

## GUIDE to the BASIC PRINCIPLES of EXTRUSION COATING

Extrusion coating is a process for applying uniform coatings of thermoplastic resins onto a variety of substrates including papers, paperboards, plastic films, metal foils, and textiles. This process offers several advantages over other coating and laminating processes:

- Highly viscous resins are applied as 100% solids. Expensive drying tunnels and solvent recovery equipment are not required.
- A wide range of coating thicknesses, e.g., from less than 1/4 mil to more than 4 mils, are easily obtained from a single extruder and die by varying the take-off speed of the coating line or adjusting the screw speed of the extruder.
- Different coating widths are easily obtained from a single extruder and die by deckling (narrowing) the widths of the molten film as it leaves the die.
- Quality coatings produced on one extrusion coating line can be readily produced using the same operating conditions on other extrusion coating lines.

### 1. The Extrusion Step

In the extrusion step, thermoplastic resins are fed as solid pellets to the hopper, converted into a homogeneous melt in the extruder barrel, and forced as a liquid film from the slot die. The key parts, shown schematically in Figure 1, are described below.

#### a. Hopper

Resin pellets are pneumatically conveyed from storage (silos for volume resins, flow bins or boxes for specialty resins) to the feed hopper. There the pellets drop through the feed throat into the feed section of a screw rotating inside the extruder barrel. The hopper is usually jacketed for water cooling to prevent the pellets from melting too soon and blocking the feed throat.

#### b. Barrel


The size of single screw extruders is described by the inside diameter of the barrel. Typical extruder sizes are 1 - 1 1/2 inches for pilot extruders, 3 1/2 - 4 1/2 inches for flexible substrate coaters, and 6 - 8 inches for paperboard coaters.

The length to diameter ratio (L/D) is an important extruder specification. The L/D is the length of the barrel divided by its nominal inside diameter. Typical extrusion coaters will have L/D of 20/1 and 24/1. Older coaters may have L/D as low as 16/1 while newer coaters may have L/D as high as 28/1. Long barrels are desired since they provide more heat transfer area and additional mixing, both of which improve uniformity of melt temperature and delivery rate.

The barrel is divided into several electrically heated zones, each of which is controlled individually. Accurate control of the barrel temperatures is essential in controlling the resin melt temperature.

### c. Screw

A metering screw consists of three sections, shown schematically in Figure 2. The function and characteristic of each section is as follows:

	<u>Section</u>	<u>Channel Depth</u>	<u>Functions</u>
 Resin Flow	Feed	Deep	Resin pellets are moved forward into the hotter barrel zones.
	Transition	Decreasing	Resin is melted, mixed, and compressed; air is vented back to the feed section.
	Metering	Shallow	Molten resin is metered at a uniform rate and at a uniform temperature through the adaptor and out through the die.

The specific metering screw shown in Figure 2 is typical of the early polyethylene screws. It has 10 feed flights, 5 transition flights, and 5 metering flights. The lead or distance between flights is equal to the inside barrel diameter. Thus this 20 flight screw would fit a barrel having an L/D of 20/1. Improved mixing and melt uniformity are obtained by using metering screws which have more of the shallow channel metering flights and fewer of the deep channel feed flights. Metering screws having 25% feed flights, 25% transition flights, and 50% metering flights are typical for polyethylene today.

The screw speed (rpm) controls the melt flow rate out of the die. The higher the screw speed, the higher the melt flow rate and the higher the coating weight at a constant coating line speed. Increasing the screw speed will also increase the amount of heat generated by internal frictional forces. More internal heat means that less external heating is required. Excessively high screw speeds may lead to unwanted temperature and pressure fluctuations.

#### d. Breaker Plate And Screen Pack

The breaker plate is located between the front end of the barrel and the adaptor. It converts the rotary motion of the melt leaving the screw to a laminar flow. The plate is pierced by a large number of equally spaced holes, usually 1/16 to 1/8 inch in diameter.

A screen pack, supported by the breaker plate, consists of several steel screens. It functions to protect the die from minor foreign particles and to increase the back pressure in the extruder.

Back pressure is often controlled by a valve in the adaptor. Higher back pressures at a given screw speed reduces the forward melt flow rate out of the die and increases the backward melt flow rate along the barrel wall. Thus higher back pressures improve mixing and melting. This is desirable with high viscosity, high temperature resins such as polyethylene where back pressures from 500 psi to 2000 psi are common.

#### e. Adaptor And Die

The adaptor guides the molten resin in a right angle bend from the breaker plate to the die with a minimum of resin hang-ups.

Two general die types are in use with polyethylene extrusion coating. The most common is the cylindrical manifold die (used at CRL) which consists of a polished one-piece manifold, slotted along its length, with adjustable die jaws mounted on the face of the manifold. The other die type is the split or coat hanger die. It differs from the cylindrical manifold die in the shape of the manifold. XBR and XLT resins have been run with both die types. The adaptor and die zones are heated independently.

The die functions to:

- Distribute the melt at a constant flow rate to the slot.
- Maintain the melt at a constant temperature.
- Force the melt from the slot as a liquid film of desired width and thickness.

The die is adjusted to have a uniform opening in the range from 0.012" to 0.030". A typical die opening for polyethylene is 0.020". The die is also equipped with adjustable deckles, either internal or external, which are used to increase or decrease the width of the molten film as it leaves the die.

Polyethylene resins are normally extruded at melt temperatures in the range from 575°F to 650°F.

## 2. The Coating Step

In the coating step, the liquid film extruded from the slot die is drawn down to the desired coating thickness in an "air gap", bonded to a substrate in the nip of a rubber covered pressure roll and metal chill roll, and solidified by contact with the chill roll. The coated substrate is cooled by continued contact with the chill roll, trimmed to remove the edge beads, and wound into a finished roll. The key parts, shown schematically in Figure 3, are described below.

### a. Air Gap

The air gap is the vertical distance from the die slot to the nip below the die. Air gaps from 4" to 5" are typical for polyethylene resins. Many extruders, including our CRL unit, have hydraulic lifts for adjusting the air gap even while coating at full line speeds.

The relatively thick molten film, i.e., about 0.020", is drawn down to thicknesses in the range from 0.00025" to 0.004" while coming in contact with the faster moving substrate. The final thickness can be changed by varying the melt flow rate (controlled by screw rpm) or by varying the substrate speed (controlled by coating line speed). For example, the coating weight can be reduced by decreasing the screw rpm or by increasing the coating line speed.

Drawdown is a term describing the minimum useable coating weight (absence of voids or caliper variations) at which a resin can be extrusion coated. It is a function of the basic resin properties and extrusion coating conditions.

The hot film shrinks or necks-in at both edges forming edge beads as it is drawn down. Neck-in is defined as the difference in inches between the width of the molten film as it exits the die and the width at the point of contact with the substrate. Neck-in is a function of the basic resin properties and extrusion coating conditions. With a given resin neck-in can be reduced by decreasing the air gap, increasing the coating line speed, or decreasing the melt temperature.

### b. Chill Roll

Uncoated substrate is pulled from the unwind stand into the nip formed by the driven chill roll and pressure roll where it is coated. The molten film should strike the substrate before contacting the chill roll to insure the best coating adhesion. The coating and substrate are then pressed together in the nip at pressures in the range of 75 - 150 pounds per linear inch.

In addition to solidifying the coating, the chill roll must cool the coated substrate fast enough to permit a clean separation of the coated substrate from the chill roll surface in less time than required for one revolution of the chill roll. A chill roll of 12 to 24 inches in diameter and cooled to about 65°F is considered typical for polyethylene extrusion coating.

The chill roll surface will determine the coating surface characteristics. A highly polished chill roll surface will produce a high gloss or transparent coating. A dull or matte chill roll surface will produce a dull or opaque coating. In addition the matte finished coatings have significantly lower coefficient of friction values than obtained from gloss finished coatings.

The chill roll is also important in making laminations. In this case one substrate enters the nip from the pressure roll side while the second substrate enters the nip from the chill roll side. The molten film falls directly into the nip, laminating the two substrates together.

#### c. Substrate Pretreatment

Converters use several techniques to improve the adhesion of the coating to the substrate. A technique common with the non-polar polyethylene is to form polar groups by oxidizing the polyethylene in the air gap. This is one of the main reasons for operating polyethylene at 575°F - 650°F.

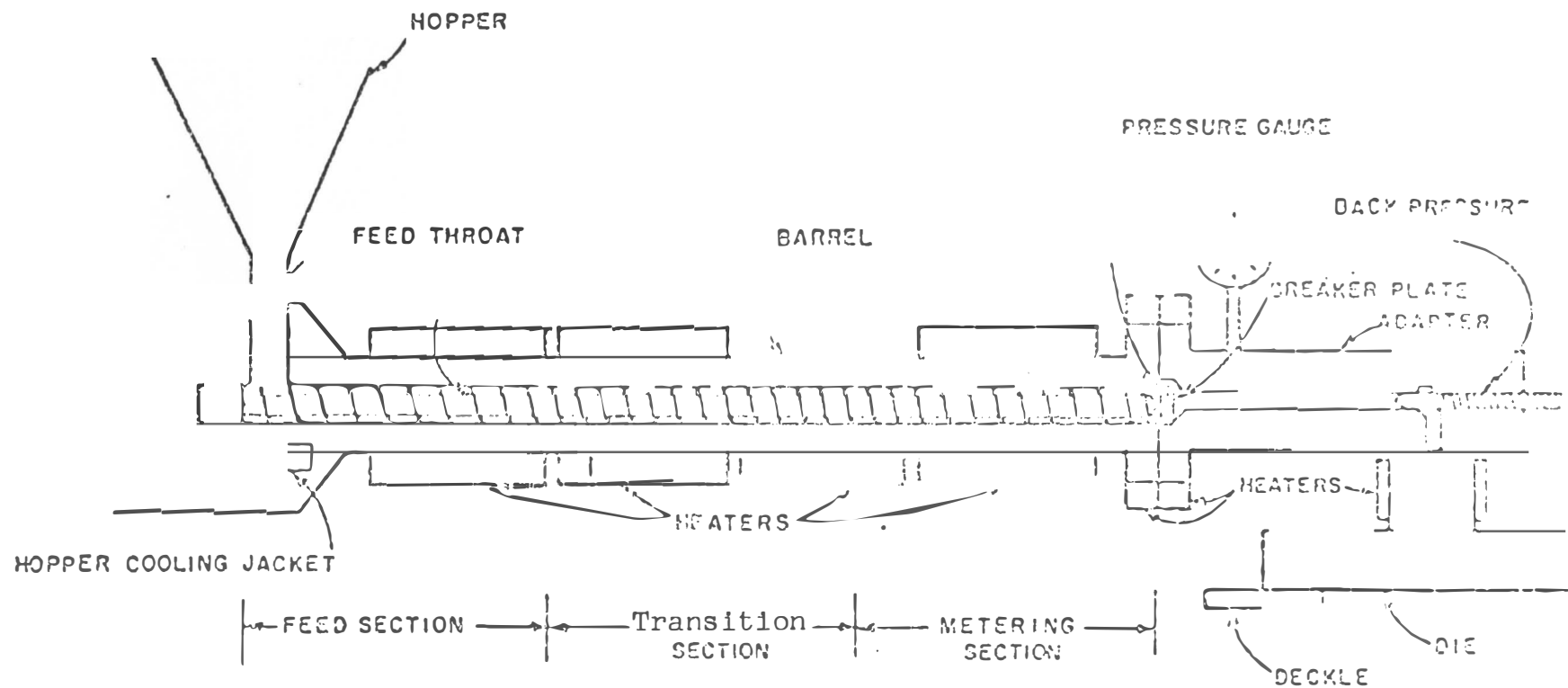
Converters must also treat the substrate with one or more of the following techniques when coating polyethylene:

- . Preheat (steam heated roll, IR heaters, or flame)
- . Corona Discharge
- . Chemical Primers

#### d. Edge Trimmers

The edge beads formed as the molten film necks-in must be trimmed before the coated substrate is rewound. The amount of trim necessary is a function of the resin neck-in.

When the coating width is narrower than the substrate width both coating and substrate are trimmed and discarded. Converters have developed techniques to permit "overcoating the substrate". This means that the coating width is wider than the substrate width and that the trim consists primarily of coating with only a small amount of substrate included.



EXTRUDER STEP

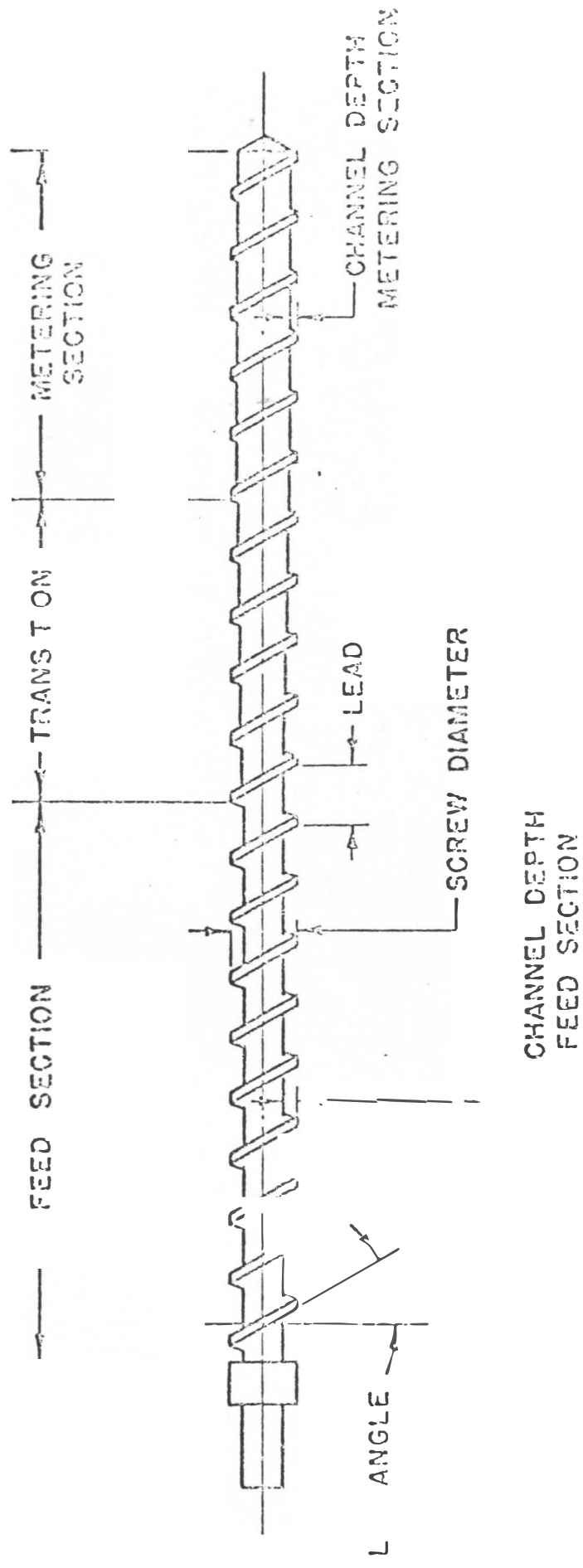


FIGURE 2  
METERING SCREW

COATING LINE

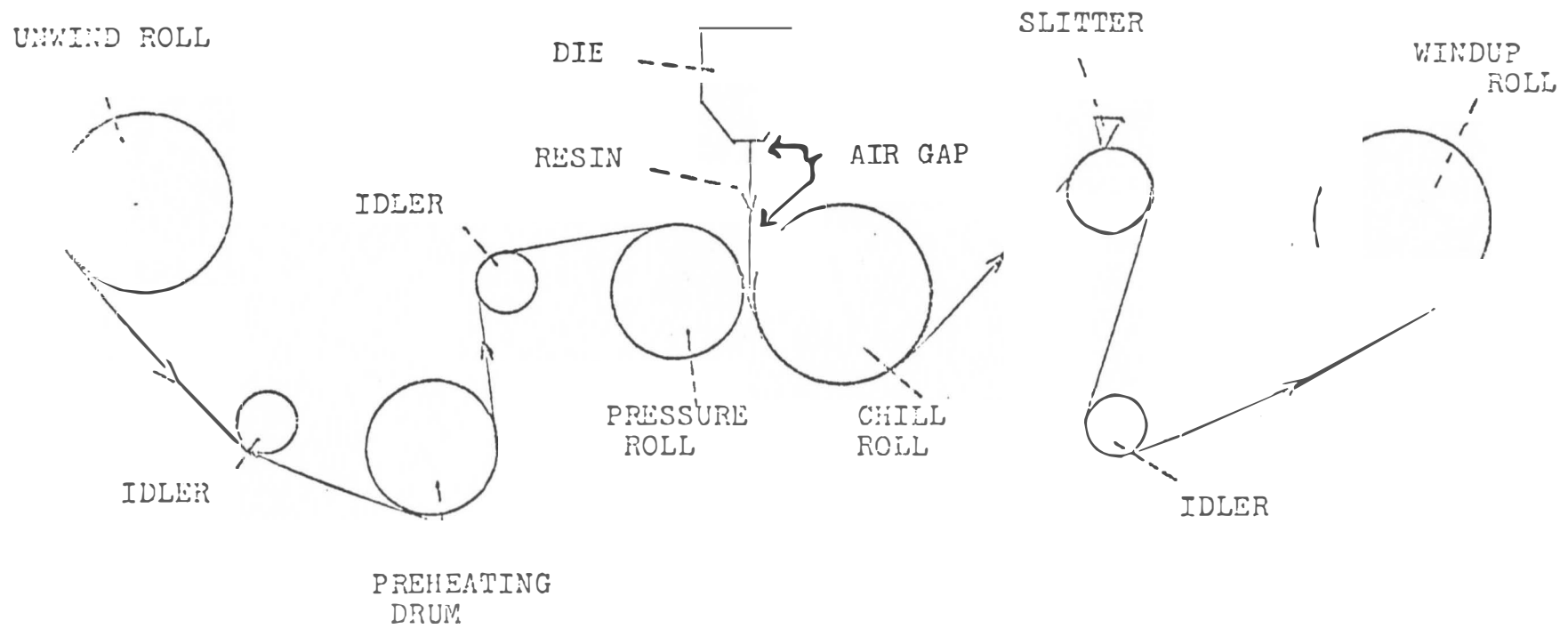


FIGURE 3