Plastics Division

A processing guide for

EXTRUSION

BAYER STYRENIC RESINS

LUSTRAN® ABS
CENTREX® WEATHERABLE POLYMERS
BAYBLEND® PC/ABS

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INTRODUCTION

PRODUCT DESCRIPTION

Bayer Corporation offers a range of styrenic materials for extrusion applications. This family of Bayer styrenic polymers includes Lustran® ABS resins, Centrex® weatherable polymers, and Bayblend® alloys.

Lustran ABS Resins

Lustran ABS resins are thermoplastic materials based on the polymerization of acrylonitrile, butadiene, and styrene. These resins offer a wide range of performance properties, including toughness, strength, and chemical resistance, and can be processed under a range of conditions for an array of applications. Both clear and opaque extrusions can be produced with Lustran ABS resins.

Lustran ABS resins can be sheet- or profile-extruded as a single layer or coextruded into multilayer structures. Sheet or profiles can be smooth or embossed. Sheet or profiles can be subsequently reheated and shaped using techniques such as thermoforming, and can be cemented, machined, sawed, painted, plated, printed, hot-stamped, or welded. Other technical manuals are available on fabricating, plating, decorating, and thermoforming.

Centrex Weatherable Polymers

Centrex weatherable polymers are thermoplastic materials based on AES (acrylate-ethylene-styrene, also sometimes called EPDM, ethylene-propylene-diamine), ASA (acrylonitrile-styrene-acrylate), or a combination of both. The processing and property performance of Centrex weatherable polymers is similar to Lustran ABS resins with the added advantage that they resist color and property degradation even after long-term exposure to UV light.

Centrex resins offer a range of toughness and strength. Extrusions of Centrex resins are opaque. Centrex resins can be extruded into single- or multi-layer sheet and can be used as a cap layer over ABS for many outdoor applications for weatherability with a balance of cost and performance. Centrex resins can also be profile-extruded either as a single layer or in multiple layers. All of the fabrication techniques that can be applied to Lustran resins also apply to Centrex resins.

Figure 1 **Extrusion Line for Processing Bayer Styrenic Resins**

Bayblend Alloys

Bayblend resins are alloys that combine a styrenic material with polycarbonate. These PC/ABS alloys offer high heat resistance and high impact resistance, particularly at low temperatures. Bayblend resins can be sheet- or profile-extruded in single or multiple layers, and can be combined with Lustran and Centrex resins to optimize properties.

Product by Grade Type

Bayer styrenic resins are available in both injection molding and extrusion grades. These grades are typically different. The injection molding grades contain lower molecular weight components, exhibit higher melt flow rates, and require an external pellet lubricant for improved molding. The extrusion grades contain higher molecular weight components, exhibit low melt flow rates, and require no external lubricants. The characteristics of the extrusion grades of Bayer styrenic resins provide good melt strength for extrusion stability and "solidity" for superior thermoformability.

Extrusion grades of Lustran resin include both general-purpose and specialty grades. The general-purpose grades are included in the high-gloss 52 series where higher numbers indicate higher impact: i.e., 452 = medium impact; 752 = high impact; 1152 = highest impact. There is a low-gloss 56 series for which higher numbers mean higher impact, lower gloss. Generally in ABS, higher numbers mean higher impact. Lustran 752 resin is the most widely used extrusion grade.

Extrusion grades of Centrex resin vary with the type of rubber: AES, ASA, or AES/ASA. Usually, the more AES the higher the impact. There are low-, medium-, and high-gloss grades. In each case, the unique property is weatherability.

The number of extrusion grades available in Bayblend resins is limited. However, 2253, T 85, and DP2-1500 (FR) exhibit a balance of properties suited for specific extrusion applications.

Table 1 lists all current extrusion grades of Bayer styrenic polymers and typical uses.

Product by Market

Alone or in combination, Bayer styrenic extrusion resins are used in a variety of consumer applications, including recreational vehicles, truck caps, spas, tractors, heavy trucks, buses, signs, and mobile homes. Specific applications include profile trim parts, interior and exterior components, housings, and fairings.

In each application, the combination of properties and processing provide the optimum cost/performance balance. As with any product, the use of a particular grade or combination of grades should be tested to confirm expected performance. Bayer Corporation recommends prototype testing under expected end-use conditions which may include specific end-use or field testing to confirm suitability.

Table 1 **Bayer Styrenic Resin Grades Suitable for Extrusion**

Grade		Sheet			Profile
			Coextrusion		
		Monolayer	Cap	Substrate	
Lustran	130	•		•	•
	256	•			•
	266	•	•		•
	356	•	•		•
	452	•	•	•	•
	456	•	•		•
	552	•		•	•
	752	•	•	•	•
	1152	•		•	•
Centrex	401	•	•		•
	485		•		•
	601	•	•		•
	825	•	•		•
	833	•	•		•
Bayblend PC/ABS		•	•	•	•

NOMENCLATURE

Grade Designation

Bayer extrusion styrenic resins are available in unreinforced general-purpose and specialty grades in a range of appearance and impact levels. Lustran resin grades have higher impact with higher numbers. In each case, the specific data sheet has a product description that provides the major characteristics of the specific resin. All grades are supplied in pellet form. Some pellets are cylindrical while others are cubes. The bulk densities are similar.

Color Designation

Bayer styrenic resins are typically supplied in natural color, which, in most cases, is a light straw color. Most resins are opaque. The natural color designation varies with each family: 1050 for Lustran resins, 1007 for Centrex resins, and 1000 for Bayblend resins. There are a few standard colors such as black, white, or greys, for some grades. Other colors may be available on custom color orders.

COLORING THE RESIN

Lustran ABS Resins

Lustran resins can be colored with any of the conventional coloring systems. If liquid colorants are used, the carrier must be compatible with the virgin material. If color concentrates are used, the polymer base should be similar to the virgin material, preferably slightly softer in melt flow.

Check so-called “universal” colorants for compatibility. This is particularly important for white or colors where high color loadings result in high concentrations of the carrier. Incompatible materials can cause color streaking or a deterioration of the properties of sheet.

Centrex and Bayblend Resins

Some pigments suitable for Lustran resins may not be suitable for use with Centrex or Bayblend resins.

Specific guidelines have been developed for Centrex and Bayblend resins. In addition, specific concentrate suppliers have been certified to help assure the weathering performance of Centrex resins that can be affected by the pigments.

Consult the Bayer styrenic polymers technical group for the guidelines for coloring Centrex and Bayblend resins and for the list of certified color concentrate suppliers. Call Bayer Corporation at 412-777-2000.

PACKAGING AND LABELING

Bayer styrenic resins are available in 1,500-lb (675-kg) cardboard cartons and bulk trucks or railcars. The cartons have polyethylene liners in which the resin is sealed to help prevent contamination from dust, dirt, and moisture.

When opening and resealing cartons, be careful to avoid the introduction of dust or dirt. Any particulate contamination in the feedstock will show up in the finished extrusion.

Bayer styrenic resins are hygroscopic. Moisture absorption begins as soon as the resin is exposed to room air. Resin exposed to the air for as little as 15 minutes can absorb enough moisture to cause extrusion problems. Resin exposed to a moist atmosphere for a few days or processed wet will suffer a permanent reduction in physical properties. It will also produce parts with poor surface characteristics. Therefore, keep each package sealed until it is to be used.

Figure 2 **Label Information for Bayer Styrenic Resins**

LUSTRAN
ABS 752-1050
ACRYLONITRILE-BUTADIENE-STYRENE
9003-56-9
ITEM 1481398

CAUTION!
IRRITANT (PROCESSING FUMES)
FUMES EVOLVED DURING THE THERMAL PROCESSING OF THIS MATERIAL MAY IRRITATE THE EYES, SKIN AND RESPIRATORY TRACT.

AVOID INHALATION AND SKIN OR EYE CONTACT WITH THE PROCESSING FUMES. WASH THOROUGHLY IF CONTACT OCCURS.

USE LOCAL EXHAUST VENTILATION ABOVE PROCESSING EQUIPMENT.

CONTAINERS SHOULD BE KEPT TIGHTLY CLOSED TO AVOID CONTAMINATION WITH FOREIGN MATERIALS AND MOISTURE.

FOR INDUSTRIAL USE ONLY
CONSULT MATERIAL SAFETY DATA SHEET FOR DETAILS.

CERTIFIED TO ANSI/NSF STANDARD 61

IN CASE OF EMERGENCY, CALL: CHEMTREC 800-424-9300

Bayer
Polymers Division

Bayer Corporation
100 Bayer Road
Pittsburgh, PA
15205-9741

LABEL TEXT DATE:
09/30/96

MACHINE SELECTION

EXTRUDER

Bayer styrenic resins can be extruded on all modern, conventional, single-screw extruders meeting the basic criteria illustrated in Figure 3. The basic extruder size chosen is a function of the sheet or profile size and the overall desired output. The output ranges typical of extruders used for Bayer styrenic resins are summarized in Table 2.

Bayer styrenic resins process best on two- or three-stage vented extruders. Vented extruders provide a means for removing the small amounts of volatiles that may enter the system after the drying operation and affect the quality of the extrudate.

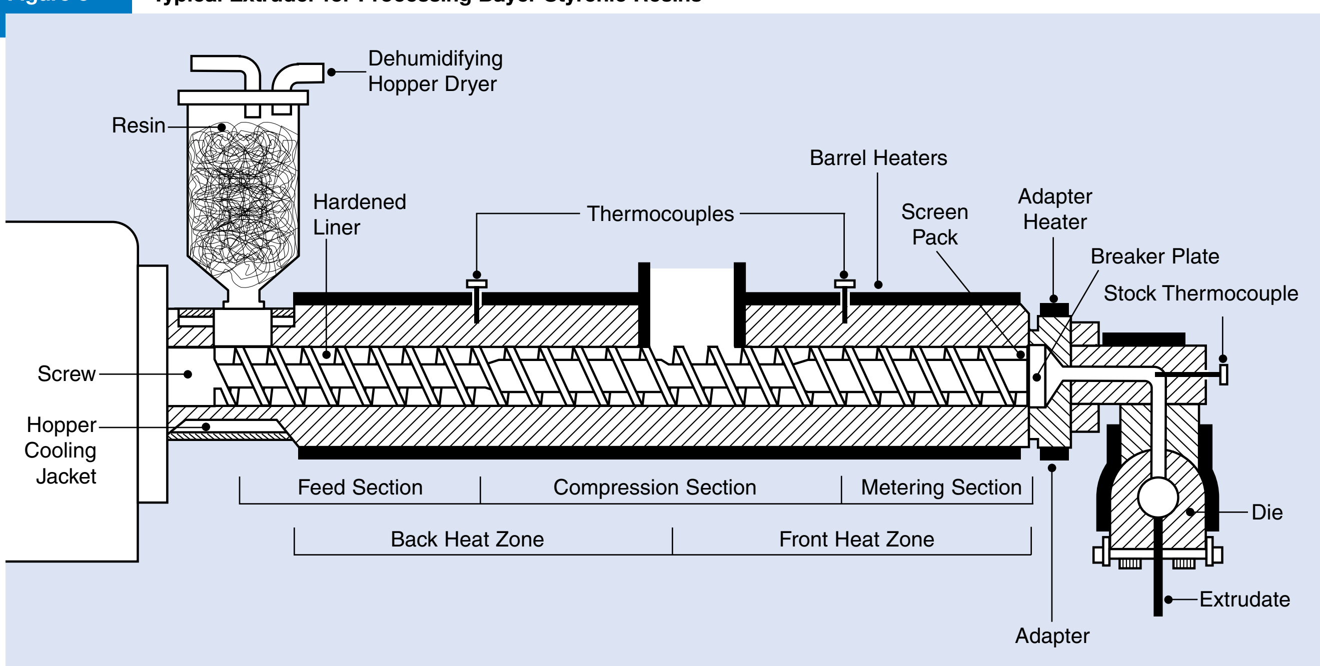
Either a top- or side-mounted vent is acceptable. A top vent performs slightly better than a side vent, but a side vent is easier to inspect and clean.

Extruders of a variety of barrel lengths and diameters can be used. For two-stage (single-vent) barrels, an L/D (length-to-depth) ratio of 24:1 to 32:1 is preferred. For a three-stage (two-vent) barrel, 36:1 to 40:1 is standard.

Whether two- or three-stage, the barrel should have an abrasion resistant, bimetallic liner, such as Xaloy.*

*Xaloy is the registered trademark of Xaloy, Inc.

Figure 3 **Typical Extruder for Processing Bayer Styrenic Resins**



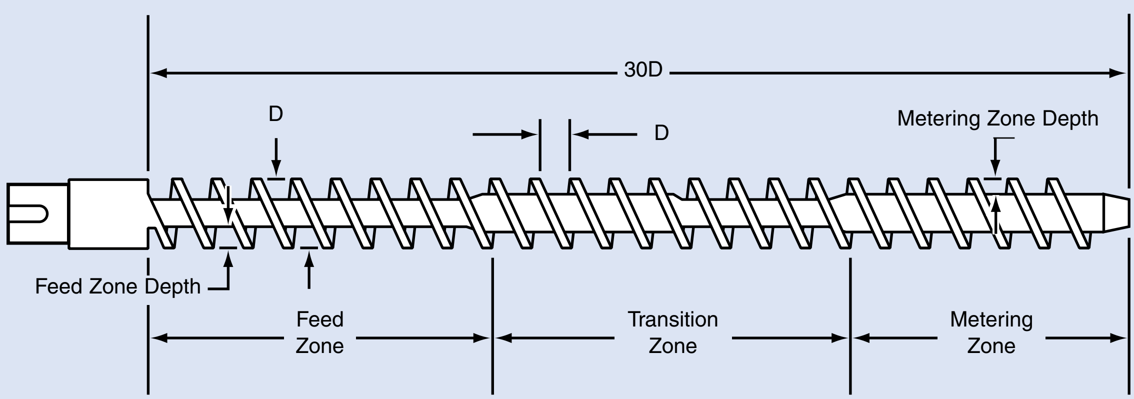
Screw

The production of quality extrusions at an optimum rate with Bayer styrenic resins is directly related to the design of the screw. A correctly designed screw accepts the pellets from the hopper-feeder and moves them forward in the barrel at a uniform rate while generating enough frictional heat at the barrel wall to help melt and mix the polymer. The flow of melt between the first and subsequent stages must be balanced; otherwise, material can flow out of the vent if the second or third stage does not carry the melt away fast enough. The screw also must discharge the melt at a constant pressure and temperature; otherwise, the extrusion may suffer variations in gauge or wall thickness and poor uniformity.

Following are important considerations for choosing a screw for extruding Bayer styrenic resins:

- A two-stage screw design having an L/D ratio of at least 30:1 is recommended.
- A first-stage compression ratio of between 2.5:1 and 3:1 is desirable. The lower compression ratio works better for tougher, more viscous polymers. The higher compression ratio works better for less viscous polymers.
- The pump ratio – the second stage metering depth divided by the first stage metering depth – should be between 1.5:1 and 2.0:1. Below 1.5:1, vent flow is common. Above 2.0:1, surging is a problem.

Figure 4 **Typical Two-Stage Screw Design for Extruding Bayer Styrenic Resins**



$$\text{Compression Ratio} = \frac{\text{Feed Depth Zone}}{\text{Metering Zone Depth}}$$

- Use screws made of SAE 4140 steel or a similar material with the flights either flame-hardened or made from Stellite* alloy.

- Screws should have a chrome-plated surface for optimum material flow.

- A removable tip is desirable to allow the later addition of a mixing segment for improved processing of custom materials.

A 4.5-in. (115 mm) screw for a 30:1 extruder which meets these criteria is shown in Figure 4.

*Stellite is the registered trademark of Cabot Corporation.

Extruder Drive

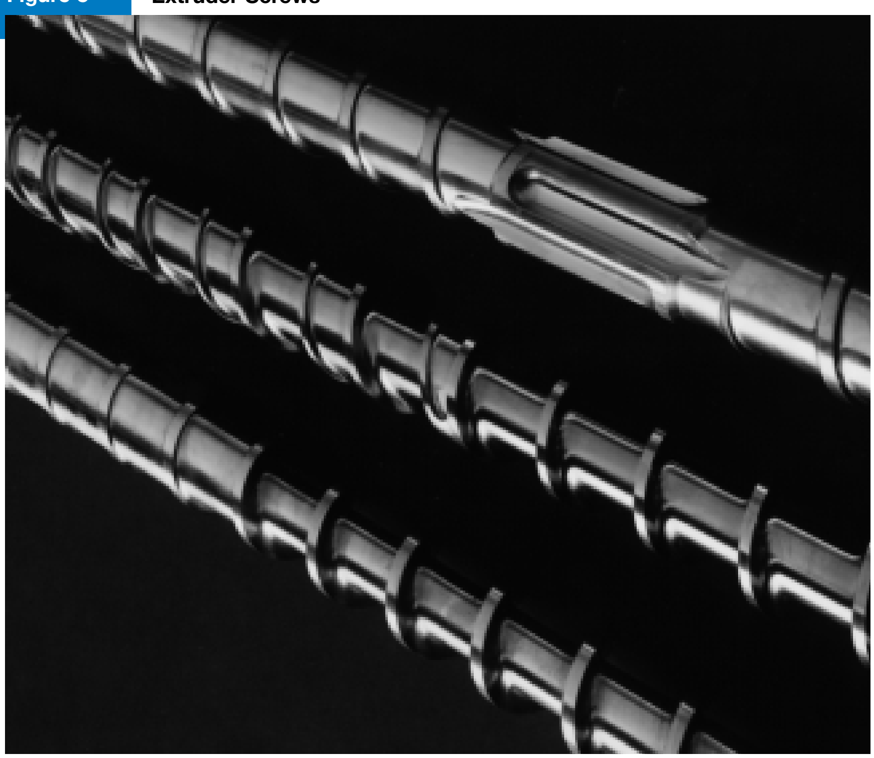
Estimated horsepower requirements for desired material output are provided in Table 2. Bayer styrenic resins require 0.1 to 0.15 hp/lb/hr. The drive units are generally equipped with some type of variable speed control. Both AC-DC drives and magnetic eddy current clutch drives are used, as well as mechanical types.

Even with an appropriately sized drive, be careful during startup to avoid damage to the drive or the screw. Overloading will occur if the barrel temperatures are set too low or the feed rates are too high.

The drive unit must maintain a uniform speed under varying load conditions. Check the performance of the drive unit periodically by timing the screw revolutions.

A drive system with an automatic current-limiting circuit is helpful but not necessary. The gearbox safety factor should be 1.25 to 1.50, minimum.

Figure 5 **Extruder Screws**



CONTROLS

Temperature Controls

Temperature control of the melt is crucial to the successful extrusion of Bayer styrenic resins. Ideally, the extruder barrel is divided into several temperature control zones. Each zone must have independent thermocouples and temperature controllers. Solid-state controllers with a digital set point are preferred, though on/off-type controllers are satisfactory. The digital set point permits more accurate operation and reduces the possibility of a controller being incorrectly set.

Since conventional thermocouples are located in the barrel wall and not directly in the melt stream, the temperature indicator shows only a relative measure of the melt temperature. Fiber-optic thermocouples, however, are able to read actual melt temperature and are desirable.

Most of the heat required to melt the resin is generated by friction as the resin is conveyed along the extruder barrel by the screw. Heaters primarily help maintain a uniform barrel temperature. Heating can be accomplished with electric resistance heaters designed to heat the barrel evenly.

Cooling can be accomplished by air, oil, or water as long as the system is properly designed to maintain a constant temperature and not override the set point nor induce swings in the barrel temperature. Most commercial extruders are water cooled.

The heating zones of the barrel must not affect one another. Heating zone overlap makes it difficult to follow the recommended operating temperature profile.

Table 2 **Extruder Drive Requirements**

Screw Diameter in. (mm)	Output lb (kg)/hr	Horsepower
2.5 (60)	100–250 (45–115)	25–100
3.5 (90)	300–800 (135–360)	50–150
4.5 (120)	700–1,500 (315–675)	100–250
6 (150)	1,200–2,000 (540–900)	150–350

The adapter and die sections of the extruder require only heating capabilities since little heat is generated by shear in these sections. Size and control the heaters to maintain the polymer melt temperature, not to raise or lower it substantially. Overheating can cause large temperature gradients (and viscosity gradients) across the melt stream and result in an uneven flow out of the die.

Pressure Controls

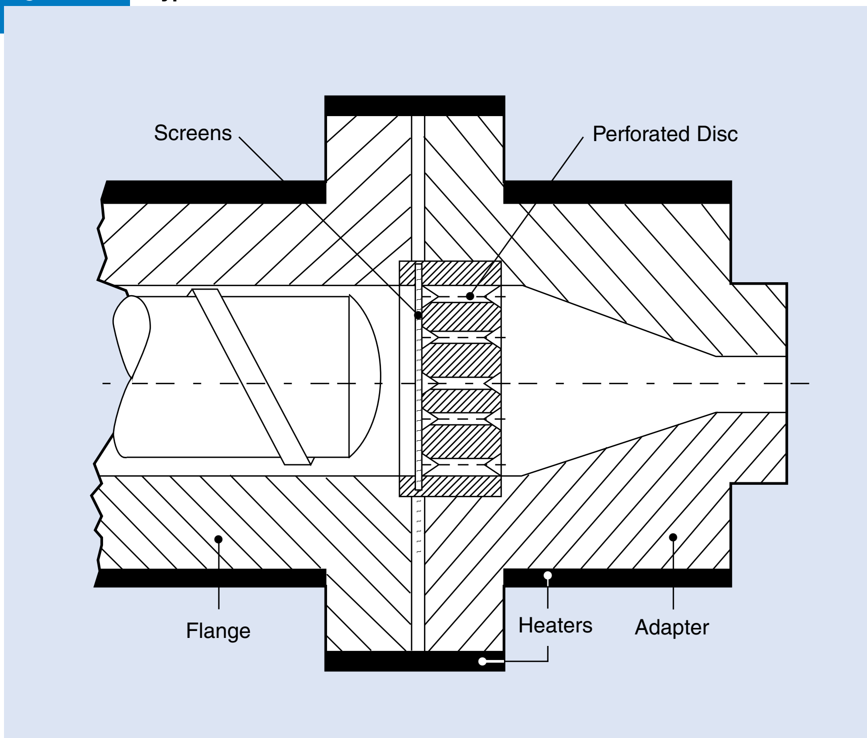
In addition to the conventional melt-pressure gauge at the front of the screw, another pressure gauge is desirable near the front of the transition zone of the screw. This additional gauge provides the maximum information needed to set the extruder conditions.

Melt pressure at the front end of the screw can be controlled either by a valve inserted in the melt stream or by changing the mesh size in the screen pack. Head pressures can be varied from about 1,000 to 5,000 psi (6.895 to 44.474 MPa) with a target of 1,000 to 3,000 psi (6.895 to 20.684 MPa).

Significant fluctuations in head pressure may indicate the need for decreasing rear-zone temperatures on the barrel. If pressure gauges are present on both sides of the screen pack, an increasing difference between the readings indicates a need to change screen packs.

The melt pressure near the front of the transition zone is important. Control it to achieve a low, steady level by balancing barrel temperatures and screw rotational speed (rpm) for the type of screw design being used. A pressure gauge should be used to monitor it over a range of 500 to 1,000 psi (3.447 to 6.895 MPa).

Figure 6 **Typical Screen Pack Installation**



ADAPTER SYSTEM

The "adapter system" refers to everything located between the extruder and the die. It may include a screen pack, gear-type melt pump, static mixer, and coextrusion adapter.

As the melt leaves the end of the screw, it should be a homogeneous mass consistent in both temperature and composition. Some inconsistency at this point can be corrected with the use of a static mixer or melt pump. However, make an effort to correct any inconsistency in the extruder, because a lack of homogeneity could lead to problems further downstream at the die lips.

Screen Pack

A screen pack, as illustrated in Figure 6, consists of one or more layers of wire mesh screen and a breaker plate to support the screens. A screen pack may be placed at the output end of the screw to accomplish one or more of the following functions:

- To strain particulate matter from the melt stream.
- To provide additional back pressure to control mixing in the metering zone of the screw. The pressure and temperature at this point are influenced by: (1) the mesh and number of screens used; (2) the diameter of the breaker plate holes; (3) the diameter of the breaker plate; and (4) the bore diameter of the adapter after the breaker plate.
- To provide additional local mixing.

The screen pack can be manually removed and changed, or it can be incorporated in a manual or automatic screen changer. An automatic screen changer does not require shutting down the line to make a change.

A typical screen pack for removing particulates contains an ASTM mesh number combination of 20-80-40-20 (upstream to downstream) or a symmetrical pack of 20-40-80-40-20. This will stop any large foreign particles that might have been picked up in regrinding or handling with only a moderate pressure drop. With dies of small openings, especially profile dies, use only a coarse mesh pack (20-40-20), or none at all, to avoid plugging.

A screen as fine as 200 mesh can be used to remove contamination. Finer screens will increase the back pressure and possibly affect throughput rates.

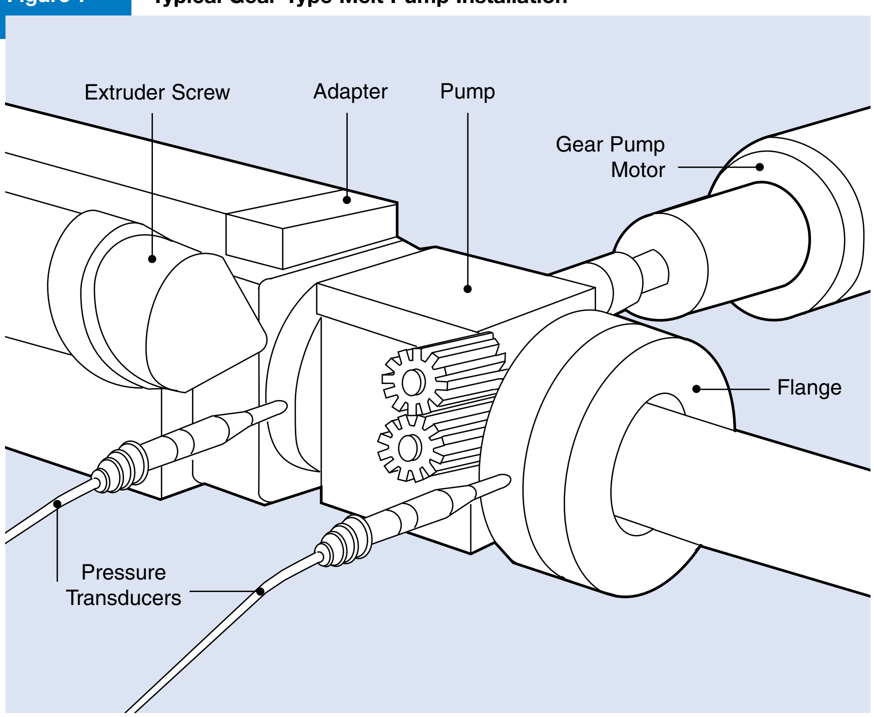
Monitor the melt pressure behind the screen pack to know when the screen is plugging. Excessive back pressure from plugged screens results in high melt temperatures and/or reduced rates. A gate valve is often located after the screen pack to help adjust back pressure. This can be helpful in attaining the proper melt.

Melt Pump

A microprocessor-controlled gear-type melt pump, as shown in Figure 7, can improve performance and efficiency when extruding single- or multiple-layer sheet or profiles. It can help to achieve better control of the process and produce more uniform sheet gauges and wall thicknesses. The gear pump can correct problems inherent with a screw extruder such as purging and temperature or pressure spikes. These problems can cause unsteady output and poor control of sheet or profile accuracy.

The gear pump divides the extruder output into small, volumetrically controlled increments and forwards them at a very precise rate. It can generate the pressure required to force the polymer through the die without the heat buildup which occurs when the extruder must generate the pressure.

Figure 7 **Typical Gear-Type Melt Pump Installation**



Because it allows for more latitude in resins, a gear pump makes it possible to extrude a variety of materials and resin grades without changing screw profiles. For the same reason, a gear pump makes it easier to coextrude combinations of Lustran, Centrex, and Bayblend resins.

Static Mixers

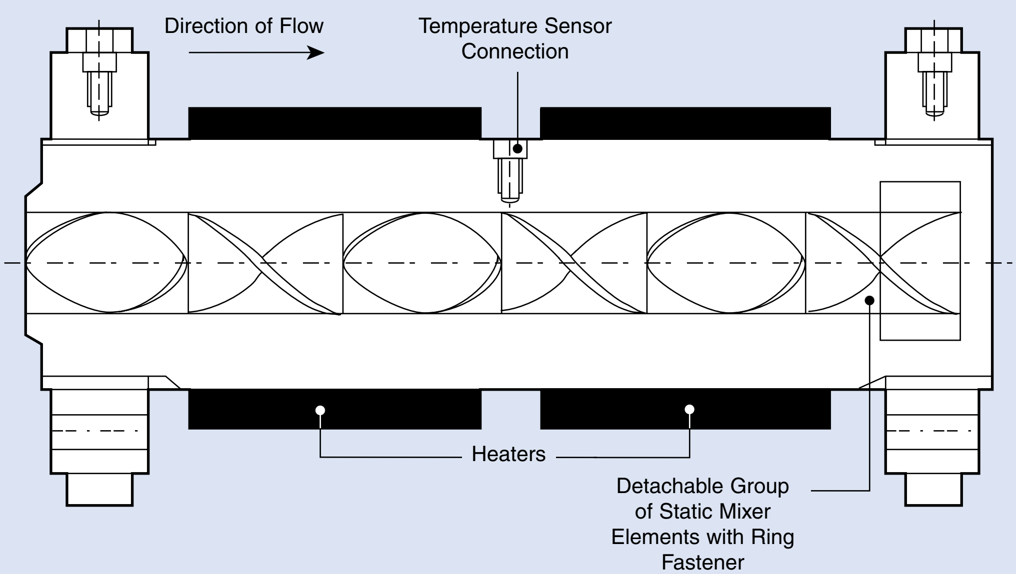
Using a static mixer between the extruder and the die may be helpful in achieving uniform mixing and precise temperature consistency of the melt at high output rates, especially under one or both of the following conditions:

- Regrind is being processed with virgin pellets.
- Colorants are being added to the melt.

Head pressure and melt pressure must be held constant in order to maintain uniform sheet gauges and profile wall thicknesses.

Figures 8 and 9 show one type of static mixer in the adapter. The passive elements of the static mixer cause the material to subdivide and recombine in order to increase the homogeneity of the melt. The result is a more stable extrusion process with less output surge. It is important that the mixer elements be removable for cleaning and the mixer be a type that does not generate excessively high back pressure.

Figure 8 **Typical Static Mixer Installation**



Provide sufficient heat-up time when starting up the extruder, especially if the material is in the mixer from shut-down. To prevent excessive pressures and damage to the extruder, keep the extruder's rpm low until material flows from the die.

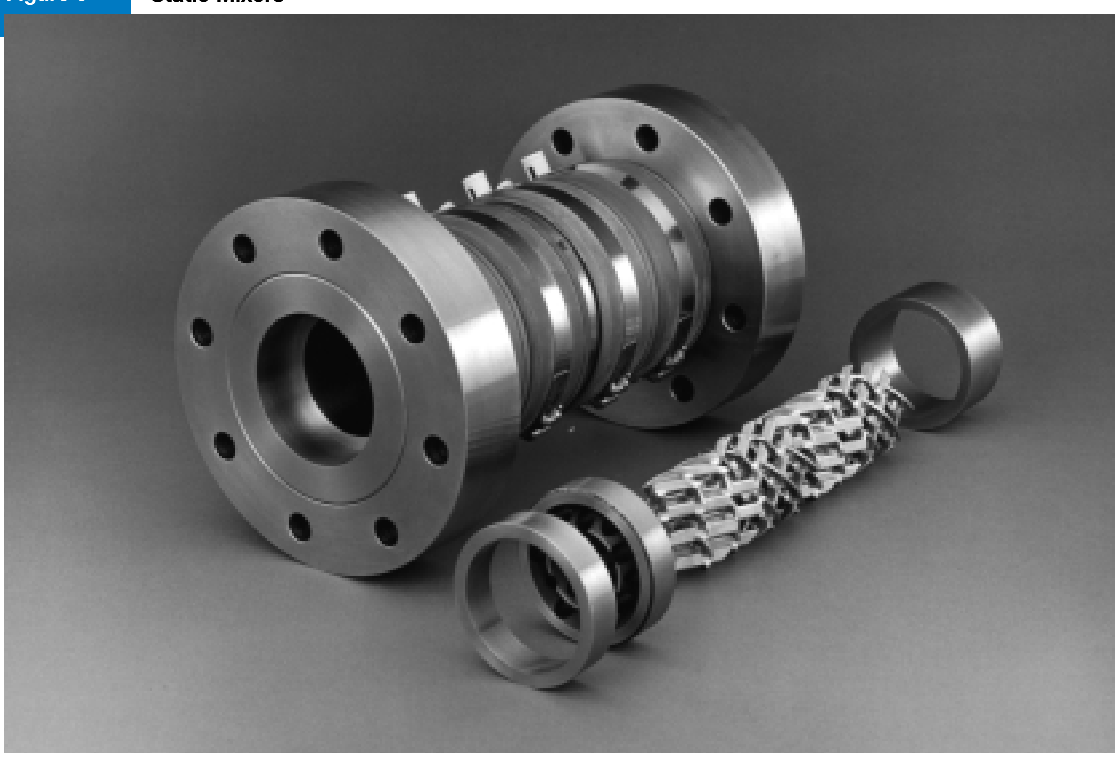
Adapter Body

Install a standard adapter body between the extruder and the die when a melt pump or static mixer is not used. The adapter should be as short as possible and have a streamlined flow channel. Use an adapter that is constructed to withstand a minimum of 10,000 psi (68.948 MPa), has a melt pressure and melt temperature sensor, and heaters adequate to maintain the melt temperature. A valved adapter can be used but is not recommended.

MACHINE VENTILATION

Locate a venting hood at the forward, die end of the extruder to remove any fumes generated by the extruding process or during purging.

Figure 9 **Static Mixers**



DOWNSTREAM SYSTEMS

This section is intended as a general guideline for converting Bayer styrenic resins to sheet, or for extruding various shapes from Bayer styrenic resins. Additional assistance may be obtained by contacting a Bayer Corporation Technical Group representative for styrenic resins at 412-777-2000.

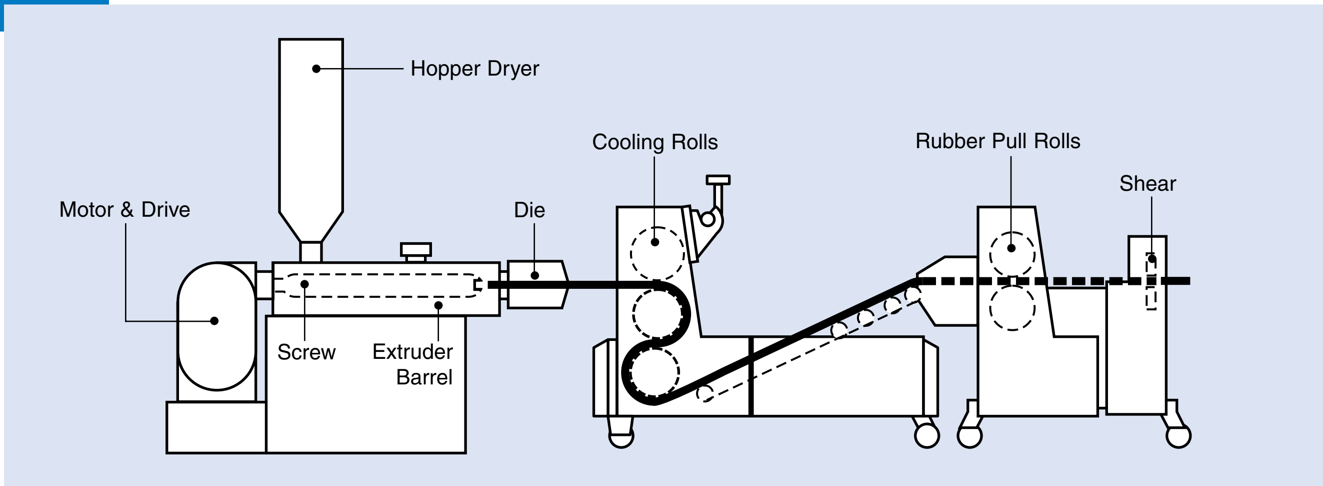
SHEET

A typical sheet extruding line is shown in Figure 10. It consists of polishing rolls, pull rolls, and a shear. Polishing rolls cool the sheet, correct for minor gauge variations, and impart the desired surface to the sheet. The pull rolls, usually rubber, take the sheet off the final cooling roll and feed it to the shear. The shear cuts the sheet to length.

Polishing Rolls

The quality of the sheet is directly related to the surface quality of the polishing rolls. Therefore, chrome-plated rolls which have been ground to a surface of 3 to 6 µin. (76 to 152 µm) are desired for good gloss. The rolls must be perfectly round and revolve with equal peripheral speed. Positive stops for setting the roll gap and precise control of the roll pressure are important

Figure 10 **Typical Sheet Extruding Line**



for ensuring uniform sheet gauge. The volume of water through the rolls is crucial for cooling and temperature control. The rate usually ranges between 40 and 60 gpm (65 and 225 lpm). Treated water in a closed loop minimizes scale build-up on the inner walls of the rolls.

Roll stands are available with horizontal alignment or alignment that can be adjusted between vertical and horizontal. Some roll stands contain four or five rolls. These stands enable optimum cooling when several different materials are run on the same line, or for materials having different melt strengths and which must enter the rolls at different angles. By moving the relative alignment of the rolls, cooling time and contact time can be modified to meet specific needs for surface appearance.

Figure 11 shows a three-roll stand with an "up-stack" alignment. This alignment is common in custom processing and for embossing heavy-gauge sheet. When embossing the sheet in this alignment, the embossing roll is typically the middle roll. This aids in obtaining the detail of the embossed roll pattern because the melt temperature is highest at the exit of the die. In addition, the embossed surface is up and will not be scratched as the sheet is pulled across the take-off and toward the shear. An "up stack" also works better for heavy-gauge sheet because the sheet can "fall" down to the pull rolls rather than being pulled up.

Figure 11 "Up-Stack" Roll Stand

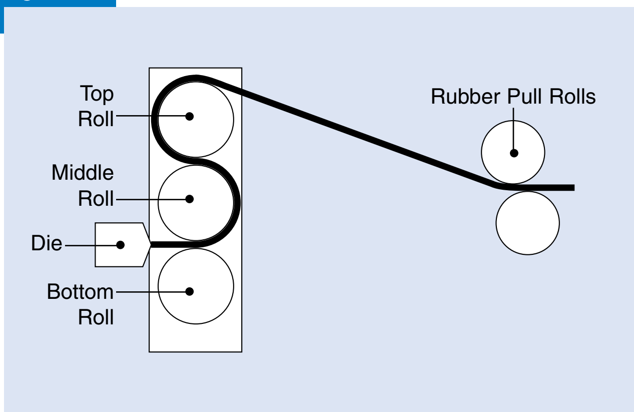
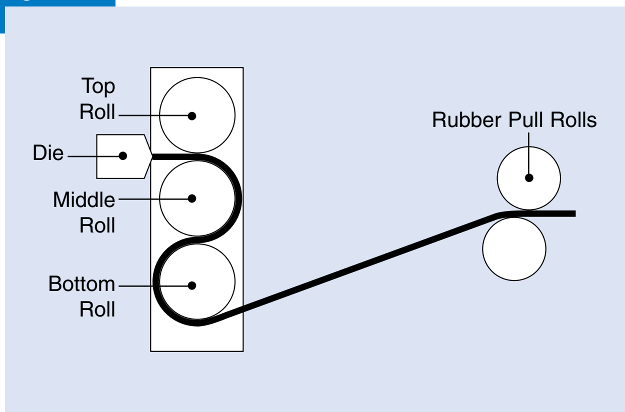


Figure 12 "Down-Stack" Roll Stand



Roll temperatures typical for Bayer styrenic resins on an "up-stack," embossed middle-roll system are shown in Table 3.

A "down-stack" roll alignment, as shown in Figure 12, can also be used. These are more common for thin-gauge sheet and for producing sheet with a smooth, high-gloss surface. The smooth, high-gloss surface is a result of transferring the finish of the bottom roll onto the cooled sheet as it travels around the roll.

The roll temperatures recommended for cooling sheet extruded of Bayer styrenic resins on a "down-stack" roll stand are also shown in Table 3.

Maximum smoothness and gloss are achieved by adjusting the roll temperatures to obtain the surface temperature profile shown in Figure 13, as measured with an infrared optical pyrometer. Best results are obtained on sheet extruded from Bayer styrenic resins when the A_2 temperature — the surface temperature of the sheet as it contacts the bottom roll — is between 310˚ and 350˚F (155˚ and 175˚C). Achieving these temperatures is dependent on using a cooling roll of the proper diameter.

The cooling capacity of the roll stand must be sized to the extrusion rate of the extruder. Stock temperature, sheet thickness, and linear rate are important in optimizing roll diameter. Generally, when processing ABS at 800 lb/hr

Table 3 **Typical Roll Temperatures for "Up-Stack" and "Down-Stack" Roll Stands**

Roll Position	"Up-Stack"	"Down-Stack"
Top	180˚–220˚F (85˚–105˚C)	175˚–225˚F (80˚–110˚C)
Middle	200˚–250˚F (90˚–120˚C)	150˚–175˚F (65˚– 80˚C)
Bottom	150˚–170˚F (65˚–75˚C)	175˚–225˚F (80˚–110˚C)

(360kg/hr) on a 4.5-in. (115-mm) line, 12-in. (305-mm) diameter rolls are sufficient. At rates in excess of 2,000 lb/hr (910 kg/hr), use rolls 24 to 30 in. (610 to 760 mm) in diameter. A roll that is too large is not a problem since the roll temperature can be elevated. In some cases double-width dies are used and the sheet is split in the center or it is turned 90˚ to reduce the linear rate.

Figure 14 translates linear rate for various sheet thicknesses into suggested roll diameters in order to obtain a 310˚ to 330˚F (155˚ to 165˚C) A_2 temperature. For example, if the estimated linear rate of 200-mil sheet is 5 ft/min. (1.5 m/min.), then the estimated roll diameter would be 18 in. (455 mm) and the range about 16 to 20 in. (405 to 510 mm).

The conversion from lb/hr (kg/hr) to ft/min. (m/min.) is:

$$\text{Linear Rate (ft/min.)} = \frac{.0361 \cdot (\text{lb/hr})}{w \cdot t}$$

where w = sheet width (die width), in.
t = sheet thickness, in.

$$\text{Linear Rate (kg/min.)} = \frac{.0361 \cdot (\text{kg/hr})}{w \cdot t}$$

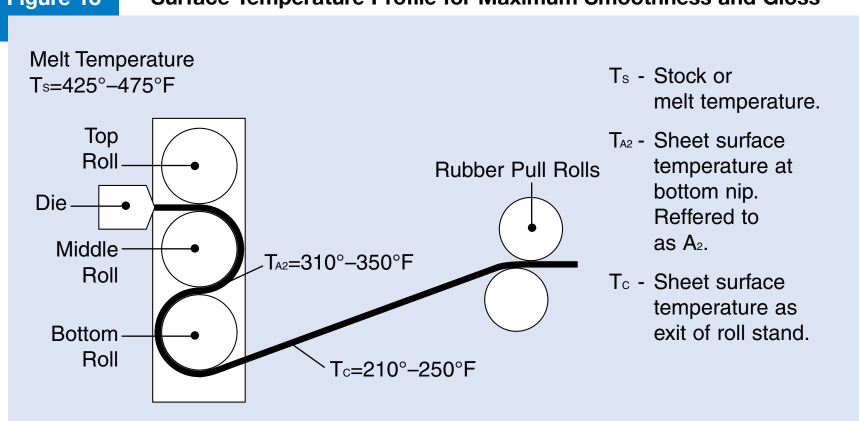
where w = sheet width (die width), mm
t = sheet thickness, mm

In general, as linear rate increases, greater cooling capacity and, therefore, larger cooling rolls are required.

On "down-stack" roll stands, a moderate to high bottom roll pressure helps ensure polishing roll contact and good polishing. Similarly, on "up-stack" roll stands, a moderate to high bottom roll pressure is recommended, but to help ensure embossed pattern detail. In both cases, the goal is to transfer the surface appearance of the rolls, whether polished or embossed, onto the sheets.

The roll stand is positioned as close to the die as possible to cool the sheet and avoid surface oxidation. A bank of small, uniform rolls smaller than the diameter of a pencil feeds the roll nip between the top or bottom roll and the middle roll. The roll gap should be 3% to 5% smaller than the desired gauge for positive contact between the rolls and to remove minor surface defects.

Figure 13 **Surface Temperature Profile for Maximum Smoothness and Gloss**



Pull Rolls

Pull rolls keep the sheet moving and feed it to the shear. They do no cooling or shaping. Pull-roll speed is usually linked to the cooling-roll speed, so dual adjustments are not necessary. The pull-roll unit should be equipped with a differential speed control so that the pull rolls can be adjusted to run slightly faster than the cooling rolls, keeping a slight tension on the sheet.

SHEARING AND SHEET HANDLING

The shear should be designed to cut the sheet uniformly and prevent chatter marks. Thicknesses up to 0.300 in. (7.5 mm) are usually sheared. Beyond this thickness, sawing is often used, though heavy-duty shears are available.

Stack the cut sheet manually or with a commercial stacking unit on pallets. Storing the sheet in de-ionized air will reduce the dust pick-up from static charges generated during processing. Wrapping stacked sheet in 8- to 10-mil polyethylene (PE) film will help reduce moisture absorption and keep the sheet clean. Two layers of 3- to 4-mil PE film offer even better moisture protection. The absorption of moisture can decrease the forming range of the sheet and cause craters in the surface of formed sheet.

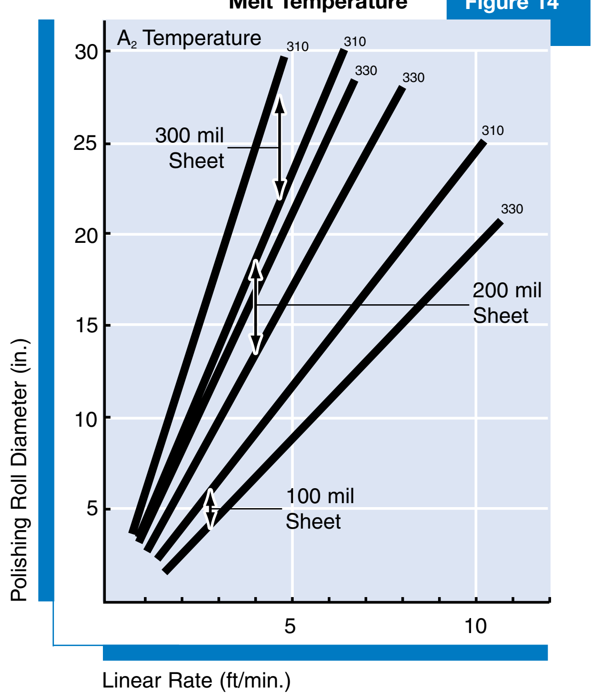
SHEET THICKNESS (GAUGE) MONITOR AND CONTROL

Holding gauge to between ±3% and ±5% is possible when manually controlling gauge. If material distribution problems occur when thermoforming sheet with a manually controlled gauge, increase overall sheet gauge by 5% to 10% to relieve the problem.

With automatic measuring and gauge control systems, it is possible to hold gauge to between 0.5% and 1%. Better gauge control can result in fewer thermoforming problems and substantial material savings. In some cases, better control also can allow gauge reduction. Automatic measuring and gauge control systems are ideal when extrusion runs are long, only a few different materials are processed on the same line, and only a few different thicknesses are required. There is gauge equipment available that can measure the cap thickness as well as the overall sheet thickness.

Suggested Polishing Roll Sizes at a 450˚F (235˚C) Melt Temperature

Figure 14



Some automatic systems control gauge by adjusting line speed and screw speed. Others control die bolt heats to adjust the distribution of material across the sheet. And still other systems use computers to control particular configuration setups that can be recalled, improving sheet consistency from run to run, providing faster start-ups, and reducing cost and scrap.

Contact your Bayer Corporation Technical Group representative for styrenic resins at 412-777-2000 for more information on gauge monitoring and control.

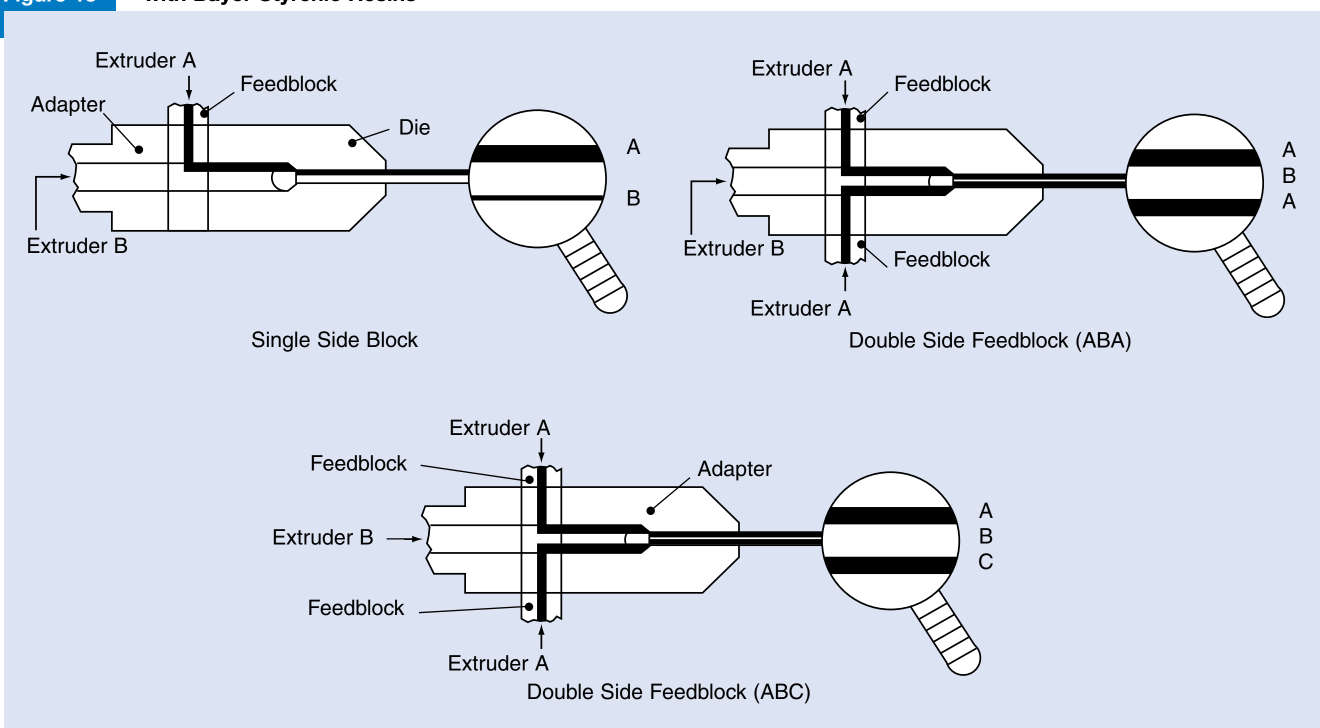
COEXTRUSION

Coextrusion is the simultaneous extrusion of two or more materials out of a single die. It can provide a whole range of products that combine the benefits of multiple materials into a single sheet. Coextrusions can be of two similar generic materials such as two grades of Lustran® ABS, two different colors of the same grade, or two or more totally different polymers such as Centrex®, Lustran® ABS, and Bayblend® resins.

For coextrusion to be successful, the materials must be chemically compatible. These compatible materials are fused together in the melt stage so that they cannot be separated and will not delaminate. Two dissimilar or incompatible materials can be coextruded by using a tie or glue layer between them. However, any scrap materials will not be reusable as regrinds and therefore the cost of the sheet will increase.

Plastics that are to be coextruded also must have similar melt viscosities at the extrusion processing temperature to distribute the layers uniformly. Extrusion grades have been developed to match flows and improve coextrusion.

Figure 15 **Coextrusion Structures Possible with Bayer Styrenic Resins**



Specific equipment has been designed and manufactured for coextrusion. This equipment is either a special die, called a multi-manifold die, or a feed-block positioned between the extruder and the die. Gauge control systems are indispensable in achieving uniform material distribution and layer thicknesses.

Typical structures of sheet coextruded of Bayer styrenic resins include A/B, A/B/A, and A/B/C, as shown in Figure 15.

Consult your Bayer Corporation Technical Group representative for Bayer styrenic resins at 412-777-2000 and the equipment suppliers to ensure the proper match of materials and equipment.

PROFILES

Successful profile extrusion with any resin depends strongly on correct die design (see “Profile Dies,” page 36). Profiles may be cooled by water immersion or by air directed onto the profile at a point near the die. Manipulate the airstream together with a holding tool and flow control in the die (by variac adjustment) to achieve and hold exact dimensions.

DRYING

Styrenic resins are hygroscopic, meaning that they will absorb and react with moisture in the atmosphere. Resin exposed to the atmosphere begins absorbing moisture immediately. Moisture in the resin adversely affects processing and the quality of the extruded part. So even though Bayer styrenic resins are supplied in sealed cartons, it is essential to use a desiccant dehumidfying hopper dryer to keep the resin dry during processing.

Moisture removal is only one reason for predrying the resin. Preheating the resin can increase output by at least 10%. Preheating also provides controlled and uniform feedstock temperature which results in more uniform output and better gauge control.

Warm to room temperature any sealed cartons which have been stored in unheated warehouses before opening them. This will help prevent rapid condensation of ambient moisture on cool pellets.

Single cartons can take 24 hours or more to warm. Stacked cartons can take a week or longer.

Table 4 **Proper Moisture Content for Bayer Styrenic Resins**

Venting	Maximum Moisture Content of Feedstock Pellets After Drying
None	0.03%
Single Vent	0.06%
Double Vent	0.10%

DRYING EQUIPMENT

Desiccant Hopper Dryer

Use a desiccant dehumidifying hopper dryer to remove moisture from Bayer styrenic resins and to maintain proper resin moisture content during processing. A desiccant dehumidifying hopper dryer circulates air from the resin hopper through a desiccant bed which removes the moisture. The dry air is then returned to the hopper. A desiccant dehumidifying hopper dryer ensures proper resin drying even during warm, humid weather.

The proper resin moisture content for Bayer styrenic resins varies, depending on whether the extruder is vented or unvented, and, if vented, whether the extruder has one or two vents. A guide for proper resin moisture content for Bayer styrenic resins is provided in Table 4.

The dryer must meet the following requirements to properly remove moisture from Bayer styrenic resins:

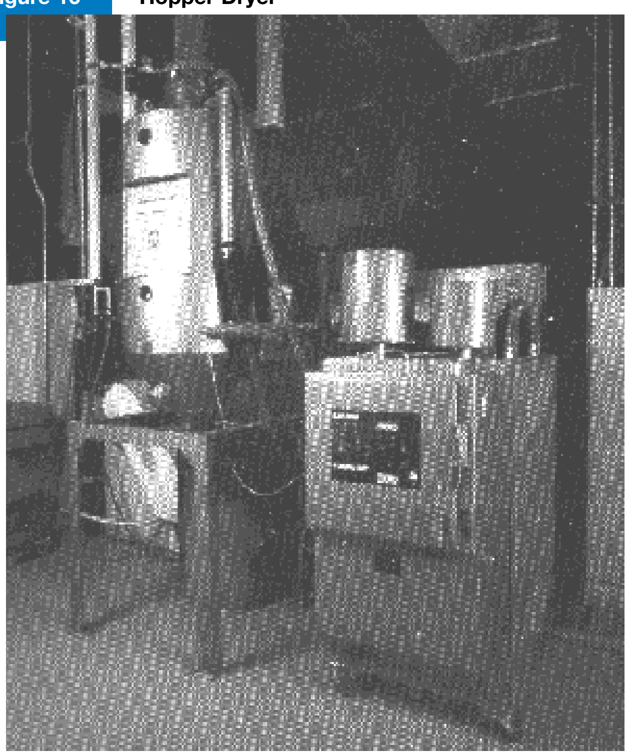
- Hopper capacity should be sufficient to ensure that the resin remains in the drying hopper at least 3 to 4 hours prior to being extruded.
- Hopper inlet air temperature of 180˚ to 220˚F (85˚ to 105˚C). Temperatures in excess of 230˚F (110˚C) may cause the pellets to block in the hopper.
- Airflow to the hopper of 1.0 cubic foot per minute (CFM) for every pound of resin per hour of throughput.
- Dew point of the inlet air to the hopper at 0˚F (-18˚C) or less.

Some recent dryer designs perform to less demanding requirements. However, use caution when deviating from these guidelines since the quality of sheet and parts extruded from Bayer styrenic resins critically depends on low moisture content.

A typical desiccant dehumidifying hopper dryer system and airflow are shown in Figures 16 and 17. Note that the hopper is tall and cylindrical and has a diverter cone to diffuse the air uniformly and reduce channeling of the pellets.

The desiccant beds have heaters for recharging the beds periodically. Check them regularly to ensure that they are working properly. During recharging the temperature of the bed is elevated to 400˚ to 500˚F (205˚ to 260˚C) and must be cooled before the dryer automatically switches to the

Figure 16 **Typical Desiccant Dehumidifying Hopper Dryer**



recharged bed. Dry air should be used to cool the bed — not atmospheric air which could be very moist. The extrusion of sheet that looks wet immediately after switching to a recharged desiccant bed could indicate a problem with either the heaters or the design of the bed cooling system.

If the hopper dryer has not been used for 24 hours, dry-cycle it before introducing the Bayer styrenic resin. This will ensure that the desiccant is dry prior to processing (refer to the manufacturer's recommendations for the procedure). Then load the resin and dry it for at least 3 to 4 hours prior to being introduced to the extruder.

Proper inlet temperature and dry air alone do not guarantee dry feedstock. If a moisture problem persists, it may be due to low air velocity. A quick check of feedstock temperature entering the throat of the extruder can confirm the problem. If all conditions are correct, the pellets should be at 150˚F (65˚C) or higher. A handful of these pellets should be too hot to hold for more than a few seconds.

Additional information for resolving resin drying problems is provided in Table 5. Or consult your Bayer Corporation Technical Group representative for styrenic resins at 412-777-2000

Figure 17 **Typical Desiccant Dehumidifying Hopper Dryer Airflow**

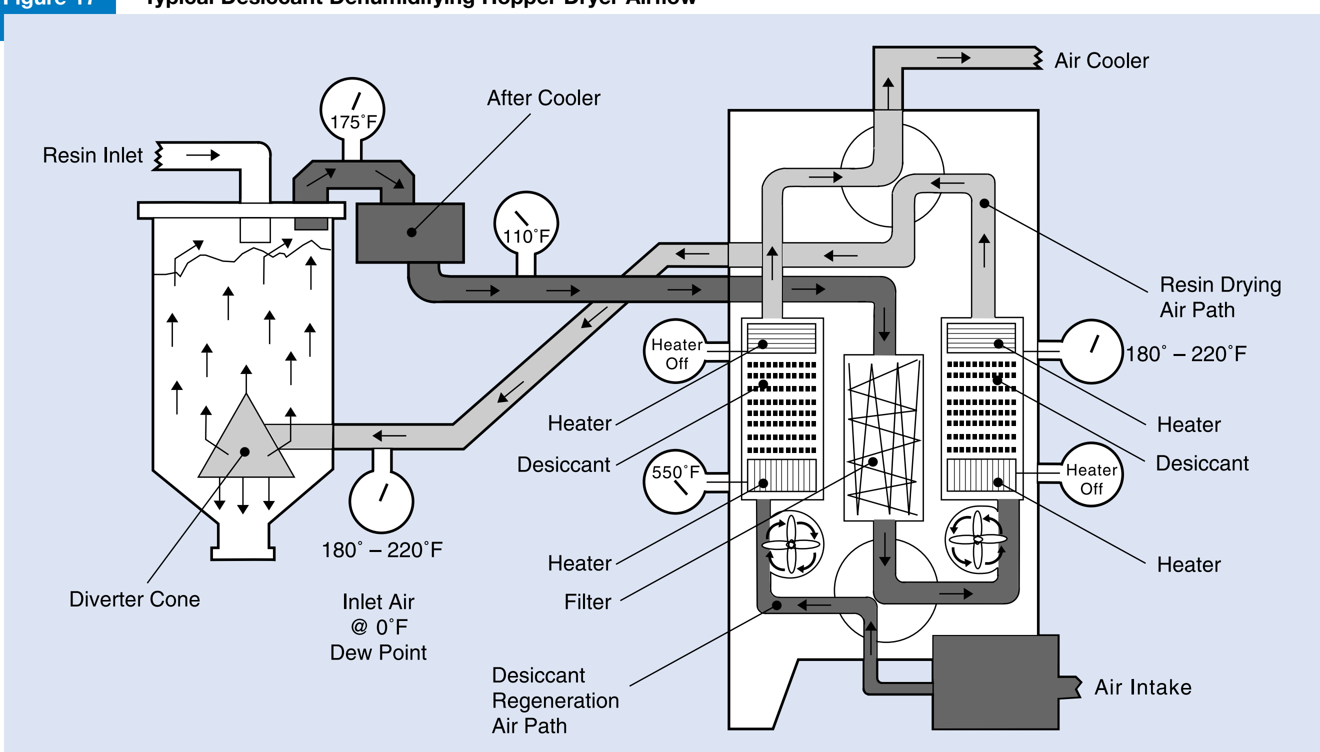


Table 5 **Dehumidifying Hopper Dryer Troubleshooting Guide**

Improper Drying Condition	Drying Equipment Defect	Possible Corrective Action
Poor Dew Point	• Dirty filter(s).	• Clean or replace filter(s).
	• Saturated desiccant.	• Dry-cycle machine for several complete cycles. Saturated desiccant is a common problem with machines that are not in continuous use.
	• Excessive return air temperature.	• Add after-cooler on return air line.
	• Burned-out heater(s).	• Repair or replace heater(s).
	• Contaminated or worn-out desiccant.	• Replace desiccant.
	• Bad heater thermostat or thermocouple.	• Repair or replace thermostat or thermocouple.
	• Malfunctioning regeneration cycle timer.	• Adjust or replace timer.
	• Air control butterfly valves not seating.	• Adjust valve seating.
	• Moist room air leaking into the dry process air.	• Check all hose connections and tighten as required. • Check all hoses for leaks and replace as needed. • Check filter covers for secure fit and tighten as required.
	• Desiccant beds not switching.	• Check electrical connections. • Check switching mechanism.
Material Residence Time in Hopper Too Short	• Dryer hopper too small for the amount of material being processed per hour.	• Use a larger dryer hopper.
	• Not keeping hopper at least 2/3 filled.	• Keep drying hopper full.
Incorrect Process Air Temperature	• Incorrect drying air temperature.	• Dial in correct temperature of 180° – 230°F (85° – 110°C).
	• Dryer temperature controller malfunction.	• Repair or replace controller.
	• Thermocouple malfunction.	• Repair or replace thermocouple.
	• Faulty process air heating elements.	• Repair or replace heating elements.
	• Supply voltage different than required heater voltage.	• Check supply voltage against nameplate voltage.
	• Non-insulated inlet-air hose.	• Repair or replace inlet-air hose.
	• Excessive changeover temperature.	• Increase reactivation airflow.
Insufficient Inlet Airflow (Good dew point but resin still wet.)	• Dirty or clogged filter.	• Clean or replace filters.
	• Incorrect blower rotation.	• Change blower rotation. (Consult equipment manufacturer's electrical instructions.)
	• Obstruction in air ducts.	• Remove air duct obstruction.

MACHINE PREPARATION

Purging and Cleaning

Before extruding Bayer styrenic resins, thoroughly purge or mechanically clean any residual material from the machine. Use a commercially available purging compound. Acrylic is sometimes used. Or use a stiffer (higher viscosity) resin from the same resin family. After purging, run some resin through the extruder until the melt is free of any contamination.

Mechanical cleaning is more thorough than purging and is preferred by many processors. The same procedure can be used either prior to extruding Bayer styrenic resins or upon completion of an extrusion run. Follow these steps:

1. Flush the cylinder rapidly with the purging compound.

2. Disassemble the equipment while still hot and immediately remove as much of the polymer as possible.

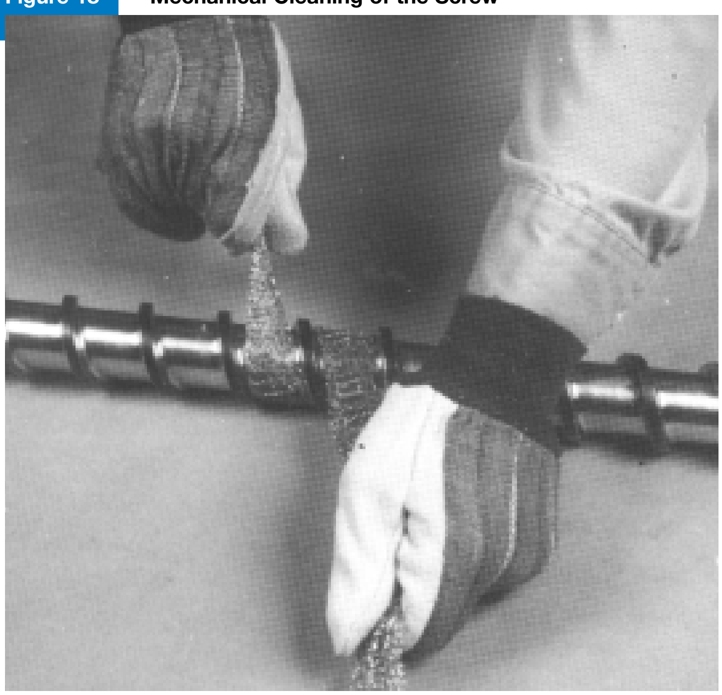
3. Turn off the heat on the main cylinder and push the screw forward until a few flights are exposed.

4. Remove the hot melt with a brass brush and a brass knife. Push the screw forward and clean it this way until all flights are clean.

5. Remove the screw and clean the barrel with a rotary brush on an extension rod attached to an electric drill.

Clean the adapter and any die parts with complex or hard-to-clean channels either by heating them in an oven at 750˚F (400˚C) for 4 to 6 hours or by soaking them in a solvent such as methyl ethyl keytone (MEK). Allow all of the parts to cool before placing them in the solvent. Follow OSHA and NIOSH recommendations on care and handling.

Figure 18 **Mechanical Cleaning of the Screw**



Material Changeover

Take special care changing over from one material to another. In addition to purging or thoroughly cleaning the equipment, always monitor the die pressure and motor amperage because the previous material may have had drastically different melt rheology.

STARTUP PROCEDURE

Processing Temperatures and Machine Conditions

Suggested processing conditions for extruding Bayer styrenic resins are listed in Table 6. Use these profile parameters as guidelines for setting initial machine conditions.

Many factors such as machine configuration and die design affect the determination of the final extrusion conditions. Therefore, the final conditions used may vary considerably from those listed here.

The desired temperature profile is one which plasticizes the material mostly by heat conduction from the barrel and only partially by the mechanical action of the screw. Since the power requirement for the extruder drive is strongly affected by the temperature setting on the zone next to the hopper, this control can frequently be used to offset any equipment limitation in the horsepower of the drive. Changes as small as 10˚F (5˚C) on this zone can affect the power requirement by as much as 20%.

Table 6 **Suggested Processing Conditions for Extruding Bayer Styrenic Resins**

		Bayer Styrenic Resins		
		Lustran ABS	**Centrex**	**Bayblend**
Drying	Time	3–4 hr	3–4 hr	4–5 hr
	Inlet Air Temperature	180˚– 200˚F (80˚–90˚C)	180˚– 200˚F (80˚–90˚C)	200˚– 210˚F (90˚–100˚C)
	Dew Point	-20˚F (-30˚C)	-20˚F (-30˚C)	-30˚F (-35˚C)
	Moisture	0.03%	0.03%	0.03%
Extruder Temperature		420˚– 450˚F (215˚–230˚C)	420˚– 450˚F (215˚–230˚C)	450˚– 475˚F (230˚–245˚C)
Die Temperature		410˚– 465˚F (210˚–240˚C)	410˚– 465˚F (210˚–240˚C)	475˚– 490˚F (245˚–255˚C)
Melt Temperature		420˚– 465˚F (215˚–240˚C)	420˚– 465˚F (215˚–240˚C)	450˚–525˚F (230˚–275˚C)
Roll Temperature				
(Down-Stack)	Top	200˚F (90˚C)	200˚F (90˚C)	225˚F (110˚C)
	Middle	165˚F (75˚C)	165˚F (75˚C)	190˚F (85˚C)
	Bottom	200˚F (90˚C)	200˚F (90˚C)	240˚F (115˚C)
Roll Temperature				
(Up-Stack)	Top	200˚F (90˚C)	200˚F (90˚C)	240˚F (115˚C)
	Middle	190˚F (85˚C)	190˚F (85˚C)	190˚F (85˚C)
	Bottom	180˚F (80˚C)	180˚F (80˚C)	225˚F (110˚C)

The most important processing parameter is melt temperature. Measure this with a melt probe pyrometer or an IR (infrared) pyrometer. An IR pyrometer is safer because it does not require contact with the hot melt.

Checks Prior to Startup

Make the following checks before starting up the extruder:

1. Check the moisture level of the resin.

2. Check the extruder and die for cleanliness. See “Purging and Cleaning,” page 30, for more information.

3. Preheat the extruder, adapter section, and die to the temperatures recommendation in Table 6. Allow 1/2 to 1 hour soak time after the temperatures are reached.

4. Check that the feed throat cooling system is working.

5. Check that the take-off system is at the proper temperature.

Starting the Extruder

“Starve-feed” the extruder at low rpm until the melt leaves the die at an acceptable die pressure and drive amperage. Then start normal gravity feeding and slowly increase the screw speed to the desired operating range.

As the extrudate comes out of the die, guide it through the cooling and take-off equipment. Adjust the take-off speed to match the extruder speed.

Monitor the amperage and die pressure continuously during startup and any subsequent temperature changes. Avoid operating an extruder without a die pressure indicator or a safety relief valve between the end of the screw and the screen pack location, whether or not a screen is used.

Gradually lower the temperature on the front of the extruder until an acceptable melt strength is achieved without a dull appearance on the surface of the extrudate or unacceptably high die pressures.

SHUTDOWN PROCEDURES

Temporary Shutdown

When brief interruptions in the extruding cycle occur, slow the extruder to prevent degrading of the material in the barrel and die. If the machine is to be shut down for 2 or more hours before extrusion is resumed, purge the machine and turn off the heat.

Long-Term Shutdown

When extrusion is completed, purge the machine thoroughly followed by a mechanical cleaning. (See "Machine Preparation, Purging and Cleaning," page 30.)

REGRIND

Up to 40% regrind may be used with virgin material, depending upon the end-use requirements of the extruded part and provided that the material is kept free of contamination and is properly dried. (See "Drying," page 26, for details.) Regrind levels in excess of 40% may deteriorate the appearance and mechanical properties of the extruded sheet or part. High levels of regrind may also require some changes in the extrusion conditions to maintain the desired output rates, depending on the particle size of the regrind.

Any regrind used must be generated from properly extruded sheet, parts, or thermoforming trim scrap. All regrind used must be clean, uncontaminated, and thoroughly blended with virgin resin prior to drying and processing. Under no circumstances should degraded, discolored, or contaminated material be used for regrind. Materials of this type should be discarded.

Lustran ABS, Centrex polymer, and Bayblend alloy are compatible, so regrind of these materials may be mixed. However, do not mix regrind of Lustran ABS with polystyrene, polyethylene, or polypropylene.

Improperly mixed and/or dried resin may diminish the desired properties of the Bayer styrenic resin. You must conduct testing on finished parts produced with any amount of regrind to ensure that your end-use performance requirements are fully met. Regulatory organizations, e.g., Underwriters Laboratories (UL), may have specific requirements limiting the allowable amount of regrind. Because third-party regrind generally does not have a traceable heat history nor offers any assurance that proper temperatures, conditions, and/or materials were used in processing, extreme caution must be exercised in buying and using regrind from third parties.

Regrind is usually a mixture of resin ranging from fine dust to large, irregular chunks. Of particular concern is a high level of regrind with a high percentage of fines, or dust-like particles. This dust can act as a lubricant and cause feed problems. In addition, this dust can affect the appearance of the sheet through buildup on the cooling rolls. A fines removal system may be required if this problem is serious.

The use of regrind material should be avoided entirely in those applications where resin properties equivalent to virgin material are required, including but not limited to, color quality, impact strength, resin purity, and/or load-bearing performance.

TOOLING

The following information is presented as an overview. Detailed information is available in the *Plastics Design Manual*, which can be obtained by contacting your Bayer Corporation Technical Group representative for Bayer styrenic resins at 412-777-2000.

SHEET DIES

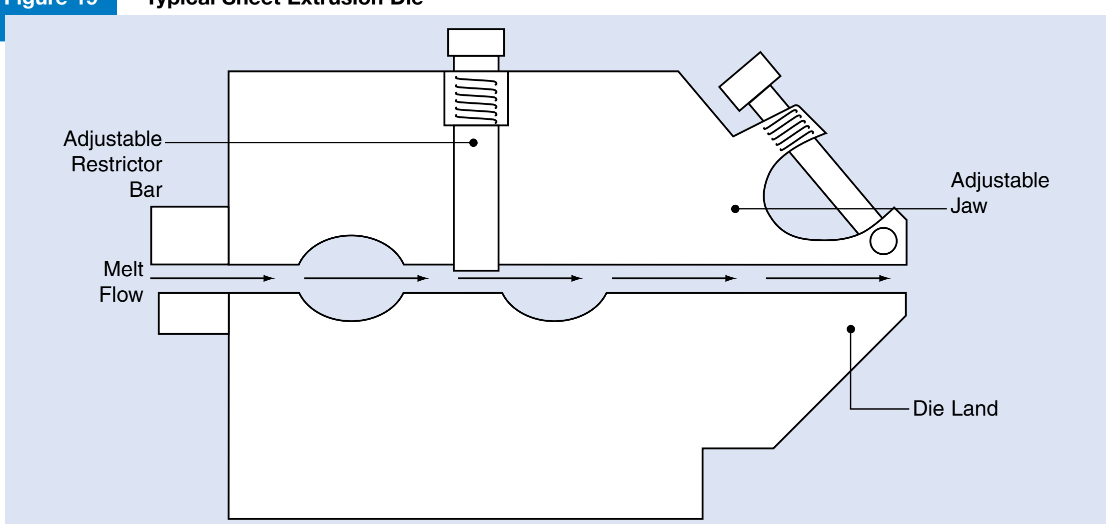
Bayer styrenic resins run best on streamlined manifold dies, sometimes called "coathanger" dies having flexible lips. Streamlined dies, designed for minimum dwell time promote even flow of the melt and eliminate material hang-up in dead spots.

The die should be constructed to operate at pressures of 1,500 to 3,200 psi (10 to 20 MPa) on 4.5 in. (115 mm) extruders. Chrome plating on all interior surfaces of the die will minimize flow resistance and improve the surface characteristics of the sheet.

The die land length should be selected based on the thickness of the sheet to be extruded. A land length of 2 in. (50 mm) should be used for sheet from 0.040 to 0.150 in. (1 to 4 mm), while sheet up to 0.500 in. (13 mm) may require a land length of 3 to 4 in. (75 to 100 mm). The longer land increases the internal die pressure to allow better control of the melt in the die and helps improve the surface quality of the sheet.

An adjustable restrictor bar and an adjustable lip enable variation and control of thickness across the sheet. Tapered die lips allow greater latitude in the operating melt temperature range than a straight-face die.

Figure 19 **Typical Sheet Extrusion Die**



Set the die lip gap equivalent to the desired sheet gauge. Heavy-gauge sheet (>0.125 in./>3 mm) may require a setting 5% to 10% greater than the sheet thickness for optimum gauge control. The settings should be uniform across the entire die width.

Set the temperature of the die approximately at the stock temperature. The intent is to simply keep the melt constant and not heat or cool it. The end zones of the die are often set 10˚ to 20˚F (-12˚ to -7˚C) hotter than the center zones to help distribute the polymer across the whole die. Die settings vary between 400˚ and 480˚F (205˚ and 250˚C), depending on the specific material and screw design.

Separate heater controllers for the die body, die ends, and die lips (if extended lips are used) are required to achieve close control over temperature gradients. This allows better control of both the melt temperature and flow through the die, and can be helpful in distributing the polymer out to both ends of the die. Proportionating controllers are better than the on-off type.

Balance the melt profile exiting the die by adjusting the restrictor bar, bowing it slightly in the middle to restrict flow there and force it out to the ends. Once properly set, the melt profile for a given polymer will remain constant. Changes should not be necessary, and a need for frequent changes may be a sign of problems elsewhere.

Deckle bars or dams are sometimes used to produce narrow sheet or adjust sheet width to minimize scrap. However, material can "hang up" in the die behind the bars and degrade. In addition, deckle bars disrupt the desired streamline flow of material through the die, especially in the new computer-designed flow channel dies. Material and pressure buildup behind the bars can cause heavy sheet edges which prevent good polishing roll contact in the center of the sheet. This results in lower sheet gloss. Therefore, for short runs it may be better to eliminate the deckles and trim the thin edges off the sheet, while for long runs a properly sized die is best.

PROFILE DIES

The dimensions of dies for extruding profiles with Bayer styrenic resins depends on the specific resin grade selected, the size of the extruder, and desired dimensions of the extruded part.

Figure 20 shows a side and end view of a profile die for a flat shape. To achieve the desired size, the proper die width "W" and die thickness "T" must be determined. These are different than the final part width and thickness. In general, the die opening will be larger than final part dimensions. For large profile extruders (3.5 or 4.5 in./90 or 115 mm barrel diameters) the die opening may be 5% to 10% larger.

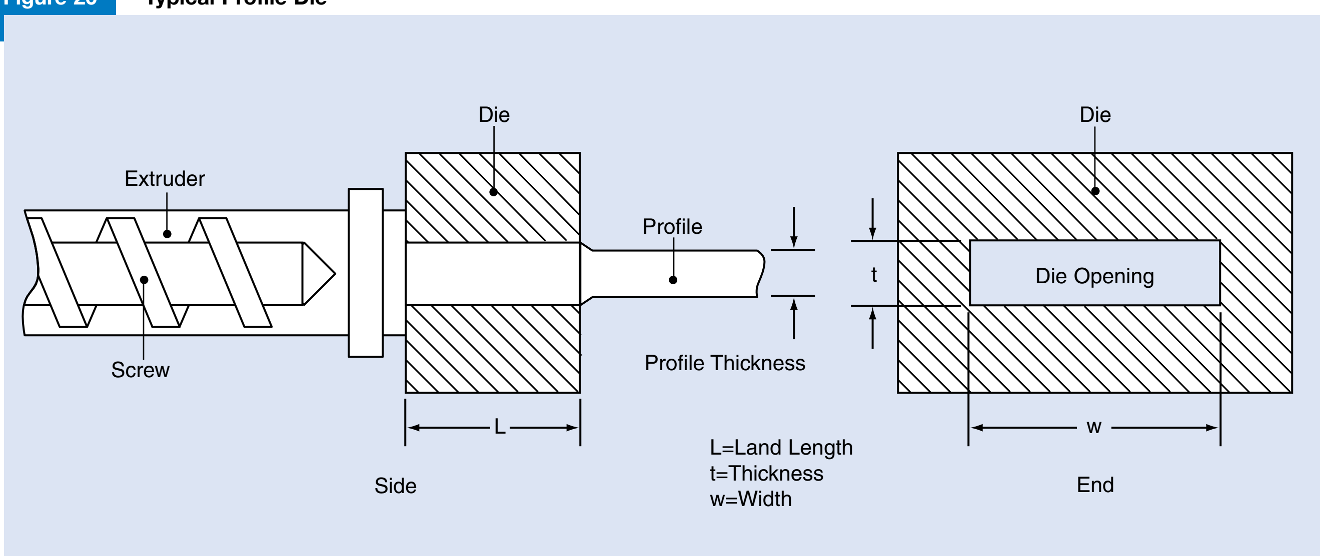
The proper land length "L" must also be determined. The land length will increase with the increase in the die opening. Some designs refer to L/D where "D" is really the thickness. For small extruders the L/D is in the range of 10:1 to 15:1, meaning the land is 10 to 15 times the thickness. For larger extruders with higher throughputs, the L/D can vary from 25:1 to 50:1.

Determining the correct profile die dimensions has typically been by trial and error. Today, there are computer software models that predict the key dimensions using basic material characteristics such as viscosity and die swell versus shear rate, the part dimensions, and extruder output.

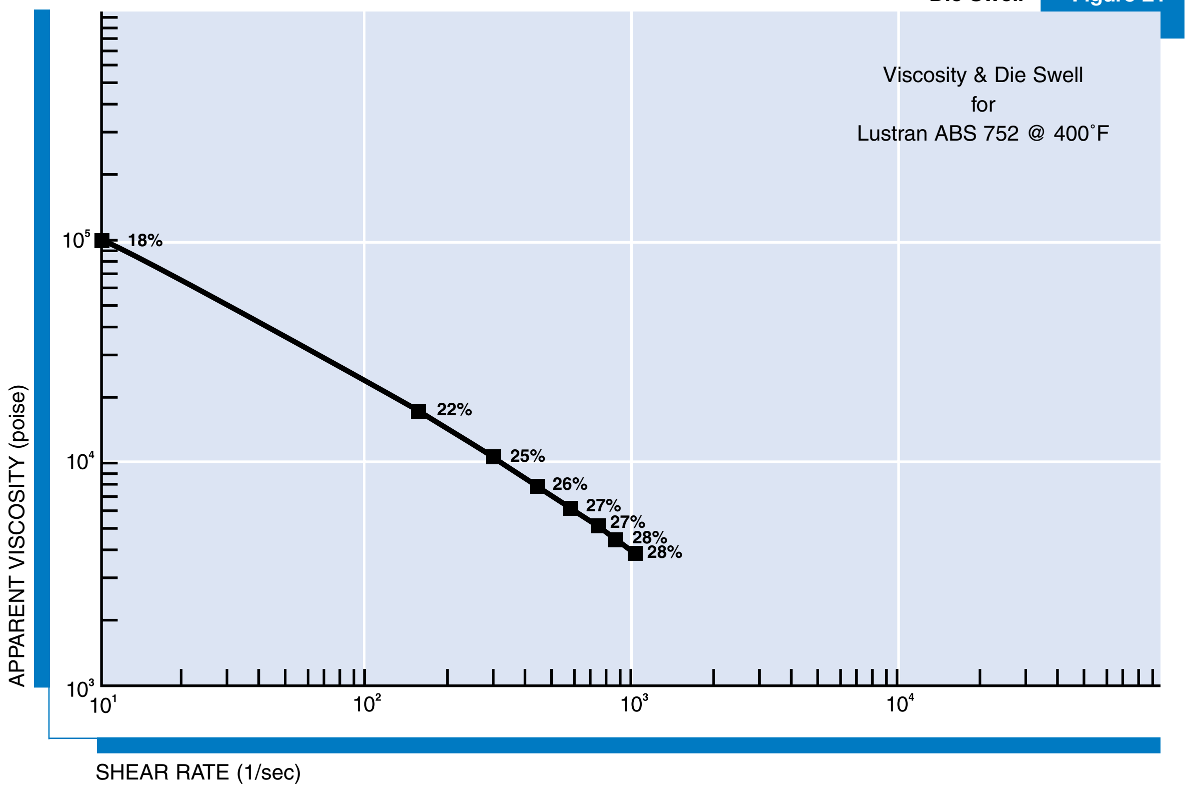
Figure 21 shows the viscosity and die swell versus shear rate for Lustran 752 resin. Each resin will be different.

The software models also work with coextruded profiles. For assistance with determining profile extrusions die dimensions or more information on computer software for determining these dimensions, consult your Bayer Technical Group representative for Bayer styrenic resins at 412-777-2000.

Figure 20 **Typical Profile Die**



Die Swell **Figure 21**



Description of Problem	Possible Causes	Possible Corrective Action
Surging	• Starving screw.	• Lower heat in barrel zones. This moves the melt zones forward and will increase the material flow. • Check for any material blockage. Note flow of pellets at throat and flow by vent. • Lower dryer temperature to reduce feed temperature.
	• Insufficient back pressure.	• Close gate valve to increase back pressure. • Increase screen pack. • Close die manifold and/or restrictor bar. • Lower heat in gate and screen changer.
	• Non-uniform feedstock temperatures.	• Check dryer. • Check regrind level.
	• High stock temperature.	• Lower barrel profile.
	• Poor screw design.	• Use another screw or recut existing screw.

Description of Problem	Possible Causes	Possible Corrective Action
Vent Flow	• Output of screw first stage higher than second stage can handle.	• Reduce output of first stage by: ✓ Raising temperature of first and/or second extruder barrel zone. • Increase output of second stage by: ✓ Opening gate valve. ✓ Raising front barrel zone and die temperatures. ✓ Raising restrictor bar. • Redesign screw.

Description of Problem	Possible Causes	Possible Corrective Action
Dimpling	• Air entrapment.	• Reduce rear barrel temperature. • Reduce hopper drying temperatures. • Reduce screw speed. • Vary particle size if feedstock includes regrind. • Check vent for plugging or vacuum. • Redesign screw.
	• Gross moisture.	• Increase drying temperature. • Check function of hopper dryer. • Check dew point of dryer inlet air. • Check vacuum vent system.
	• Volatiles, pits.	• Cool stock. • Check vent for plugging or vacuum.

Description of Problem	Possible Causes	Possible Corrective Action
Lines		
Continuous Lines in Extrusion Direction	• Die imperfections. • Hang-up on the distributor bar of die lips.	• Polish and rechrome die lips. • Remove stagnant material.
Discontinuous Lines ("Chicken Tracks")	• Moisture.	• Increase resin drying time and/or temperature. • Use vented extruder with vacuum. • Redesign hopper dryer for: ✓ Greater capacity. ✓ Recycling of pellets. ✓ Dehumidified air.
Lines Perpendicular to Extrusion Direction	• Roll too hot, causing sheet to alternately adhere and release, leaving a mark.	• Cool down roll.
	• Pulsating roll movement.	• Increase tension in rolls. • Eliminate backlash in gear train. • Tighten chain, if a chain drive is used.
Parabolic Lines in Extrusion Direction	• Roll bank is too large and non-uniform or nip buildup.	• Reduce pressure on roll where bank is occurring. • Adjust die for improved gauge if bank is not uniform.
	• Extruder is surging.	• Check regrind. • Check for changing feedstock temperature and eliminate.
	• Starved feeding due to resin pellets fusing in the hopper dryer.	• Reduce drying temperature. • Clean out plug. • Install a thermometer and monitor temper-ature in hopper.
	• Inadequate blending of regrind with virgin pellets, causing the extrusion rate to vary and pulsate.	• Eliminate stratification of materials by blending thoroughly. • Redesign hopper to prevent channeling. • Install agitators in hopper.
Herringbone Patterns or "Chicken Tracks"	• Moisture in resin.	• Improve pellet drying.

Description of Problem	Possible Causes	Possible Corrective Action
Rough Surface	• Nip buildup.	• Reduce nip roll pressure. • Adjust sheet gauge.
	• Contamination from previously run material.	• Purge or mechanically clean extruder.
	• Insufficient back pressure due to a short, deep-flighted screw.	• Add screens. • Tighten distributor bar. • Add valve to extruder to restrict flow. • Use a longer length screw with shallower flights.

Description of Problem	Possible Causes	Possible Corrective Action
Dull Sheet	• Sheet too thin.	• Adjust gauge.
	• Rolls out of round.	• Re-machine and re-finish rolls.

Description of Problem	Possible Causes	Possible Corrective Action
Discolored Streaks or Particles	• Contaminated resin.	• Clean resin silos, transfer systems, and hopper feeder, especially when resin of different characteristics are being extruded consecutively.
	• Contamination in the extruder barrel or die due to material hang-up and/or decomposition.	• Purge or mechanically clean extruder. • Mechanically clean screw. • Clean interior of die. • Use die with chrome-plated interior.

Description of Problem	Possible Causes	Possible Corrective Action
Discoloration of Entire Sheet	• Dirty regrind.	• Minimize volume of regrind in feedstock blend. • Keep regrind as clean as possible and use as soon as possible.

Description of Problem	Possible Causes	Possible Corrective Action
Rough Surface Texture or Grain	• Moisture.	• Increase hopper drying time. • Increase hopper dryer inlet air temperature. • Use vented extruder with vacuum. • Redesign hopper dryer for: ✓ Greater capacity. ✓ Recycling of pellets. ✓ Dehumidified air.
	• Poor Mixing in extruder.	• Reduce inter-product mixing. • Increase screen pack to increase back pressure and mixing in the barrel. • Increase valve pressure to increase back pressure and mixing in the barrel.
	• Nip buildup.	• Reduce nip roll pressure. • Adjust sheet gauge.
	• Inadequate die land length.	• Increase die land length.
	• Inadequate roll pressures and/or temperatures.	• Increase roll temperatures to retard setup and improve roll polishing.

Description of Problem	Possible Causes	Possible Corrective Action
Poor Gloss	• Improper die lip opening.	• Adjust lip opening, setting it 5% to 10% more than the sheet gauge.
	• Improper roll gap.	• Adjust roll gap, setting it 3% to 5% under the desired sheet thickness.
	• Improper polishing roll temperatures.	• Adjust melt temperature. • Adjust roll temperatures.
	• Bank too large at top roll.	• Increase roll speed and/or adjust restrictor bar to decrease bank.
	• Melt temperature too low.	• Increase melt temperature by varying rpm of screw or barrel temperature in the metering section. • Increase back pressure by doing one or more of the following: ✓ Adjust the restrictor bar. ✓ Increase screen pack. ✓ Increase valve pressure.
	• Die temperature too low.	✓ Increase die temperature.
	• Roll pressure too low.	• Increase pressure or top and bottom rolls.
	• Roll pressure not uniform.	• Adjust non-uniform and excessively large bank in nips. • Check for cocked rolls and adjust stops, air pressure, and springs as necessary.
	• Roll temperatures too low.	• Increase roll temperatures, especially of the top and bottom rolls.

Description of Problem	Possible Causes	Possible Corrective Action
Separation (Peel-Off) of Web from Middle Roll	• Gauge imbalance; bottom roll pressure too high.	• Reduce roll pressure, adjust gauge, then slowly increase roll pressure.
	• Temperature of middle roll too high.	• Reduce temperature of middle roll.
	• Bottom roll gap too tight.	• Adjust bottom roll gap, making sure both sides are set the same.
	• Die lip opening too small.	• Open die lips.
	• Misaligned sheet.	• Align roll stand and take-off equipment to be perpendicular to the die.

Description of Problem	Possible Causes	Possible Corrective Action
Excessively High Orientation	• Excessive bead (bank) at nip.	• Adjust gauge. • Reduce bead. • Reduce top roll pressure.
	• Low polishing roll temperature.	• Increase polishing roll temperature.
	• Speed differential between polishing and pull rolls.	• Adjust roll speeds to reduce differential.
	• Distance between die and nip too great.	• Reduce distance between die and nip.
	• Die lip opening too large.	• Reduce die lip opening to 5% to 10% over desired gauge.

SAFETY PRECAUTIONS

GENERAL

Wear safety glasses and/or face shields when processing Bayer styrenic resins, especially during purging. Use proper gloves and other appropriate garments when handling hot tools and auxiliary equipment. Material safety data sheets (MSDS) are available and should be consulted prior to processing Bayer styrenic resins.

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Appropriate literature has been assembled which provides information concerning health and safety precautions that must be observed when handling Bayer Corporation products mentioned in this publication. Before working with any of these products, you must read and become familiar with the available information on their hazards, proper use, and handling. This cannot be overemphasized. Information is available in several forms, e.g., material safety data sheets and product labels. Consult your local Bayer Corporation representative or contact the Product Safety and Regulatory Affairs Department in Pittsburgh, Pennsylvania at 412-777-2000.

For materials mentioned that are not Bayer Corporation products, appropriate industrial hygiene and other safety precautions recommended by their manufacturer(s) should be followed.

GENERAL INFORMATION

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Styrenics Product Management
100 Bayer Road, Building 8
Pittsburgh, PA 15205-9741
Phone: 412-777-2000

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