Bayer

Polymers Division

A processing guide for

EXTRUSION

TEXIN

THERMOPLASTIC POLYURETHANES

TABLE OF CONTENTS

INTRODUCTION

MACHINE SELECTION

DOWNSTREAM SYSTEMS

DRYING

OPERATION

TABLE OF CONTENTS, *continued*

INTRODUCTION

PRODUCT DESCRIPTION

Texin resins are thermoplastic polyurethane elastomers (TPU) based on polyesters, polyethers, and blends of polyurethane and polycarbonate, which exhibit a wide range of properties for an array of applications. Finished parts made from Texin resins possess all of the excellent properties which are normally associated with polyurethane elastomers. These properties include:

- High tensile and tear strength.
- Excellent abrasion resistance.
- Excellent resistance to fuels, oils, ozone, and oxygen.
- High elasticity and resilience combined with high load-bearing capacity and hardness.
- High impact resistance and vibration dampening properties.

In extruded form, Texin TPU resin can be used directly, or it can be laminated, thermoformed, or bonded by heat, adhesives, or solvents. Lamination to many other substrates can be accomplished directly from the hot melt.

Product by Grade Type

Texin resins are available in unreinforced general-purpose grades of various hardnesses.

Although each of the Texin resin grades can be injection molded, many grades can also be extruded. Texin 285 (formerly Texin 480A) resin is the one most commonly extruded. It is especially suitable for general extrusion and for conversion to sheet. In addition, it exhibits a satisfactory melt strength and can be controlled over a relatively wide span of temperatures to produce an extrudate which can range from transparent to translucent to opaque. Table 1 lists various grades of Texin resin suitable for extrusion.

Several modifications of the standard Texin resin grades are available which have been designed to meet specific requirements. Properties intermediate to those of the standard grades can also be obtained by blending any combination of Texin resins, provided they are chemically compatible and thoroughly mixed. For some applications, it is necessary to mix different formulations in a melted state to achieve the required blend uniformity.

Further details about the suitability of extruding Texin resins or blending Texin resins for your application are available by contacting a Bayer Corporation Technical Group representative for Texin resin at 412-777-2000.

Product by Market

Texin TPU resins are used to extrude a variety of consumer applications such as shoe components and outdoor foul weather gear. Industrial/mechanical applications include tubing, fire hose linings, cable jacketing, and fuel lines. Medical applications include a variety of diagnostic devices, tubing and catheters, and connectors. Common film applications are fuel and oil containment, tarps, and safety glass laminations.

As with any product, the use of Texin resin in a given application must be tested (including field testing, etc.) in advance by the user to determine suitability.

NOMENCLATURE

Grade Designation

Texin resins are available in unreinforced general-purpose grades of various hardnesses. The last two digits and the suffix letter assigned to each grade of the Texin resin indicate the approximate Shore hardness of a part made from the resin. For example, a part made from Texin 985 (formerly Texin 985A) resin has a typical Shore A hardness of 85± 3.

Color Designation

Texin TPU is supplied as natural resin in pellet form. The extruded part color can vary from nearly transparent to translucent to opaque depending on the wall thickness of the article. Some grades of Texin resin are also offered in black or gray color as a "salt and pepper" pellet blend.

COLORING THE RESIN

Coloring Texin resins can be accomplished by blending in color concentrates or by dry blending the pigments directly onto the pellets. A list of color concentrates, pigments, and dyes suitable for Texin resins is available by contacting your Bayer Corporation Technical Group representative for Texin resins at 412-777-2000.

Before blending any colorants into Texin resins, be sure the resin is dry. (See "Drying," page 22.) If a color concentrate is used, dry it in the same manner as Texin resins. Dry pigments or dyes at a temperature as high as practical. Many inorganic pigments contain water which must be removed before the pigment is incorporated into the resin. These pigments may be adequately dried by heating them to 450°F (233°C) for 30–45 minutes.

After the pigment has been properly dried, tumbler-blend it or the color concentrate into the Texin resin pellets in the desired concentration for 5–10 minutes. If some time will elapse before the color blend is processed, protect it from exposure to moisture. Dry the color blend prior to introducing it to the extruder.

COLORING EXTRUDED PARTS

When a given part must be produced in a wide range of colors and it is uneconomical to extrude each color separately, dip dying may be employed. Parts extruded of Texin resins can be successfully dyed with colorants known

Figure 1 **Label Information for Texin TPU Resins**

as "disperse dyes." However, some regulatory organizations (e.g., FDA) limit the choice of colors that may be used.

PACKAGING AND LABELING

Texin resins are available in 300-lb (135-kg) drums, 1,000-lb (450-kg) cardboard cartons, and bulk trucks. The drums and cartons have polyethylene liners in which the resin is sealed to help prevent contamination from dust, dirt, and moisture.

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

Texin resin is 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.

Table 1 Texin Resin Grades Suitable for Extrusio

Grade					
New Number	Old Number	Film	Sheet	Profile	Tube
Polyester					
285	480A	●	●	●	●
Polyether					
970U	970D		●	●	●
985	985A	●	●	●	●
990	990A	●	●	●	●
950	DP7-1018	●	●	●	●
950U	DP7-1047	●	●	●	●
985U	DP7-1051	●	●	●	●
945U	DP7-1052	●	●	●	●
990R	DP7-1078	●	●	●	●
Blends					
4203	4203		●	●	●
4206	4206		●	●	●
4210	4210		●	●	●
4215	4215		●	●	●
Developmental					
DP7-1030	DP7-1030		●	●	●
DP7-1077	DP7-1077	●	●	●	●
DP7-1089	DP7-1089	●	●	●	●
DP7-1097	DP7-1097	●	●	●	●
Polyether Aliphatics					
DP7-3005	DP7-3005	●	●	●	●
DP7-3006	DP7-3006	●	●	●	●
DP7-3007	DP7-3007	●	●	●	●
Medical					
5286	5286	●	●	●	●
5265	5265		●	●	●
5187	5187	●	●	●	●
5370	5370		●	●	●

The recommendations for machine selection, in this section, and in "Operation," on page 26, are based on the need for exercising more control over the melt temperature of the material than is necessary with other thermoplastics which can tolerate somewhat wider latitudes. This is important because the rheological behavior of polyurethane polymers is non-Newtonian. In other words, their melts change from a high-viscosity state to a low-viscosity state within a relatively narrow temperature range. Large temperature gradients within a melt will affect the control and continuity of the extrudate.

When extruding with Texin resins, the desired maximum temperature gradient in the melt as it enters the die is 5°F (3°C).

EXTRUDER

Texin resins can be extruded on all modern conventional, single-screw extruders meeting the basic criteria illustrated in Figure 2.

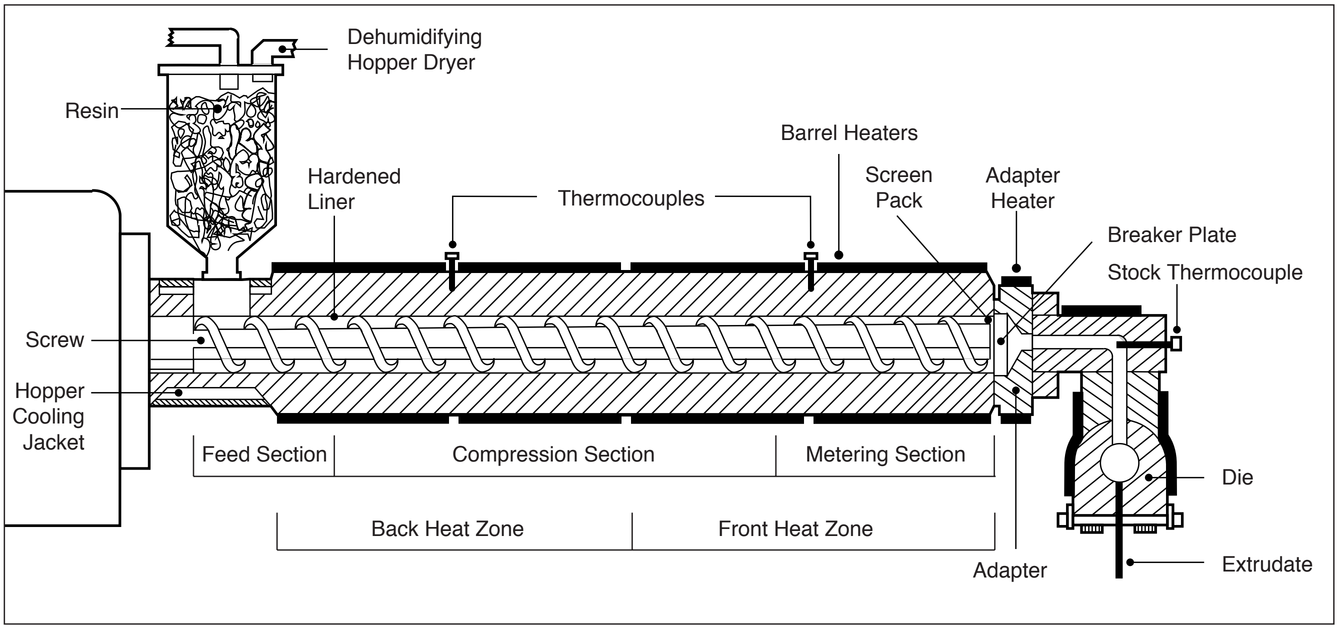
Unvented Barrels

For an unvented barrel, a length-to-diameter (L/D) ratio of at least 20:1, preferably 24:1–30:1, is desirable to ensure a uniform melt. Shorter barrels may cause some surging of the extrudate as it leaves the die. Longer barrels may generate excessive frictional heat at higher extrusion rates.

Vented Barrels

Vented extruders in a variety of lengths and screw diameters can be used. An extruder with an abrasion-resistant,

Figure 2 **Typical Extruder for Processing Texin Resin**



bimetallic barrel liner, such as Xaloy,* is preferred.

For a single-vent barrel, an L/D ratio of 30:1–34:1 is preferred. For a double-vent barrel, 38:1 is standard.

There is no advantage to extruding any of the Texin resin grades on a vented extruder. However, vented barrels are becoming increasingly popular because they provide a means for removing the small amounts of volatiles that may enter the system after the drying operation.

*Xaloy is the registered trademark of Xaloy, Inc.

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.

Screw

Proper screw design is most critical for achieving the desired 5°F (3°C) temperature gradient in the melt. 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 screw must discharge the melt at a constant pressure and temperature; otherwise, the extrusion may suffer variations in wall thickness and poor uniformity.

Following are important considerations for choosing a screw for extruding Texin resins:

- A single-stage screw design having an L/D ratio of at least 24:1 and the specifications listed in Table 2 is recommended.
- A compression ratio of 3:1 is desirable.
- The transition zone should be long and gradual. The metering zone should be long, too (up to 50% of the screw length).
- The metering zone depth should be shallow, compared to screws commonly used with other thermoplastics, in order to homogenize the melt temperature satisfactorily.
- Use screws made of SAE 4140 steel or a similar material with the flights either flame-hardened or made from Stellite* alloy.

*Stellite is the registered trademark of Cabot Corporation.

Table 2 **Screw Specifications for Extruding Texin Resin,** L/D, 24:1

Section	No. of Diameters	Depth in. (mm)		
		2.5 in. (64 mm) Extruder	3.5 in. (89 mm) Extruder	4.5 in. (114 mm) Extruder
Feed	5	0.375 in. (9.5 mm)	0.450 in. (11.5 mm)	0.525 in. (13.5 mm)
Transition	7–13	—	—	—
Meter	6–12	0.125 in. (3 mm)	0.150 in. (3.80 mm)	0.175 in. (4.5 mm)

- 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 typical screw layout is shown in Figure 3.

CAUTION: When processing Texin resins, the transition from the feed to the metering section of the extruder screw must not be rapid. A rapid transition will produce excessive melt temperature and consequent degradation of the resin.

Screws with configurations other than recommended here, that is, compression ratios as high as 4:1 or lower than 3:1, shorter metering zones, deeper metering zones, or continuous tapers (no metering zone at all), have been used to extrude Texin resins, but with less than satisfactory results. When the preferred screw design is not available, an acceptable extrudate can usually be produced at the expense of output by running at relatively low screw speeds. In addition, a screw of "marginal" design may sometimes be used if it is cored for water cooling and maintained at an optimum temperature with a heat exchanger to maintain the desired melt temperature gradient.

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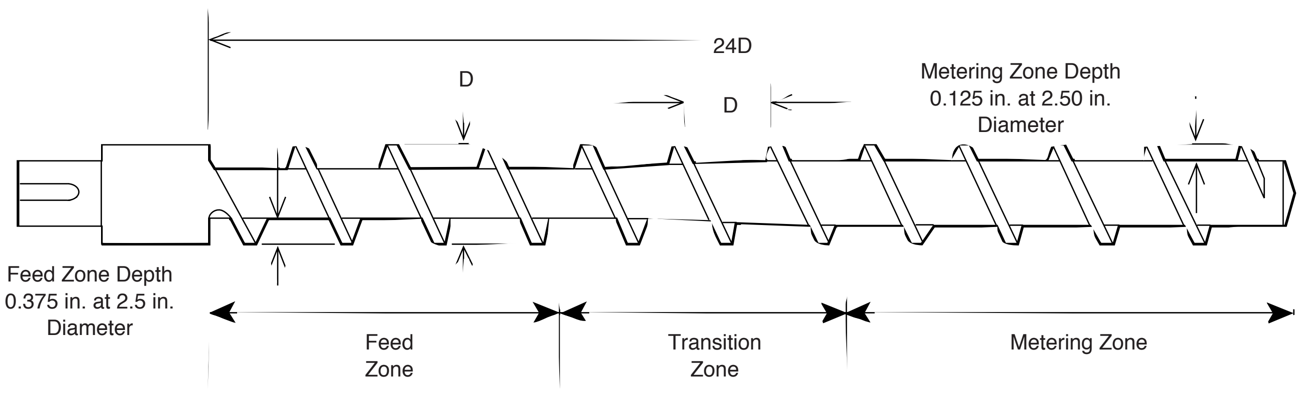
Extruder Drive

Estimated horsepower requirements for desired material output are provided in Table 3. The data are based on a 24:1, 2.5-in. (64-mm) extruder with a single-stage screw having the specifications listed in Table 2.

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

Figure 3 **Typical Screw Design for Extruding Texin Resin**



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

Extruder Hopper and Feed Zone

Most types and styles of feed hoppers are acceptable as long as they are covered or connected to a drying system. Resin may be fed from the hopper into the barrel using either a top or side port. It helps to have cooling in the feed section to ensure a smooth rate of feed and to prevent resin bridging.

Texin resin feeds efficiently through a smooth feed bushing. A grooved feed zone is not recommended but can be used. If a grooved zone is unavoidable, use a lower-compression screw.

CONTROLS

Temperature Controls

The feed-throat area must be water-cooled to help prevent the resin from bridging. Full water flow can be used in the jacket as long as no condensation or water seepage occurs in the feed throat. Forced-air cooling is preferred for the barrel under certain special conditions.

Ideally, the extruder barrel is divided into at least five temperature control zones. Each zone must have independent thermocouples and temperature controllers. Three-mode, proportional-integral-derivative (PID) 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.

Heating can be accomplished with electric resistance heaters designed to heat the barrel evenly. Cooling can be accomplished by air 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. Air cooling is preferred.

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

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.

Table 3 **Extruder Drive Requirements**

Screw Diameter	Drive Requirements	Maximum Speed*
1.5 in. (45 mm)	20 hp (kW)	40 – 100 rpm
2.5 in. (60 mm)	50 hp (kW)	35 – 85 rpm
3.5 in. (90 mm)	100 hp (kW)	30 – 75 rpm
4.5 in. (120 mm)	200 hp (kW)	20 – 60 rpm

* The high end of the speed ranges listed may be employed with a proper screw design.

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 500 to 4,000 psi (3.45 to 27.60 MPa) with a target of 1,500 – 2,500 psi (10.35 – 17.25 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.

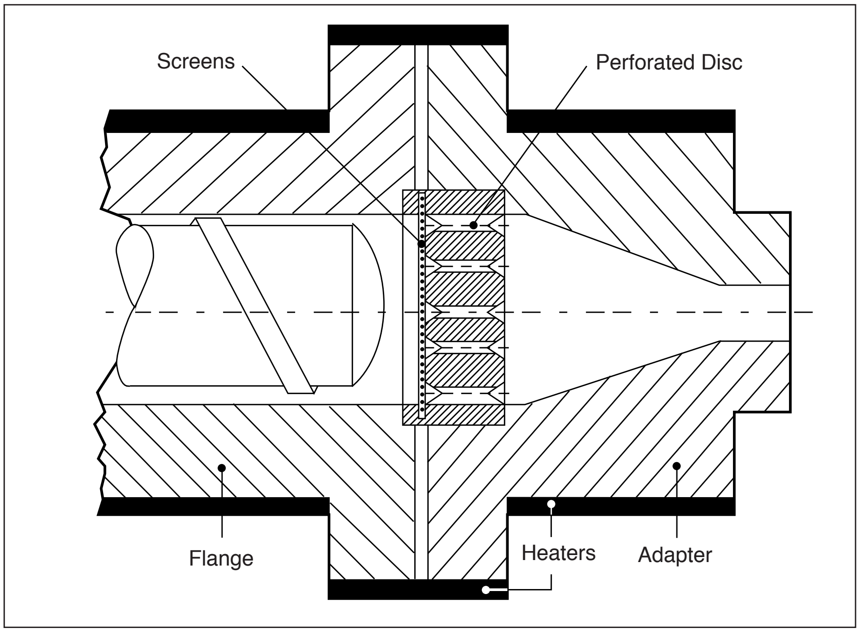
The melt pressure near the front of the transition zone is important. Control it to achieve a low, steady level by balancing barrel temperatures and screw rotational speed (rpm) for the type of screw design being used. A pressure gauge should be used to monitor it over a range of 500 – 1,000 psi (3.45 – 6.90 MPa).

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 Texin polyurethane elastomer melt leaves the end of the extruder 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.

Figure 4 **Typical Screen Pack Installation**



Screen Pack

A screen pack, as illustrated in Figure 4, 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. Continuous screen changers are not recommended.

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.

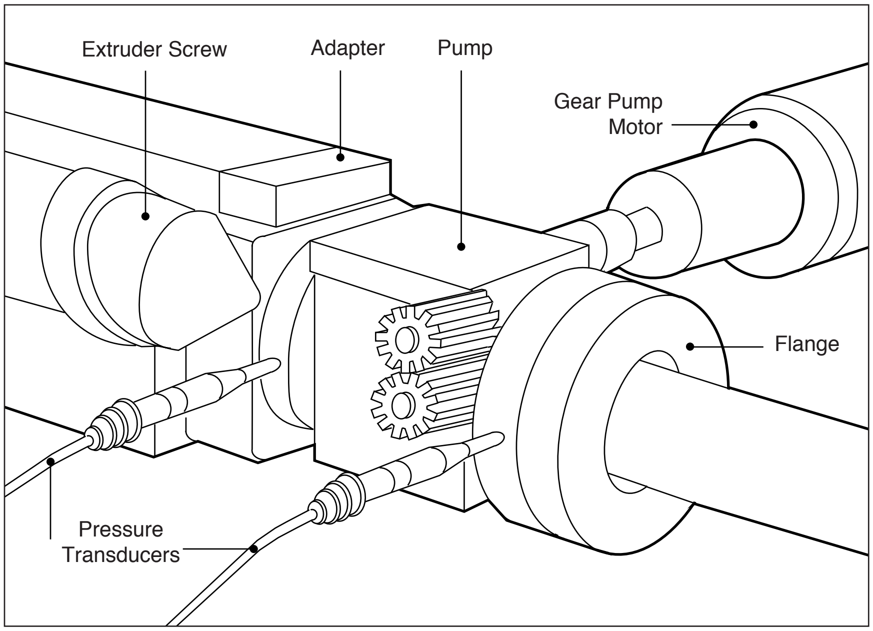
A screen size as fine as 240 mesh can be used to remove contamination. Finer screens will increase the back pressure and possibly affect throughput rates.

Monitor the melt pressure behind the screen pack to know when the screen is plugging.

Melt Pump

A microprocessor-controlled gear-type melt pump, as shown in Figure 5, can improve performance and efficiency when extruding close-tolerance profiles and consistent-gauge films, or when high pressure and temperature at the end of the extruder are a problem. The gear pump can correct problems inherent with a screw extruder such as pulsating output, poor volumetric accuracy, and undesirable temperature/pressure relationships. It divides the extruder output into small, volumetrically-controlled increments and forwards them at a very precise rate. The pump 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. However, Texin resin is somewhat shear sensitive, so use a gear pump with caution.

Figure 5 **Typical Gear-Type Melt Pump Installation**



Static Mixers

Using a static mixer between the extruder and the die may be helpful when the screw provides only marginal mixing or when the temperature consistency of the melt must be very precise. Examples of such cases include:

- The use of particularly hard-to-disperse pigments.
- The extrusion of parts with very thin sections.
- The use of wide sheet dies or complex profile dies.

Figure 6 shows one type of static mixer in the adapter. 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.

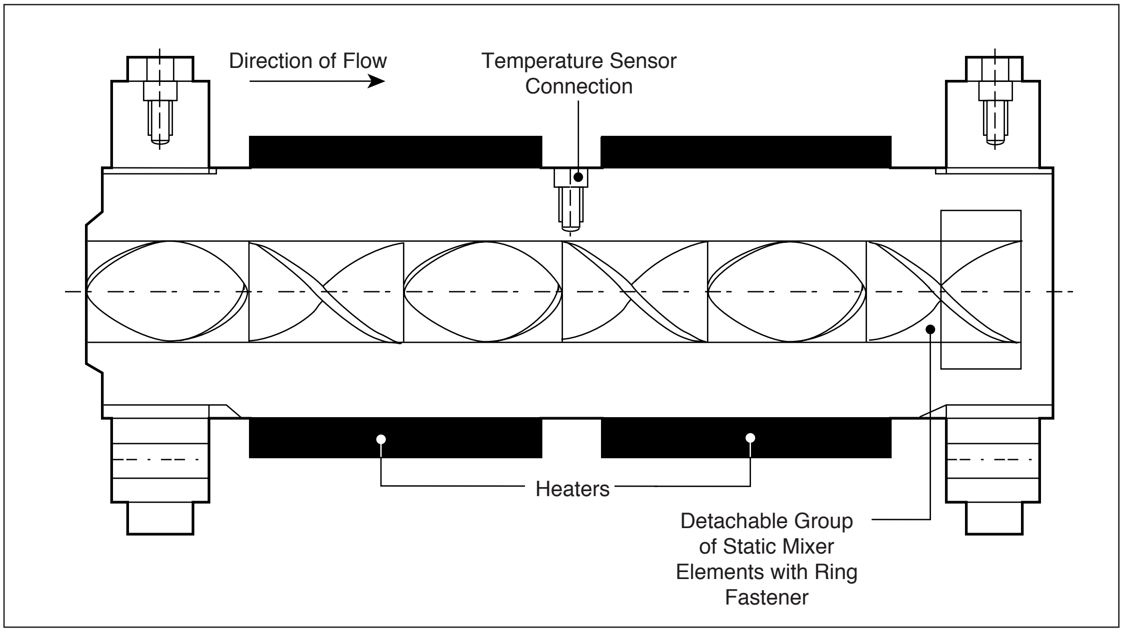
Adapter Body

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 (69 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 6 **Typical Static Mixer Installation**



DOWNSTREAM SYSTEMS

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

SHEET

A typical sheet extruding line is shown in Figure 7. For best results with Texin extrusion-grade resins, use a calender with rolls having a Teflon* coating. Coated rolls are desirable because freshly extruded webs of Texin elastomer are often sticky and will block to the surface of a conventional chrome polished roll.

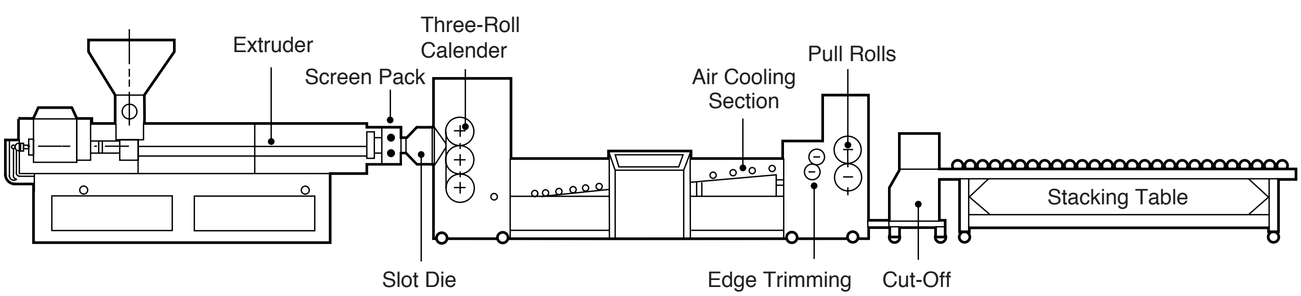
Maintain the roll temperatures at or just below room temperature. If only polished chrome rolls are available, then run them at as cold a temperature as possible and spray a dry fluorocarbon mold release agent onto the rolls, especially the center roll as required. Cool the web using the conventional "S" wrap technique.

If interleaving is necessary, use a material such as Paterson parchment paper #27-81T.

Typical temperature conditions for sheet-extruding Texin resin are provided in Table 4.

*Teflon is the registered trademark of E.I. DuPont de Nemours & Company, Inc.

Figure 7 **Typical Sheet Extruding Line**



Note: Sheet extrusion line shown is for rigid sheet. For elastomeric sheet, substitute a turret winder for the stacking table.

FILM

Cast Film

Film at a thickness of 0.10 in. (2.54 mm) or thinner can also be extruded from Texin resins with a flat film die, which is similar to a sheeting die. The film is extruded downward onto a chill roll or into a temperature-controlled water bath.

Before the development of adequate chill-roll systems, flat film was made by extruding downward into a water bath. The water bath system quenches rapidly and equipment cost is low. However, it is difficult to get precise control over the water temperature, and vibrations or currents can mark the film.

The film first strikes the main cooling roll, also called the chill roll, which is made of chrome-plated steel or other hard, corrosion-resistant alloy. It may be coated with Teflon for better release. This roll is hollow and baffled to aid heat transfer and maintain an even temperature on the entire roll surface. At least one auxiliary roll is usually employed right after the first roll to form a calender stack. From these auxiliary rolls the cooled film passes through pull rolls into a winder.

Take-off equipment is similar to that used for sheet extrusion, as shown in Figure 7. The film passes around an idler roll and then between two driven nip rolls. The film is trimmed to the required width by rotating knives.

The edges of cast film must be trimmed to get a neat, tight roll of uniform thickness before passing to final wind-up. Slitters can be mounted just before the winder to cut the film to an exact width.

An "air knife" also may be used on the first roll to force the moving film into close contact with the roll. This prevents air entrapment and improves cooling, both of which help to increase production rate. Sometimes an additional current of air is set on the other side of the descending film of hot plastic — not blowing on the film directly, but rather across it to create a vacuum between the film and the roll. This augments the action of the air knife directly blowing the first side.

Table 4 Typical Temperature Conditions for Extruding Film and Sheet from Texin Resin*

Hopper	Barrel Settings					
Zone 1	Zone 2	Zone 3	Zone 4	Adapter	Die	Melt
360°F (182°C)	370°F (188°C)	380°F (193°C)	380°F (193°C)	380°F (193°C)	380°F (193°C)	400°F (204°C)
380°F (193°C)	400°F (204°C)	410°F (210°C)	410°F (210°C)	430°F (221°C)	420°F (216°C)	410°F (210°C)

* Based on a 2.50-in. (64-mm) screw.

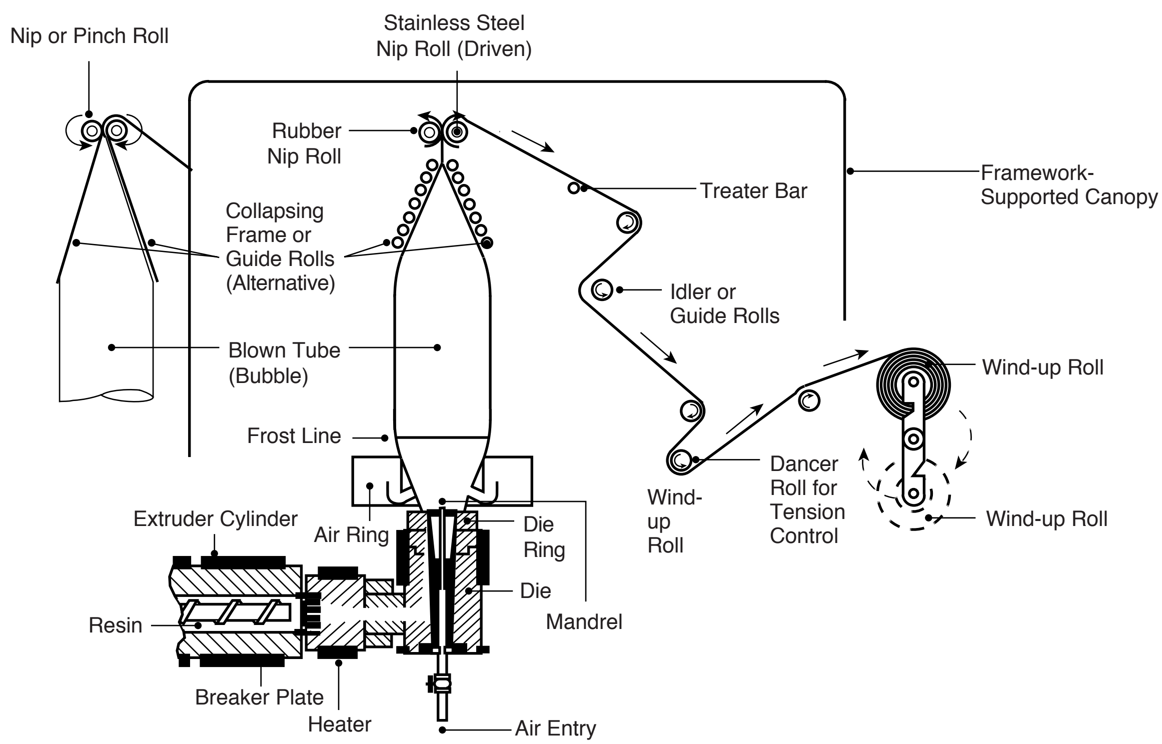
Although thickness is well-controlled with adjusting bolts on the die, high and/or soft spots can still occur on the finished roll. This can be corrected by reciprocating the wind-up from side to side, but this creates more scrap than usual. The use of a center winder and good tension controls can also alleviate some imperfections.

The variables of film casting include melt temperature and pressure, temperature of the chill roll(s), the distance between the die lip and the roll, and the balance between extrusion rate and linear film speed. These variables determine the time that the extrudate travels through the air to reach the chill roll. This in turn affects the amount of neck-in (reduction of width) and the ease of drawing to low thicknesses. Some imbalance in mechanical properties is inevitable because all the pull is in one direction. However, if the melt temperature is high and the travel time in the air is very short, all drawdown will take place quickly and the tendency to splitting due to one-direction orientation is minimized.

Blown Film

The equipment used to produce blown film is shown in Figure 8. Blown film is extruded through a ring die. The ring die has a mandrel in the center to produce a hollow tube of elastomer. Air is blown into the tube through the mandrel

Figure 8 **Blown Film Tower**



to inflate and expand the tube and thin the walls, forming a moving bubble.

An air ring around the blown tube cools and shapes the bubble, making a "frost line." Room temperature air is sufficient for cooling a bubble of Texin TPU elastomer.

Use an air ring which baffles the air for a uniform, jet-free flow all around. The most common type of ring produces a high volume of air at a relatively low velocity. If the velocity is too high, and/or airflow is not uniform, visible bands will be produced on the film. Thickness uniformity might also be affected, and the stability of the bubble may be impaired.

Air rings are available with adjustable airflow orifices to control the airflow velocity and angle of impingement on the hot film. This helps to stabilize the bubbles and improve cooling.

Annular inserts can be employed to use large rings with small dies.

Guide rolls or a collapsing frame flatten and guide the blown tube to the nip or pinch rolls at the top of the tower. The collapsing frame may be made of smooth, hard wooden slats, 2–3 in. (50–75 mm) wide, set every 4–6 in. (100–150 mm) transverse to the direction of the moving tube. Some lines use composition board which has a slightly rough surface to prevent sticking. The boards may be perforated to improve cooling. The collapsing frame may also be made of sand-blasted metal or cloth. The cloth may be coated or impregnated with plastic. Metal frames with holes and forced air act as air baffles and are often used for tacky films to reduce drag on the frame itself.

The distance between the die and the nip roll at the apex of the collapsing frame (cooling tower height) is important, as is the angle of the forming planes. These factors help determine the cooling time and are often adjustable.

The flattening apparatus must be firmly mounted to remain properly aligned over the die. Misaligned or wobbly forming planes may cause wrinkles and winding problems.

Additional mechanical aids are also frequently used to keep the bubble moving straight and wrinkle-free. For example, an internal "wishbone" can be rigidly connected to the die, extending upward and spreading the film smoothly just before it passes into the nip rolls. A stabilizer device comprised of four horizontal bars whose positions are adjusted to form a square that surrounds the moving bubble 6–10 ft (2–3 m) above the die, or an adjustable cage also can be used to help keep the bubble in the proper shape.

At the apex of the collapsing frame or guide rolls is a pair of nip rolls, one rubber and one steel, which draws the film through the take-off. These nip rolls are 6–12 in. (150–300 mm) in diameter, with even larger diameters needed for the widest of film to prevent deflection and consequent uneven contact. Most systems have the tube passing partially around the steel nip roll and then down one side of the cooling tower through a series of idler rolls to floor level, where the film is accumulated in wind-up rolls.

There are two variations of take-up equipment available for blown film. The first is a "fountain" arrangement, whereby the film edges are trimmed right after the nip rolls and the two resulting layers are separated. Each film layer is passed down either side of the take-off. This requires a winding station on either side of the cooling tower.

For efficient trimming, another pair of driven nip rolls is set just above the first pair, and the film is trimmed while firmly held between the two pair. This arrangement makes the individual flat films more accessible for in-line post-production operations. However, the thinner single layers must be handled more carefully for proper winding.

The second method is an upper-level winding arrangement, whereby the winders are at or near the level of the nip rolls. The proximity of the winders to the nip makes handling easier. The winders are independently driven. Use drives which will wind the film at proper and variable tension, but not pull so strongly that they override the nip rolls and affect the draw and dimensions of the film.

Automatic roll changing is available which automatically cuts the film and starts the following film on a new core. Some units include a length-measurement device which actuates the automatic changer when a preset length of film has been collected.

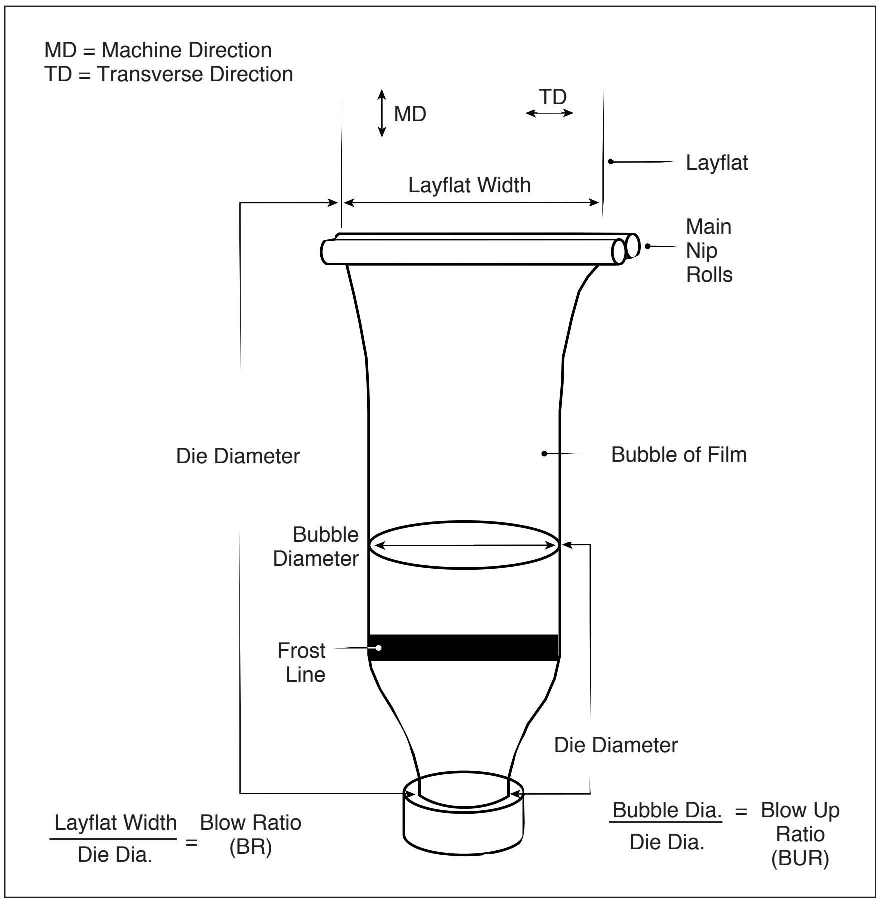
To start the film web through the tower, bunch the first extrudate together and pass it up through the nip rolls and into the winder. Threading a length of paper, cloth, or rope through the system and hooking it onto the extrudate at the die eliminates pulling the film through the system by hand. Another practice is to leave a cool and stationary bubble from the previous run over the die to "hook up" at the start of the next run.

The "bunch" and following film cannot be too thick or it will not go through the nip rolls. Form the initial tube by introducing air through the mandrel in small amounts to keep the tube slightly blown. After the threading is complete, introduce more air to bring the bubble to the desired size. Adjust die bolts to get uniform tube thickness, and balance the extrusion and winder speeds to get the desired film thickness. Be careful to keep the die faces clear of molten resin which can degrade, become difficult to remove, and cause die lines.

Begin the extruder slowly, 4–8 rpm on a 4.5-in. extruder, to bring the initial extrudate through the die and control the formation of the bubble. Set the nip roll pressure low at first. Then increase extruder speed and nip roll pressure when bubble size is achieved.

The elements of blown film are shown in Figure 9. A blow-up ratio (BUR) of 1.5:1 to 1.8:1 is optimum. Avoid BURs over 2:1 for Texin TPU resin.

Figure 9 **Elements of Blown Film**



A high BUR yields the strongest film because the increased stretching has an orientating effect on the material's polymer chains. A high BUR also means that a smaller and less expensive die is needed for any given film size. But a high BUR also encourages bubble instability, requires more drawdown, and magnifies all the imperfections of the die. Bubble instability can lead to wrinkles, thickness variation, and "walking" of the film along the wind-up roll.

The frost line height will vary, depending on the extrusion conditions and the grade of Texin resin being processed. In general, however, a frost line of 8 in. (30 mm) is sufficient.

The polymer chains of the elastomer can be oriented parallel to the plane of the film to produce superior tensile strength, flexibility, toughness, and shrinkability. Running the extruder faster and lowering the BUR will achieve more orientation. Running the extruder at a slow speed with a large BUR results in little or no orientation.

TUBING

Hollow tubing is extruded from Texin resin using a hollow die through which a mandrel extends. Air admitted through the mandrel at a pressure of a few inches of water determines the inside diameter (ID) of the tubing. The speed of the take-off relative to the extruder determines the wall thickness. The outside diameter (OD) of the tube is dependent on the ID and wall thickness. In general, allow the extruder to settle at some constant, acceptable level of operating conditions and confine all efforts to achieve size to the take-off and extrudate cooling.

Extruding tubing with Texin resins is strongly dependent on the ability of the extruder to deliver a formed tube from the die within a very narrow temperature range so that the tubing has appreciable melt strength.

Typical extruder settings for tube extrusion of Texin resin are shown in Table 5.

Vacuum sizing boxes with very fine vacuum control and non-blocking inlet channels and wafers can be used to extrude tubing with stiffer Texin resins. However, the use of vacuum sizers such as those used with rigid thermoplastics is very difficult to control with softer thermoplastic polyurethanes and is not recommended because the extruded tube will block at the inlet, usually due to sticking at the ring of vacuum holes. Rather, size the extruded tubing simply by internal air pressure, and external pull speed cooling.

Use a conventional vacuum sizing box, or even more simply, just a sizing ring positioned within 1 in. (25 mm) of the die face. Supply water to the ring so that it is completely lubricated and the tubing rides through it on a film of cold water. Allow for some shrinkage to size in the selection of the sizing ring ID. Determine the shrinkage by trial-and-error for each size and wall thickness of tubing.

Pass the tubing through a ring of water immediately as it comes out of the die. Carefully adjust the water flow to form

Table 5 **Typical Conditions for Extruding Tubing, Profiles, and Wire Coatings from Texin 985 (Formerly Texin 985A) Resin**

Die	Zone 3	Zone 2	Feed	RPM	Amps	Melt	Back Pressure (psi)
411°F (209°C)	410°F (208°C)	404°F (205°C)	409°F (207°C)	60	13	390°F (200°C)	2,250

an even ring around the tubing without excessively splashing onto the tubing as it falls into the circulating water bath. Keep the water temperature at or below 100°F (38°C).

Use water cooling baths of maximum possible length when extruding tubing with Texin resins in order to minimize residual blocking of the tube. A warm water bath improves cooling more than a cold water bath. For best results, do not permit the water temperature to fall below room temperature.

Guide the tubing with non-blocking rollers so that it stays submerged beneath the water for the full length of the bath. Thin-wall tubing does not have to be completely submerged in the water bath to achieve adequate cooling.

Carefully adjust the grasping pressure of the puller to avoid pinching which may cause the tubing to set permanently out of round. In addition, be careful when cutting the tubing to length to avoid completely blocking it off.

CROSSHEAD

The same type of capstan unit common in the wire coating industry for making polyethylene-coated wire can be used with few alterations to coat substrates with Texin polyurethane elastomers. Introduce the wire or other substrate to be coated into the die at right angles to the extruder and immediately feed it into a long water bath as it comes out of the die. Because the line speeds for some wire coatings may be in the range of hundreds of feet per minute, the wire may be doubled back on itself for multiple passes through the same water bath, or it may be turned into another bath for a total water bath immersion of several hundred feet or more.

A quench in cold water right out of the die is sufficient for cooling thin wall coverings of Texin elastomers up to a thickness of 50 mils. Above 50 mils it may be necessary to raise the water temperature in the first water bath as high as 120°F (50°C) and increase the distance between the crosshead die and the initial water bath by as much as 3 ft (1 m) in order to avoid too-rapid cooling of the elastomer. Cooling the elastomer too rapidly can result in the formation of voids.

Add a fungistat in the cooling water for long runs to avoid a greenish, fungal growth in the cooling water system surge tank. Or adjust the bath to accommodate an appreciable addition of make-up water to the circulating system every hour.

PROFILES

Successful profile extrusion with any grade of Texin resin depends strongly on correct die design (see "Profile Dies," page 32). Profiles may be cooled by water immersion, similar to tubing and crosshead extrusion. Profiles having relatively thin walls may be cooled simply 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.

Use long water cooling baths when extruding profiles with Texin resins to minimize residual blocking. Profiles as thick as 0.50 in. (13 mm) have been successfully extruded with Texin resins. Extruding shapes thicker than 0.375 in. (10 mm) can be very difficult if a void-free part with a slick, uniform surface is required. Sections as thin as 20 mils (0.51 mm) are common.

Relatively small profiles can be extruded with Texin resins. Thicknesses less than 100 mils can usually be obtained with an ideal equipment set-up and patience in working out the die to achieve the desired dimensions. Draw-downs of over 100% can be achieved with Texin resins.

Texin resins are hygroscopic, meaning that they will absorb and react with moisture in the atmosphere. As Figure 10 shows, Texin 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 Texin resin is supplied in sealed drums and cartons, it is essential to use a desiccant dehumidfying hopper dryer to keep the resin dry during processing.

Warm to room temperature any sealed containers which have been stored in unheated warehouses before opening them. This will help prevent rapid condensation of ambient moisture on cool pellets. Single drums or cartons can take 24 hours or more to warm. Stacked containers can take a week or longer.

DRYING EQUIPMENT

Desiccant Hopper Drying

Use a desiccant dehumidifying hopper dryer to remove moisture from Texin resin and to maintain proper resin

Moisture Absorption Rate of Texin Resin **Figure 10**

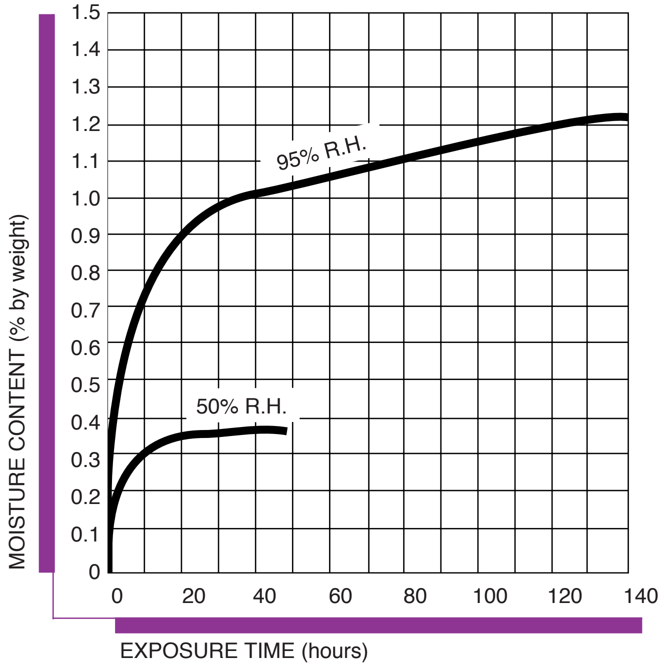


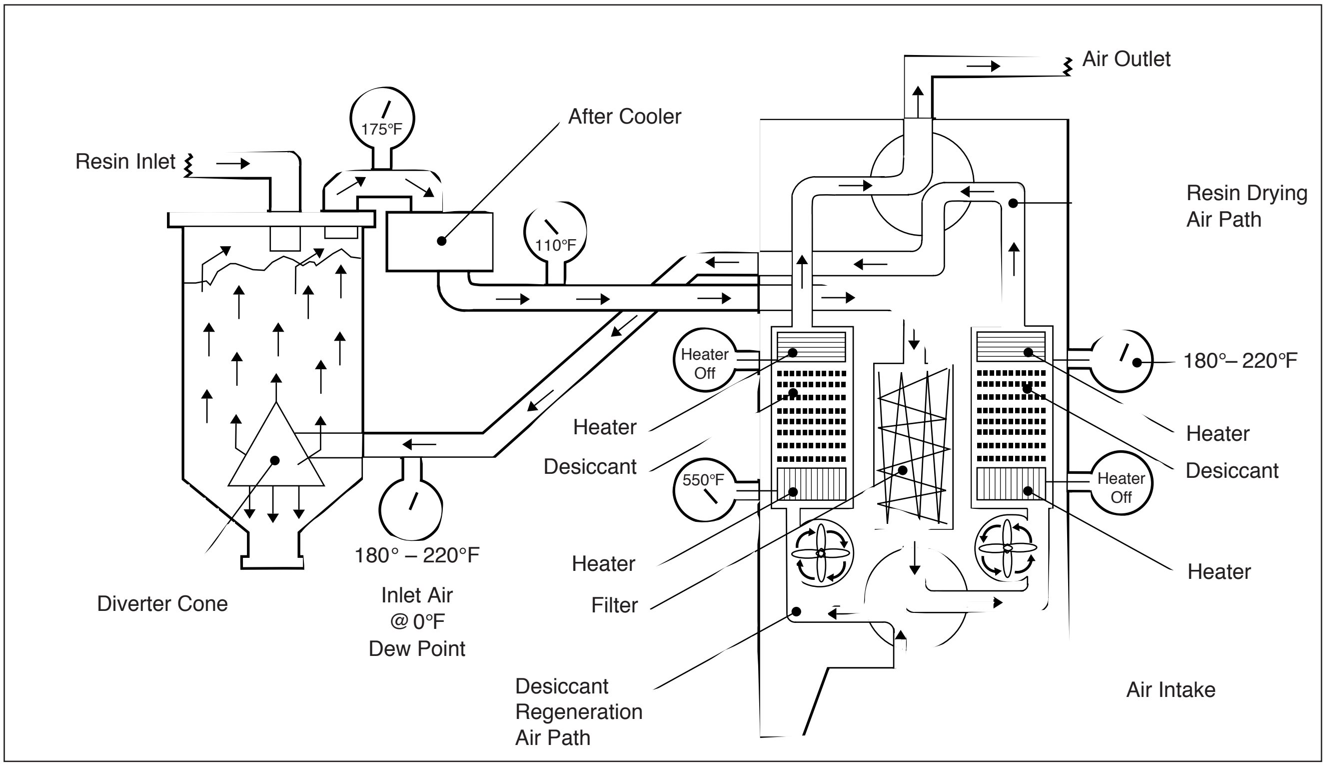
Figure 11 **Typical Desiccant Dehumidifying Hopper**

moisture content of less than 0.03% during processing. The dryer must meet the following requirements to properly remove moisture from Texin resin:

- Hopper capacity should be sufficient to ensure that the resin remains in the drying hopper at least 2 hours prior to being extruded.
- Hopper inlet air temperature of 180°–220°F (85°–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 extruded polyurethane elastomer parts critically depends on low moisture content.

Figure 12 **Typical Desiccant Dehumidifying Hopper Dryer Airflow**



A typical desiccant dehumidifying hopper dryer system and airflow are shown in Figures 11 and 12. Note that the hopper is tall and cylindrical and has a diverter cone to diffuse the air uniformly and reduce channeling of the pellets.

If the hopper dryer has not been used for 24 hours, dry-cycle it before introducing the Texin resin. This will ensure 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 2 hours prior to being introduced to the extruder.

Hot Air Oven Drying

The use of a conventional hot air drying oven is not recommended as a substitute for a dehumidifying hopper dryer. However, if it is the only method available, then the recommended oven temperature is 200°–220° (93°–104°C) for 1–4 hours. Place the resin pellets in the drying trays at a depth of 1 in. (25.4 mm) or less. Dry no other types of resin in an oven containing Texin resin. Once oven-dried resin has been put in the hopper, close and heat the hopper during processing. Otherwise, the resin should remain in that hopper for no longer than 1 hour.

Another way to avoid unwanted moisture absorption by oven-dried resin is to transfer small amounts of dried resin from the oven tray to the hopper during extrusion.

If regrind is used, dry it to the same moisture content level as required for virgin pellets. In fact, it may be necessary to dry regrind longer than virgin pellets due to the irregular shape and size of the regrind pellets. Beware of excessive "fines" (very small particles caused by grinding). Fines melt more rapidly and may cause black specks to form.

Figure 13 **Bubble Formation Due to Improperly Dried Resin**

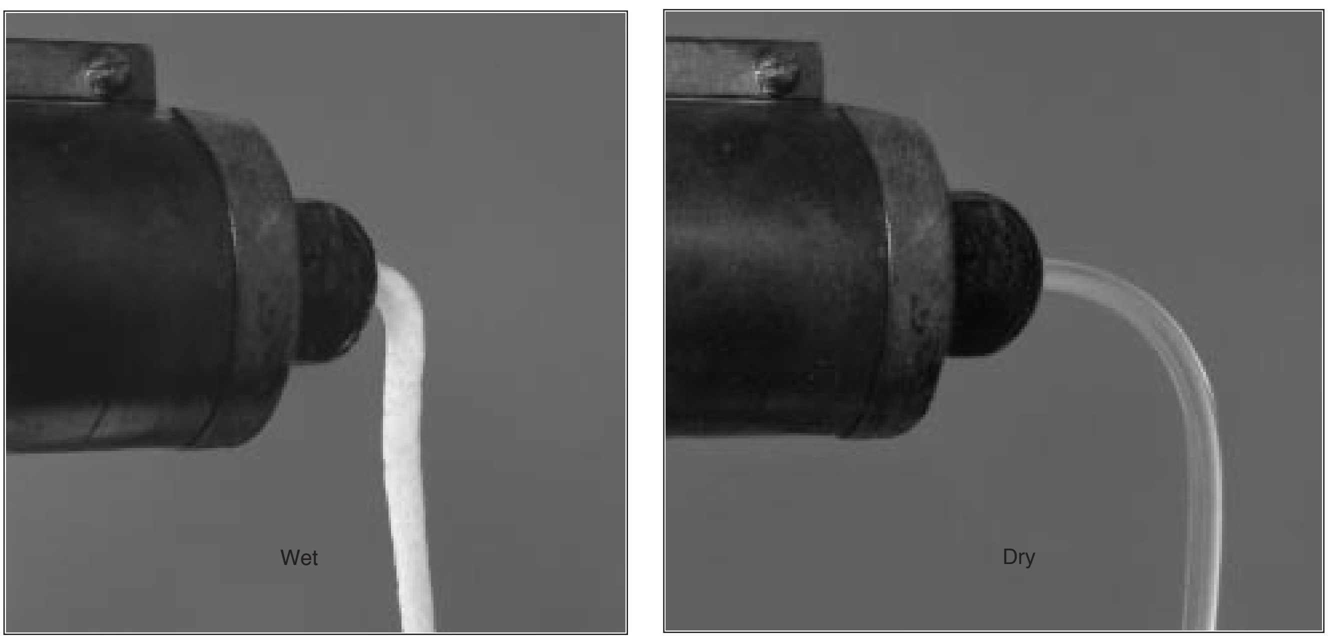


Table 4 **Dehumidifying Hopper Dryer Troubleshooting Guide**

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° – 220°F (85° – 105°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 name-plate 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 Texin resins, thoroughly purge or mechanically clean any residual material from the machine. Polystyrene (PS) or acrylic are the best materials for use as purging compounds. After purging, run some Texin resin through the extruder until the melt is free of any contamination.

High-density polyethylene (HDPE) can also be used as a purging compound. Best results are obtained using HDPE together with silica-type purging compounds.

Mechanical cleaning is more thorough than purging and is preferred by many processors. The same procedure can be used either prior to extruding Texin 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.

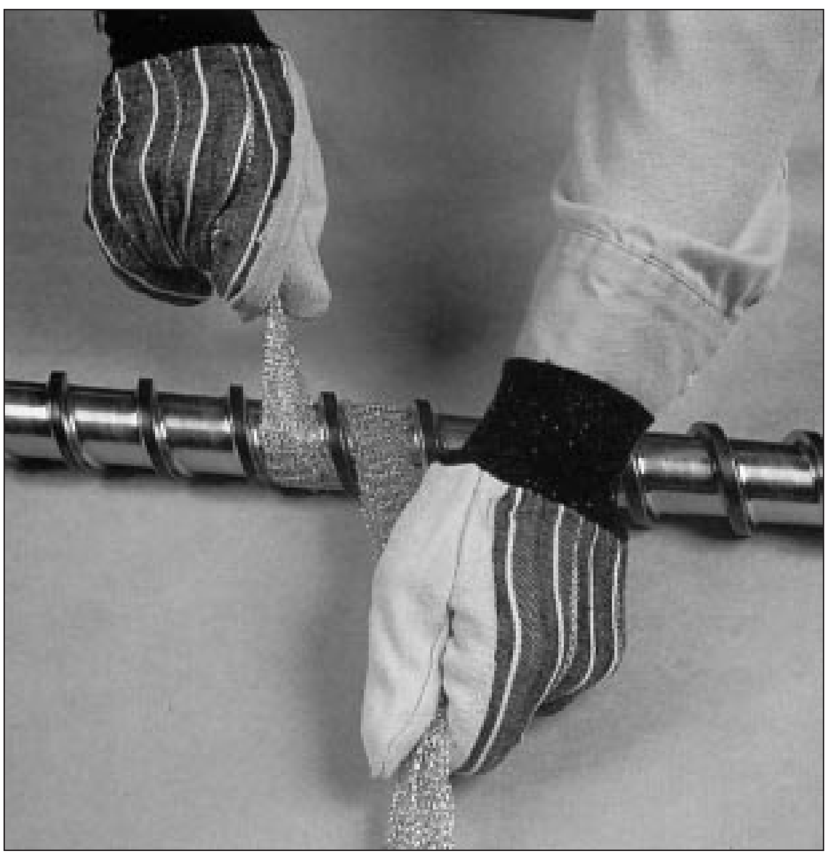
3. Turn off the heat on the main cylinder and push the screw forward until a few flights are exposed.

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 – 6 hours or by soaking them in dimethyl acetamide. Allow all of the parts to cool before placing them in the solvent. Follow OSHA and NIOSH recommendations on care and handling.

Figure 14 **Mechanical Cleaning of the Screw**



Material Changeover

Take special care changing over from one material to another when the extruder has been used to process materials other than Texin resins. In addition to purging or thoroughly cleaning the equipment, always monitor die pressure and motor amperage because the previous material may have had drastically different melt rheology from Texin resins.

STARTUP PROCEDURE

Processing Temperatures and Machine Conditions

Suggested starting conditions for extruding Texin resins with an unvented barrel are listed in Table 6. The temperatures listed assume that the extruder is equipped with the general-purpose screw described on pages 9 and 10. 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

Table 6 Suggested Starting Conditions for Extruding Texin Resins

Zones	Grades†			
	480A, 985A, 990A, DP7-1051, DP7-1052, DP7-1077, DP7-1078, DP7-1097, 5187, 5286	**DP7-1018, DP7-1030, DP7-1047, DP7-1089, 5265**	**970-D, 4203**	**4206, 4210, 4215, 5370**
Processing Temperatures				
Hopper	← 180°–220°F (85°–105°C) →			
Rear	360°–390°F (183°–199°C)	380°–410°F (193°–210°C)	410°–455°F (210°–235°C)	430°–450°F (221°–232°C)
Middle	360°–400°F (183°–204°C)	380°–420°F (193°–216°C)	415°–460°F (213°–238°C)	440°–460°F (227°–238°C)
Front	360°–410°F (183°–210°C)	390°–430°F (199°–221°C)	420°–460°F (216°–238°C)	440°–460°F (227°–238°C)
Adapter	360°–410°F (183°–210°C)	390°–430°F (199°–221°C)	420°–460°F (216°–238°C)	440°–465°F (227°–242°C)
Die	370°–415°F (188°–213°C)	400°–440°F (204°–227°C)	425°–465°F (218°–241°C)	450°–475°F (232°–246°C)
Melt*	**385°–465°F (196°–241°C)**	**385°–465°F (196°–241°C)**	**385°–465°F (196°–241°C)**	**385°–465°F (196°–241°C)**
Machine Conditions				
Cushion	← 0.125 in. (3.175 mm) Max. →			
Back Pressure	← 200 psi (138 bar) Max. →			
Screw Speed	← 40–80 rpm →			

* To obtain the proper melt temperature, measure the melt with a heated pyrometer probe.
† Refer to Table 1, page 7, for previous grade designations.

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%.

For equipment which is very undersized in horsepower, or for a part which can be run at extruder speeds greater than about 40 rpm, a "reverse profile" may be used whereby the zone next to the hopper is deliberately set higher than zones closer to the extruder head.

In no case, however, should this zone be operated at a temperature greater than about 450°F (232°C) for any of the Texin resin grades. In all cases, run a trickle of water through the feed throat jacket to minimize any tendency of the resin to bridge.

Use a melt pyrometer to determine the temperature of the initial melt and to avoid exceeding the proper melt temperature for the grade being extruded by more than 10°F (5°C). Adjust the barrel temperature controls in considerably smaller increments than is common with other thermoplastics.

The appearance of the extrudate changes slowly from unsatisfactory to acceptable even when the correct barrel settings have been made. However, if an unfavorable adjustment is made in any operating condition, including barrel temperature control, the appearance of the extrudate will change rapidly from acceptable to poor. This change can take place in as little as 5 minutes, while to improve the appearance of the extrudate may take as long as 30 minutes after the proper adjustment has been made.

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 26, 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 set 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 with high-density polyethylene (HDPE) and turn off the heat.

Long-Term Shutdown

When extrusion with Texin resins is completed, purge the machine thoroughly followed by a mechanical cleaning. (See “Machine Preparation, Purging and Cleaning,” page 26.)

TRANSPARENCY

Transparent extrusions may be achieved with most extrusion grades of Texin resin except the 4000 series. Transparency is dependent upon the time-temperature relationship of the resin in both the drying hopper and the extruder barrel. Sufficient drying time is important, particularly if the extrusion and take-off rates are rapid. As the rpm of the extruder screw increases, the extrudate can become somewhat cloudy.

REGRIND

Although it has been found that a 20% ratio gives the best results, up to 50% 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 (180°– 220°F for 1–3 hours). (See “Drying,” page 22, for details.) Any regrind used must be generated from properly extruded parts, trimmings, and/or film. 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.

Improperly mixed and/or dried resin may diminish the desired properties of Texin 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.

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.

POST-EXTRUSION CONDITIONING

Most parts extruded of Texin resins are placed in service without annealing because they attain essentially all of their ultimate properties shortly after normal fabrication. Thus, post-mold conditioning is generally unnecessary.

However, when lower compression set or better creep and tensile decay are required for the application, post-curing the parts will enhance these properties.

To achieve ultimate mechanical properties immediately after fabrication, anneal the extruded parts at 230°F (110°C) for 4–16 hours. A circulating air oven with a temperature control accuracy of ±9°F (±5C°) is satisfactory for post-extrusion annealing.

If the parts are stored for a period of 2–3 weeks after extrusion, then the cure achieved from exposure to ambient air will approach that of elevated temperature cures.

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

SHEET DIES

All conventional sheet dies are suitable for extruding Texin resins. However, the "coat hanger" design (see Figure 15) is preferred over the "T" design because of the additional streamlining which promotes even flow of the melt and eliminates material hang-up in dead spots. An adjustable restrictor bar and one adjustable lip enable variation and control of sheet thickness across the profile. Tapered die lips allow greater latitude in the operating melt temperature range than a straight-face die.

Separate controllers for the die body, die ends, and die lips (if extended lips are used) are required to achieve close control over temperature gradients. Proportionating controllers are preferred over the on/off type.

CAST FILM DIES

Dies for cast film are similar to those used for casting sheet. They are usually center-fed, heated by resistance bands, blocks, or cartridges, and are often supported by a separate cartridge or frame.

A casting die seldom has an adjustable choker bar. Instead, the internal flow path is designed to compensate for the more difficult flow to the ends, and a "coat-hanger" manifold is the result. Lips are adjusted by a row of bolts pushing and pulling a separate and removable lip bar. Some dies have an integral and flexible adjustable lip, which allows a very smooth, streamlined path. Even in these dies the actual lip edges may be removed and interchanged for easier maintenance and versatility.

BLOWN FILM DIES

Dies for blown film are either center-fed or side-fed. Center-fed dies are preferred since all points on the lip are equidistant from the feed-entry point. This is desirable for uniform flow, which yields uniform thickness. Side-fed dies are sometimes less expensive and are particularly useful for large diameters. Moreover, side-fed dies can

Figure 15 **90° Coat Hanger Die**

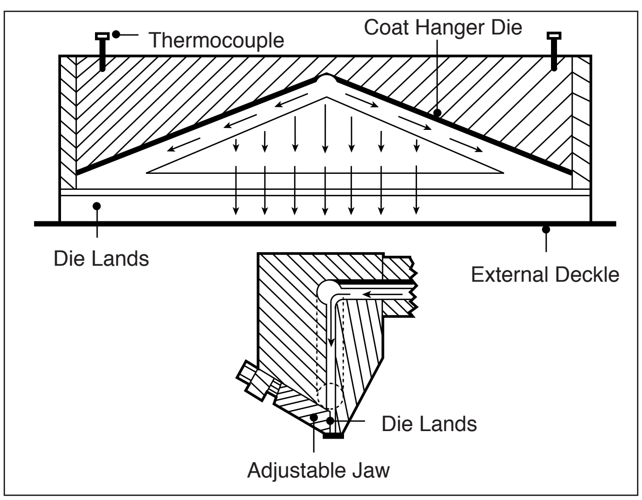
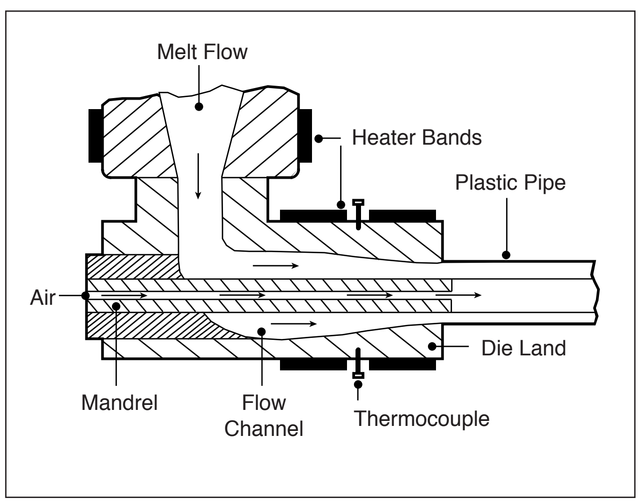


Figure 16 **Crosshead Tubing Die**



produce uniform film over a limited range of melt viscosities. Adjustments are possible, but always at some sacrifice. For example, an eccentric core can result in unequal stresses, and a raised temperature requires more cooling.

The flow path of a well-designed die will be as streamlined as possible. Any stagnation will eventually produce bits of decomposed material which will get into the film, causing "fisheyes," or even breaks in the bubble. The bits of degraded material can also lodge in the die lips and cause die lines, which weaken the film and mar its appearance.

The gap is set by the operator. Too small a gap increases die resistance and may cause overheating in the extruder and/or a reduced output rate. Too large a gap may require more drawdown to achieve a given thickness of film. Since the polymer is limited in its drawing rate and ability, a large gap may require a slower output rate or a higher temperature.

The die gap is adjusted by several bolts around the die which shift the outer ring from both sides, making the opening slighly oval. This will not usually cure an uneven thickness problem and may permanently deform the die.

Film dies are usually heated by bands or similar resistance heaters. Induction heaters and circulating heat-transfer fluids are also used.

TUBING DIES

All tubing dies used for extruding with Texin resins should be equipped for internal air sizing whereby the air is admitted through the mandrel of the die and is maintained at a very low pressure to hold the tubing to the correct ID. The required pressure will usually be in the range of 0–10 in. of water. This pressure must be held with exactness in order to hold tube dimensions. (See Figures 16 and 17.)

CROSSHEAD DIES

The "tubing on" type of crosshead die is most satisfactory for the application of Texin elastomers to a variety of substrates such as wire, polyethylene tube bundles, and reinforcement mesh, to name a few (see Figure 18). It is most desirable to have a vacuum attachment to the air space of the die in order to remove air from the space between the extrudate and the substrate. Drawdown ratios should be the same as those for tubing dies so that the substrate is pulled faster in linear feet per minute than the tube exiting the die.

Figure 17 **Straight Tubing Die**

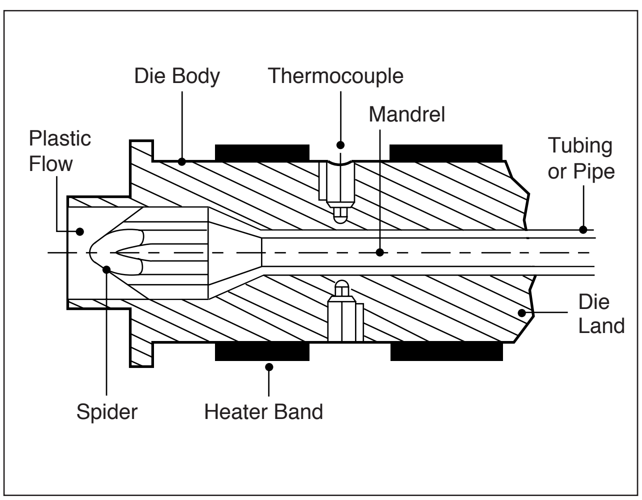
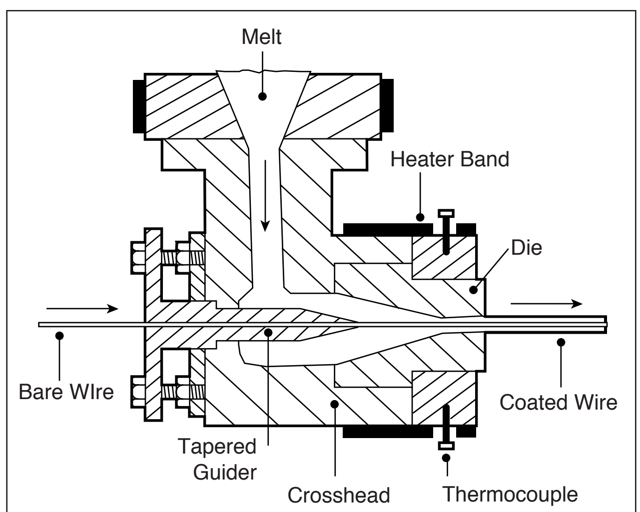


Figure 18 **Crosshead Wire Coating Die**



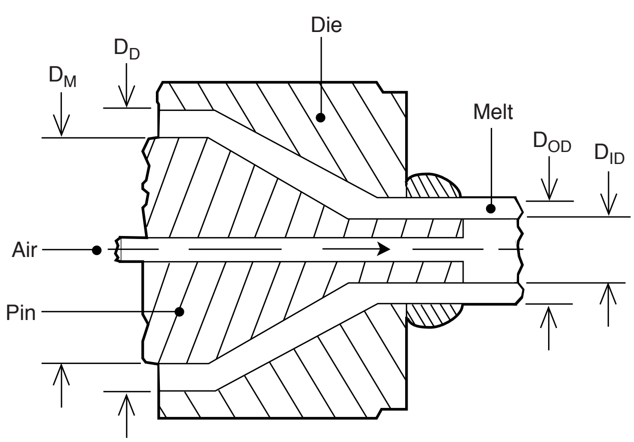
PROFILE DIES

The dimensions of dies used to extrude profiles from Texin resin usually must be determined by the "cut-and-try" method. However, there are several techniques which can minimize the number of trials:

- Make the drawdowns of the thick sections of the profile less than the drawdowns of thin sections.
- Calculate the drawdown ratio (see Figure 19).
- If possible, divide the profile into symmetrical sections equipped with either band or cartridge heaters, which will aid in attaining size.
- Equip any tubular feature of the profile die with the ability to apply internal air pressure through the mandrel to hold the ID as described in "Tubing Dies" on page 31.

In addition, it is often possible to design into the die a provision for a "flow plate." This is a valve-type plate in which the rough outline of the profile is made by drilling suitably spaced small holes. This plate need be only about 0.365 in. (9.25 mm) thick, and may be drilled initially with deliberately undersized holes, then adjusted as required after the first trial run.

Figure 19 **Calculating Drawdown Ratios for Profile Dies**



$$\text{Drawdown Ratio (DDR)} = \frac{(D_D)^2 - (D_M)^2}{(D_{OD})^2 - (D_{ID})^2}$$

D_D = Diameter of die orifice
D_M = Diameter of the mandrel (pin)
D_{OD} = Desired outside diameter of the tubing
D_{ID} = Desired inside diameter of the tubing
Recommended range is 20% for I.D. and 30% – 50% for wall thickness.

CAST SHEET AND FILM

Description of Problem	Probable Causes	Possible Corrective Action
Applesauce	• Resin incompatibility.	• Check resin compatibility (chemical and rheological). • Make sure previous resin is completely purged.
	• Temperature too high (degradation).	• Decrease temperature.
	• Temperature too low (increased viscosity).	• Increase temperature.
Draw Resonance	• Draw ratio too high.	• Decrease die gap.
	• Temperature too high.	• Decrease polymer temperature. • Repair runaway heaters.
Edge Tear	• Draw ratio too high.	• Decrease die gap. • Increase coating weight.
	• Die end temperature too low.	• Increase temperature of die ends.
	• Improper polymer temperature.	• Adjust temperature to optimum.
Excessive Odor	• Over oxidation.	• Decrease melt temperature. • Decrease air gap.
Gauge Bands	• Unclean die.	• Clean die interior periodically. • Scrape inside of die lips to dislodge foreign material.
	• Improperly adjusted die.	• Adjust die bolts. • Measure die gap periodically.
	• Temperature variations.	• Repair heater malfunctions. • Keep temperature of adapter, transfer pipe, and die close to temperature of extruder melt temperature.
	• Temperature too high.	• Lower temperature settings. • Repair malfunctioning heaters or controllers.

CAST SHEET AND FILM, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Gels	• Resin contamination.	• Keep resin storage and extruder areas clean.
	• Thermal degradation (cross-linking).	• Decrease polymer temperature. • Increase screw speed. • Check for hot spots.
	• Poor purging.	• Use proper purging techniques.
	• Poor mixing.	• Increase back pressure. • Increase number or density of screen-packs.
Heat Degradation	• Heat degradation.	• Decrease temperature. • Increase screw speed. • Clean non-streamlined areas often.
	• Hydrolysis.	• Blanket resin with nitrogen at feed throat. • Check dryer for proper functioning. • Check resin moisture.
Molten Curtain Breaks	• Draw ratio too high.	• Decrease die gap. • Increase coating weight.
	• Improper melt temperature.	• Adjust to optimum.

CAST SHEET AND FILM, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Pin Holes	• Substrate roughness.	• Increase polymer thickness.
Surging	• Hopper bridging (improper feeding).	• Lower feed zone temperature.
	• Improper screw design.	• Use different resin or screw.
	• Screw bridging.	• Reduce temperature on profile or run reverse temperature profile.
Voids	• Moisture.	• Avoid abrupt temperature changes in product storage. • Check for leaks in resin handling system. • Protect hygroscopic resin from humidity.
	• Polymer degradation.	• Maintain melt temperature below recommended maximum.

EXTRUDER AND FEEDSTOCK

Description of Problem	Probable Causes	Possible Corrective Action
Poor Feeding	• Feed throat too hot. • Too much regrind that is either too fine or too coarse. • Resin temperature too high.	• Lower feed zone temperature. • Use higher ratio of virgin pellets to regrind. • Decrease melt temperature.
Material Degrading in Extruder	• Contamination from previously run material. • Contamination from hopper loader filter.	• Purge or mechanically clean extruder. • Clean hopper loader filter.
Contaminated Extrudate	• Dry desiccant filter leaking. • Damaged screen pack. • Excessive dust in material preparation or extrusion area.	• Clean or replace dryer desiccant filter. • Replace screen pack. • Keep each bag or carton of resin sealed until it is to be used.

BLOWN FILM

Description of Problem	Probable Causes	Possible Corrective Action
Applesauce	• Poor mixing.	• Use water cooling in screw. • Increase screen mesh to increase back pressure within allowable limits.
	• Extrusion temperature too high or too low.	• Adjust temperature gradually to optimum.
	• Poor resin quality.	• Check resin homogeneity.
Blocking	• Insufficient amount of anti-blocking additive.	• Check amount of anti-blocking additive.
	• Winding tension too high.	• Adjust winding tension.
	• Frost line too high.	• Check frost line level. • Adjust temperature.
	• Inadequate cooling or ambient temperature too high.	• Reduce output. • Raise main nip rolls. • Cool using refrigerate air.
	• Overtreatment.	• Avoid overtreatment.
	• Excessive static electricity in film web.	• Check and control static electricity.
Chatter in Film or Bubble	• Excessive air ring velocity.	• Decrease air rate.
	• Air ring lip gap.	• Increase lip gap.
	• Friction in the collapsing frame.	• Modify the surface to decrease friction. • Decrease melt temperature.

BLOWN FILM, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Poor Film Clarity	• Poor resin quality or wrong resin grade.	• Check resin.
	• Extrusion temperature too high or too low.	• Adjust extrusion temperature gradually.
	• Inadequate film cooling.	• Check cooling system.
	• Low blow-up ratio.	• Check and adjust blow-up ratio.
	• Poor mixing due to low-shear extruder and die.	• Check extruder and die.
Die Lines or Bubble Tears	• Oxidation on the die lip.	• Stop the screw and clean the die lip to a bright finish with a copper pad. • Scrape the edges of the die lip carefully with a piece of brass or copper shim stock. • Apply light coat of silicone to die lip.
	• Hard gel or foreign matter inside die.	• Clean mandrel and upper portion of die. • Clean area of die land below die.
	• Insufficient blending of molten polymer as it flows around die.	• Increase mixing in extruder. • Increase adapter and die temperatures. • Increase screen mesh to increase back pressure.
Droop on Film Edges	• Film edges rolling before nips.	• Adjust gap on top of collapsing frame. • Adjust side collapsing boards.

BLOWN FILM, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Gauge Variations	• Die gap uneven.	• Check die gap.
	• Non-uniform air velocity in air ring.	• Adjust volume of air through air ring.
	• Uneven die ring temperature.	• Adjust temperature.
	• Extruder surge.	• Check extruder drive speed. • Check feed section housing. • Check temperature controllers. • Remove screw cooling. • Raise temperature of first barrel zone up to 50°F (10°C) in 10°F (3°C) increments.
	• Improper nip drive speed.	• Check nip drive speed.
	• Loose chain drive.	• Adjust chain drive.
	• Bubble not “popped” by air ring.	• Increase air volume or change die lip gap.
Gel and Fish Eyes	• Poor mixing.	• Check mixing.
	• Contaminated resin.	• Clean resin silos, transfer system, and hopper feeder periodically, especially when resin of different characteristics are being extruded consecutively.
	• Flaking from dirty screw or barrel.	• Clean screw and barrel.
	• Excessive use of recycled film or off-grade pellets to virgin material.	• Adjust the ratio of regrind and off-grade pellets to virgin material.
	• Burned polymer.	• Check for burned polymer.
	• Poor resin quality.	• Check resin homogeneity.

BLOWN FILM, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Sag in Film	• Wrong bubble geometry.	• Reduce nip height in order to collapse film at a higher temperature (175°–225°F / 80°C –110°C) before nip.
	• Bubble cooled unevenly.	• Check iris contact. • Check side collapsing boards.
Scratches	• Film contacting auxiliary equipment.	• Polish coarse surfaces of wood or metal causing the problem. Points to check include: ✔ Bubble guides ✔ Tent ✔ Treater ✔ Idler roll ✔ Dancer roll ✔ Gusset former ✔ Film folders ✔ Slitting blade holders ✔ Static eliminators • Control film tension
Splits	• Insufficient cooling.	• Check cooling source.
	• Frost line too high.	• Check frost line level.
	• Blow-up ratio too high.	• Check blow-up ratio.
	• Nips set too tight, especially if old and hardened rubber nip rolls are used.	• Check and adjust nips.
	• Die lines or bad weld lines from die.	• Decrease temperature to build up pressure.
	• Scratches from splinters in collapsing frame or other sharp objects.	• Eliminate source of scratches.
	• Degraded particles of dirt lodged under or in die lips.	• Check and clean die lips.

BLOWN FILM, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Poor Film Strength	• Insufficent blow-up ratio.	• Increase blow-up ratio.
	• Thin spots in film.	• Check for gauge variations.
	• Extrusion temperature too high or too low.	• Adjust temperature gradually.
Uneven Width (Can cause uneven rolls.)	• Tension changes or is too high.	• Check tension and try to reduce it as roll builds.
	• Air leakage from bubble.	• Check for air leak at air inflating point on die.
	• Bubble pumping or breathing.	• Check collapsing frame and ensure it is not too tight. • Check for too much air velocity in air ring.
	• Web wander in line ahead of winding station.	• Check web tension.
	• Variable tension in edge trimming or slitting station.	• Check tension.

BLOWN FILM, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Wrinkles	• Wide gauge variations across web.	• Make adjustments to ensure uniform die opening, air velocity around air ring, and die temperature.
	• Insufficient cooling or high frost line.	• Use cooler air to increase bubble cooling. • Lower extrusion temperature.
	• Bubble bounce.	• Ensure a smooth bubble collapse in tent to keep bubbles from sticking to guide rolls or forming tent. • Eliminate air drafts around bubble.
	• Poor alignment of tent and primary nip rolls with center of die.	• Align tent and primary nip rolls to provide uniform take-up tension and smooth film track.
	• Rolls out of alignment.	• Check roll alignment.
	• Excessive tension or unbalanced idlers.	• Check tension and speed of downstream rolls.
	• Rough surfaces in collapsing area.	• Eliminate rough surfaces.
	• Collapsing and cooling of bubble are uneven.	• Adjust the gap at top of collapsing frame and side collapsers. • Minimize bubble movement by reducing stalk height.

TUBE

Description of Problem	Probable Causes	Possible Corrective Action
Indented Pock Marks	• Air bubbles on surface of tube in water bath.	• Cool with large-volume, low-velocity water cascade.
Raised Pock Marks	• Water droplets on surface in air cooling zone.	• Shield hot tube from splashing.
Surface Defects Appearing at Die	• Contamination in resin melt.	• Change or replace screen pack. • Use finer mesh screen in screen pack. • Check resin for particulates. ✔ Keep extruder and storage areas clean. ✔ Keep cartons or bags of resin sealed until use.
	• Thermal degradation of polymer.	• Decrease polymer temperature. • Increase screw speed.
	• Variable tension in edge trimming or slitting station.	• Check for hot spots in extruder barrel. • Measure to control moisture content.
Rough Surfaces Inside or Outside	• Moisture in resin.	• Check resin drying procedure. • Check dryer. • Blanket resin at feed throat with nitrogen.
	• Low melt temperature.	• Raise melt temperature.
	• Unclean die.	• Clean die with copper pad. • Scrape edges of die carefully with brass or copper shim. • Apply light coat of silicone grease to die. • Soak in dimethyl acetamide.

TUBE, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Rough Surfaces Inside or Outside, ***continued***	• Melt fracture at die.	• Increase melt temperature. • Re-purge and clean at screw. • Use die with longer lands. • Use die with smaller internal entrance angles into the die-land section.
	• Insufficient mixing.	• Increase melt pressure. • Decrease temperature of screw. • Decrease screw speed. • Change screw for one of better design.
Discolored Material	• Thermal degradation of resin.	• Reduce melt temperature. • Increase screw speed. • Check for hot spots in extruder barrel. • Check all controllers and heaters.
Split in Tube Wall	• Weld line failure due to insufficient melt temperature or excessive extrusion speed or low die lip pressure.	• Increase melt temperature. • Reduce screw speed. • Increase die lip viscosity. • Use die with increased land length to develop more pressure.
	• Excessive drawdown.	• Check for unbalanced orientation in direction of extrusion.

TUBE, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Circumferential Ridges (ID/OD)	• Periodic drag on mandrel/die.	• Increase temperature of mandrel/die.
	• Vibration in take-off equipment.	• Repair take-off.
Circumferential Waviness	• Material surge.	• Use smaller first sizing plate. • Check plate for wear and nicks. Repair or replace, if necessary.
	• Uneven water cascade.	• Provide uniform flow of water around tube.
	• Insufficient mixing.	• Increase melt pressure. • Decrease temperature of screw. • Decrease screw speed. • Change screw for one of better design.
Unbalanced Wall Thickness	• Hot or cold spots in die.	• Decrease or increase temperature of die.
	• Take-off misaligned at die.	• Align take-off with die. • Center mandrel.
Tube Out of Round	• Sizing devices inadequate or out of shape in water trough.	• Replace sizing devices.
	• Tubing is too warm when it reaches the puller.	• Reduce temperature of water in cooling trough.
Lack of Gloss	• Moisture in resin.	• Check resin drying procedure. • Blanket resin at feed throat with nitrogen.
	• Low melt temperature.	• Raise melt temperature.
		• Clean die with copper pad. • Scrape edges of die carefully with brass or copper shim. • Apply light coat of silicone grease to die.

PROFILES

Description of Problem	Probable Causes	Possible Corrective Action
Wrong Shape Proper cross section, but too small or too large.	• Too much or too little pull on the contour.	• Change draw distance from die to take-off. Longer distance = thinner section. • Change take-off speed or material temperature.
Distorted cross section.	• Unequal die temperatures may make some parts too small, others too big.	• Change the shape or location of sizing plates; fingers will help.
Proper section, but warped.	• Improper cooling and take-off.	• Provide uniform cooling and support section until it is cool enough to hold its own shape. • Slow take-off speed. • Increase temperature of cooling bath or airflow.
	• Moisture of resin too high.	• Measure and control moisture of resin.
Low Gloss	• Rough spot on die.	• Clean die with copper pad. • Scrape edges of die carefully with brass or copper shim. • Apply light coat of silicone grease to die.
	• Extrudate too cold.	• Gradually adjust extrusion temperature. • Slow cooling of extrusion.
	• Die too cold.	• Raise temperature of die to temperature of extrudate.

PROFILES, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Rough Surface	• Contaminated resin.	• Keep extruder and storage areas clean.
	• Extrudate too cold.	• Gradually adjust extrusion temperature. • Slow cooling of extrusion.
	• Die too cold.	• Raise temperature of die to temperature of extrudate.
	• Die is scratching material.	• Clean die interior periodically.
	• Moisture in resin.	• Check resin drying procedure. • Measure and control resin moisture. • Avoid abrupt temperature changes in resin storage. • Protect resin from humidity.
	• Melt fracture — exit speed at die is too great.	• Raise extruder temperature. • Reduce extruder and take-off speed. • Use die with more streamlined entrance, larger opening, or longer lands.
Surging (Cross section varies linearly.)	• Take-off speed not uniform.	• Check for broken gear teeth and worn belts on take-off.
	• Extruder may not be putting out uniform melt at uniform speed.	• Run extruder at higher pressure. • Run extruder at lower rpm. • Check for broken controller. • Use better-mixing screw.
	• Insufficient pressure in die.	• Run extruder at lower temperature. • Run extruder at lower rpm. • Use die with longer lands.

PROFILES, CONTINUED

Description of Problem	Probable Causes	Possible Corrective Action
Surging, ***continued***	• Improper or clogged screen pack.	• Change to proper screen pack. • Clean screen pack.
	• Moisture in resin too high.	• Measure and control moisture.
Die Lines (Continuous lines in machine direction.)	• Unclean die.	• Clean die interior periodically.
	• Nick or burr in take-off system.	• Check take-off system and eliminate source of scratches.
Pits on Surface	• Extrusion laid on conveyor belt while still too hot.	• Cool underside of section with air before it touches the belt. • Blow air up through holes in belt.
	• Contaminated resin.	• Keep extruder and storage areas clean.
	• Moisture in resin.	• Check resin drying procedure. • Avoid abrupt temperature changes in resin storage. • Protect resin from humidity.
	• Water bath too hot.	• Lower temperature of water bath.

GENERAL

Wear safety glasses and/or face shields when processing Texin 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 Texin polyurethane elastomer resins.

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APPENDIX A: LIST OF TABLES

APPENDIX B:
LIST OF FIGURES

INDEX

C

F

G

H

I

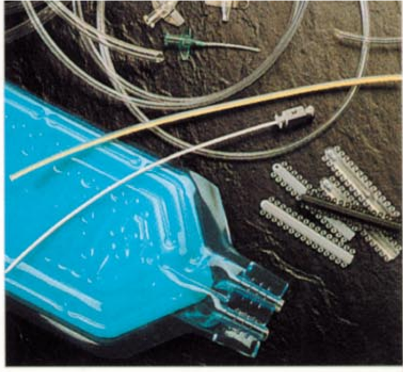
R

S

U

V

W



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