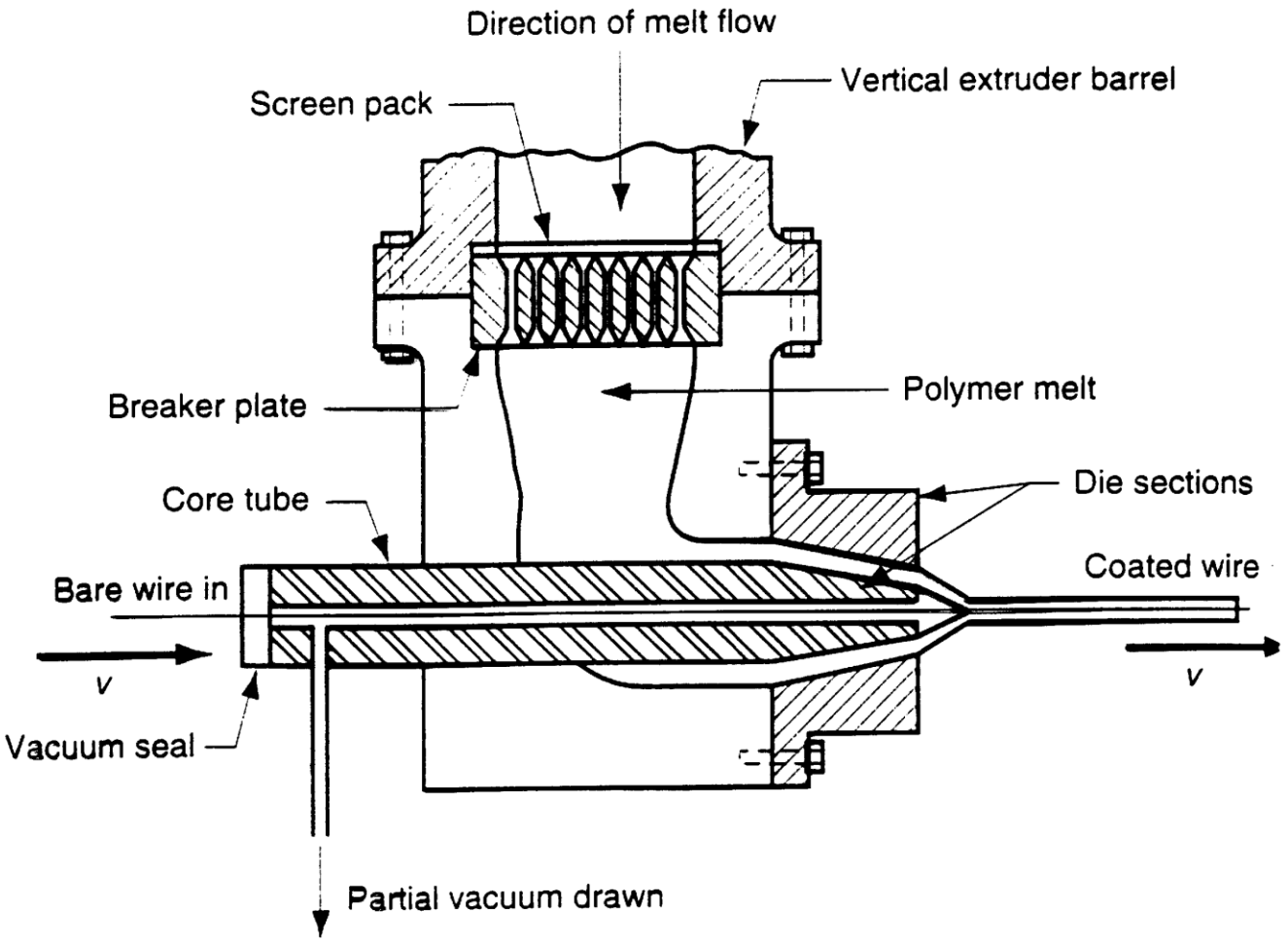


FIGURE 15.11 Side view cross section of die for coating of electrical wire by extrusion. (Some die construction details are simplified.)

Extrusion of Sheet

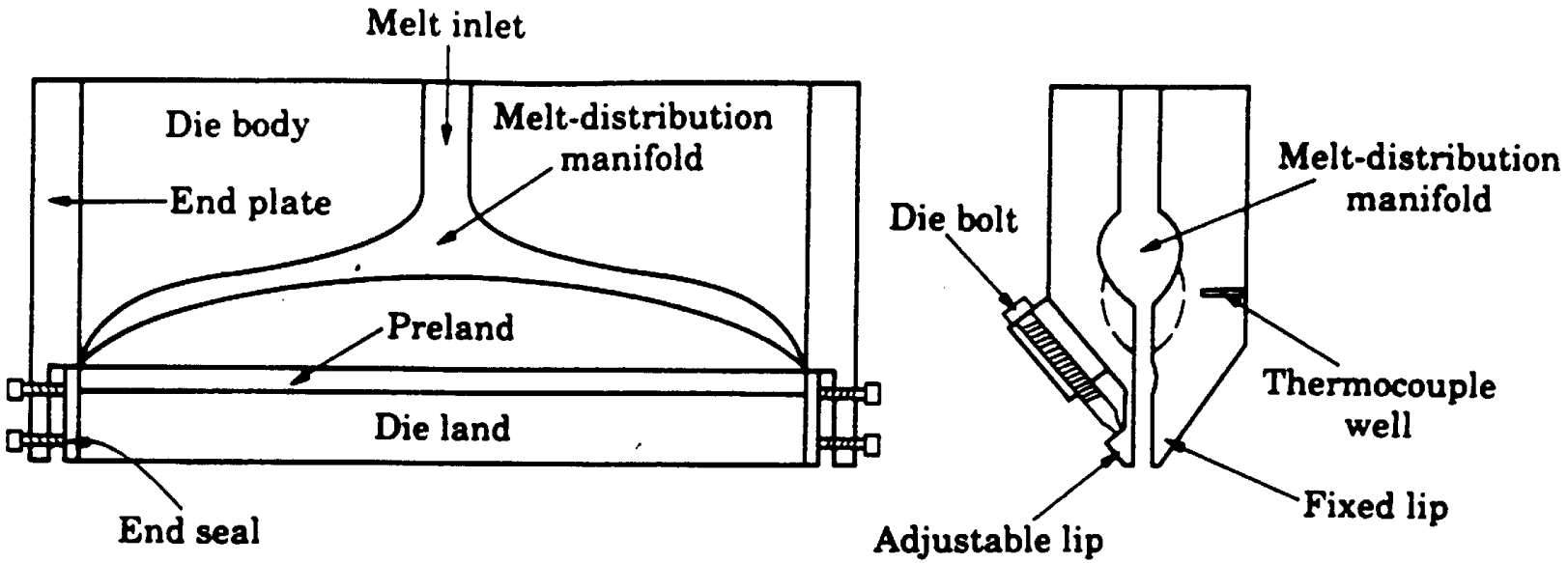
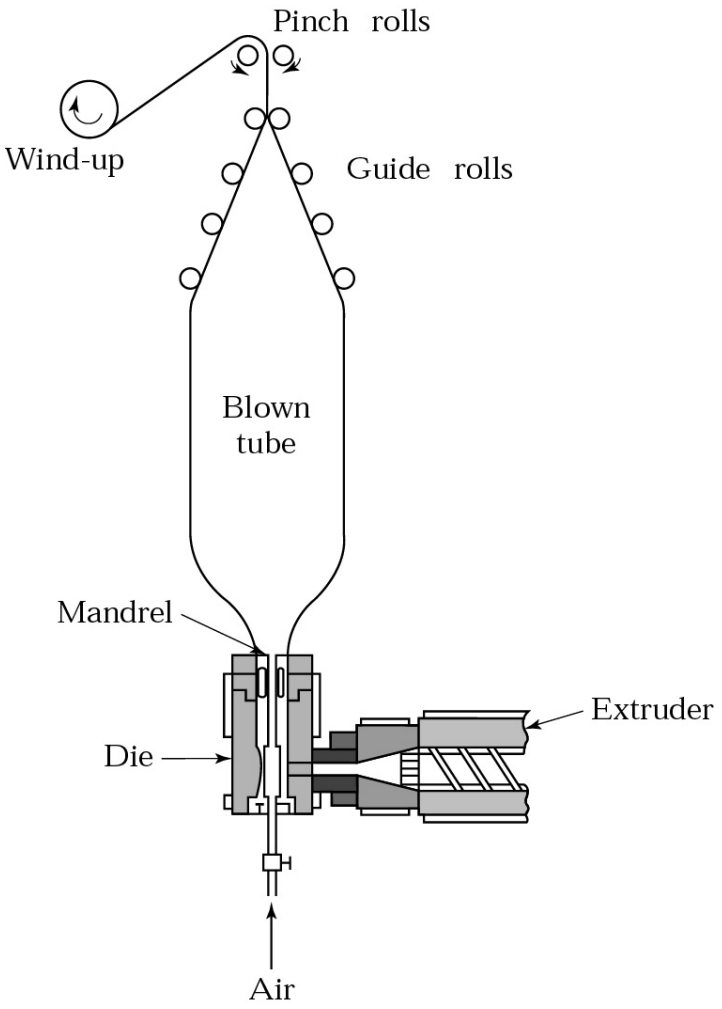


FIGURE 18.4

Die geometry (coat-hanger die) for extruding sheet. *Source: Encyclopedia of Polymer Science and Engineering*, 2d ed., Vol. 7, p. 93. New York: Wiley-Interscience, 1985.

Blown Film Extrusion

- Carried vertically
- Used to manufacture plastic film and plastic bags
- Mainly for materials such as LDPE and PVC

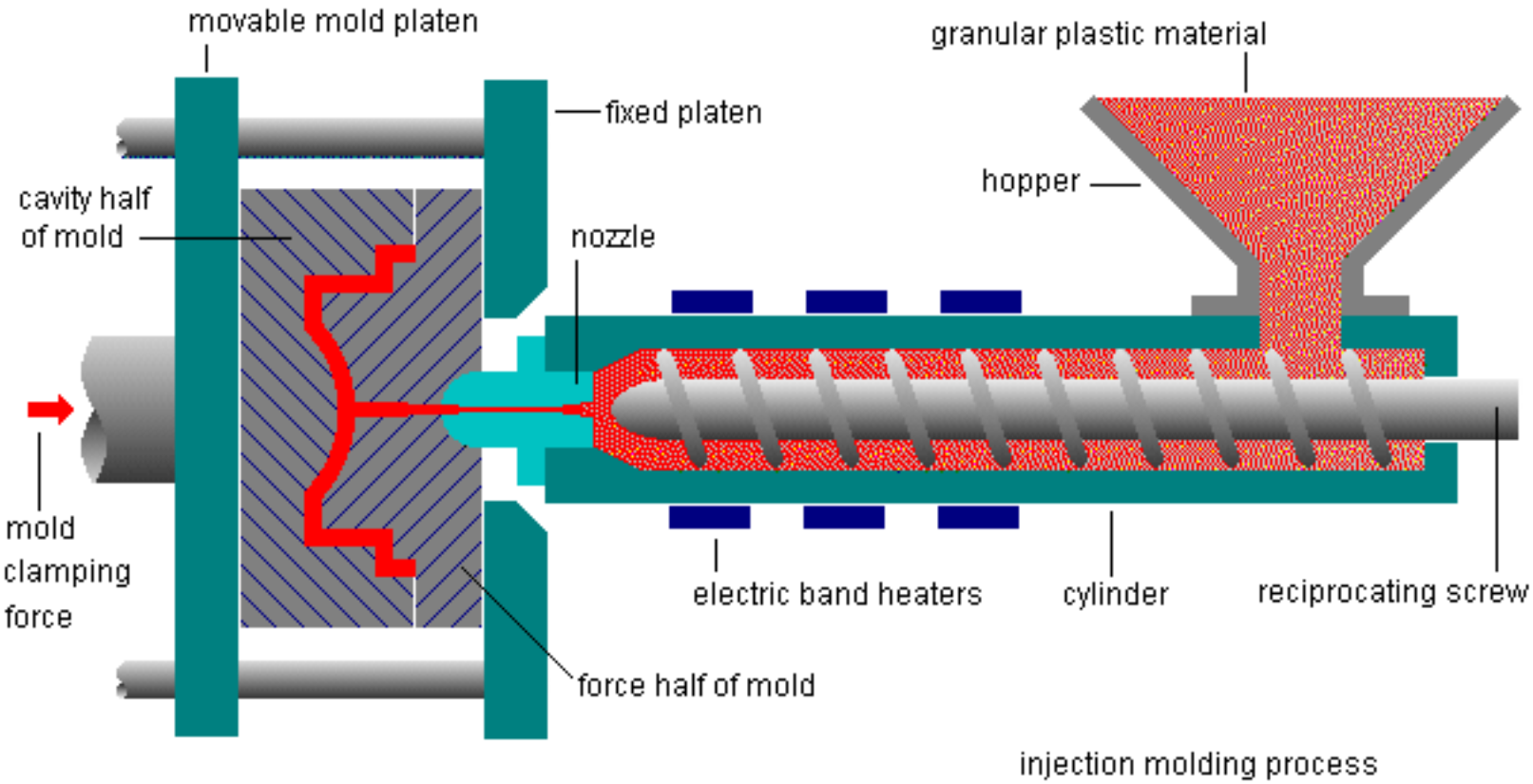


Injection Molding

- Similar to hot-chamber die casting of metals
- Pellets, granules, or powder are fed into heated cylinder, then forced into die chamber by hydraulic plunger or rotating screw system
- Pressures from 70-200 MPa (10-30 Kpsi)
- Cool molds for thermoplastics. Heated molds for thermosets
- Complex shapes and good dimensional accuracy
- Using metallic inserts, multiple materials/colors, and printed films can eliminate post processing or assembly operations

Injection Moldings

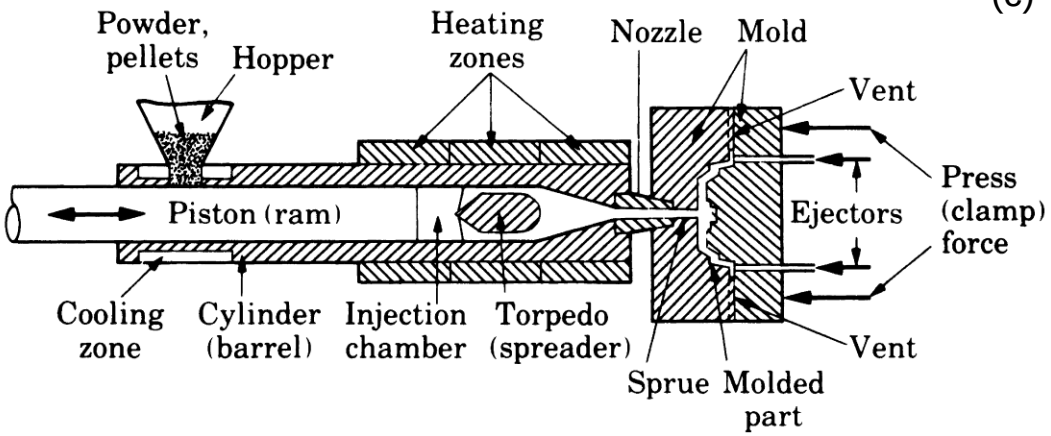
Injection Molding



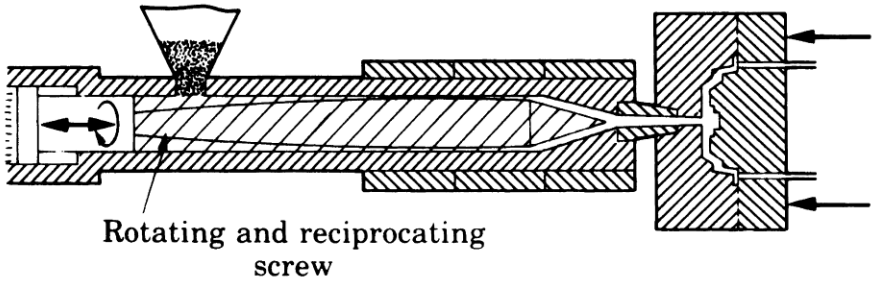
injection molding process

Injection Molding

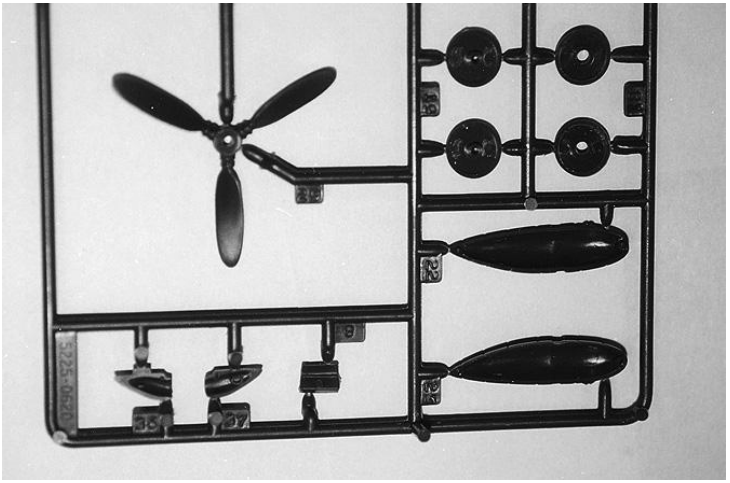
(a)



(b)



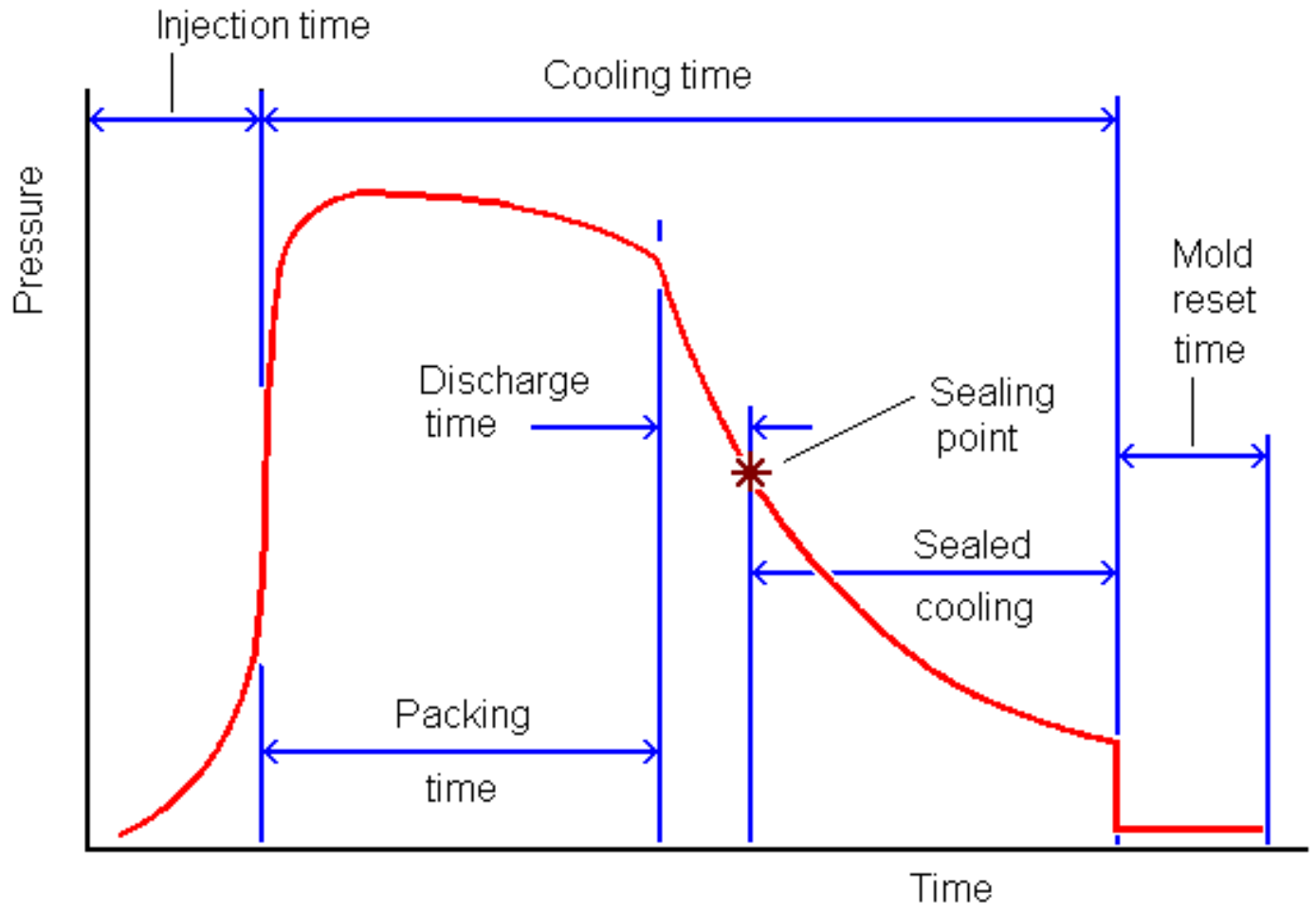
(c)



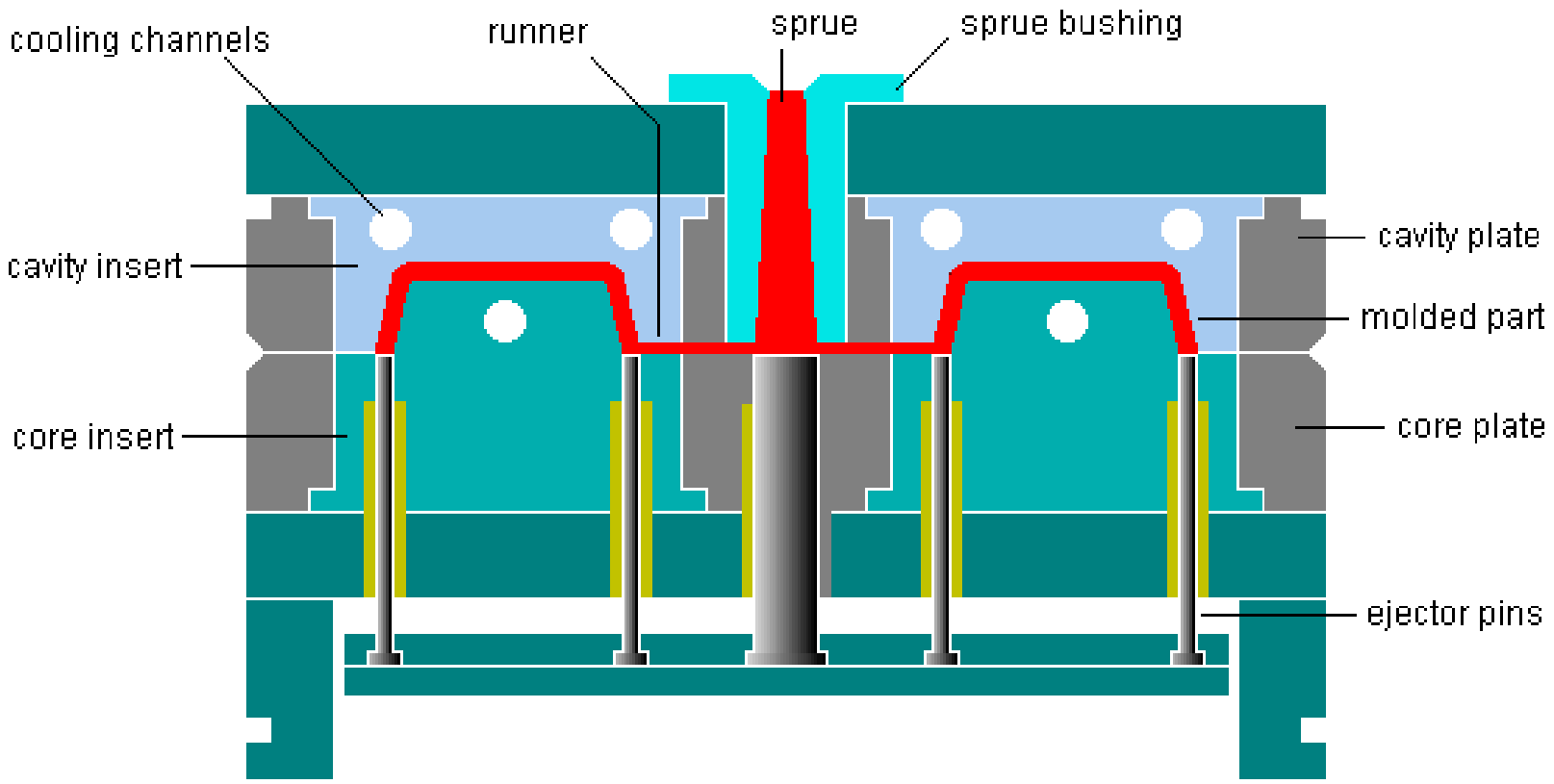
- Cold-runner molds are similar to metal casting
- More expensive hot-runner molds have no gates, runners, or sprues attached to final part

Plastic Injection Molding

Cycle Time Breakdown

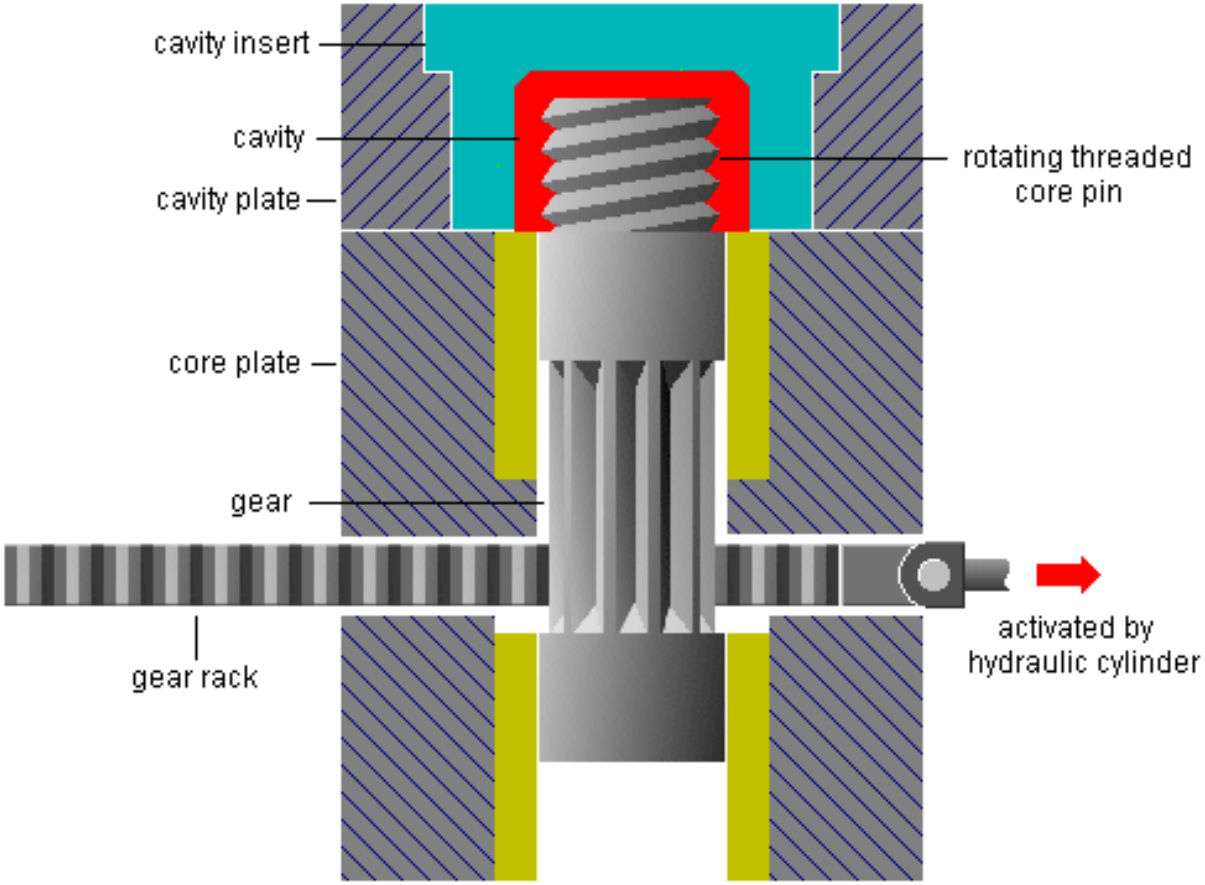


Injection Molding Two Plate Mold



two- plate and two-cavity mold

Injection Molding Die Mechanisms
Unscrewing Core



unscrewing device

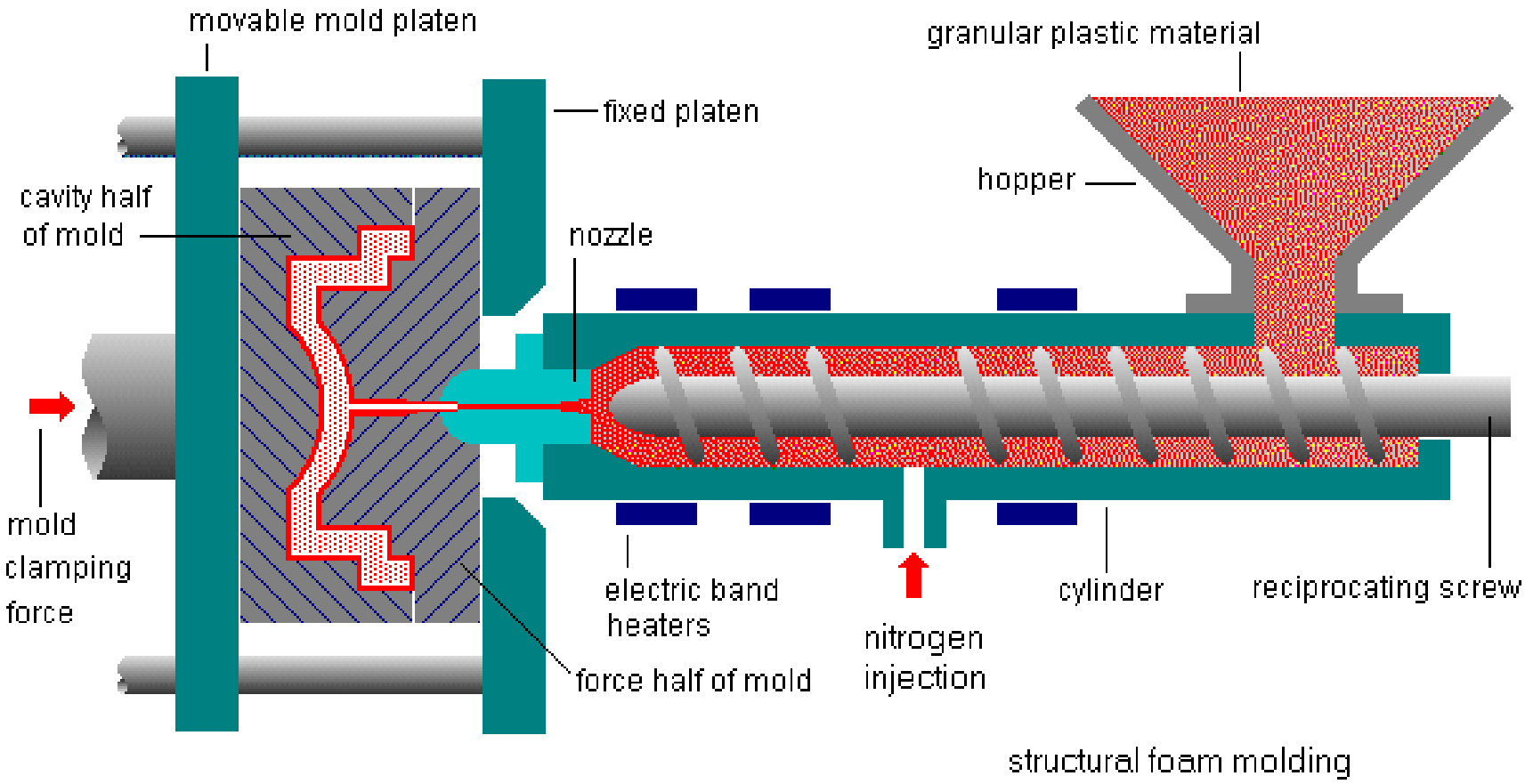
Injection Molding Capabilities

- High production rates
- Good dimensional control
- 5-60 second cycle times (or several minutes for thermoset materials)
- Molds with multiple cavities, made of tool steels (2 million cycles), aluminum (10,000 cycles), etc.
- Mold costs up to $20-200K
- Machines are usually horizontal with clamping forces 0.9-2.2 MN (100-250 tons)
- 100 ton machines cost $60-90K
- 300 ton machines cost $85-140K

Structural Foam Molding

- A variation of the injection molding process, developed for applications where stiffness is a primary concern, and particularly for large structural parts.
- Parts consist of a rigid, closed-cellular core surrounded by a continuous, solid skin.
- The polymer melt contains a dissolved inert gas; most commonly nitrogen, introduced in the extrusion screw.
- A predetermined shot size is injected into the mold cavity, the extruder valve is closed, and the foam material generates internal pressure and expands to fill mold cavity.
- A much lower pressure operation than the conventional injection molding system, which allows much larger parts to be molded.

Structural Foam Molding

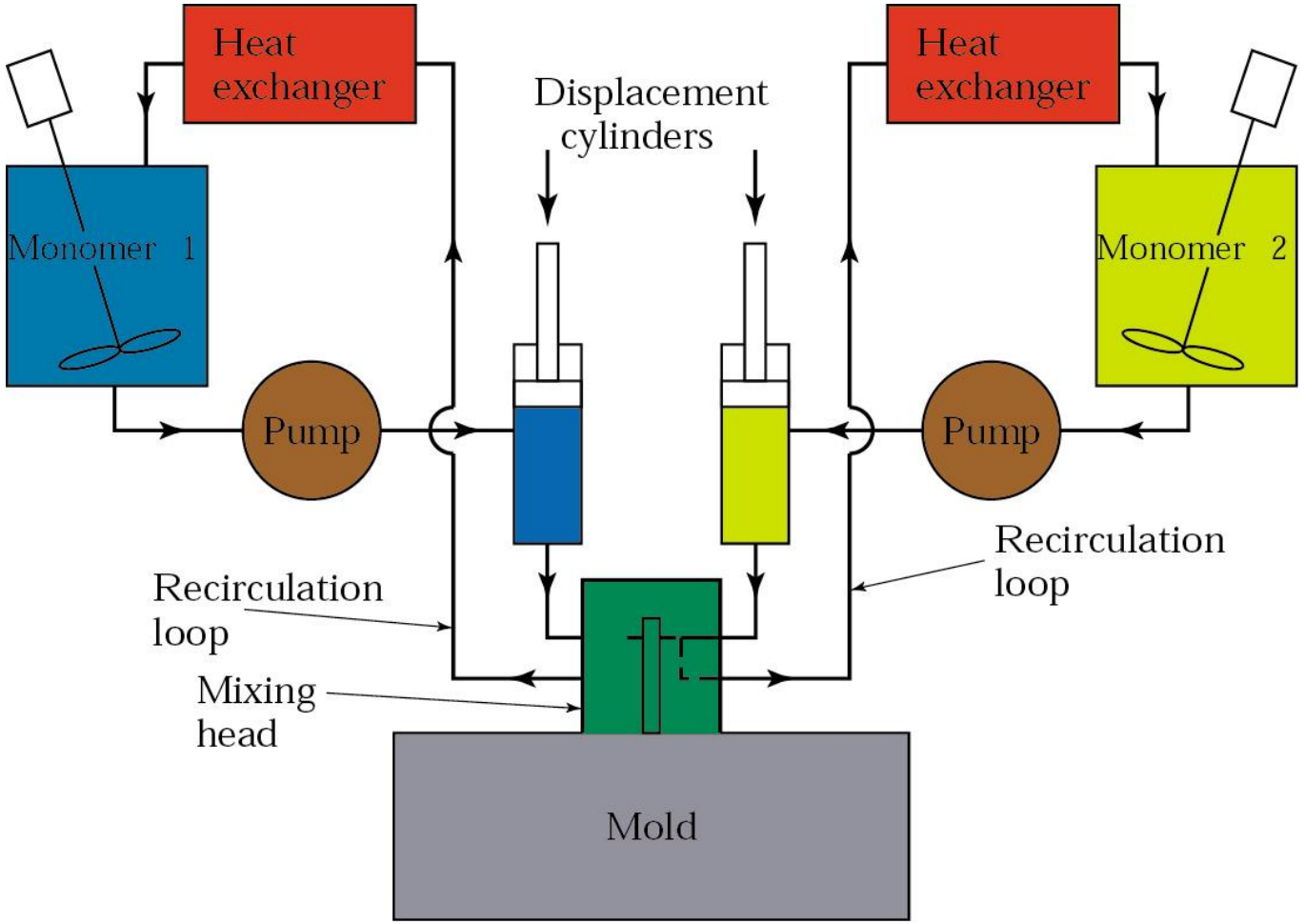


Structural Foam Moldings

Reaction Injection Molding

Chemical reaction between two polymer materials - thermoset

- Large parts
- Low tooling costs
- Car bumpers are good examples for this process



Reaction Injection Moldings

Blow Molding

- Modified extrusion and injection molding processes
- Extrusion Blow Molding
  - Small tube is first extruded, usually vertically, then clamped and air blown inside to expand it to fit a much larger diameter mold
  - Air pressures 350-700 kPa (50-100 psi)
  - Can be a continuous process (corrugated pipe and tubing)
- Injection blow molding
  - Short tubular piece (parison) injection molded, transferred to a blow-molding die
  - Plastic beverage bottles and hollow containers
- Multilayer blow molding
  - Uses coextruded tubes or parisons
  - Plastic packaging for food and beverages, cosmetics and pharmaceutical industries

Blow Moldings

Blow Molding

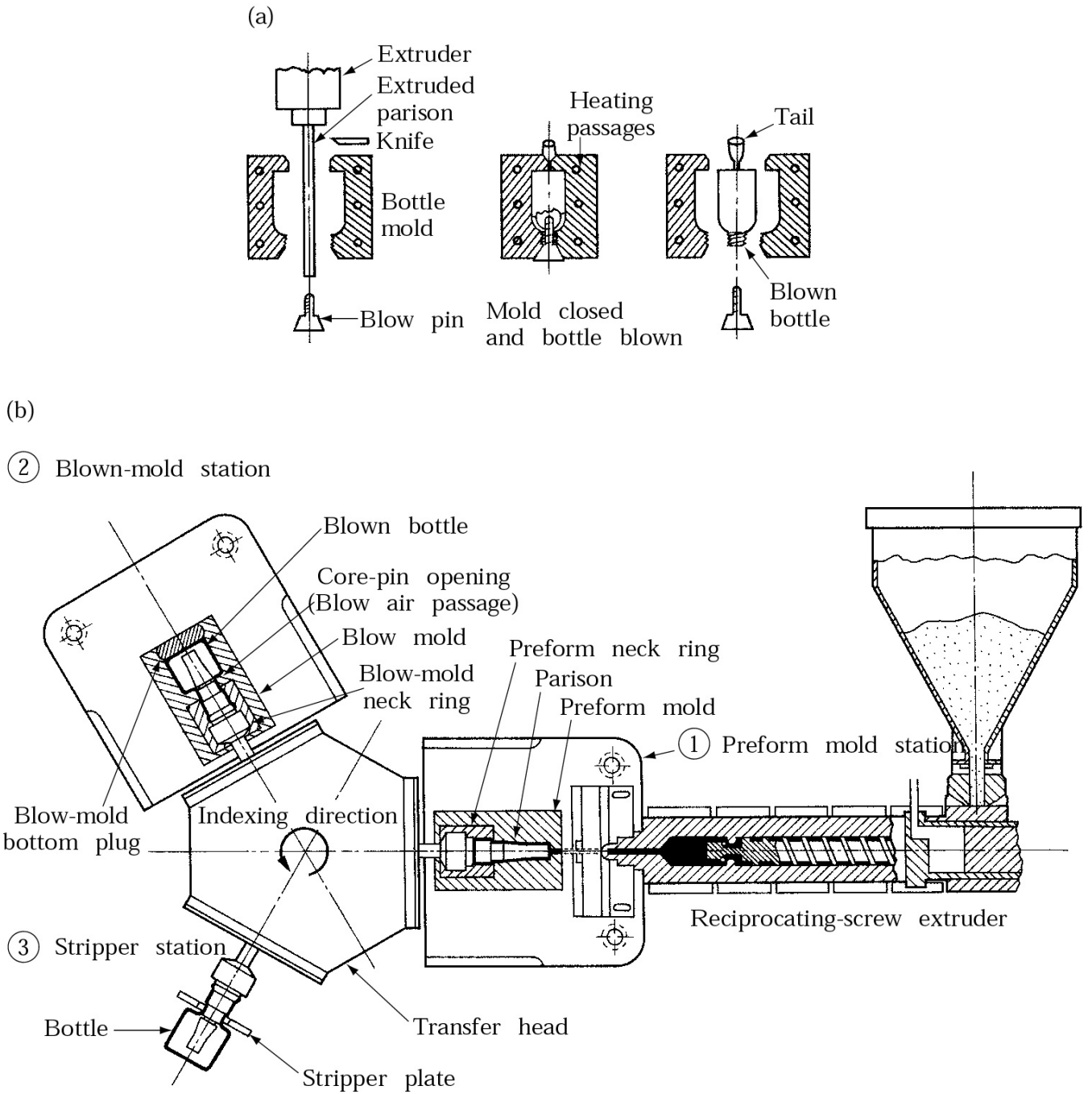
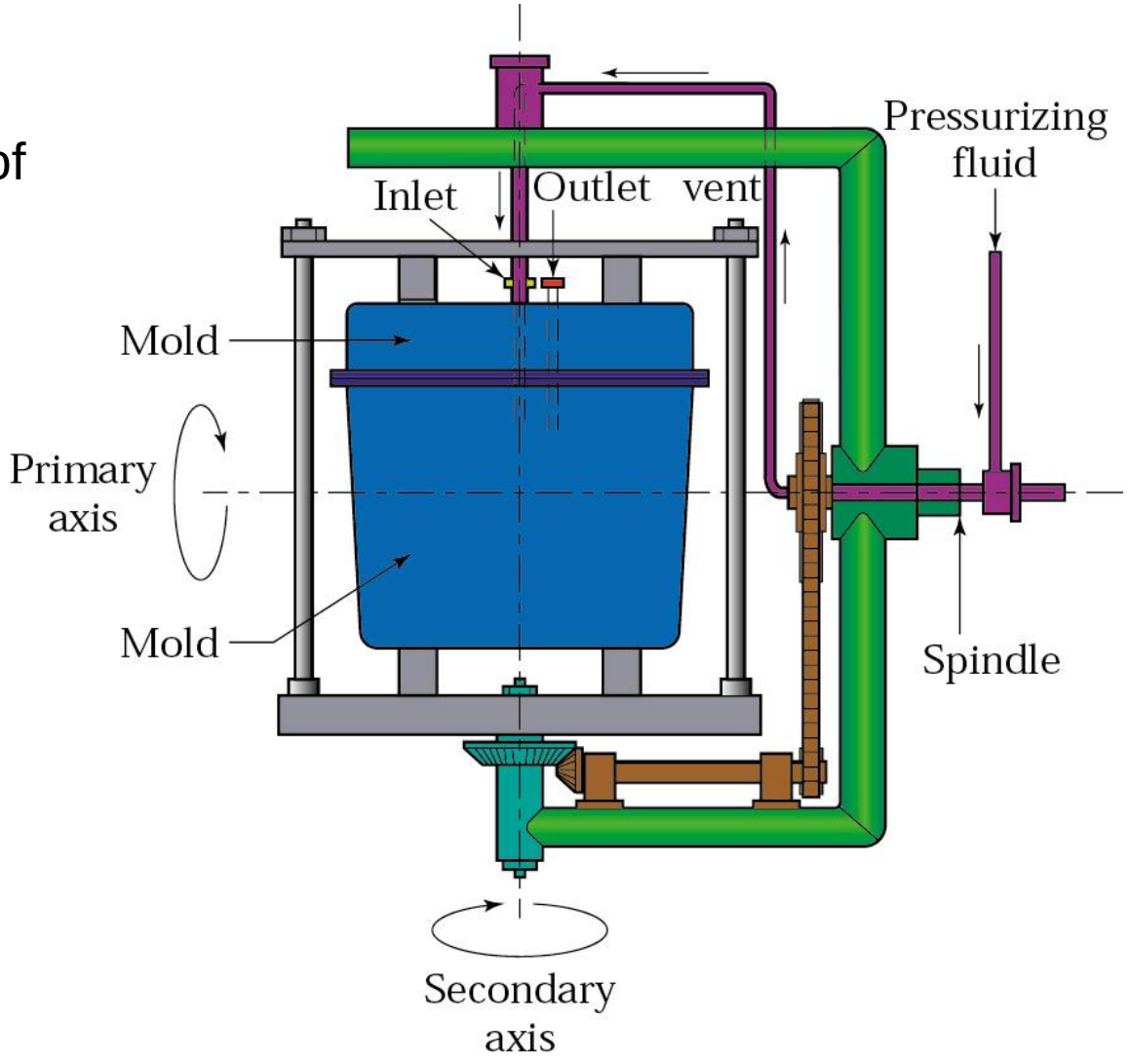


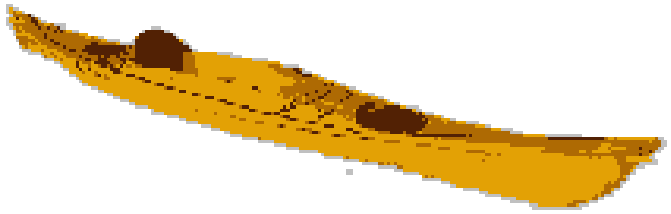
Figure 18.9 Schematic illustrations of (a) the blow-molding process for making plastic beverage bottles, and (b) a three-station injection blow-molding machine. *Source*: *Encyclopedia of Polymer Science and Engineering* (2d ed.). Copyright ©1985. Reprinted by permission of John Wiley & Sons, Inc.

Rotational Molding

- Premeasured quantity of powder placed inside warm mold
- Rotated on two axes inside a heated furnace
- Low equipment costs
- Longer process times
- Trash cans, boat hulls, buckets, toys, footballs
- 0.4 mm wall thickness possible
- Also, slush molding

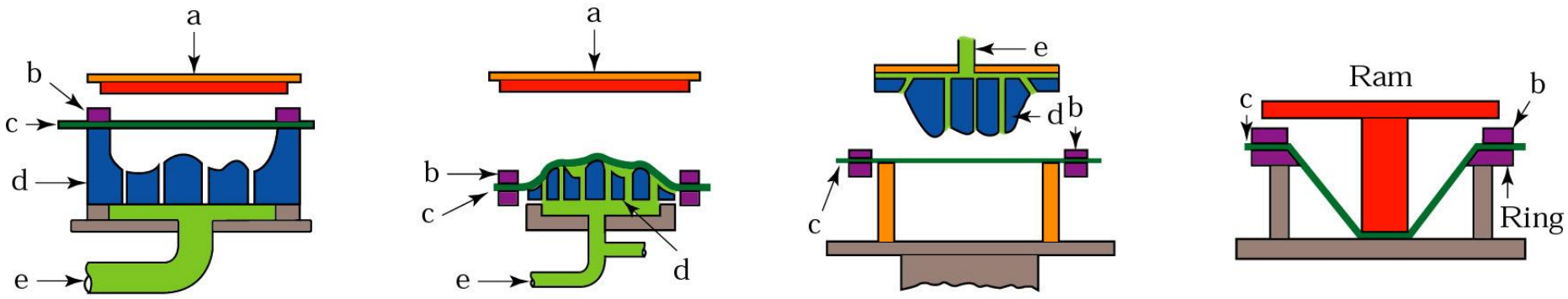


Rotational Moldings



Thermoforming

- Plastic sheet is heated to a sag point (softened, but not melted)
- Heated sheet placed over a room-temperature mold and forced against it by vacuum pressure
- Stretch forming process – material thickness variations
- Advertising signs, refrigerator liners, appliance housings, shower stalls, packaging



1.Straight vacuum forming

2.Drape vacuum forming

3Force above sheet

4Plug and ring forming

a. Heater
b. Clamp
c. Plastic sheet
d. Mold
e. Vacuum line

Thermo Formed Parts

Compression Molding

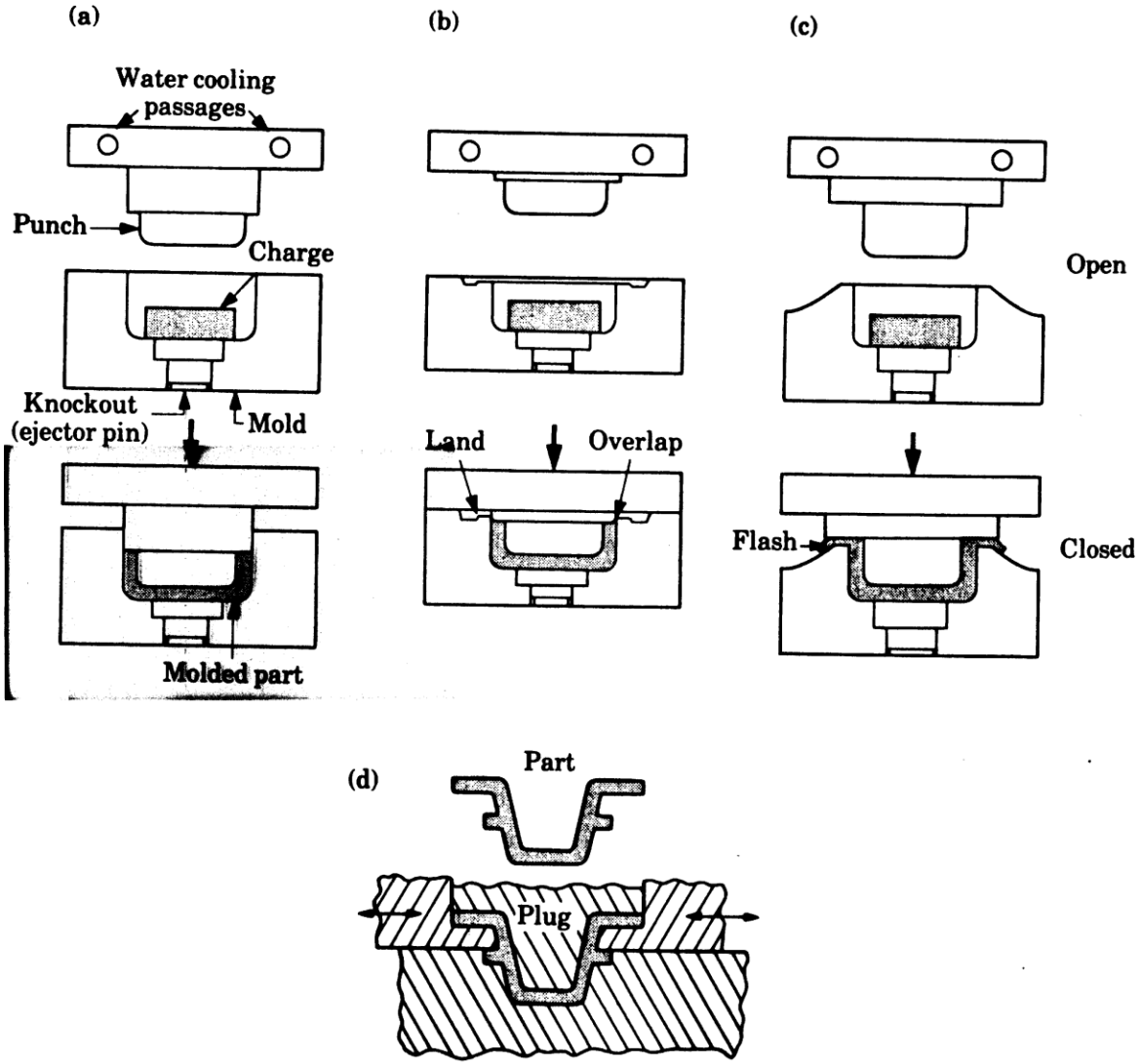


FIGURE 18.12

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.

Compression Moldings