Polymer Processing

Peng Li, Mar. 15th

Chapter 18

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What Are Polymers?

- Plastic Materials = Polymers
- Long-chain molecules built up from shorter molecules (mers) with the spine of the molecules usually comprised of carbon atoms.

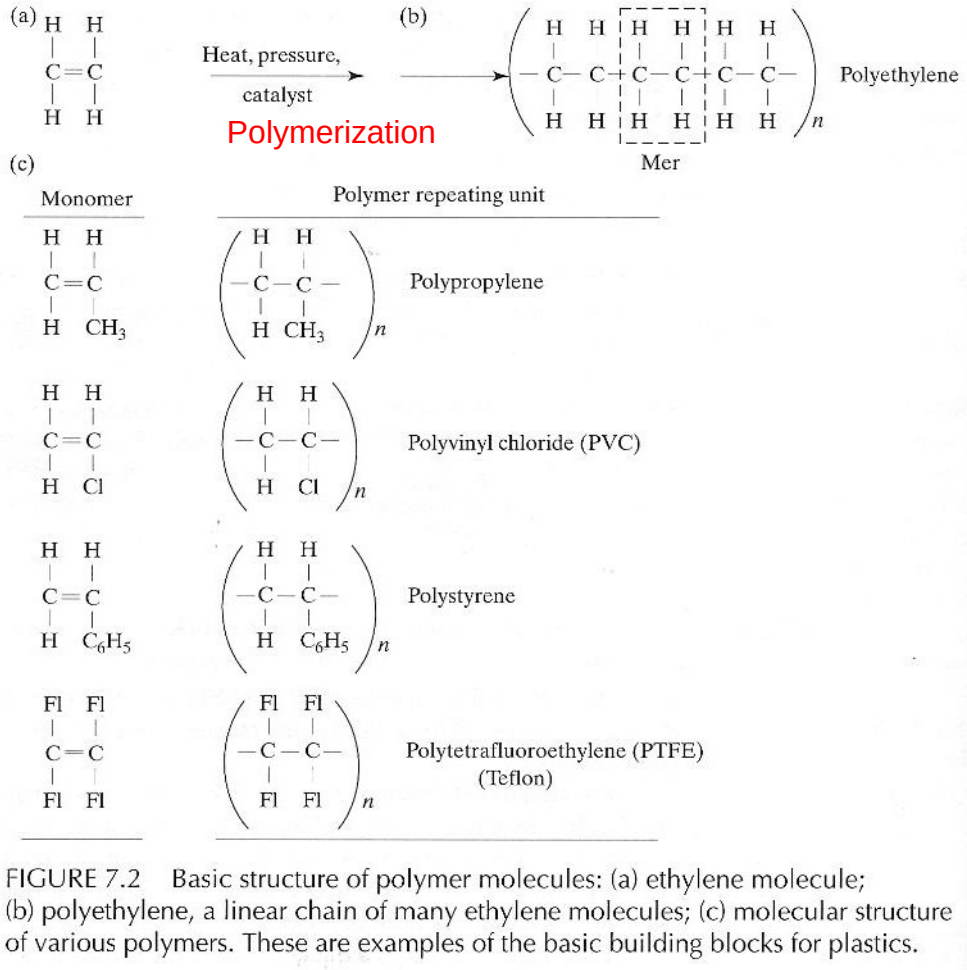


FIGURE 7.2 Basic structure of polymer molecules: (a) ethylene molecule; (b) polyethylene, a linear chain of many ethylene molecules; (c) molecular structure of various polymers. These are examples of the basic building blocks for plastics.

Polymer= …+ mer + mer + mer +…

Approx. 50 to 20,000 units

Types of Polymers

From a processing point of view, the main classes are:

- Thermoplastic: the polymer is heated to make a viscous liquid and then processed into a usable object without much additional chemistry. Example: polyethylene, polystyrene.

  Retain its plasticity.

- Thermoset: upon heating, further reaction occurs to make molecules “set up” into a useful product. Chemistry occurs, so these are sometimes called “reactive polymers”. Example: polyurethanes, phenol-formaldehyde, melamine-formaldehyde, epoxy glue.

  Become permanently hard and brittle.

Polymer Processing

- Start with coal and petroleum products, heat to polymerize to make giant molecules.
- The processing of polymers involves operations similar to those used to form and shape metals, *e.g.* molding, casting, forming, machining and joining.
- They can be processed into many shapes with relative ease (*e.g.* at lower temperatures and strengths) and in few operations.
- Want many forms: fibers, complex shaped parts, foams, laminates - sheets, so need many different processes.
- Also must deal with meltable and irreversible types.

Polymer Processing

- Thermoplastic processes: Extrusion (also films and tubes), fiber drawing, blow molding, thermoforming, injection molding …

- More for thermosets: casting, compression molding, transfer molding …

Polymer Processing

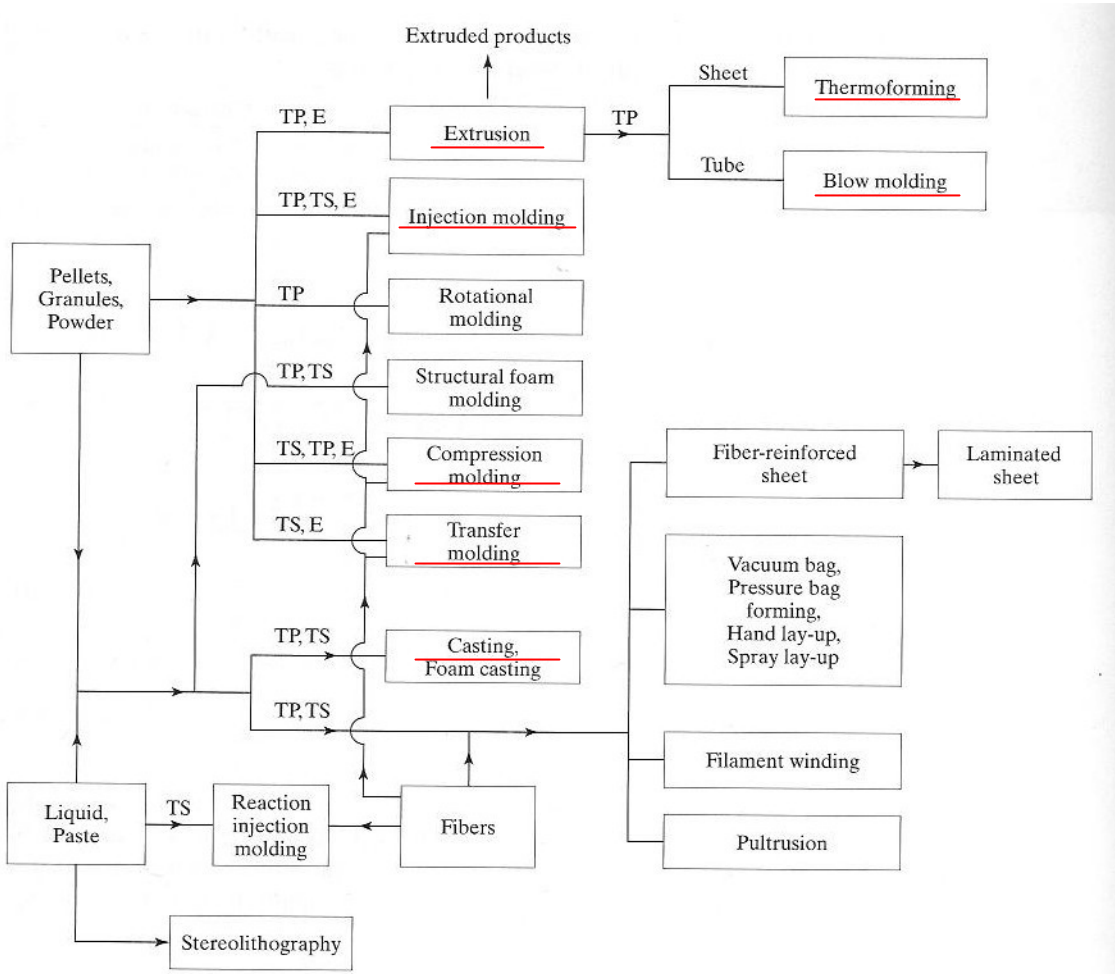
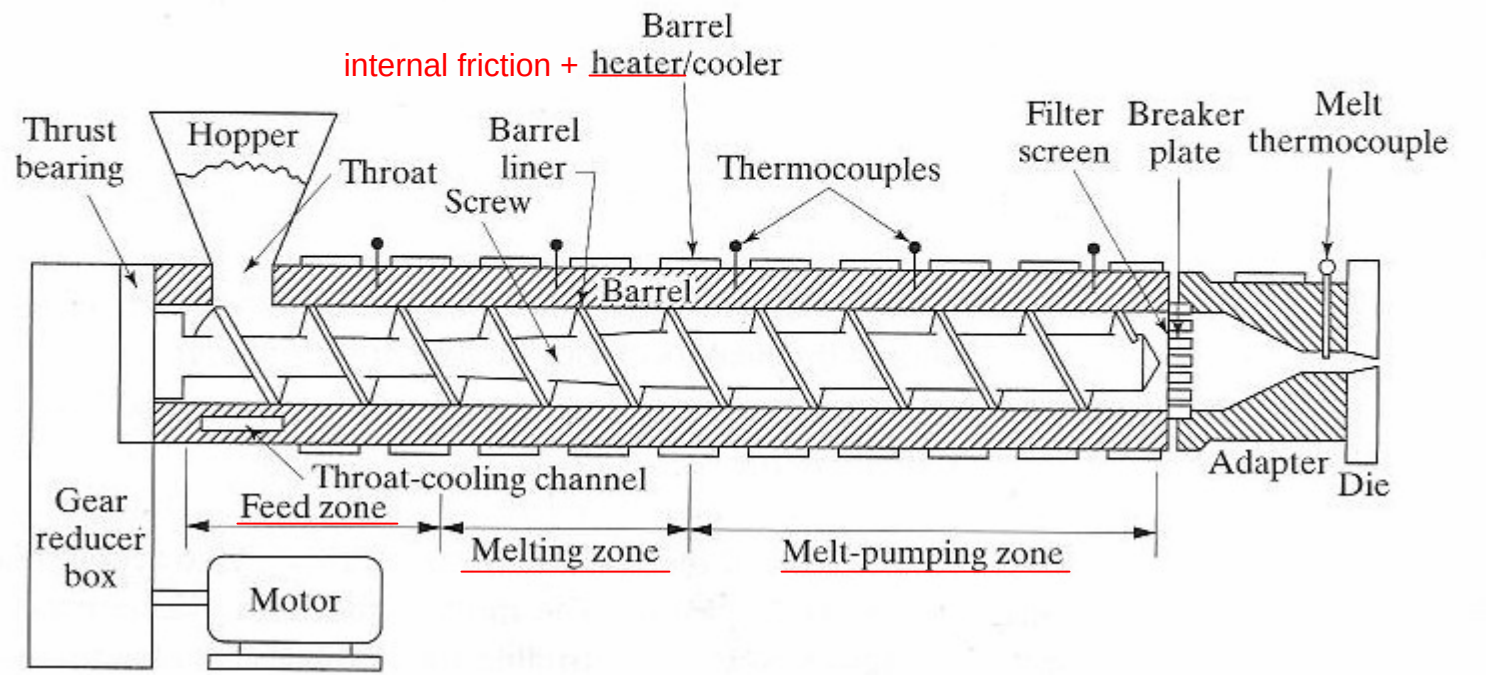


FIGURE 18.1 Outline of forming and shaping processes for plastics, elastomers, and composite materials. (TP, Thermoplastic; TS, Thermoset; E, Elastomer.)

Thermoplastic Processes – Extrusion

- Complex shapes with constant cross-section can be extruded with relatively inexpensive tooling.

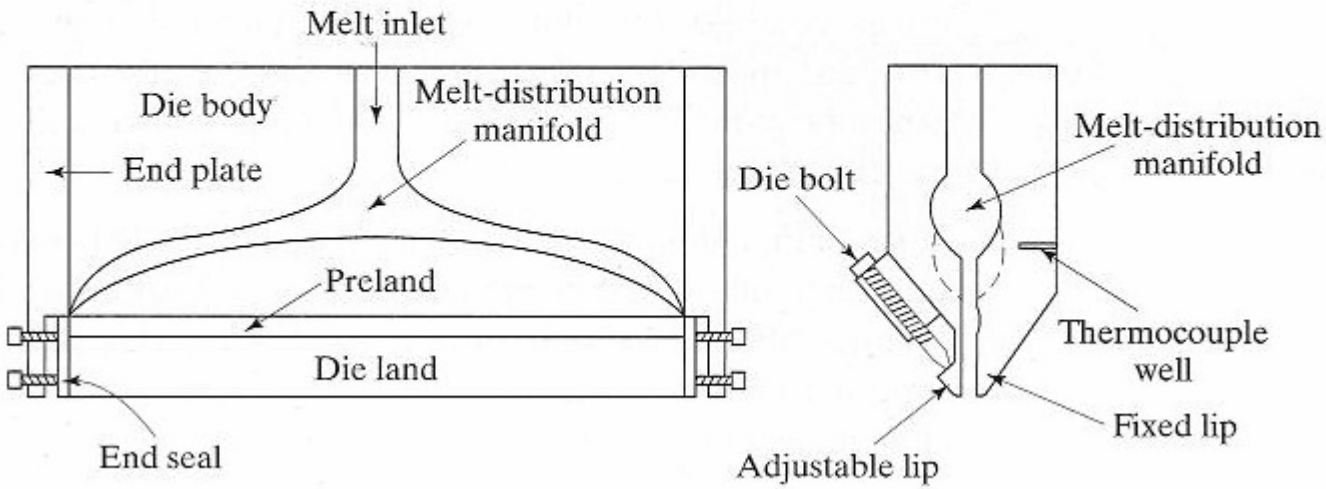
FIGURE 18.2 Schematic illustration of a typical extruder. *Source*: *Encyclopedia of Polymer Science and Engineering* (2d ed.). Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.



Thermoplastic Processes – Extrusion

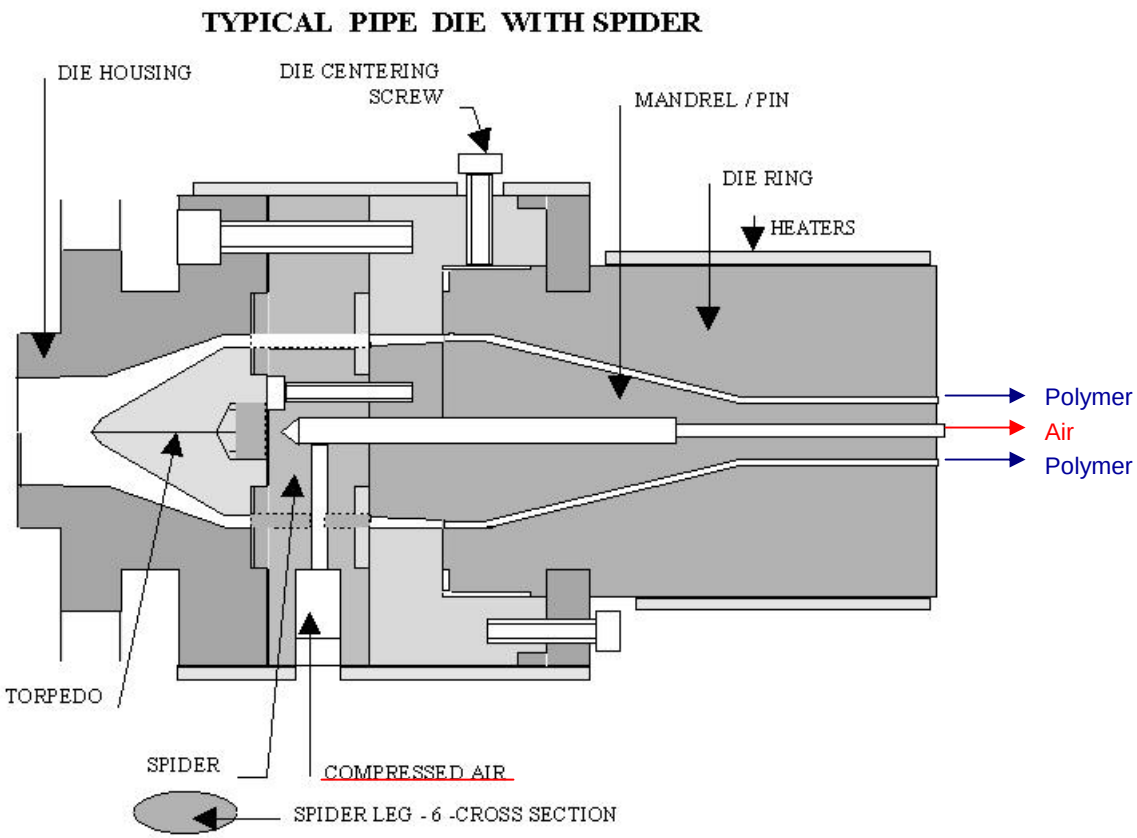
- Sheet and Film Extrusion

FIGURE 18.3 Die geometry (coat-hanger die) for extruding sheet. *Source*: *Encyclopedia of Polymer Science and Engineering* (2d ed.). Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.



Thermoplastic Processes – Extrusion

- Tube Extrusion



From http://www.balasainet.com/members/pcbolur/extrusion1.html

Thermoplastic Processes – Extrusion

- Blown Films → Wrapping films and Bags

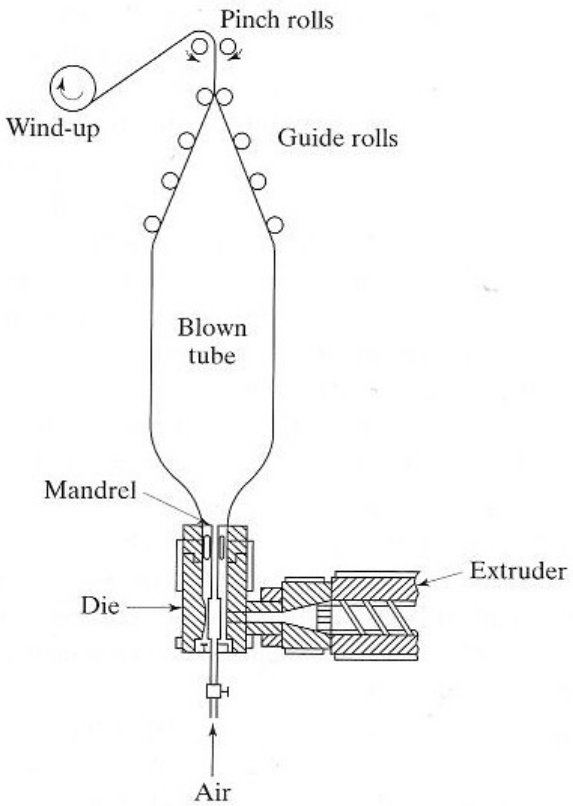


FIGURE 18.4 Schematic illustration of the production of thin film and plastic bags from tube first produced by an extruder and then blown by air. *Source*: D.C. Miles and J.H. Briston, *Polymer Technology*, 1979. Reproduced by permission of Chemical Publishing Co., Inc.

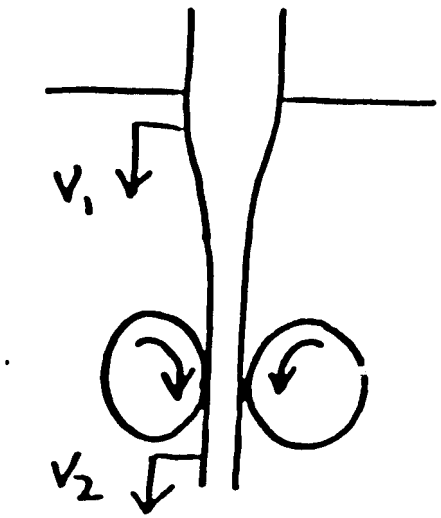
Thermoplastic Processes – Fiber Drawing

- Fiber drawing (E.g., nylon)

1) extrude molten resin

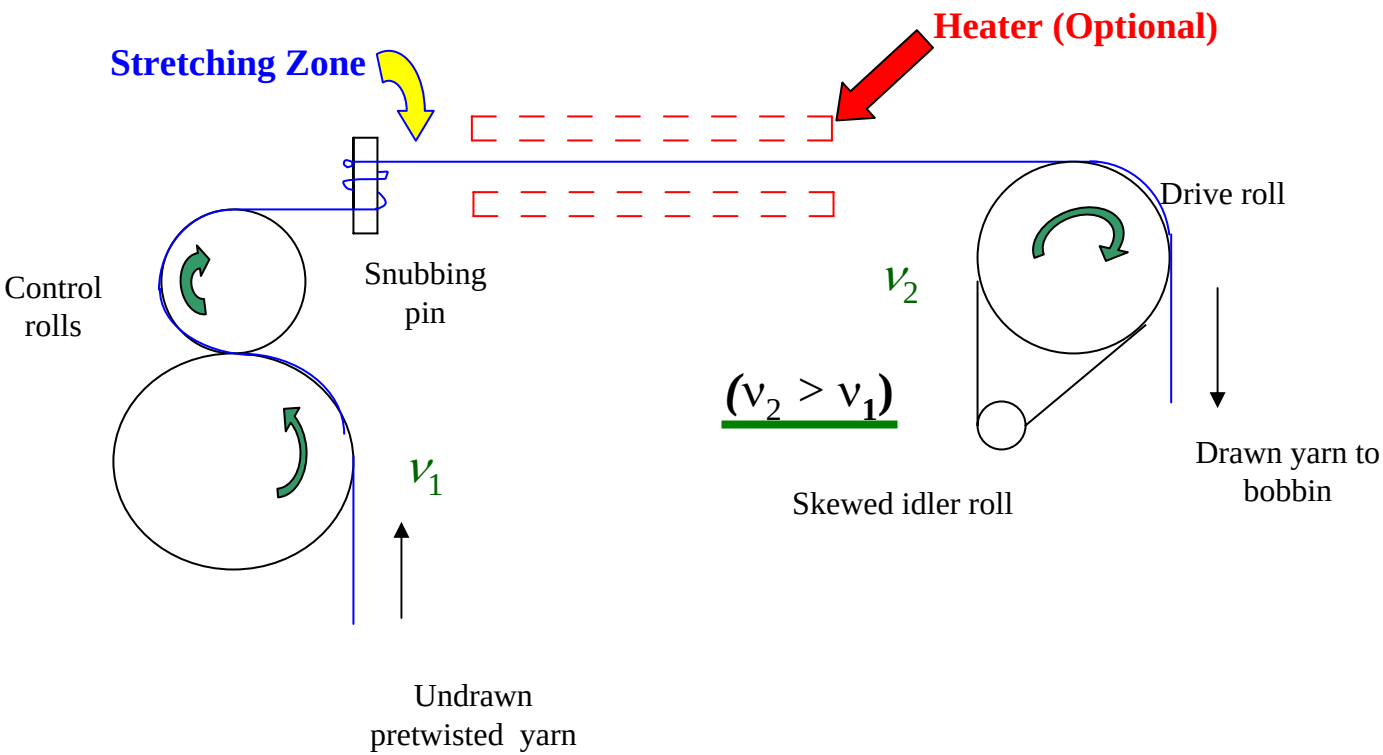
2) stretch and cool

3) pull through rolls



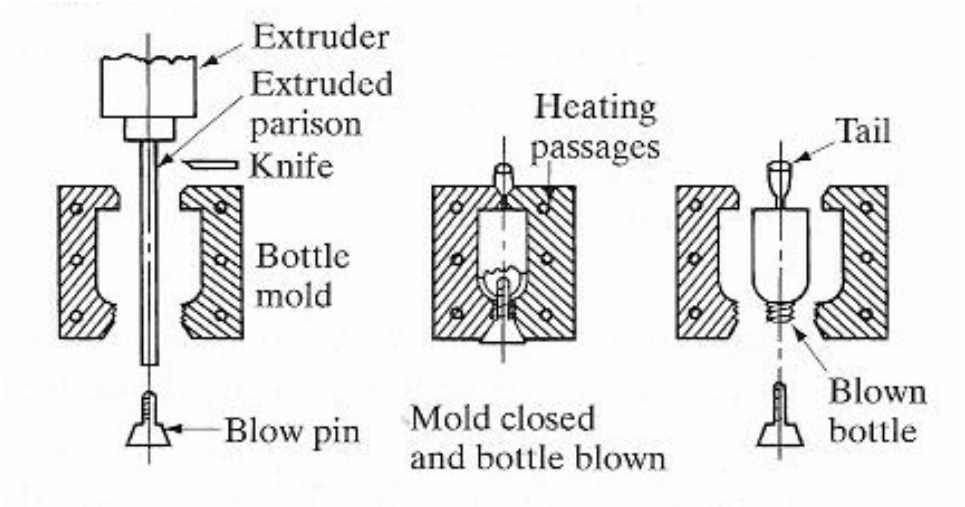
$V_2 > V_1$

Thermoplastic Processes – Fiber Drawing



Redrawn by Nadia Edwin from Billmeyer 18-5 (Riley 1956)

Thermoplastic Processes – Blow Molding



A) Extrude parison
B) Close mold
C) Blow and cool
(parison thins as it stretches)
D) Eject

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.

Thermoplastic Processes – Thermoforming

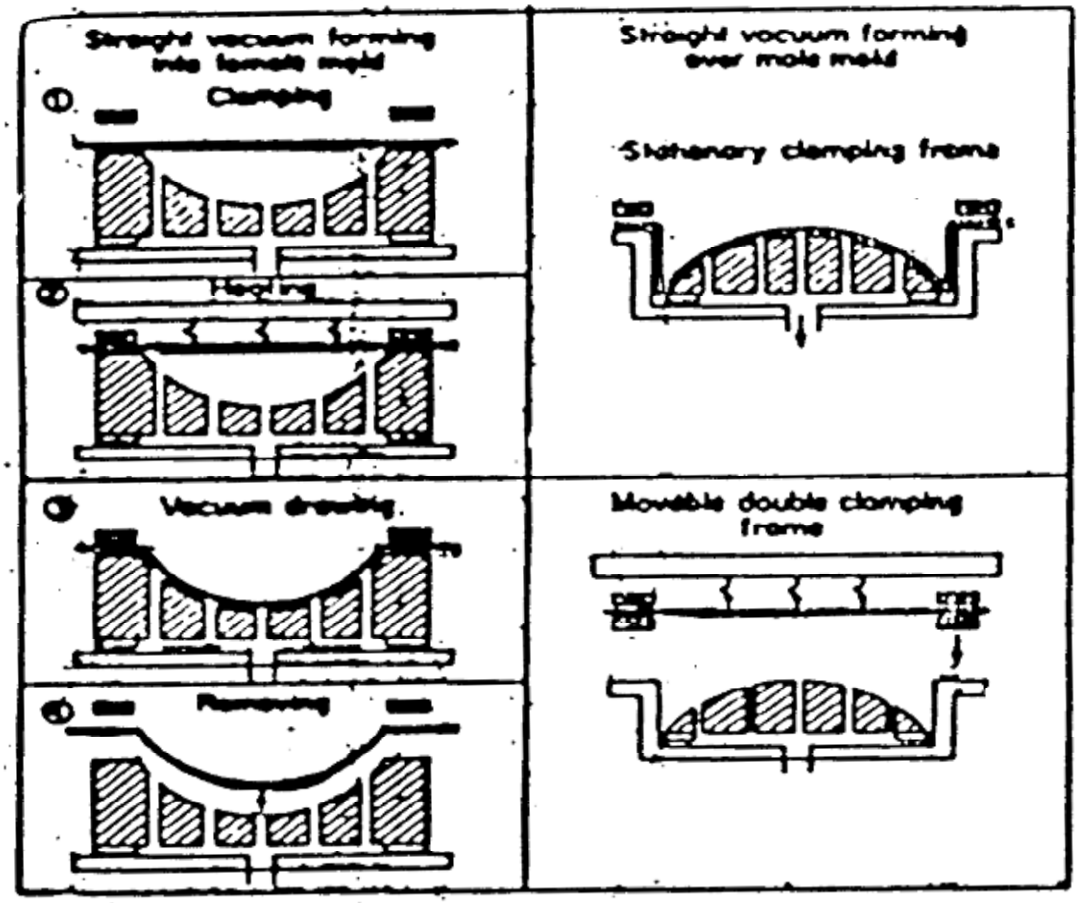
Thermoforming (for shaping thermoplastic sheets)
- Eg. fender liners, bubble food packages

1) clamp

2) heat

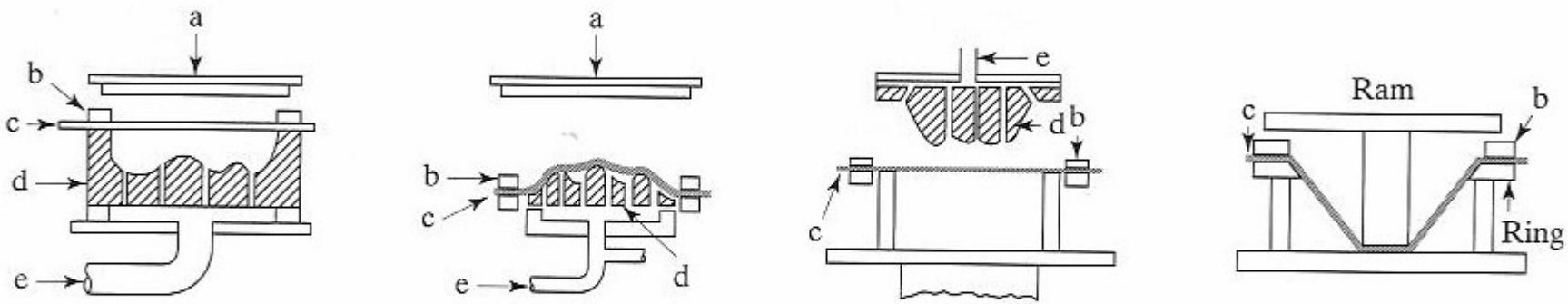
3) vacuum draw

4) remove



Thermoplastic Processes – Thermoforming

FIGURE 18.11 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.



1. Straight vacuum forming

2. Drape vacuum forming

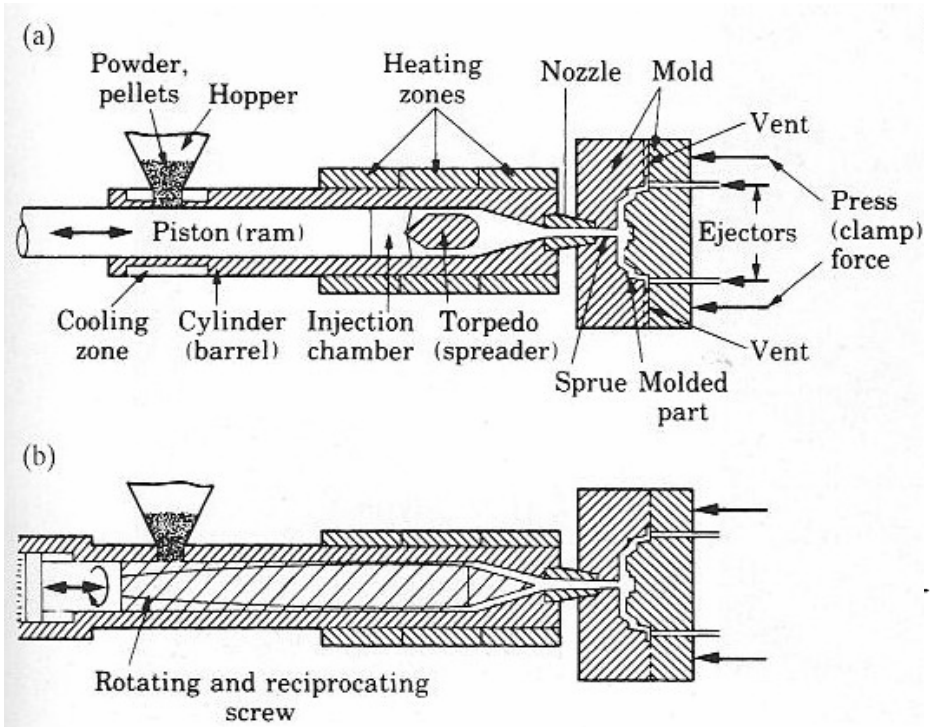
3. Force above sheet

4. Plug and ring forming

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

Thermoplastic Processes – Injection Molding

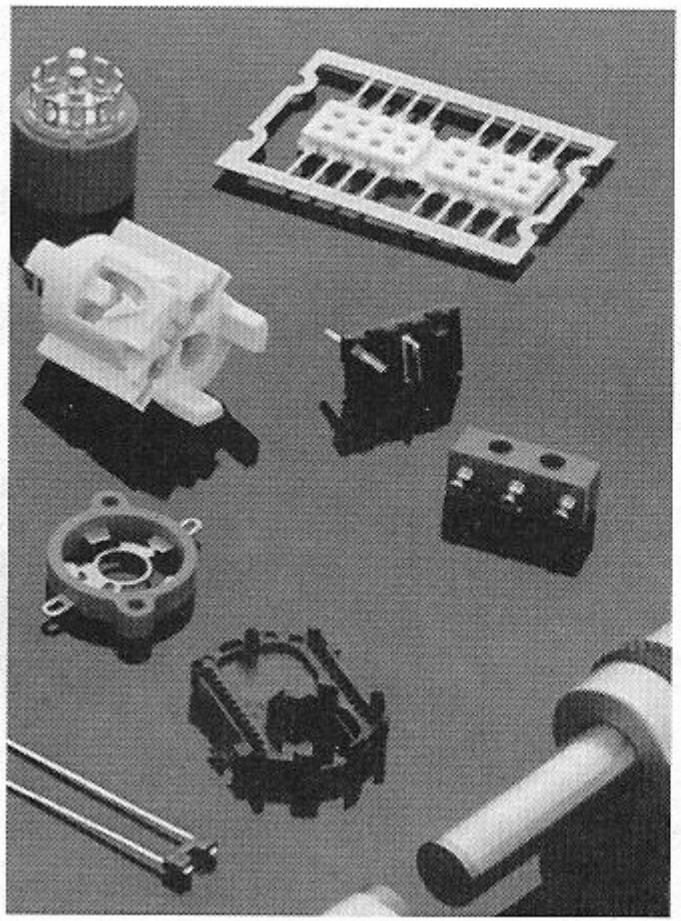
Injection Molding (thermoplastic shapes of all kinds) polymer version of die casting, high speed



1) ram "sucks" pelletized plastic from hopper into cylinder
2) ram pushes charge into heating chamber
3) plastic melts
4) ram again pushes molten plastic through nozzle into mold
5) pressure maintained until piece is solid
6) part ejected from mold

FIGURE 18.5 Injection molding with (a) plunger, (b) reciprocating rotating screw, (c) a typical part made from an injection molding machine cavity, showing a number of parts made from one shot; note also mold features such as sprues, runners. and gates.

Thermoplastic Processes – Injection Molding

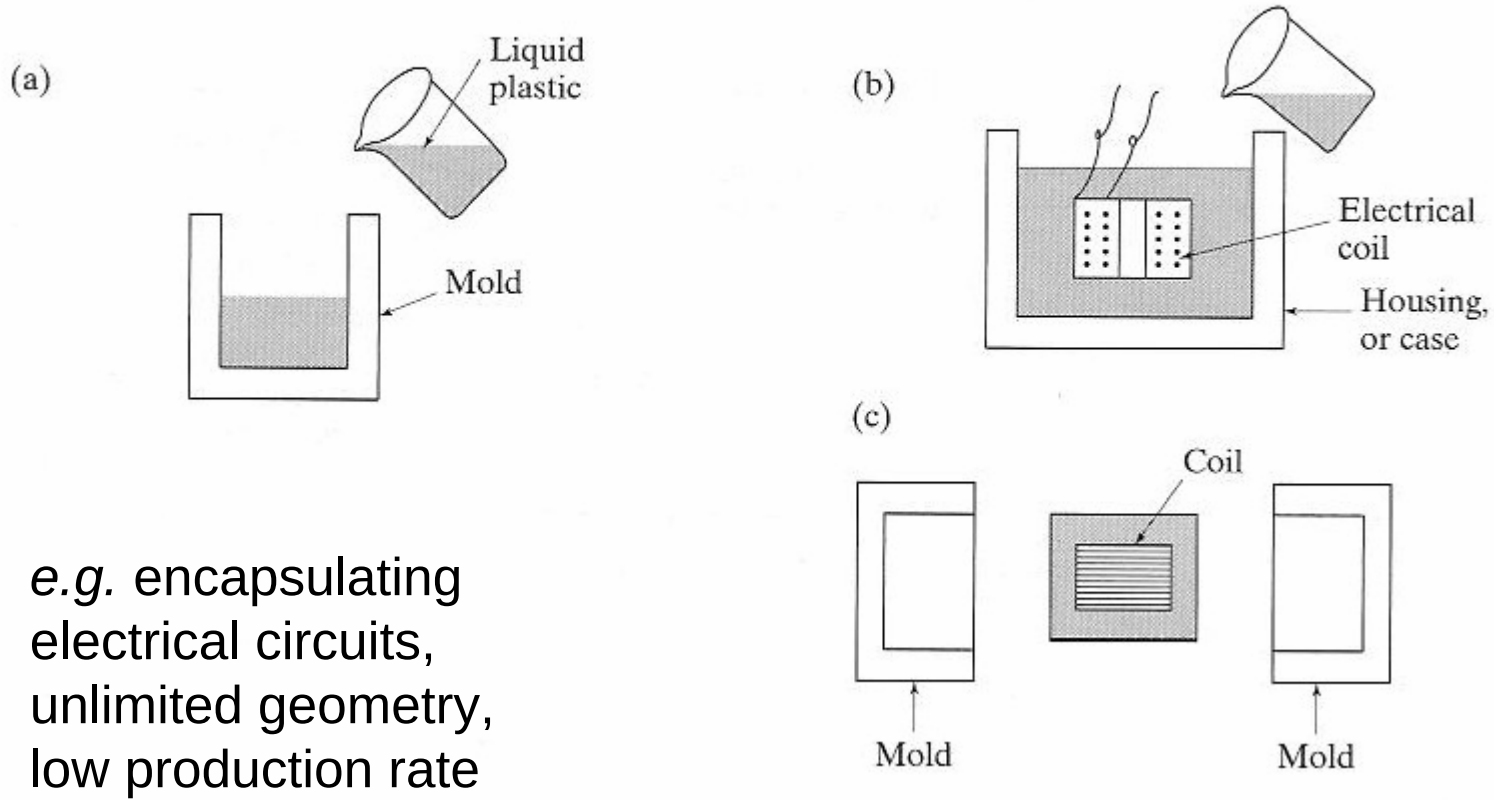


Insert molding - Metallic components, such as screws, pins and strips, can also be placed in the mold cavity and become an integral part of the injection-molded product. The most common examples of such combinations are electrical components.

FIGURE 18.6 Typical products made by injection molding, including examples of insert molding. *Source*: Plainfield Molding Inc.

Thermoset Processes – Casting

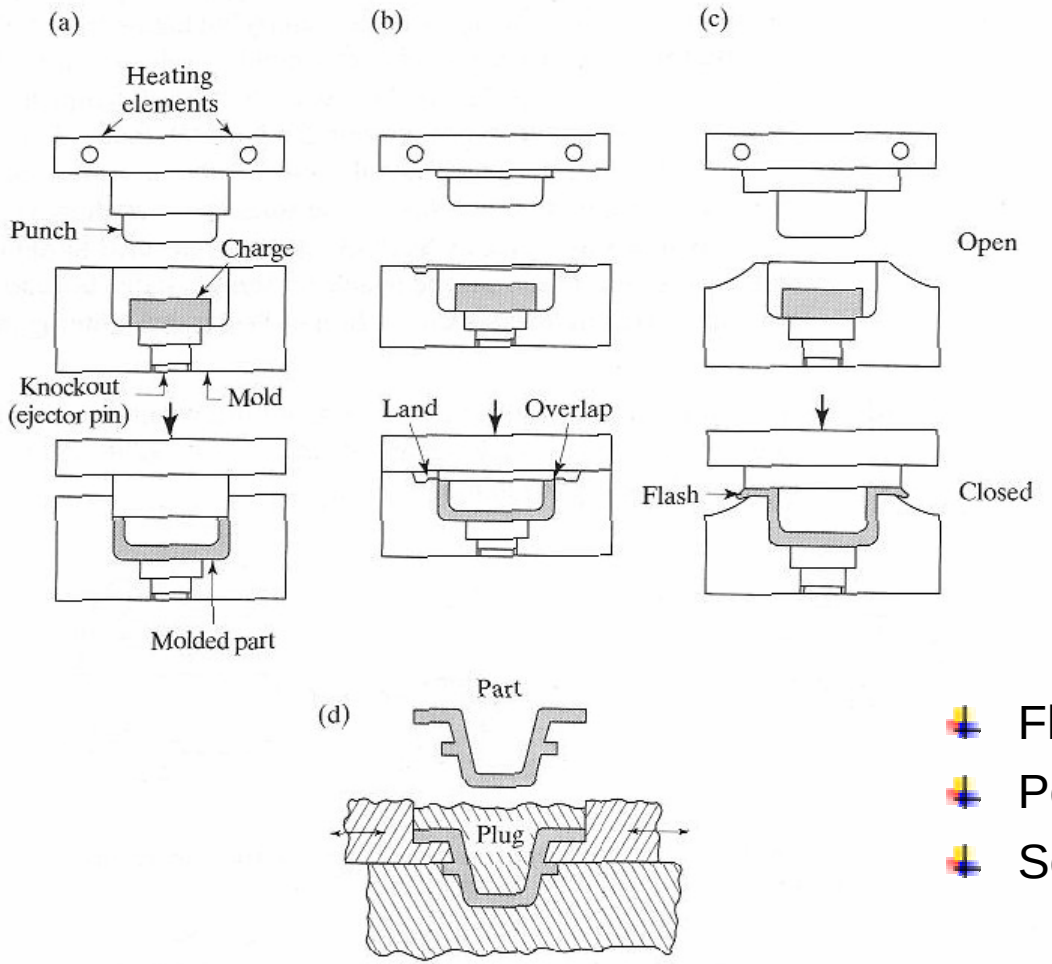
FIGURE 18.14 Schematic illustration of (a) casting, (b) potting, (c) encapsulation of plastics.



- *e.g.* encapsulating electrical circuits, unlimited geometry, low production rate

Thermoset Processes – 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.



1) heat polymer charge (solid

- **(maybe melt)**

2) push dies together (plunger enters mold cavity)

3) polymer thins and extends to fill cavity (flash forced out and cut off)

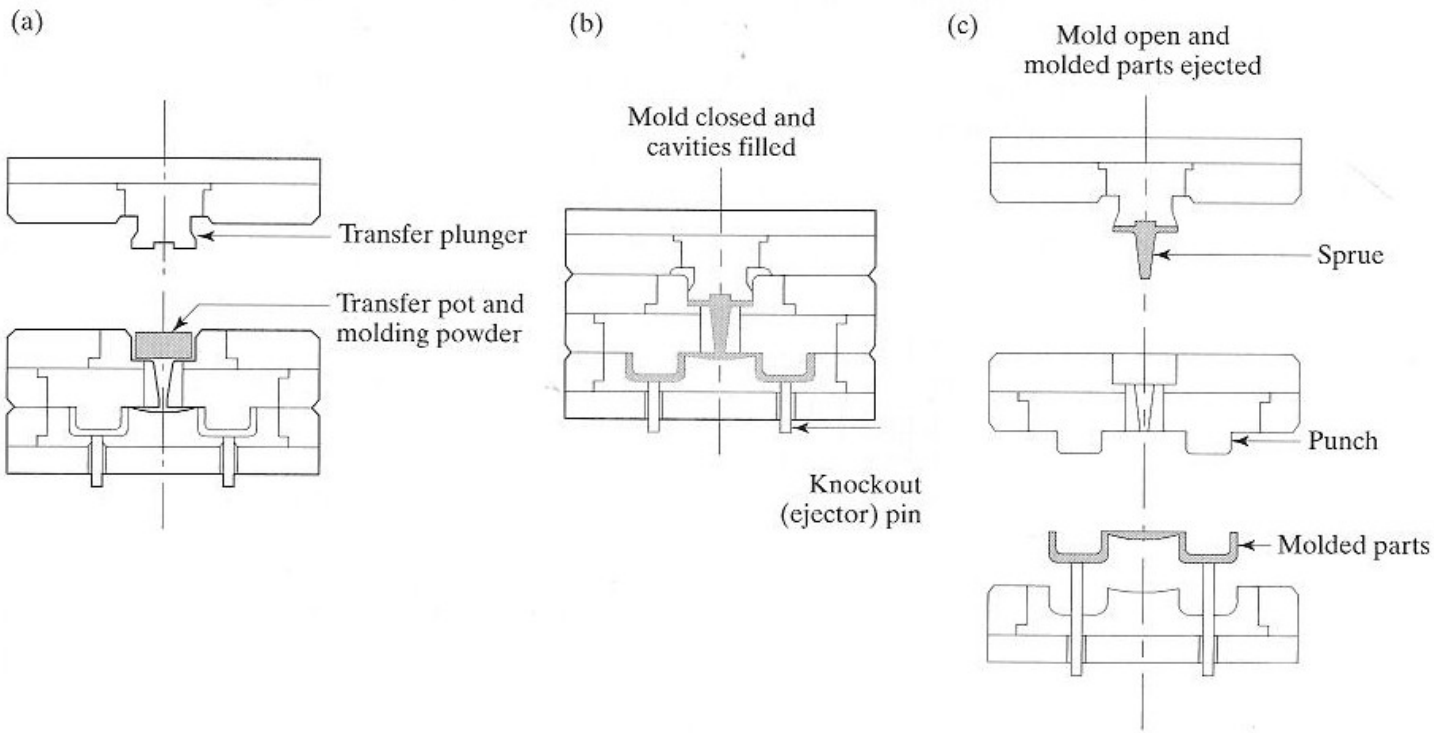
4) polymer solidifies or vitrifies at same time (like squeeze casting)

- Flash-type, for shallow or flat parts
- Positive, for high density parts
- Semipositive, for quality production

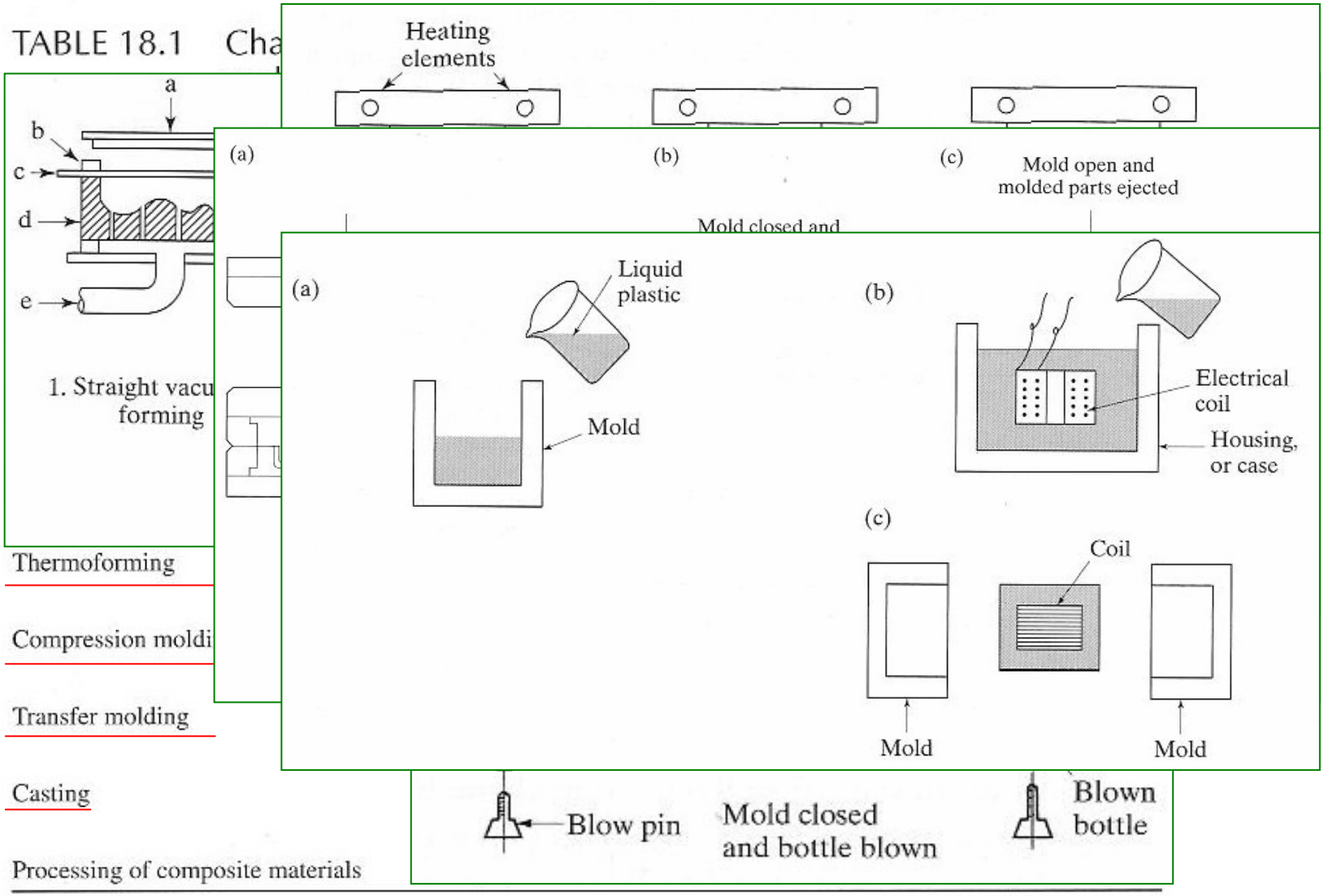
Thermoset Processes – Transfer Molding

- Combination of compression molding and injection molding.
- Used for making electrical and electronic components.

FIGURE 18.13 Sequence of operations in transfer molding for thermosetting plastics. This process is particularly suitable for intricate parts with varying wall thickness.



Polymer Processing – Brief Review



- Thanks for your patience.