한국생산기술연구원/

포장기술종합지원센터

포장재 제조를 위한 고분자가공

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고분자 가공

Polymer processing is an engineering specialty concerned with the operations carried out on polymeric materials or systems to increase or improve the material's utility.

Molecular Design -> Monomer -> Polymer

(Design to achieve functions) (Polymerization)

-> Polymer conversion operation -> Product

(Polymer Processing) (for human beings)

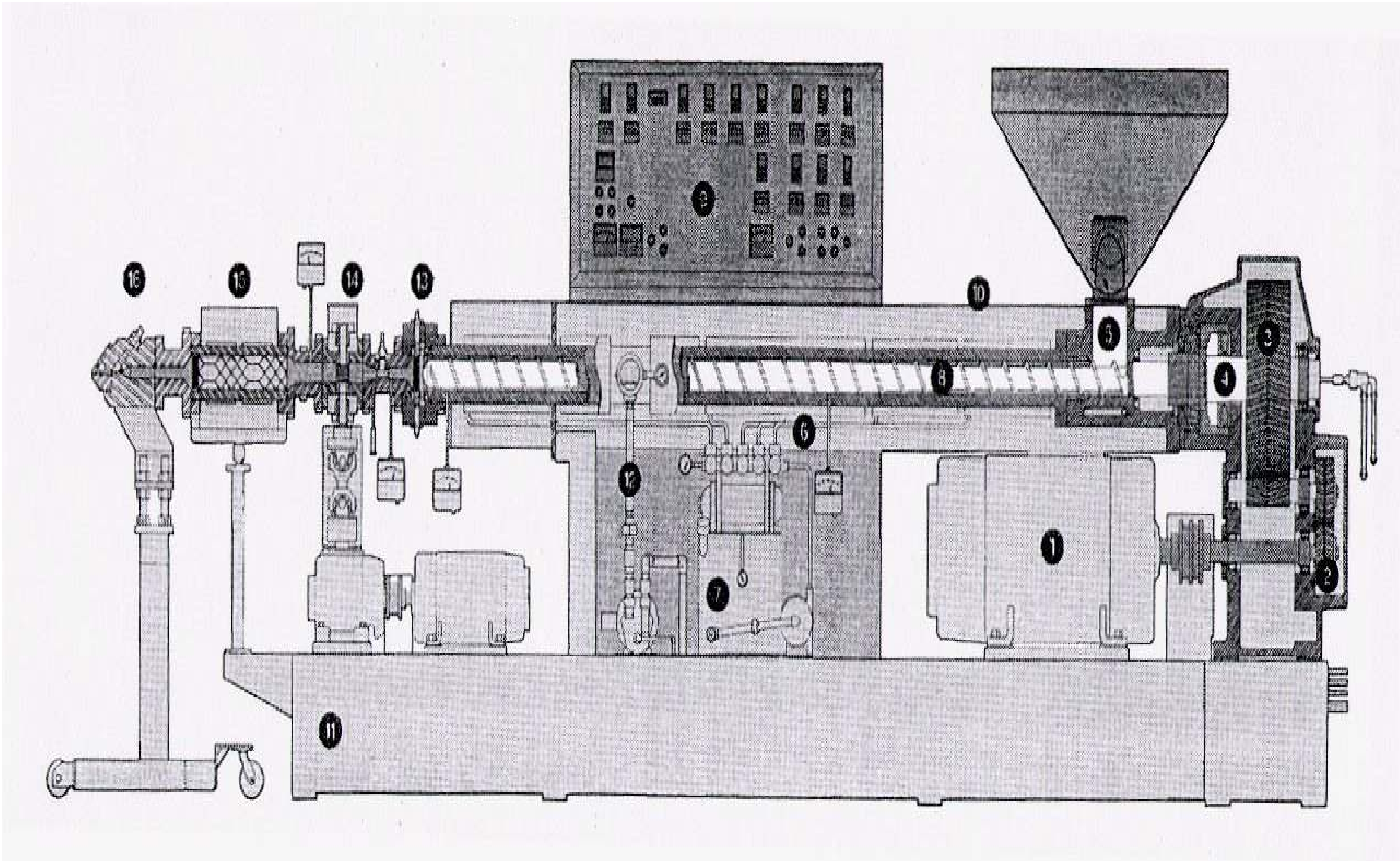


Figure 2.2 Schematics of a Welex extruder.

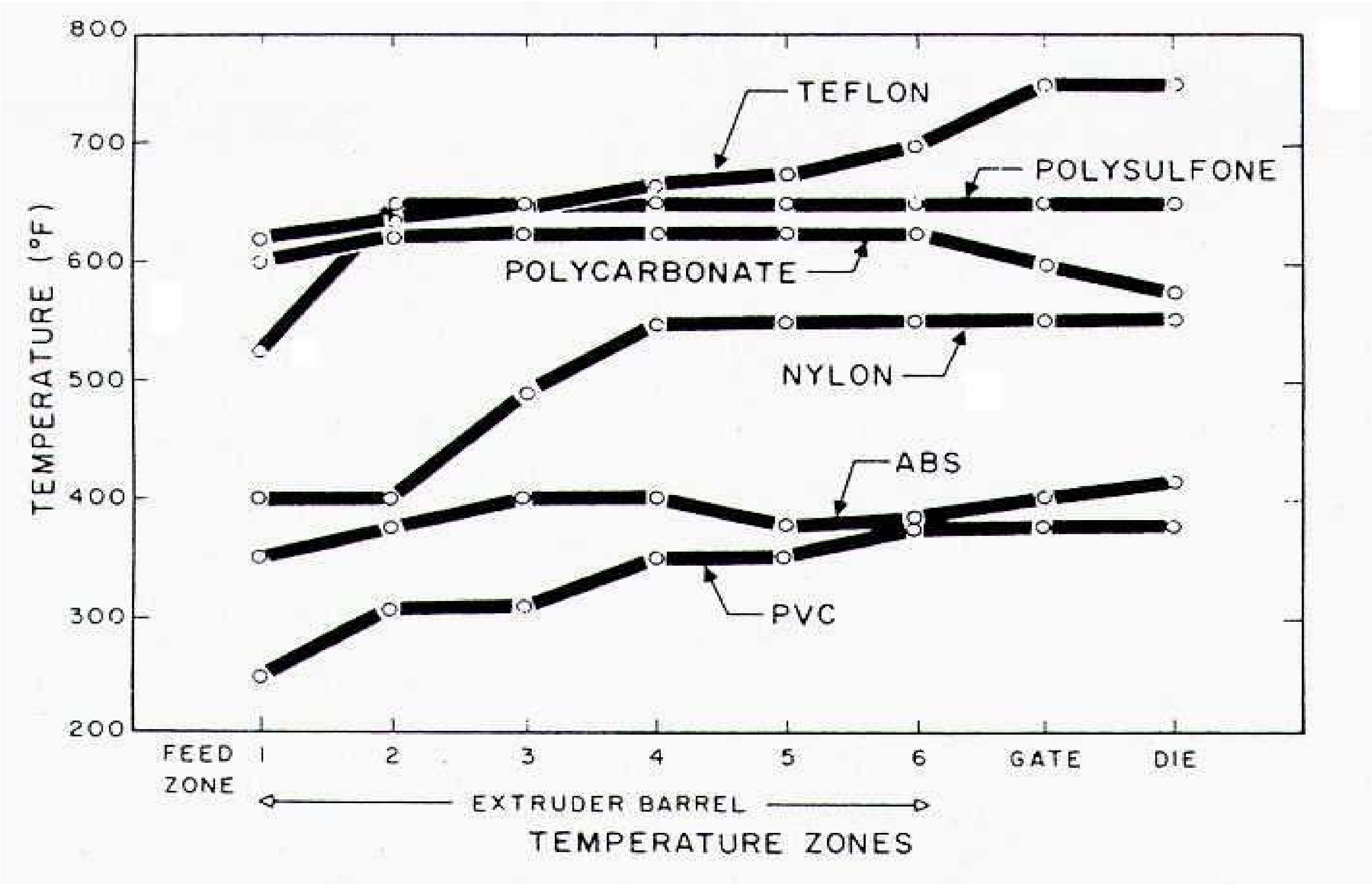


Figure 1.8 Temperature profiles of different plastics going through an extruder.

- Thermoplastic polymer:
- Thermosett polymer:

- Conversion operation:
  - Flow of polymer (Injection Molding, Extrusion)
  - Chemical reaction (Reaction IM, Thermosett)
  - Permanent change in physical properties (Thermosett)

Classification of Polymer Conversion Operation

1. Forming operation

   (Injection Molding, Extrusion, Calendering, Thermoforming, Blow molding)

   a. Physical change only (IM, Extrusion)

   b. Chemical change only (Casting of caprolactam)

   c. Physical + Chemical change

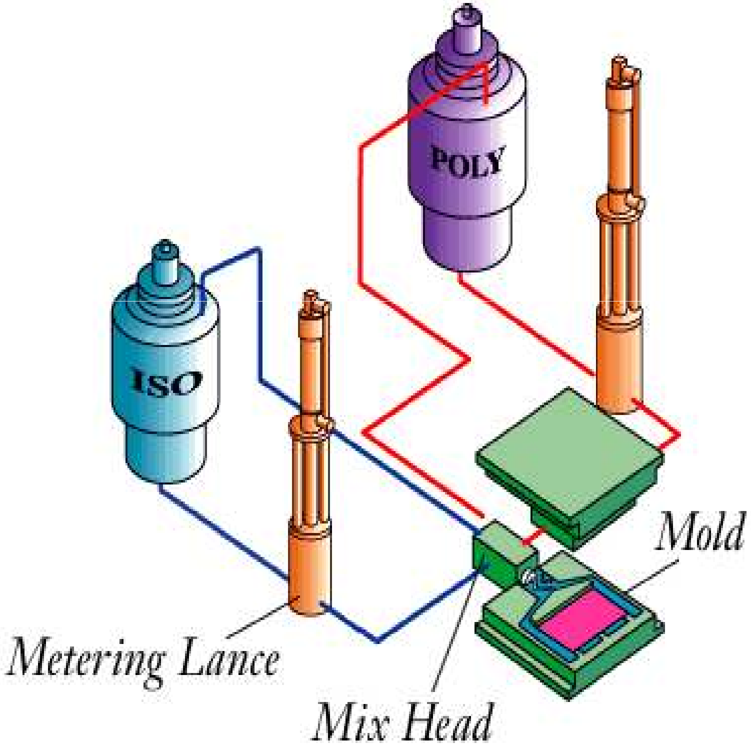
      – Reaction Injection molding (RIM)

      – IM of thermoset (Heat + Pressure)

      – Compression modling of thermosetts

        (Heat + Pressure (slow))

Reaction Injection Molding (RIM)



2. Bonding Operation

Cohesion: Both sides of the interface become molten during the sealing (bonding) operation

(PE/PE garbage bag heat sealing)

Adhesion: One side of the interface becomes molten during the bonding operation

(PE/paper, PE/Al foil)

Adhesion mechanism

1. Chemical bonding (intermolecular attraction forces)

   Plastic/Glass, Plastic/Metal, crazy glue

2. Mechanical adhesion

   One-side is coarse or rough, allow penetration of the adhesion

3. Modification Operation

– Mixing

1. Spatial mixing (randomization of the components)
2. Dispersive mixing

(Reduce the size of the ingradients,
usually involves heat and pressure;
Extruder, Two roll mill, Banbury mixer, not IM)

– Surface modification (Silverstone, Plasma, Corona, E-beam..)

– Polymer chain modification

Orientation (chain alignment)
Crystallization

- Amorphous polymer: No ordered structure
  - Polystyrene, Polycarbonate, Acrylics, PPO..
- Crystalline polymer: ordered structure
  - PET, HDPE, LDPE, LLDPE, Polypropylene, Nylon, PTFE..

Table 25-1 Structures of common polymers.

- High-density polyethylene
- Low-density polyethylene
- Ionomer
- Ethylene/vinyl acetate copolymer
- Polypropylene
- Polystyrene
- Styrene/acrylonitrile copolymer
- Impact styrene
- Acrylonitrile/butadiene/styrene terpolymer (ABS)
- Polyvinyl chloride
- Vinyl chloride/vinyl acetate copolymer
- Polyvinylidene chloride
- Polytetrafluoroethylene
- Fluorinated ethylene/propylene copolymer
- Polychlorotrifluoroethylene
- Polyvinylidene fluoride

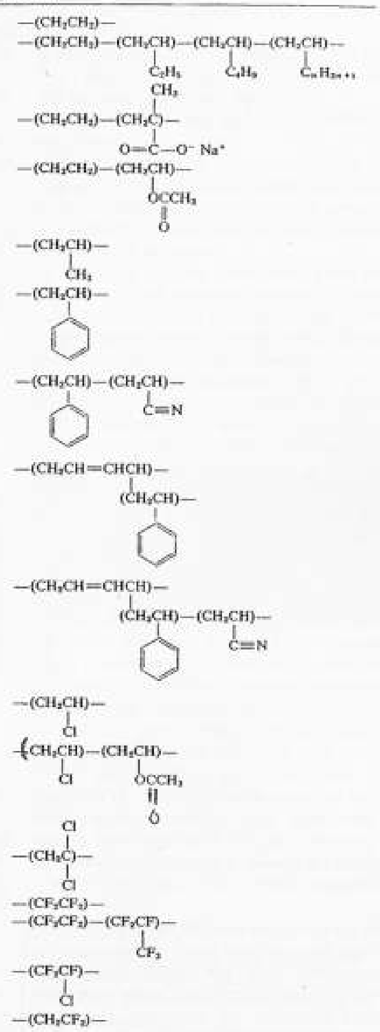


Table 25-1 (continued)

- Polymethyl methacrylate
- Polyacrylonitrile
- Phenoxy resin
- Epoxy resin
- Poly(2,6-dimethylphenylene oxide) (PPO)
- Polysulfone
- Polyoxymethylene (acetal)
- Cellulose triacetate
- Ethyl cellulose
- Polycarbonate
- Poly(ethylene terephthalate)
- Unsaturated polyester (cured)

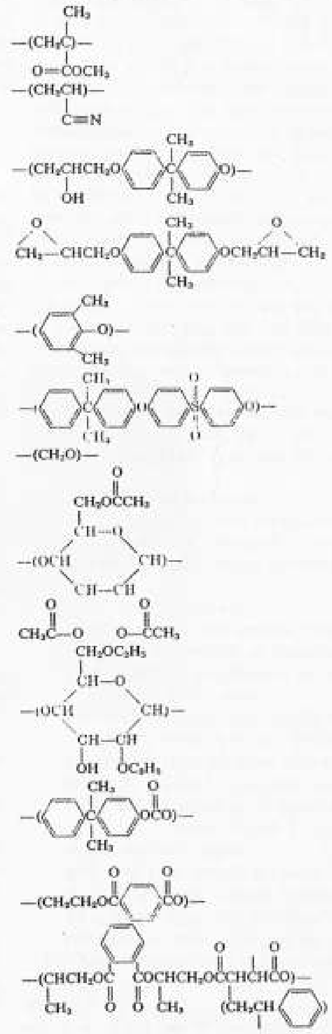


Table 25-1 (continued)

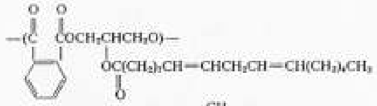
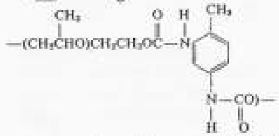
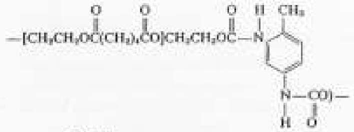
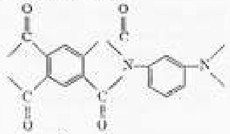
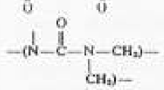
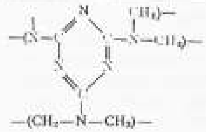
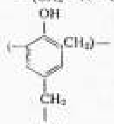
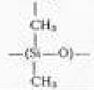
Diallyl phthalate	
Alkyd	
Polyether polyurethane	
Polyester polyurethane	
Nylon 6	
Nylon 66	
Nylon 610	
Nylon 11	
Nylon 12	
Polyimide	
Urea-formaldehyde	

Table 25-1 (concluded)

Melamine-formaldehyde	
Phenol-formaldehyde	
Silicone	

고분자가공물의 물성에 영향을 미치는 인자들

– Crystallinity

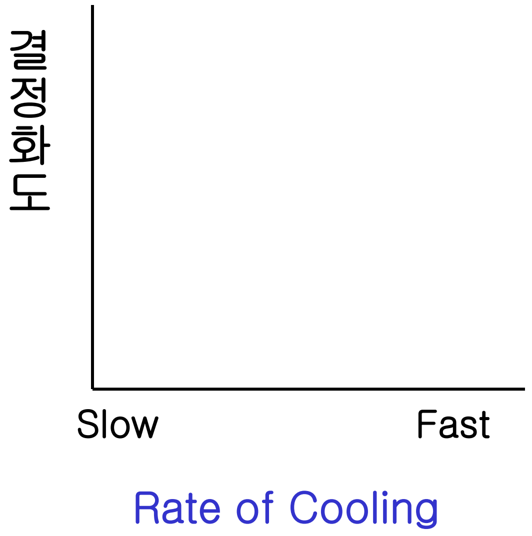
A) Time dependent

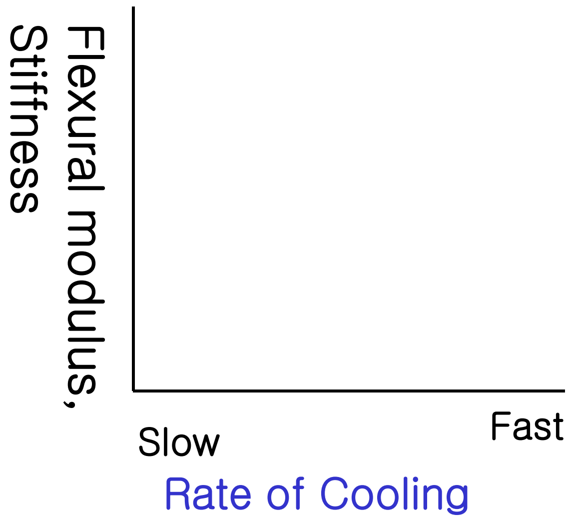
Growth of crystalline region, Rate of cooling, Mold temperature,
Water bath temperature, Blown film cooling temperature

B) Temperature dependent

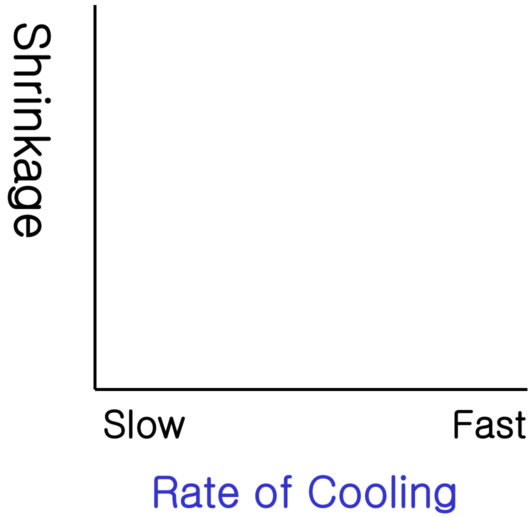
Melt state ---------------------------------→ solid

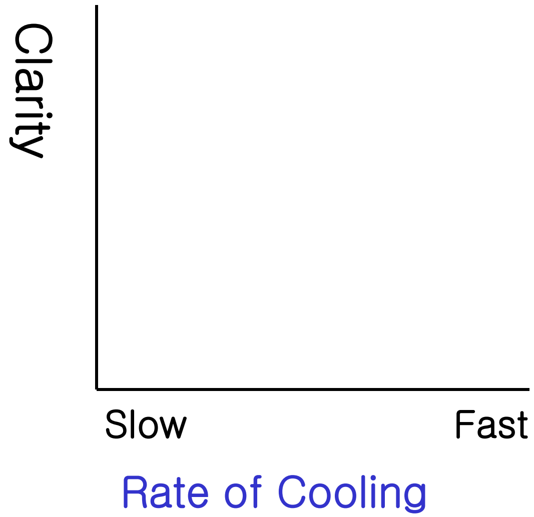
(Processing temp, Rate of cooling Property



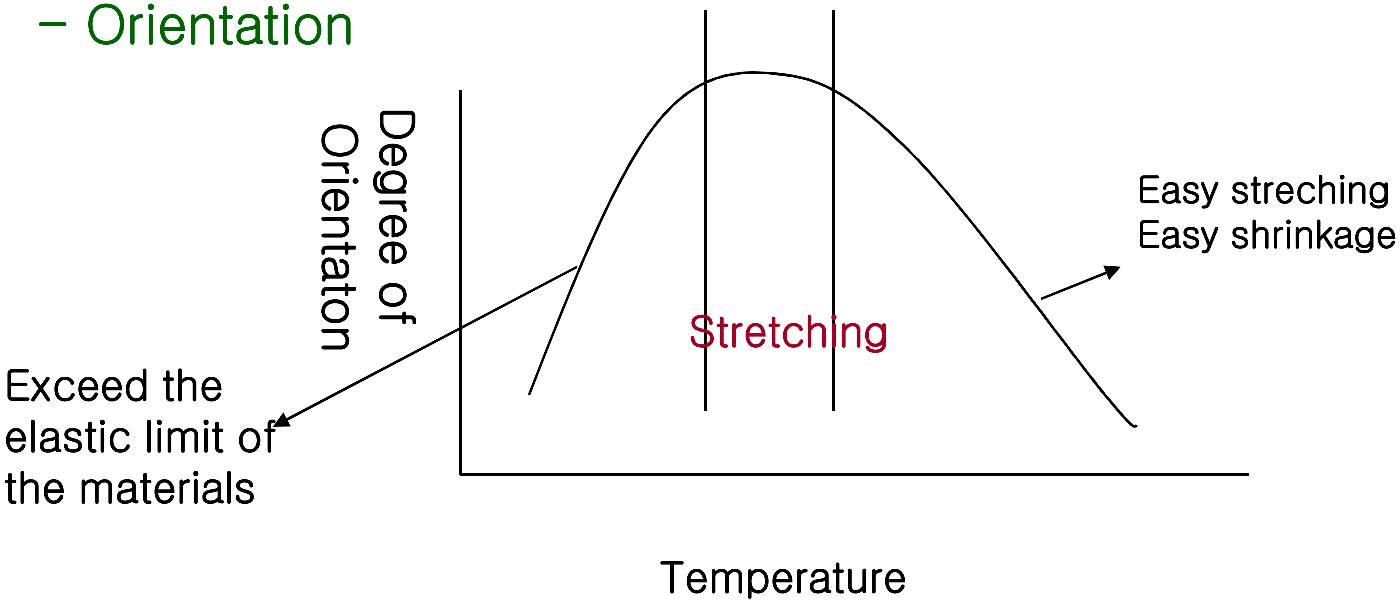


//





– Orientation



Measurement of polymer flow

- Rheology: study of flow properties of Polymer melts

1. Melt indexer (Melt Flow Index, Extrusion Plastometer)

   Most common, economic, not best

Measurement of polymer flow 2

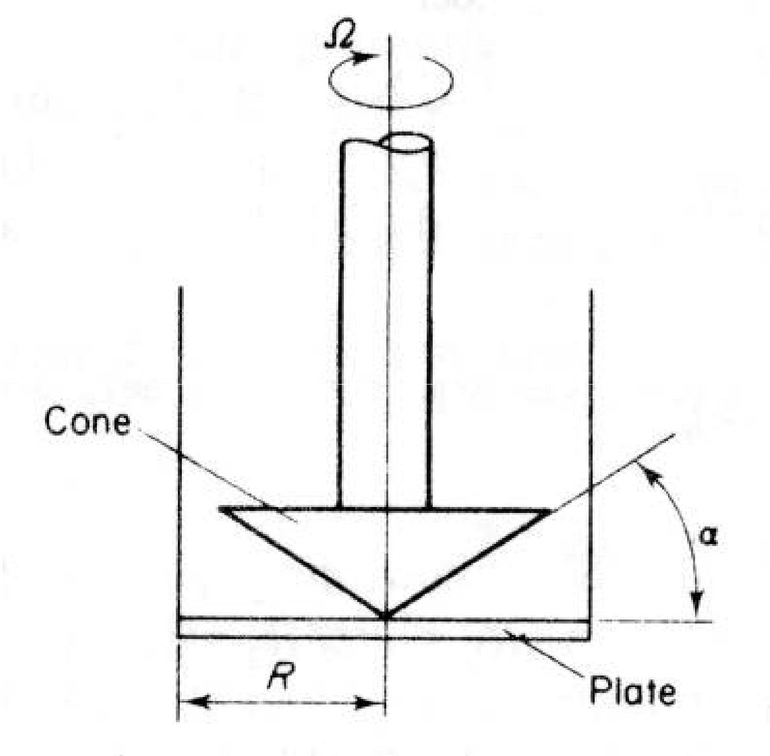
2. Capillary rheometer – Instron, Rosand

    Melt Strength Measurement

3. Brookfield Viscometer (Liquids) – Very low viscosity solution

4. Torque Rheometer – Hakke, Brabender

5. Cone and Plate rheometer – Rheometrics



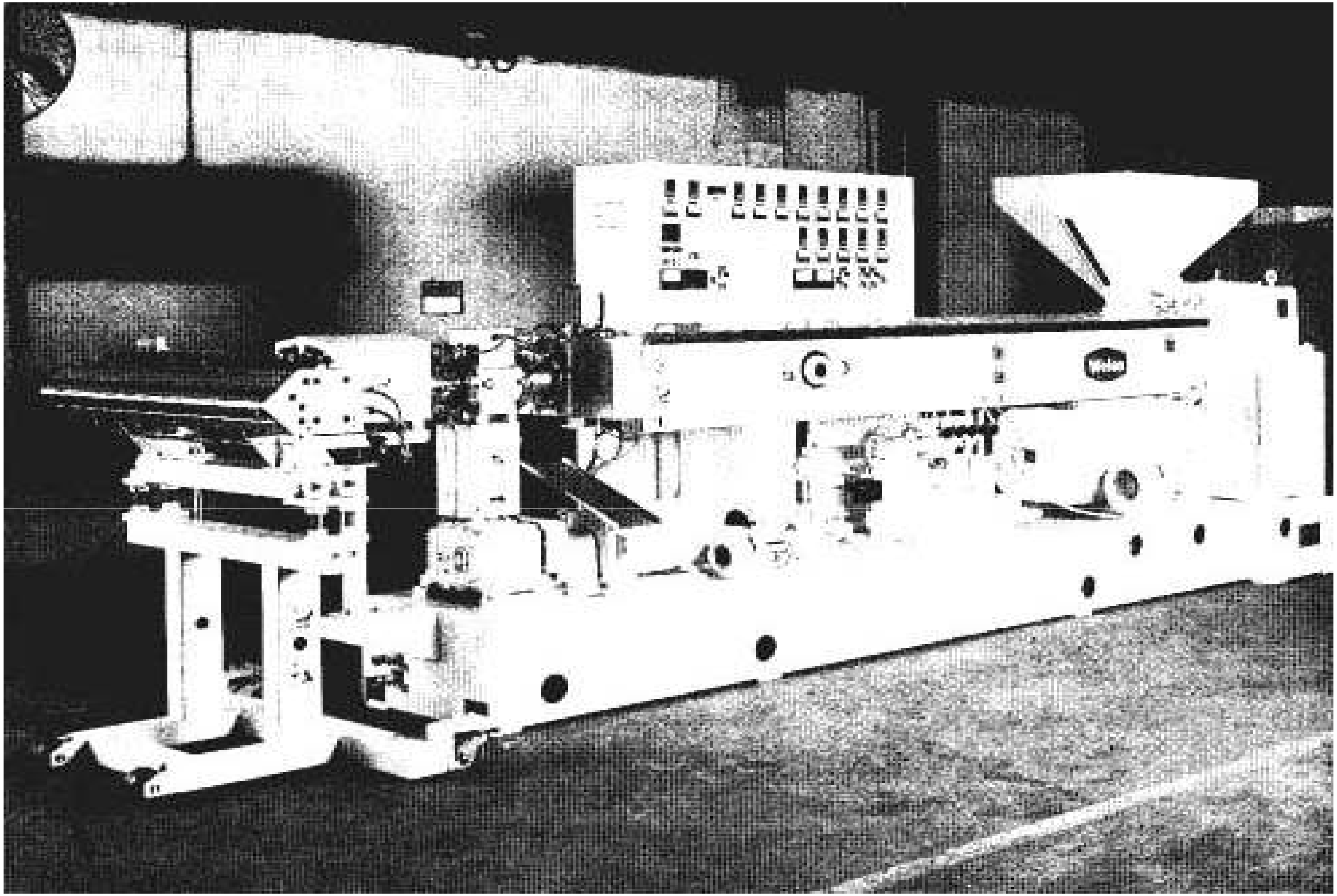


Figure 2.5 Example of Welex extruder with vent hole, screen changer, gear pump, static mixer, and sheet die.

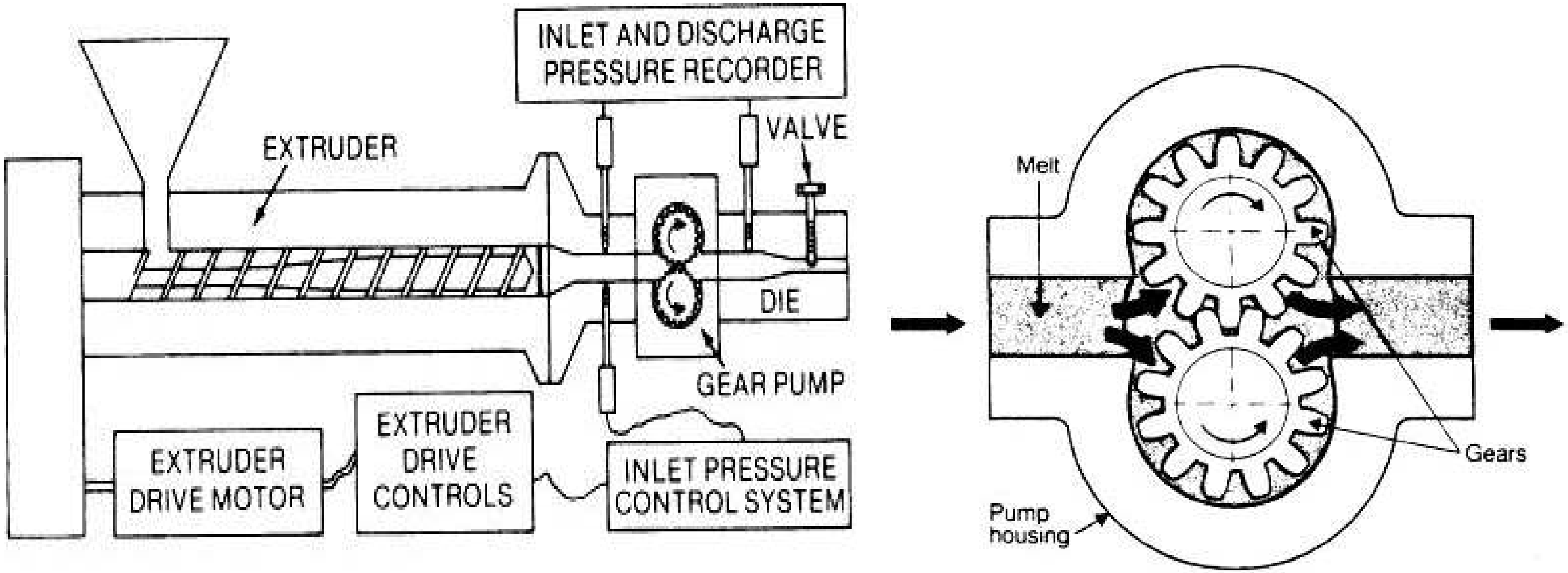


Figure 2.15 Example of gear pump in an extruder.

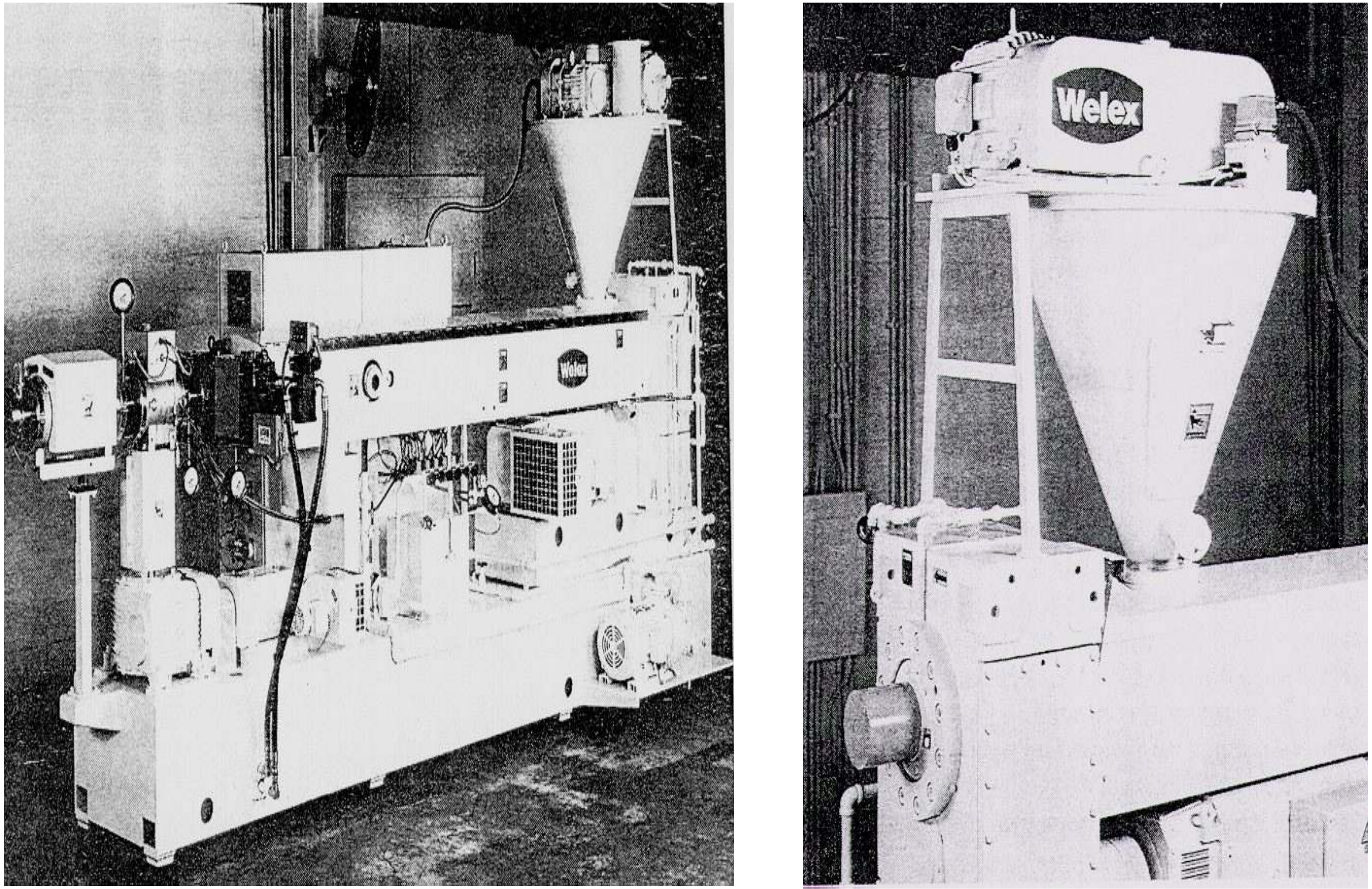


Figure 1.8 Example of a Welex extruder with crammer feeder to handle low bulk density plastics that otherwise are difficult to handle; overview and close-up.

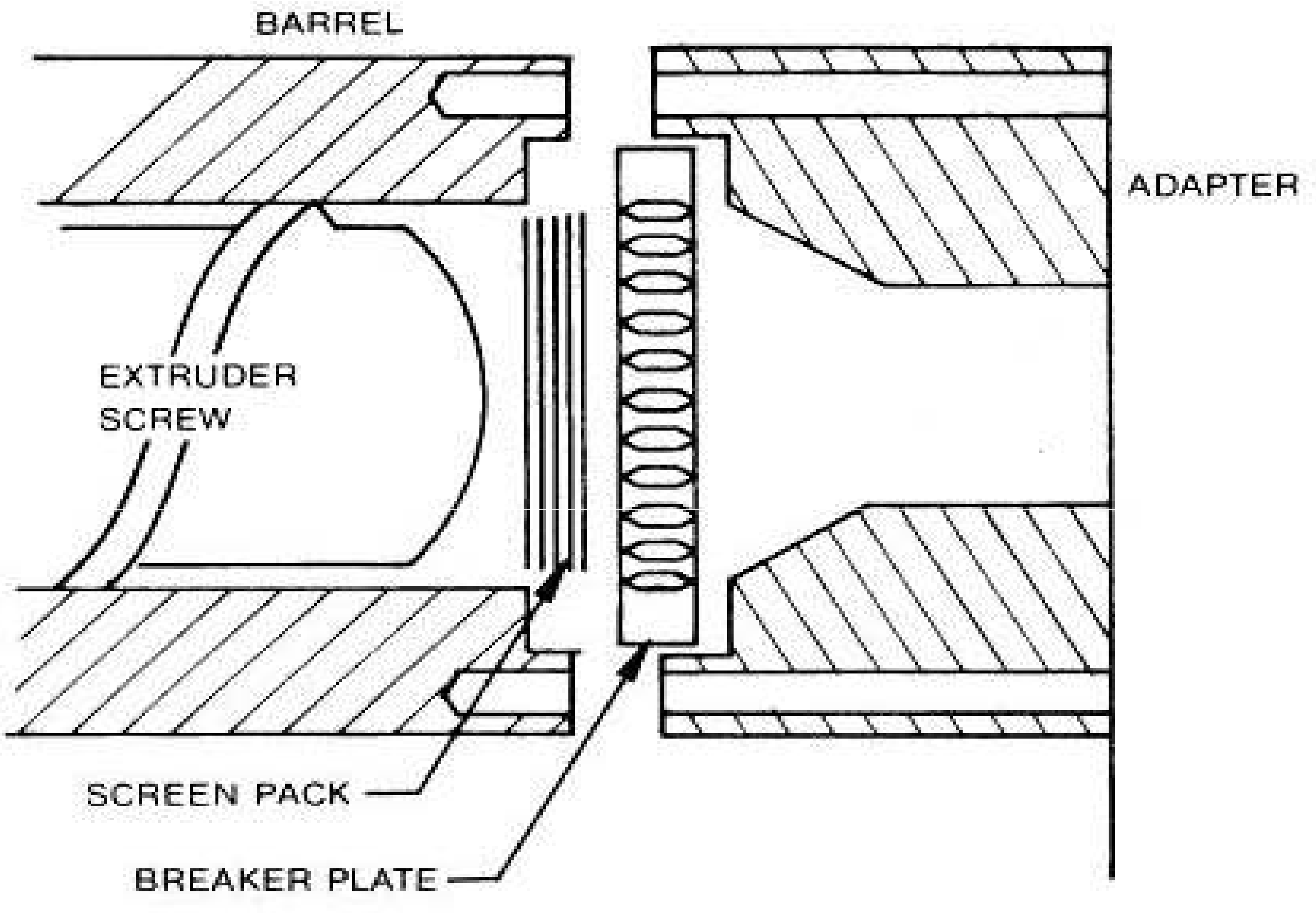


Figure 2.14 Basic layout of a screen pack.

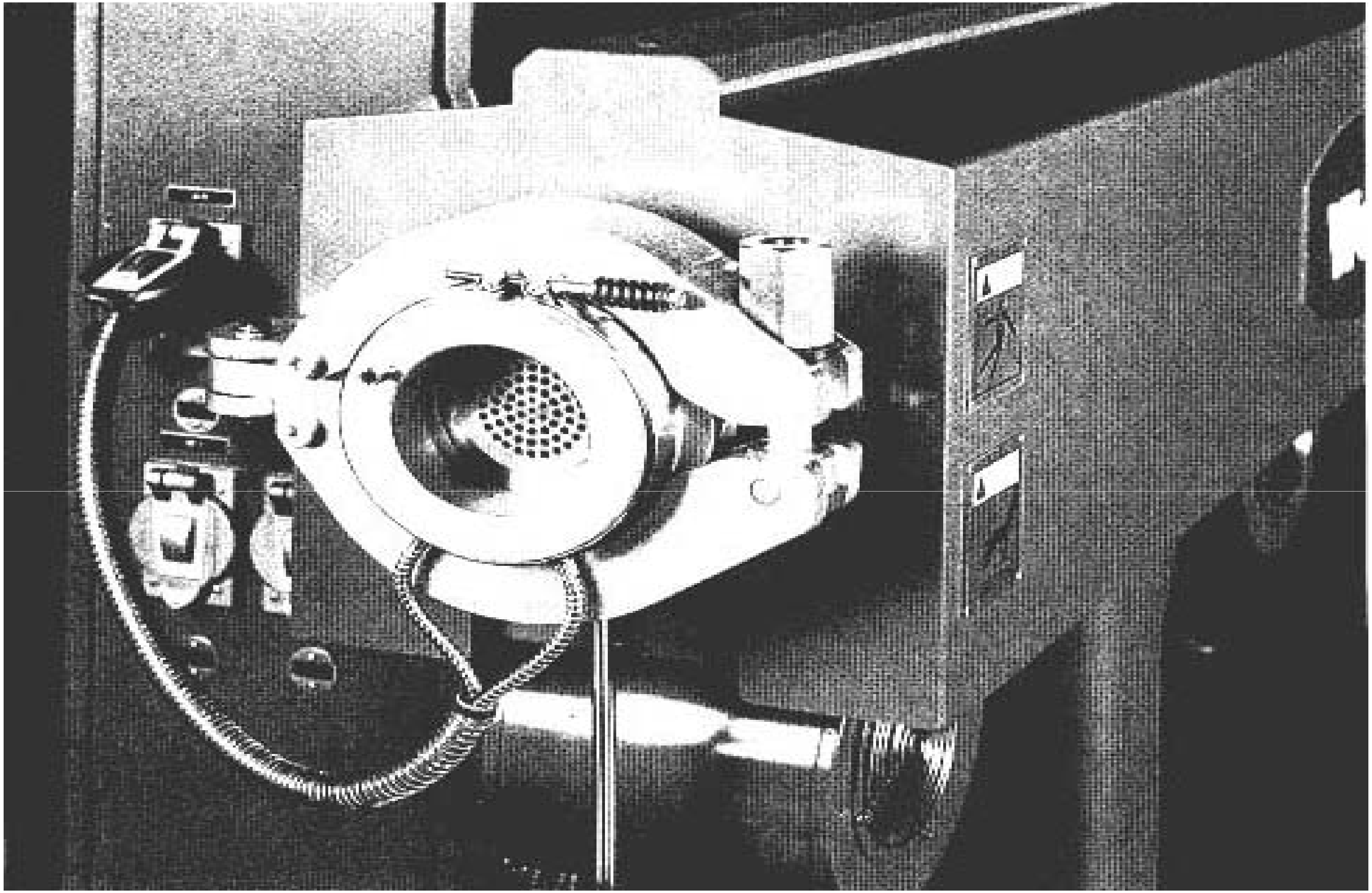


Figure 2.13 Single bolt quick die clamping front end of a Welex extruder with pressure safety bolt.

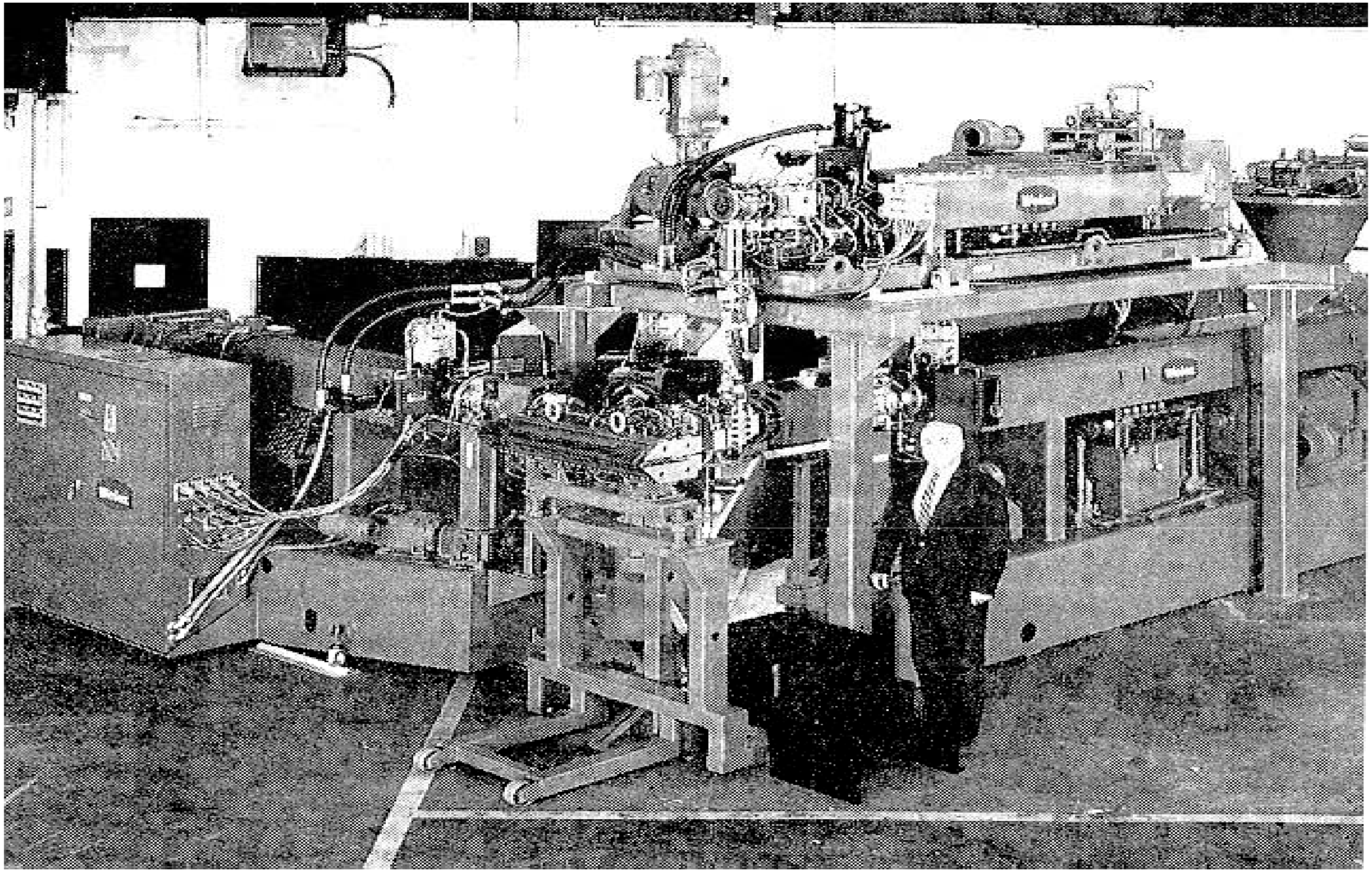


Figure 2.29 Large coextrusion sheet system (hoppers to die) with Frank Nissel, president of Welex Inc. (Blue Bell, PA 19422)and a leader in developing advanced coextrusion lines

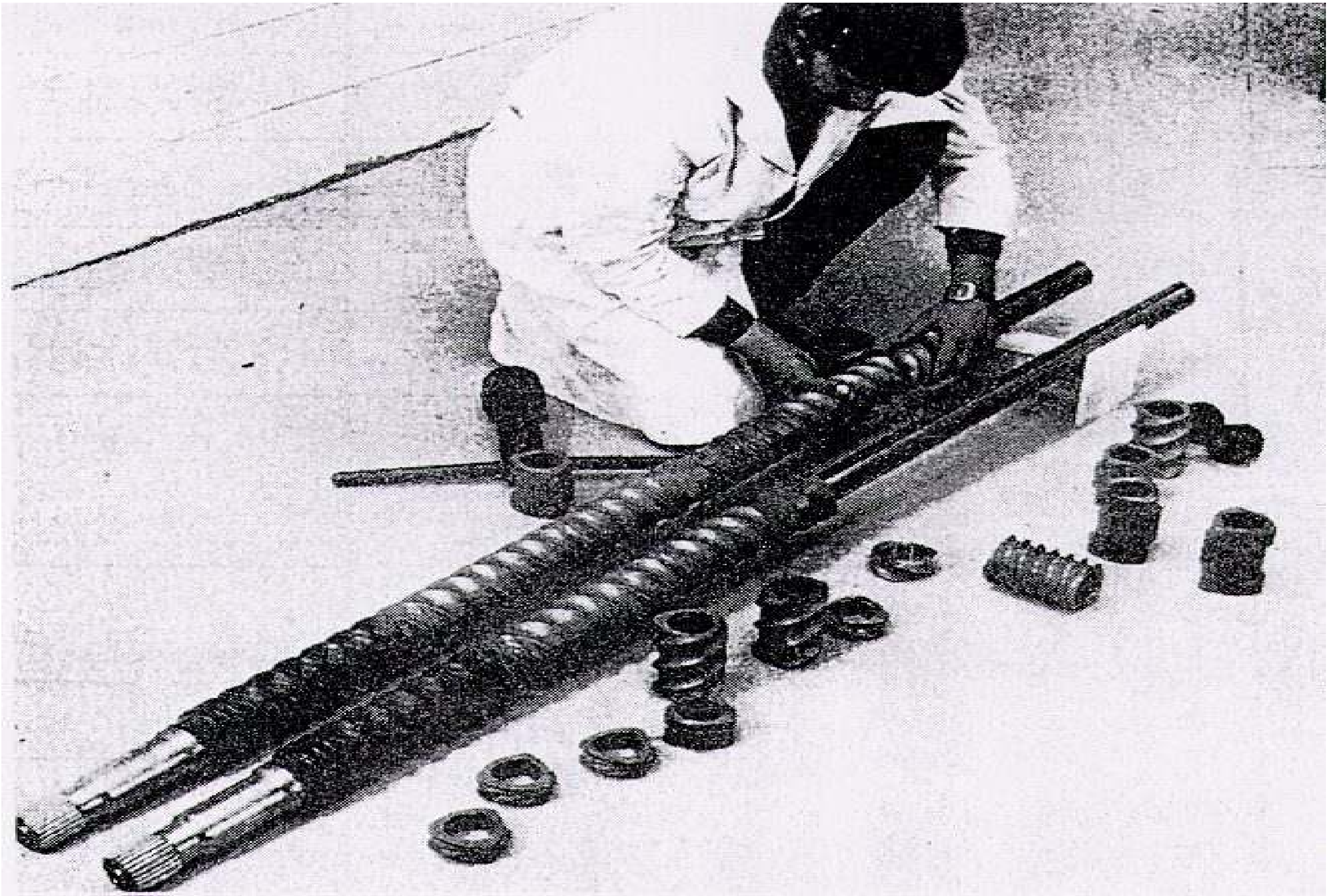
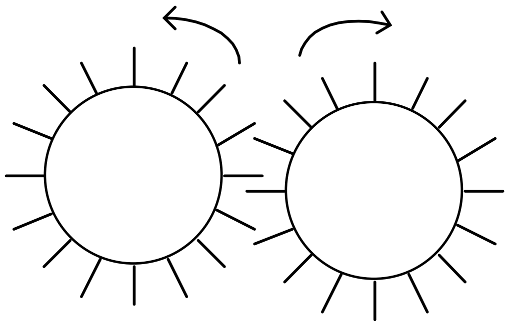


Figure 2.4 A Werner & Pfleider screw assembly offers specialized processing combinations.

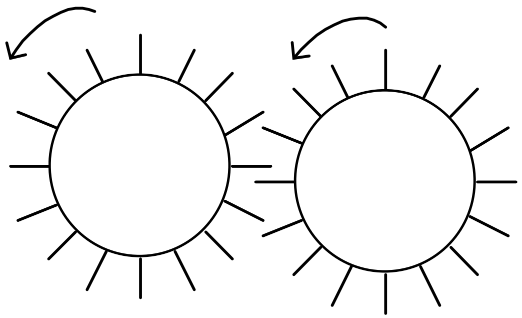
Table 2.1 Comparison of single- and twin-screw extruders

	Single-screw	Twin-screw
Flow type	Drag	Near positive
Residence time and distribution	Medium / wide	Low / narrow (useful for reaction)
Effect of back pressure on output	Reduces output	Slight / moderate effect on output
Shear in channel	High (useful for stable polymers)	Low (useful for PVC)
Overall mixing	Poor / medium	Good (useful for compounding)
Power absorption and heat generation	High (may be adiabatic)	Low (mainly conductive heating)
Maximum screw speed	High (output limited by melting, stability, etc.)	Medium (limits output)
Thrust capacity	High	Low (limits pressure)
Mechanical construction	Robust, simple	Complicated
First cost	Moderate	High

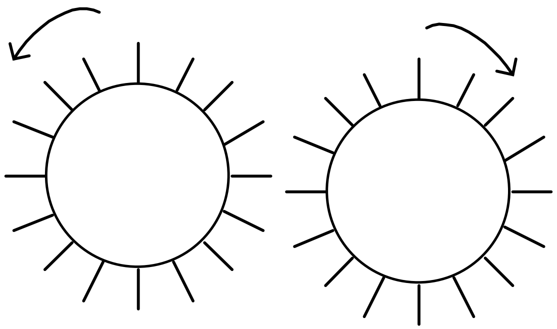
Twin Screw의 종류



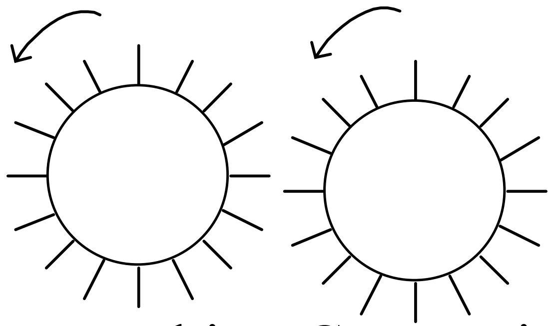
Intermeshing Counter Rotating



Intermeshing Co-rotating



Non meshing Counter Rotating



Non meshing Co-rotating

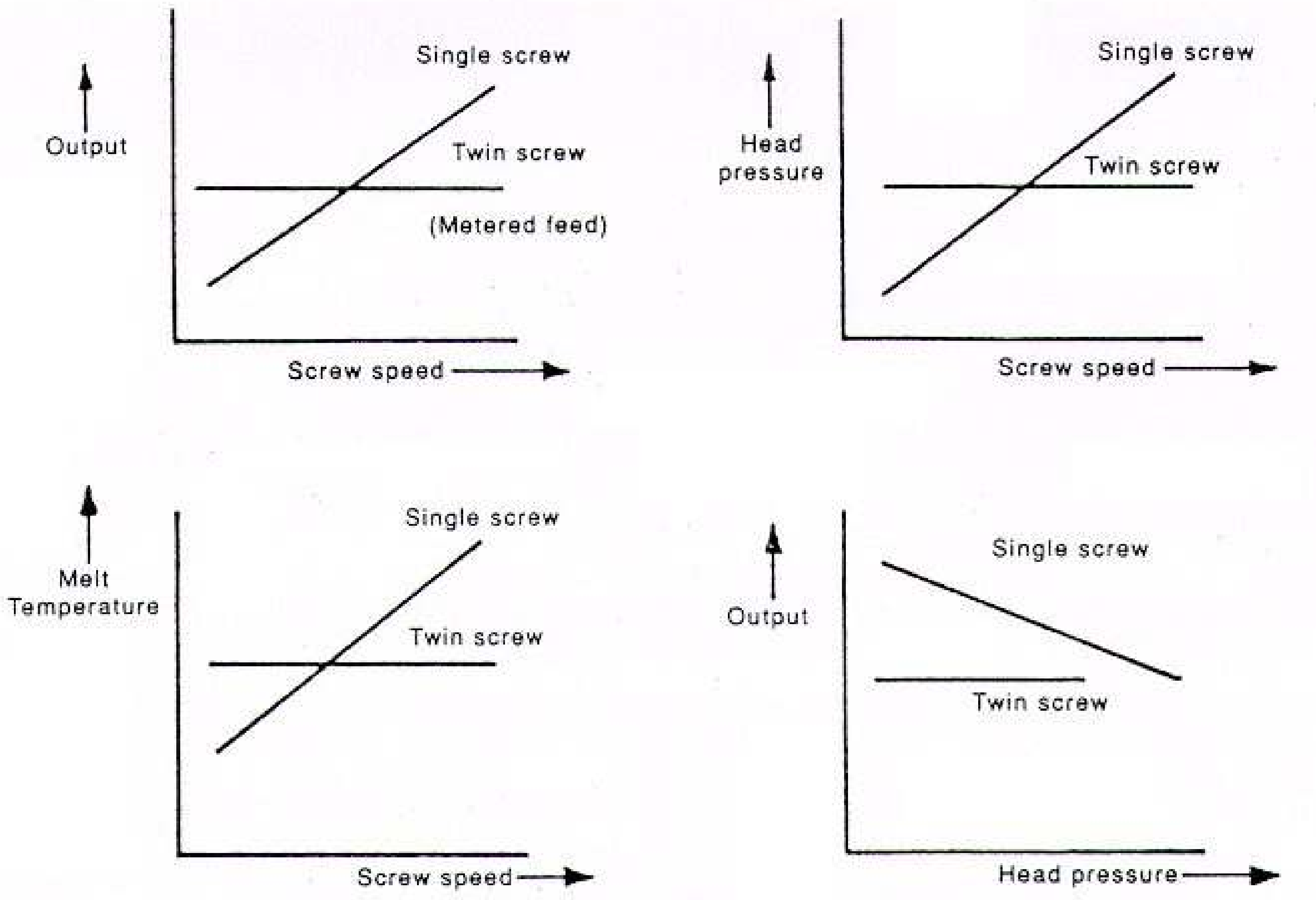
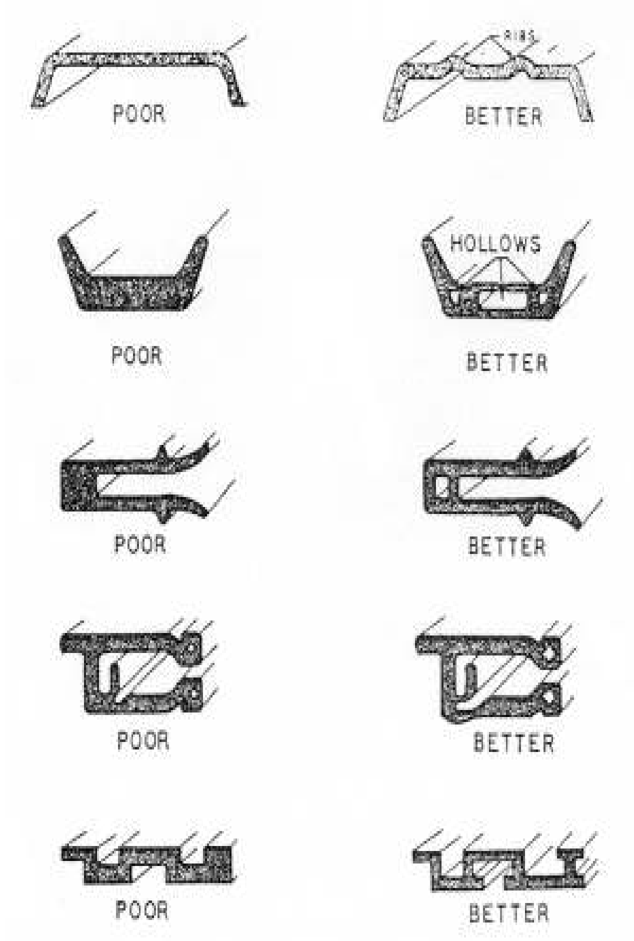
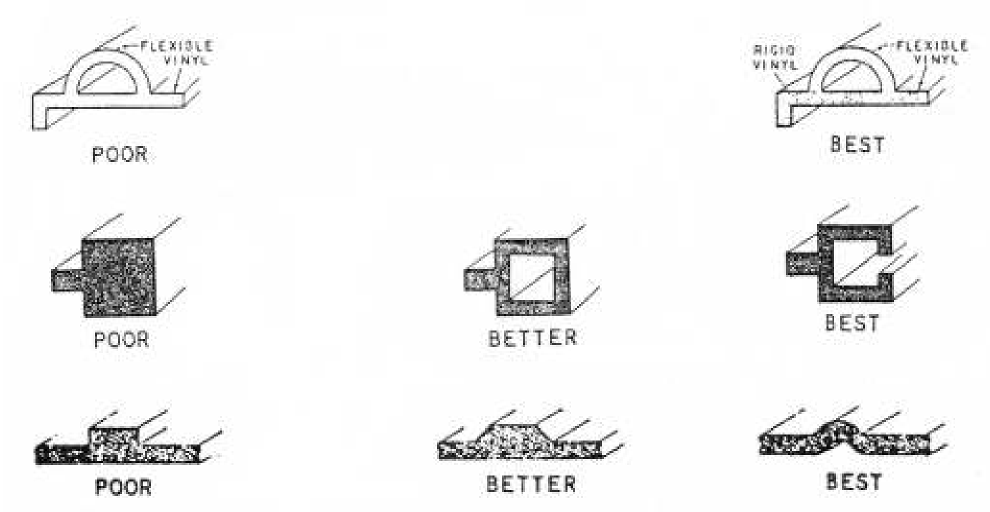
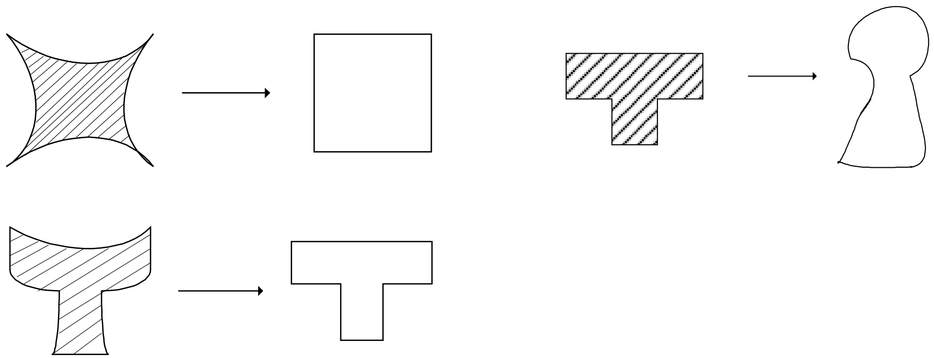


Figure 2.1 Effect of single- and twin-screw machine variables.

Die Design


POOR
RIBS
BETTER
POOR
HOLLOWS
BETTER
POOR
BETTER
POOR
BETTER
POOR
BETTER


FLEXIBLE VINYL
POOR
RIGID VINYL
FLEXIBLE VINYL
BEST
POOR
BETTER
BEST
POOR
BETTER
BEST



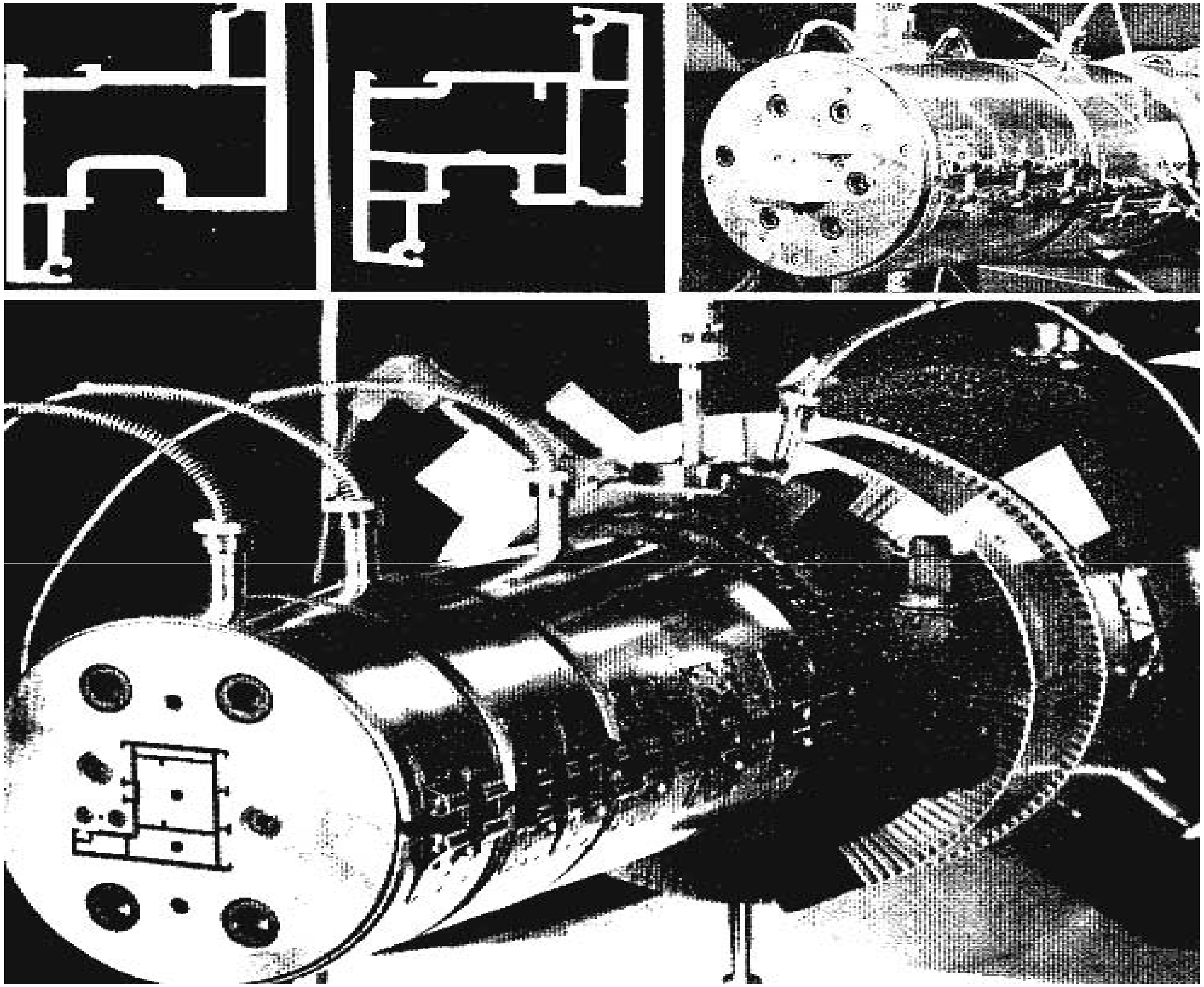


Figure 14.8 Examples of PVC cross sections for window frame fabricating.

Die Swell is affected by:

① **Molecular Weight Distribution**

② **Molecular Weight**

③ **Macromolecular Structure (Crystallinity, Amorphous)**

④ **Flow rate through the Die (θτ)**

⑤ **Die Design**

1. **Entrance Angle in land area**
2. **Die gap opening**
3. **Die length**

⑥ **Take off rate (Pelletizing or Winding)**

⑦ **Pressure in the die**

⑧ **Melt temperature**

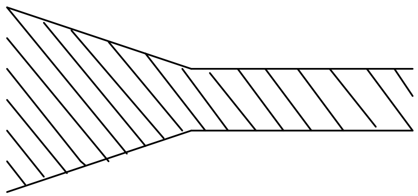
⑨ **Die temperature**

General Rules for Die Design

1) Streamline Flow

No "Dead spots" Hang up

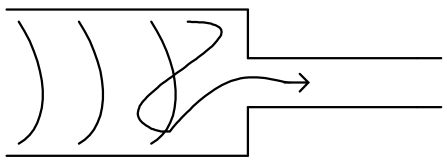
2) Steady increase in Flow Velocity as material travels through the Die.



3) Assembly and Disassembly should be easy to facilitate cleaning.

4) Land length should be 10 × die Gap opening.

5) Avoid abrupt changes in flow.



6) Use small entrance angle.

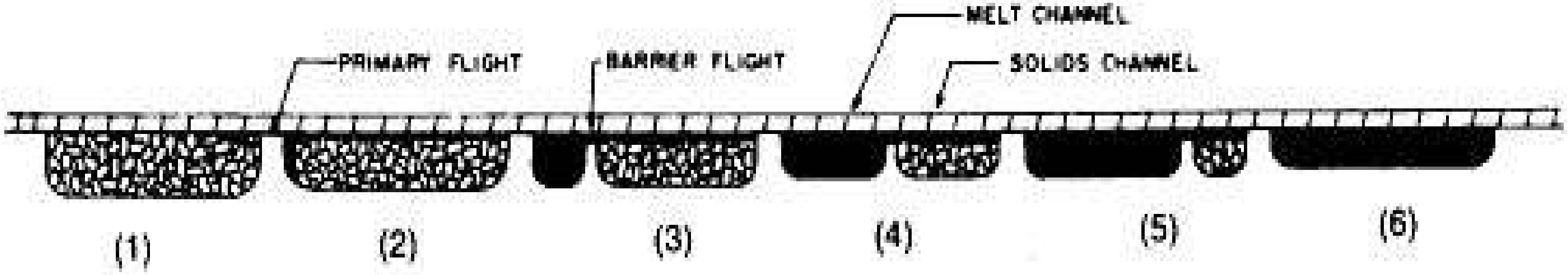


Figure 4.9 Melt model for double wave barrier screw.

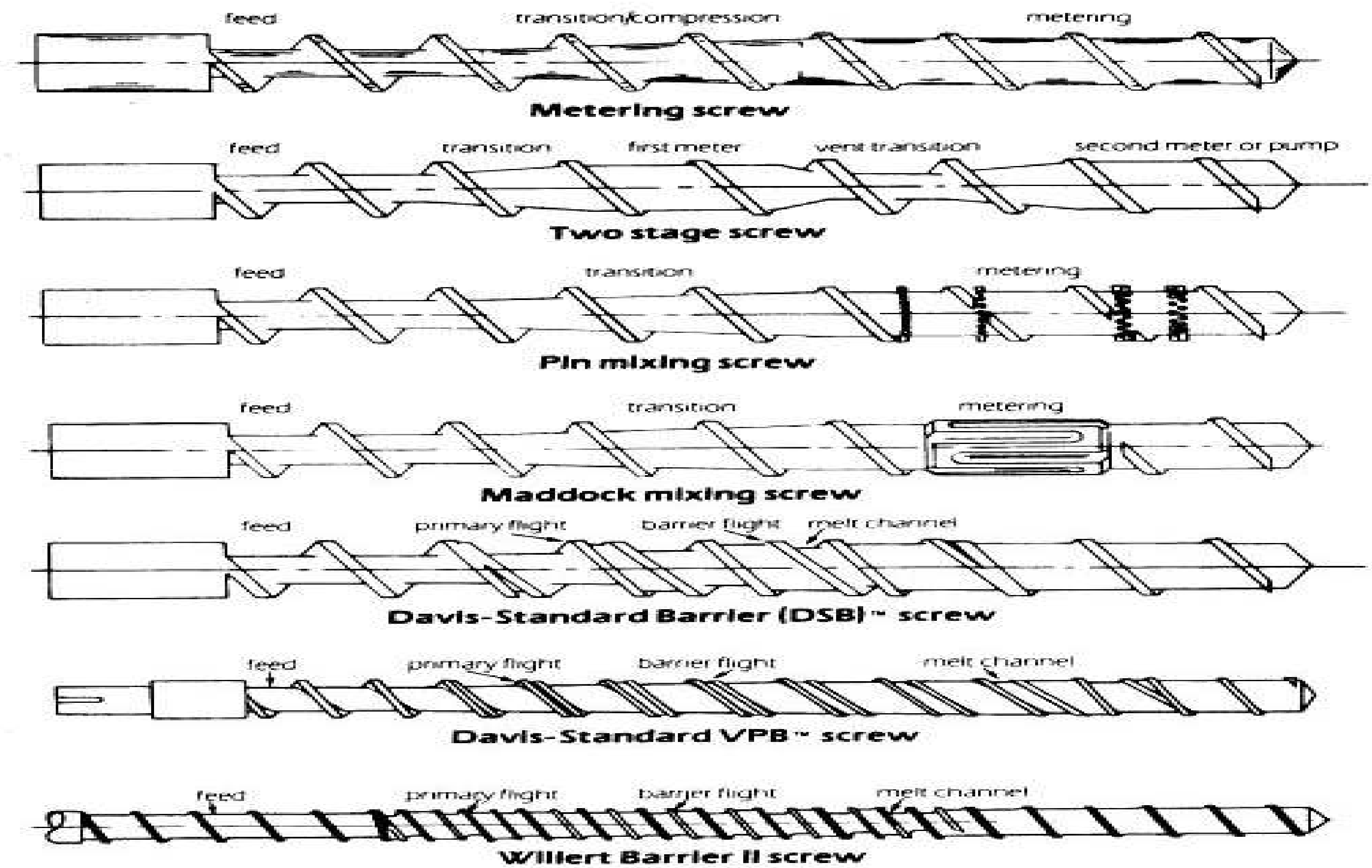


Figure 4.5 Schematic drawing of plastic melting in a screw.

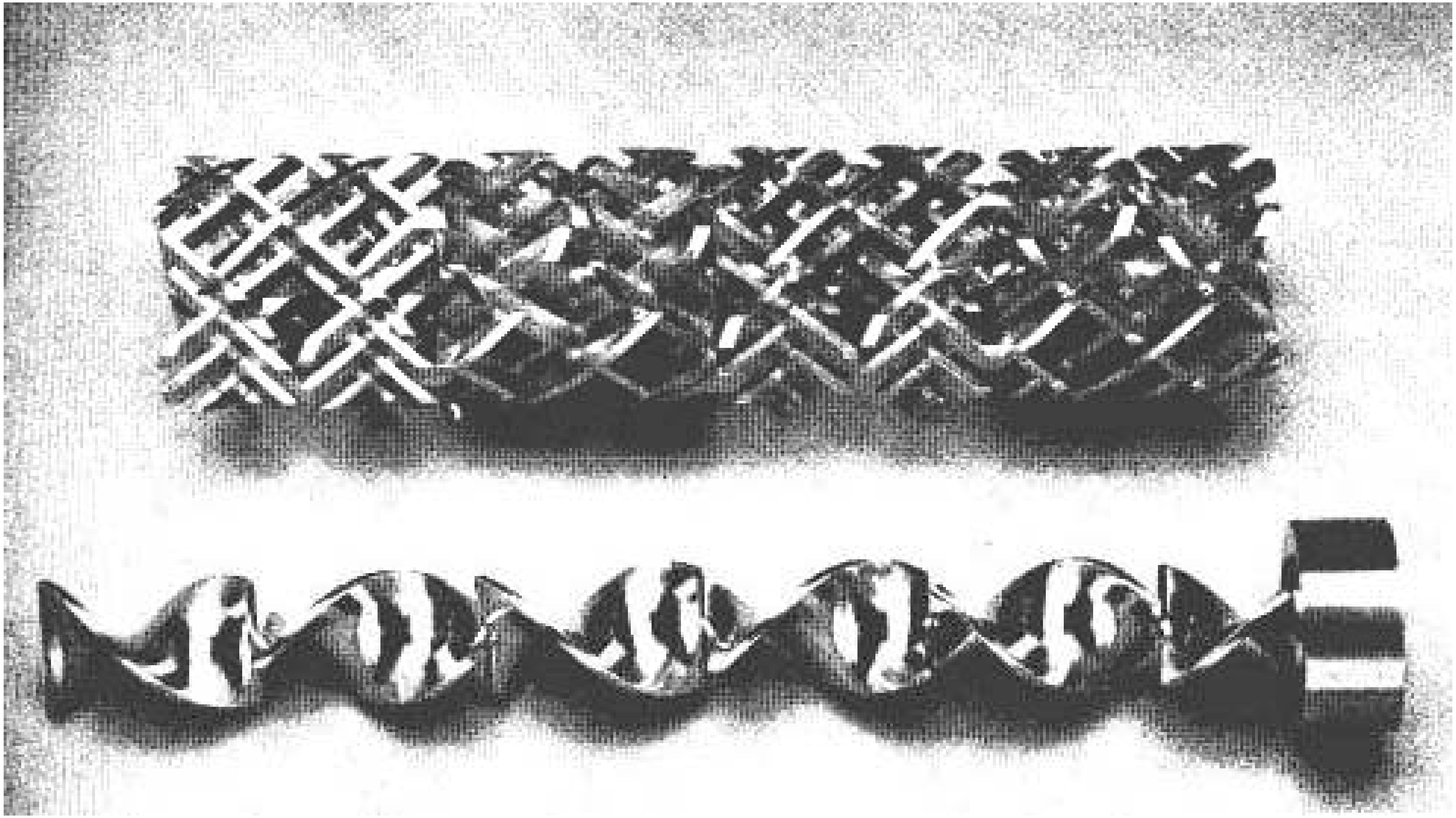


Figure 2.16 Two different styles of static mixers.

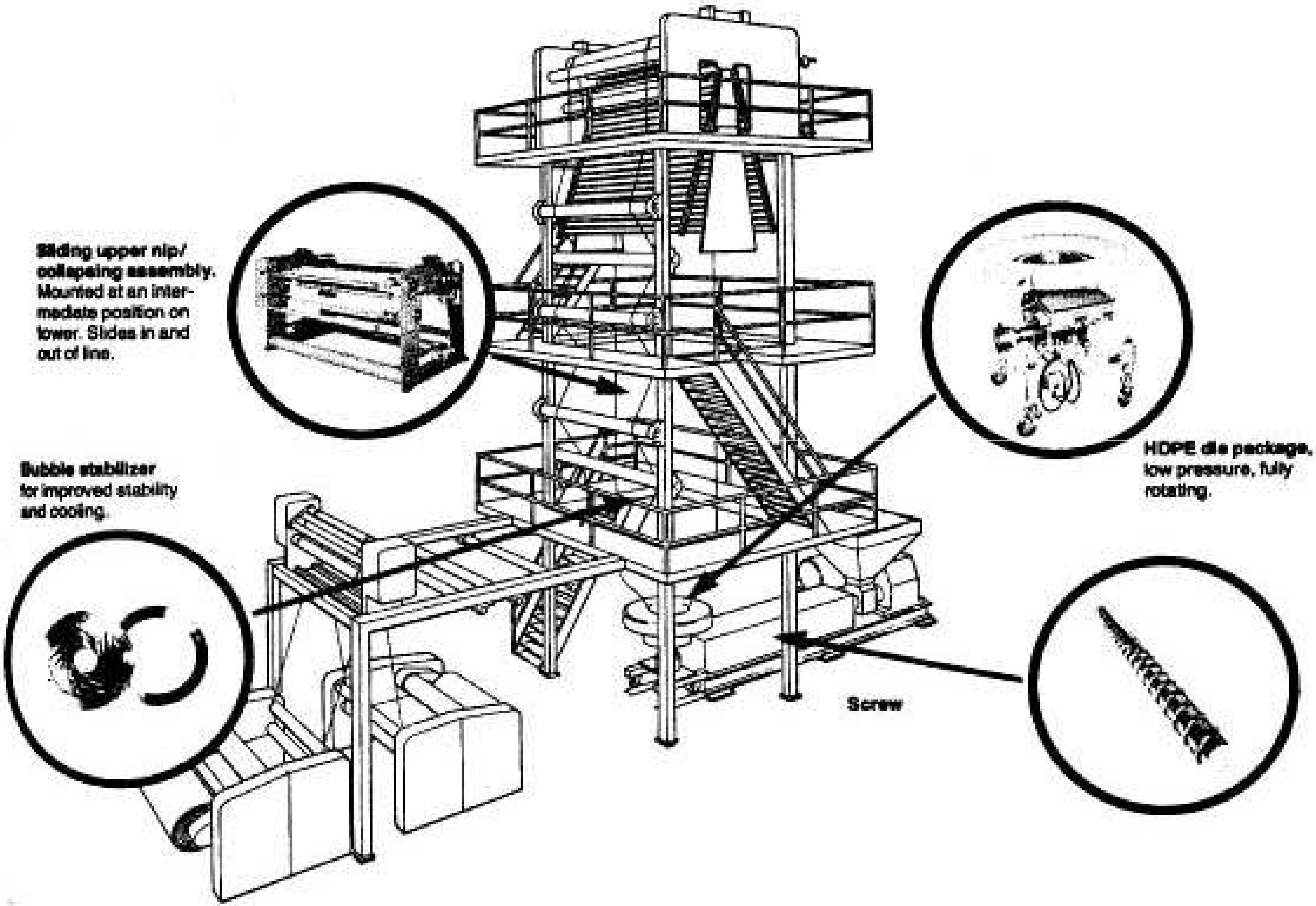


Figure 7.2 Schematic of line with flat slat collapsing frame.

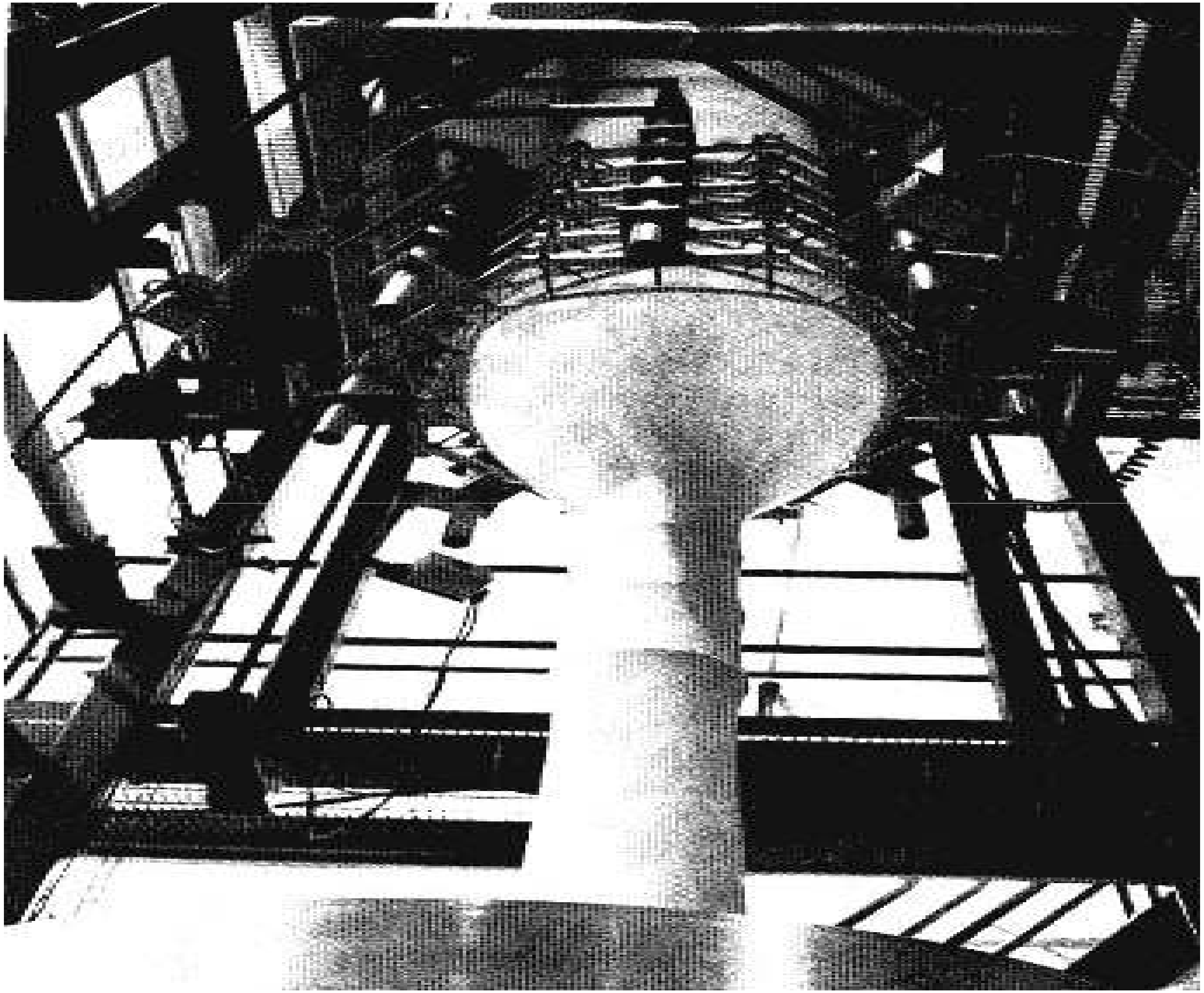


Figure 7.9 Tube includes inflatable mandrel proving structural support for high density film.

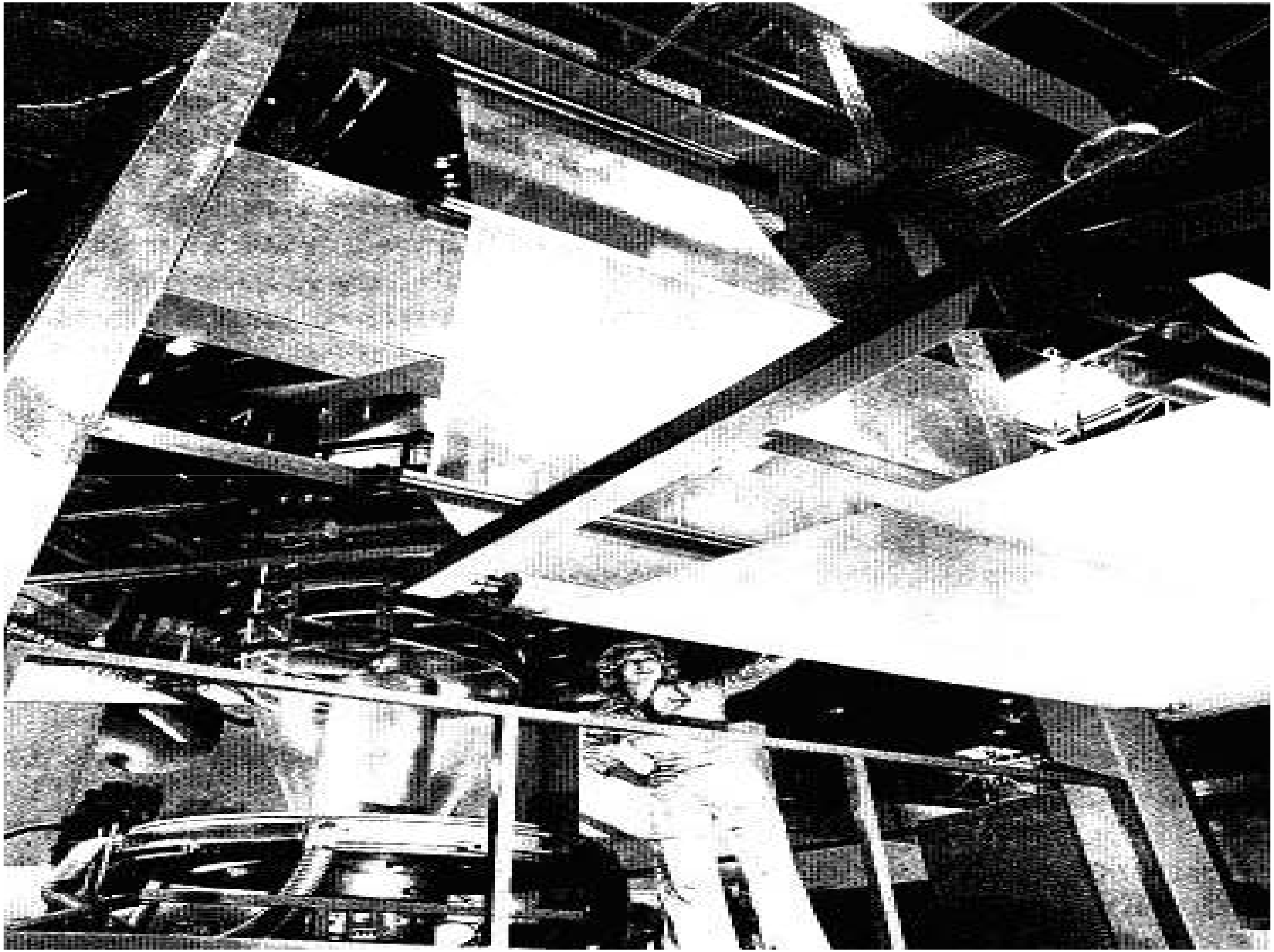
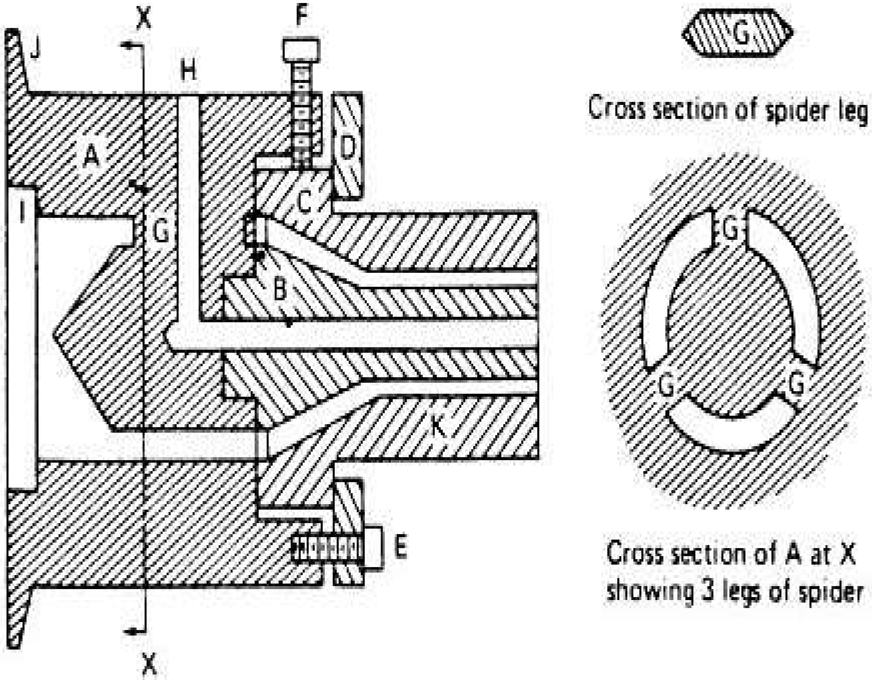
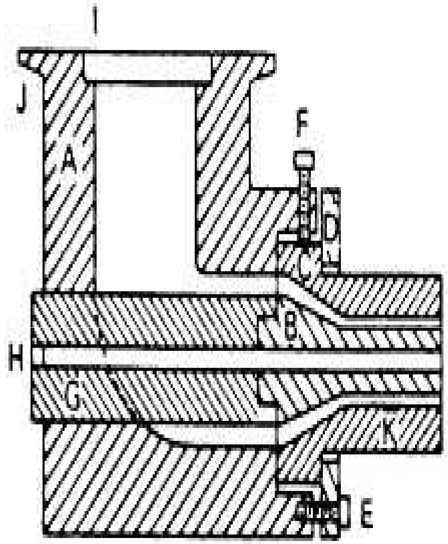


Figure 7.15 Stabilizing device for blown bubble.



A. Die body
B. Mandrel, pin, male die part
C. Die, die bushing, female die part
D. Die retaining ring
E. Die retaining bolt
F. Die centering bolt
G. Spider leg
H. Air hole
I. Seat for breaker plate
J. Ring for attachment to extruder
K. Die land

(1)



A. Die body, crosshead
B. Mandrel, pin, male die part
C. Die, die bushing, female die part
D. Die retaining ring
E. Die retaining bolt
F. Die centering bolt
G. Mandrel holder
H. Air hole
I. Seat for breaker plate
J. Ring for attachment extruder
K. Die land

(2)

Figure 5.4 Blown-film dies.

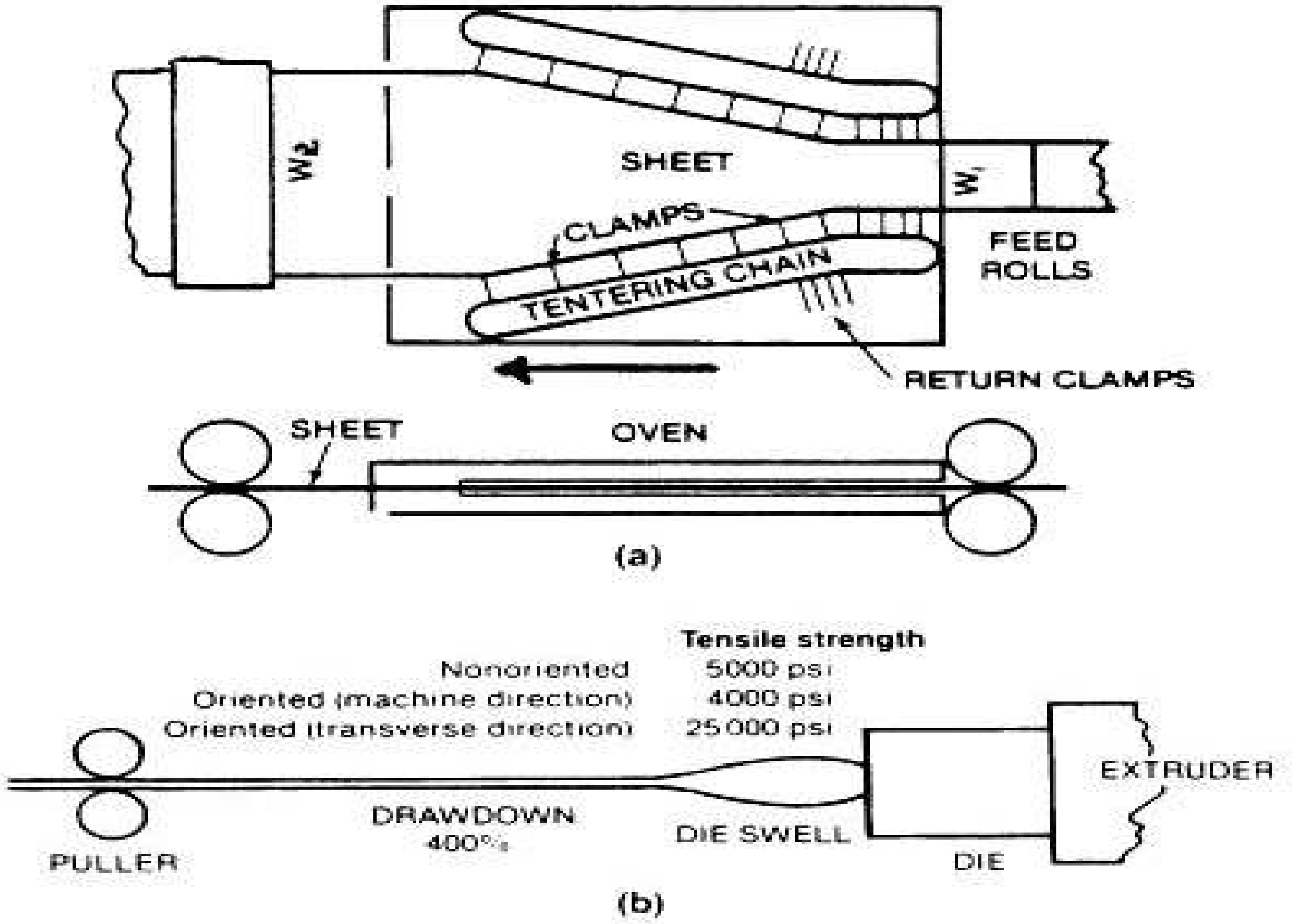


Figure 2.21 Use of tenter frame to biorient film or sheet;

(a) example or ratio of puller-roll is 4/1 (ratio of W2 to W1);

(b) drawdown phenomenon with die swell to produce orientation

(c) in the longitudinal direction.

Table 2.19 Examples of compatibility between plastics for coextrusion

	LDPE	HDPE	PP	Ionomer	Nylon	EVA
LDPE	3	3	2	3	1	3
HDPE	3	3	2	3	1	3
PP	2	2	3	2	1	3
Ionomer	3	3	2	3	3	3
Nylon	1	1	1	3	3	1
EVA	3	3	3	3	1	3

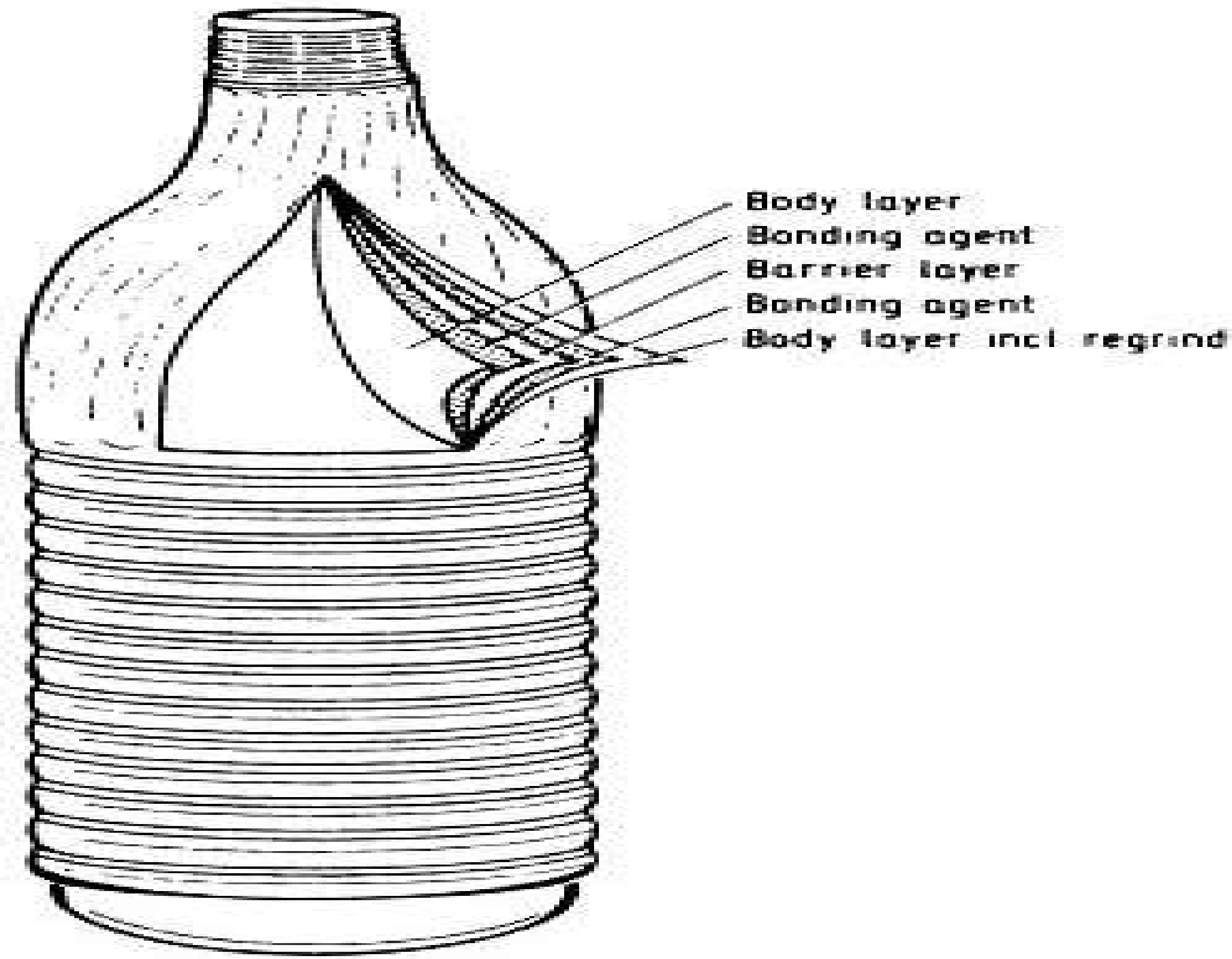


Figure 15.1 Coextrusion blow molding provides flash-free multiple layers with easy, high speed production; six or more layers can be produced at a time.

Figure 9.16 High barrier Davis-Standard 7-layer coextruded sheet line.

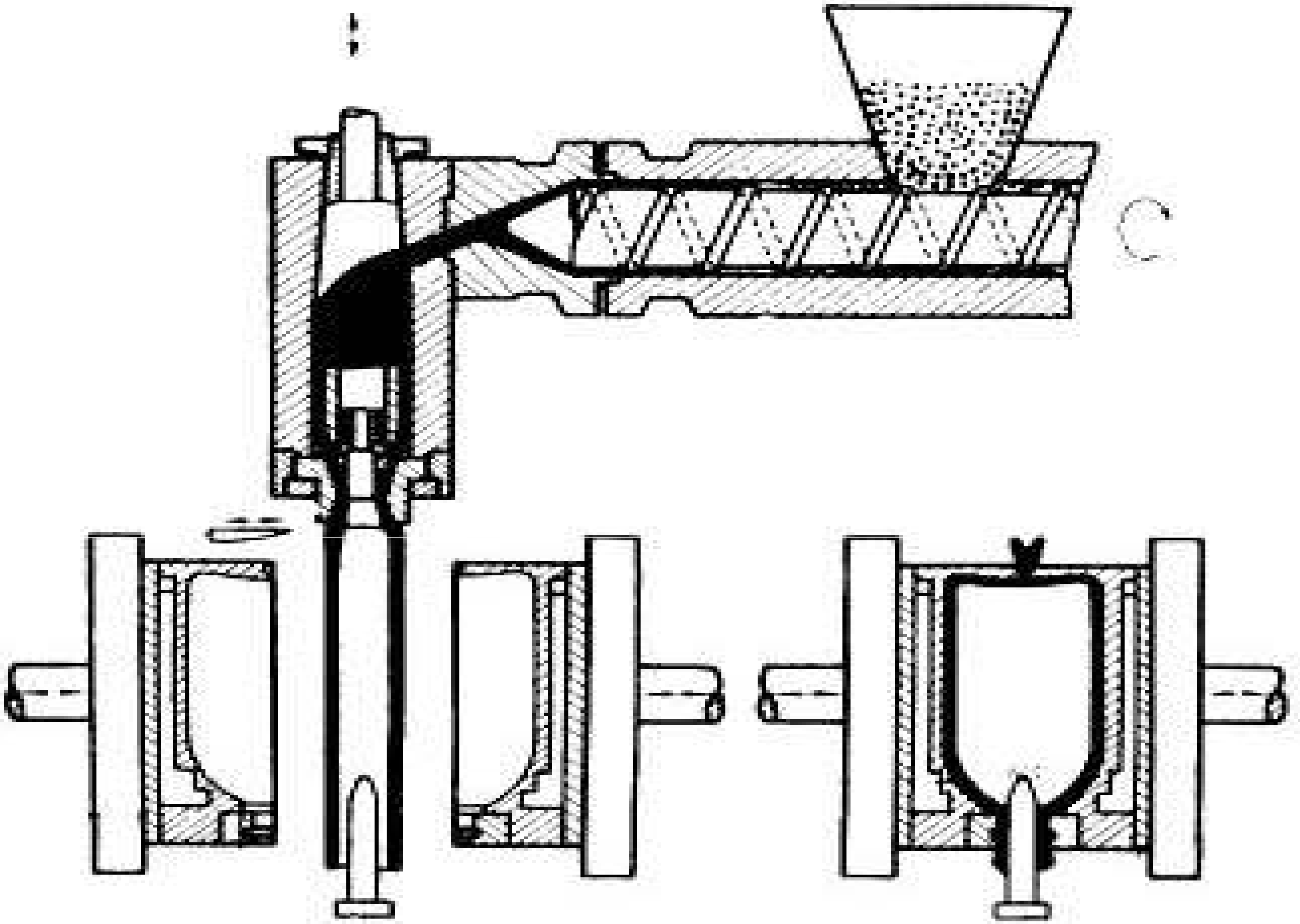


Figure 15.5 Example of intermittent EBM with accumulator in the die.

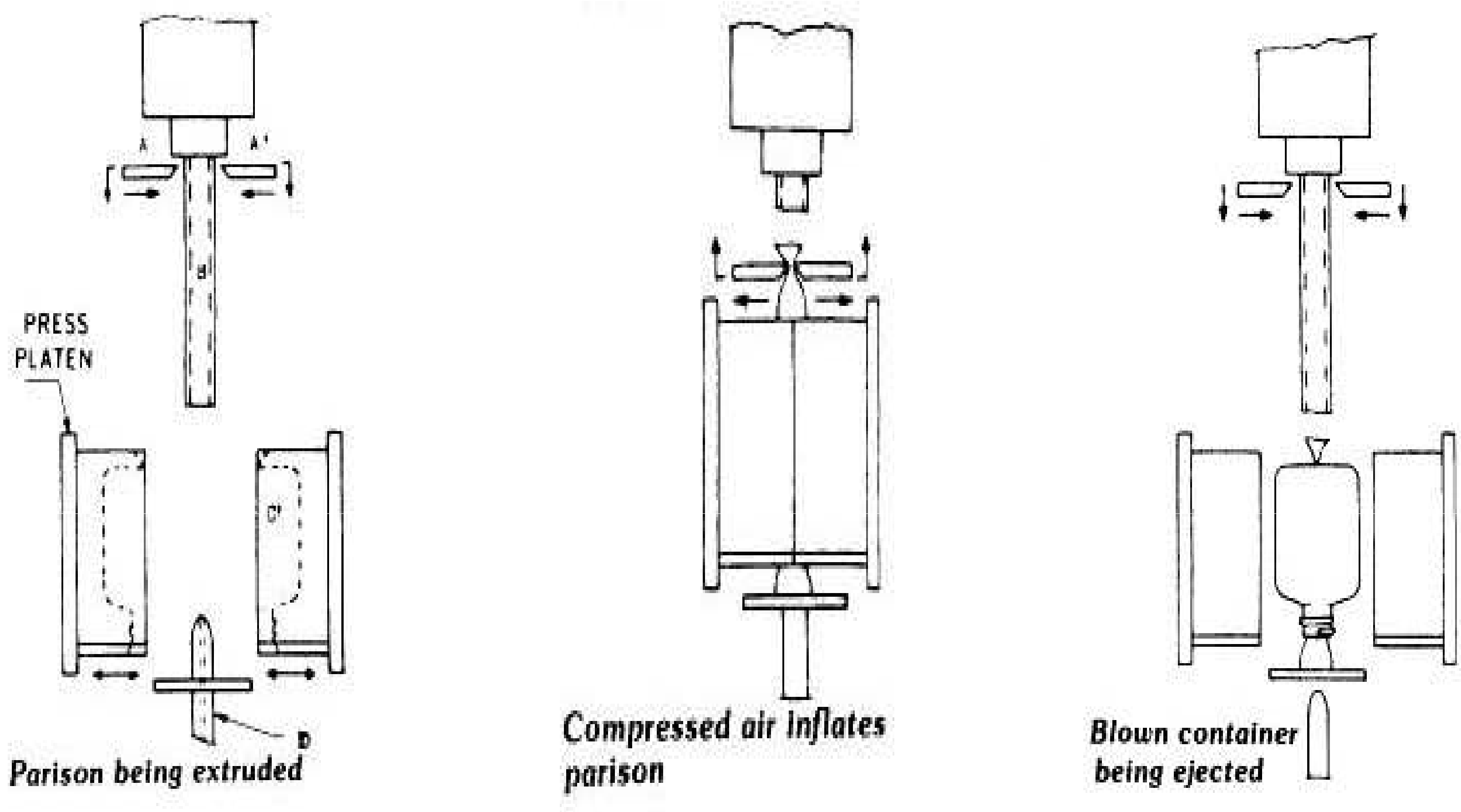


Figure 15.2 Basic continuous EBM process: A = parison cutter; B = parison; C = blow mold cavity; D = blow pin.

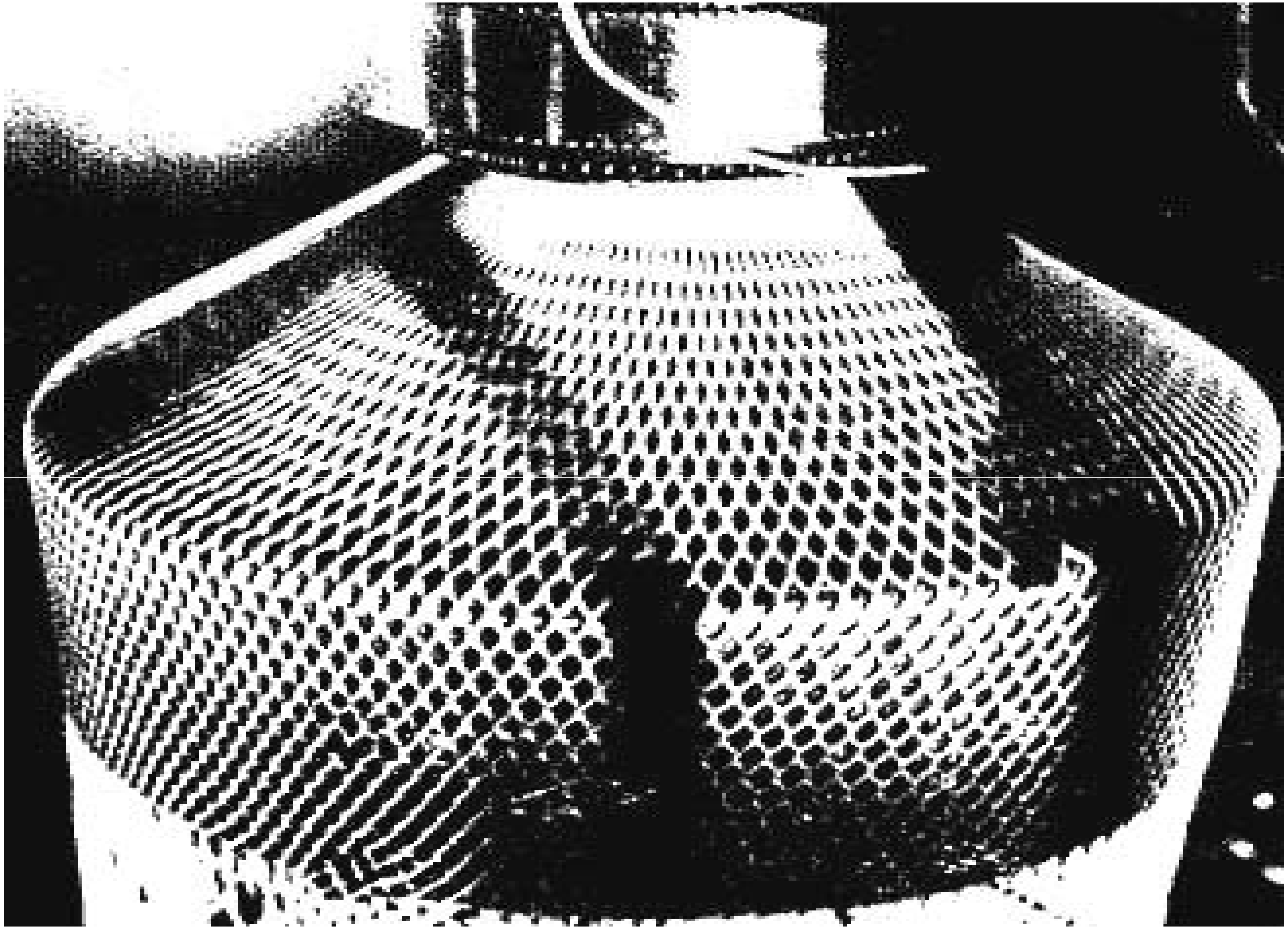


Figure 5.42 Netting exits the die and undergoes post-extrusion stretching