Tenite™ cellulosic plastics extrusion of tubing and profiles

Tubing and profiles can be produced from Tenite™ cellulosic plastic by various extrusion techniques. Equipment for this type of processing is readily available from extrusion equipment suppliers, but some of the equipment involved in tubing and profile extrusion may best be fabricated or machined in the customer's shop.

The methods and equipment involved in tubing and profile extrusion are described in this publication.

Cellulosic materials

Cellulosic plastics are noted for their toughness, hardness, strength, surface gloss, smoothness, and clarity. Physical properties required in the finished extruded product should be the governing factors in selecting the formula and flow of Tenite acetate, butyrate, or propionate. Variation in characteristics of the three Tenite cellulosic materials permits the best selection for a specific application. For example, maximum dimensional stability is obtained with each plastic by using the hardest flow of material, which will also fulfill the other physical requirements of the application; but in the same flow, butyrate has better dimensional stability than acetate or propionate.

- Tenite acetate, butyrate, and propionate are supplied by Eastman as 3.2-mm (l-in.) pellets of uniform bulk density.
- Tenite acetate is usually selected for applications where its dimensional stability is adequate under expected humidity and temperature conditions. Hardness and stiffness considerations also enter into the selection of acetate.
- Tenite butyrate is chosen over acetate and propionate when its advantages in weatherability, low-temperature impact strength, and dimensional stability are desired or where soft flows (not offered in Tenite propionate) are needed.
- Tenite propionate is selected instead of butyrate when its advantages in hardness, tensile strength, and stiffness are required.
- Tenite butyrate and propionate are available in special ultraviolet-inhibited formulations for outdoor use.
- An Eastman sales representative should be consulted when selecting materials for a particular application.
- Additional information on physical properties of Tenite acetate, butyrate, and propionate can be accessed at www.eastman.com.

Drying

Tenite cellulosics can be dried dependably year round if the proper dehumidification system is used. Desiccant systems can be used to dehumidify the air. With the proper dehumidifying dryer, Tenite cellulosics can be adequately dried in 4–6 hours with a process air dew point less than –29°C (–20°F) at a temperature of 66°C (150°F) and with an airflow of 1 cfm per lb/h. The recommended target moisture level is less than 500 ppm.

Some compressed air drying systems have also been effective for drying Tenite cellulosics.

Note: Desiccant dryers that recirculate the air must have a provision for removing the plasticizer from the return air; otherwise, the desiccant can become coated with plasticizer, which can make it progressively less effective in removing moisture from the air.

Extrusion

The first step in extruding tubing or profiles is to produce an extrudate with a uniform melt temperature. A machine suitable for this first step consists essentially of a dryer, feed hopper, heated barrel and screw, and a die (Figure 1).

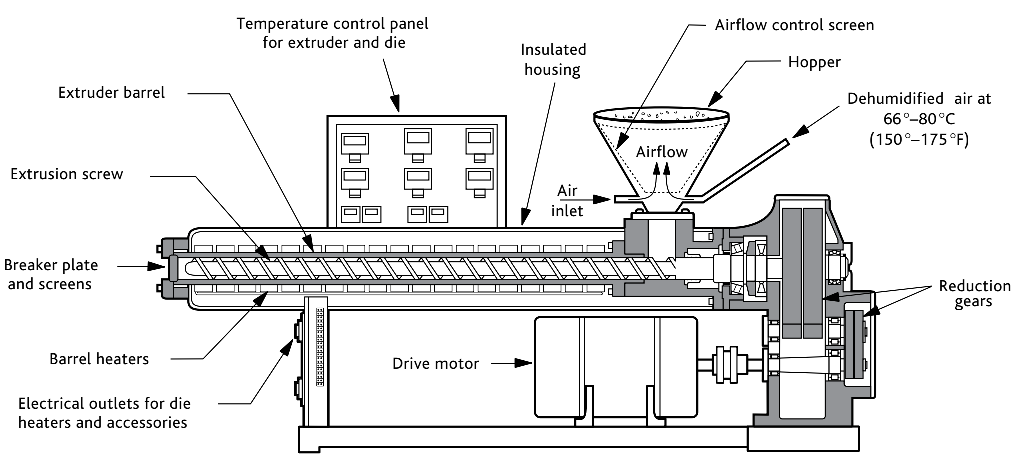
From the feed hopper located at the top of the back end of the barrel, the dried pellets feed into the extruder and are conveyed by the rotating screw. During passage through the cylinder, the pellets melt into a viscous mass that can be forced through the orifice of the die to form the extruded product.

The cylinder is normally heated by electrical resistance heaters, and the temperature is measured by a thermocouple and regulated by automatic temperature controllers. The externally applied heat and the frictional heat generated by the extruder screw are both important parts of the melting process.

The screw for extruding Tenite™ cellulosics should be designed specifically for these materials and for the particular application. Since a general screw design cannot be given to cover every application, a complete description of the equipment, application, extrusion material, extrusion rate, extruded item, etc., should be furnished to a screw design specialist. For more information on screw design, contact major extruder manufacturers or screw fabricators such as Nordson Xaloy, Barr, or Westland.

A breaker plate and a gate at the end of the barrel complete the basic components of an extruder. The breaker plate is a round metal disk with holes that are parallel to the direction of plastic flow. This plate provides a tight seal at the end of the barrel when the gate is closed and prevents material leakage. Several fine-mesh wire screens are placed on the upstream side of the breaker plate to help remove foreign particles from the plastic.

Figure 1 **Typical extruder**



Tubing extrusion

The die, attached to the extruder gate by an adapter, channels the molten material into a tubular profile. Figure 2 shows a typical offset-die design and Figure 3 a straight-die design for extruding tubing.

The outermost portion of the die or die body holds the die rings in place. The outside surface of the tubing is formed by the inside surface of the outside die ring; the inside die ring (sometimes referred to as the die pin or mandrel) shapes the inside surface of the tubing. The die ring surfaces that contact the plastic should be smooth to impart a smooth surface to the extruded product.

A restriction in the flow channel is sometimes necessary to maintain good control of the material flow through the die. The restriction in the two die designs shown in Figures 2 and 3 consists of a raised portion on the inside die ring that reduces the flow channel in that area to 0.38–0.76 mm (0.015–0.030 in.) for extruding tubing with wall thicknesses of 0.25–3.8 mm (0.010–0.150 in.). For wall thicknesses greater than 3.8 mm (0.150 in.), the restricted opening is usually around 1.5 mm (0.060 in.). The dimensions of the restricted opening are not critical, but some restriction may be necessary.

The portion of the die flow channel immediately following the restriction is referred to as the land. The usual land is about 25.4 mm (1 in.) long for each 2.54 mm (0.1 in.) of die opening, or a ratio of about 10:1.

Figure 2 **Typical offset die**

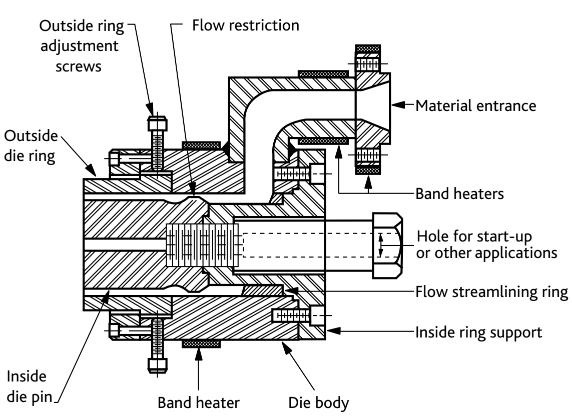
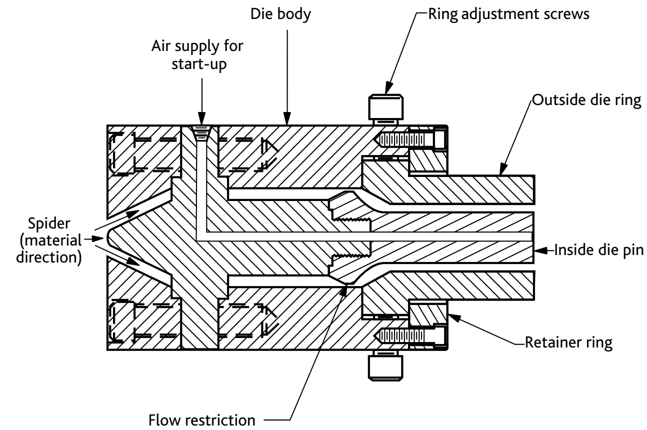


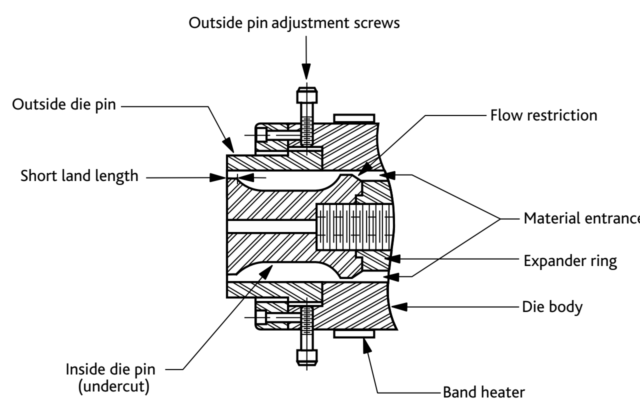
Figure 3 **Typical straight-through pipe die**



In the extrusion of thin-wall tubing, a short land is required. The inside ring can be undercut, as shown in Figure 4, to provide the correct length. The undercut area makes available a large volume, or reservoir, of material and provides uniform flow of material to the die exit.

Wall thickness uniformity can be achieved by moving the outside die ring using the adjusting screws on the outside of the die body (Figure 4).

Figure 4 **Die design for thin-wall tubing**



Drawdown

Drawdown is the ratio of the size of the extrudate (as it leaves the die) to the size of the finished product.

The diameter drawdown ratio used in extrusion of tubing from Tenite™ cellulosics is about 1.25:1 to 1.5:1, whereas the die opening can be up to 1.5:1. This allows the diameter and the wall thickness of the extrudate to be drawn down sufficiently to ensure good melt stability.

The production of thin-wall tubing may require more drawdown (sometimes as much as 2:1) than heavy-wall tubing to help prevent shear stresses at the die land, which can result in melt fracture. Melt fracture (a dull, smooth, or matte finish) can often be reduced with additional heat in the die (when on the outer surface of the part) and/or in the metering section of the barrel (when on the inner surface of the part).

Vacuum sizing

A commonly used sizing method for Tenite cellulosics tubing and pipe is vacuum sizing; the extrudate is cooled in a water bath that is under vacuum. The vacuum chamber, usually called the vacuum box, is a water bath with an airtight lid. The molten extrudate forms the seal around the sizing plate or sleeve at the entrance to the vacuum box, and a rubber gasket that fits around the cooled pipe or tube forms the seal at the exit. Figure 5 shows a typical extrusion line utilizing the vacuum-box method of sizing. There are several suppliers of vacuum-sizing equipment.

Sizing plate or sizing sleeve

For thin-wall tubing up to 25.4 mm (1 in.) in diameter, a sizing plate as shown in Figure 6 is used. For larger tube diameters and heavy-wall thicknesses, the sizing sleeve shown in Figure 7 can be used. The perforated sizing sleeve provides added support and cooling for heavy-wall tubing until partial cooling is accomplished. The walls of the sleeve should be relatively thin (0.08 or 1.6 mm [1⁄32 or 1⁄16 in.]) so that satisfactory heat transfer can be achieved. The sizing sleeve length should be about 1 mm per mm (1 in. per in.) of tube diameter. The inside surface of the sizing sleeve should have a dull, smooth sandblasted, or glass-beaded finish to minimize surface contact, which helps to prevent chatter. Shrinkage and sleeve-length allowances may vary somewhat for different Tenite cellulosic compositions and different line speeds.

Sizing plates and sleeves should be fabricated of materials that have good heat transfer characteristics but are somewhat impervious to water. Brass and bronze are commonly used metals for sizing plates and sleeves. Aluminum transfers heat better than brass or bronze but will oxidize when in contact with water for extended periods of time. If using aluminum, keep it dry when not in use and wipe and dry completely after each use. The use of low-heat transfer materials (such as steel) is not recommended.

Figure 5 **Tubing extrusion line using vacuum sizing**

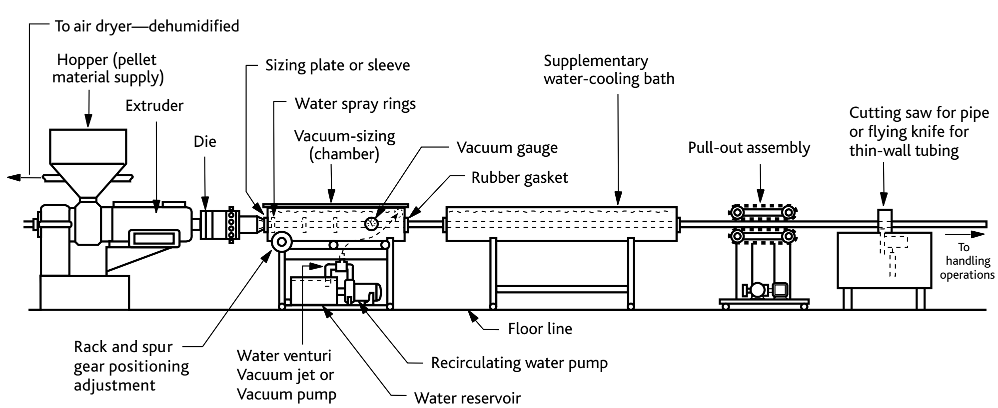


Figure 6 **Typical sizing plate**

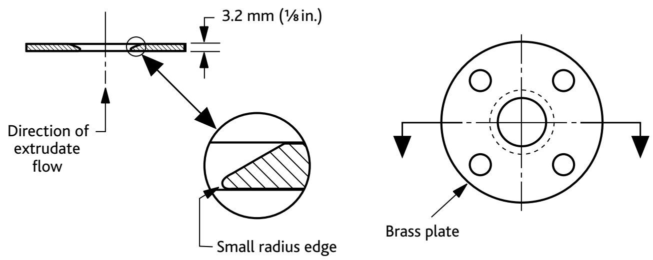
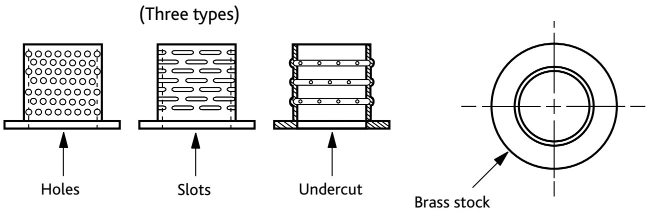


Figure 7 **Typical sizing sleeve**



Spray rings

The vacuum box should be equipped with water spray rings at regular intervals along the extruded tube. A spray ring should also be provided around the sizing sleeve. The spray rings help cool the tube during start-up of the extrusion line and provide cooling during operation by agitating the water in the cooling bath.

Noncircular tubes and hollow profiles

A tube having a noncircular profile can sometimes be made using a die with a round opening but with a sizing sleeve that is already the desired geometry or that transitions from a round entrance to the desired hollow-shape geometry at the exit. The same drawdown factor applies. An important sleeve requirement is that the circular sleeve entrance be slightly smaller than the perimeter of the noncircular exit to prevent fold lines (wrinkles) in the finished profile.

Other tubes and hollow profiles can be made by vacuum sizing. The die will have a configuration similar to the profile desired. There are limitations to the complexity of the profile or tube cross section that can be manufactured by the vacuum-sizing method.

Small-diameter tubing at high speeds

Free extrusion into water is the most effective method of producing small-diameter tubing. This may be done by extruding the tubing directly into a water bath either horizontally or vertically (Figures 8 and 9). Production rates as high as 137 m/min (450 fpm) for tubing 3.2 mm (⅛ in.) or less in diameter can be obtained in free extrusion, with tolerances as close as 0.04 mm (±0.0015 in.). Also, the internal strain level of tubing produced by this method is not considered excessive.

Figure 8 **Free horizontal extrusion into water**

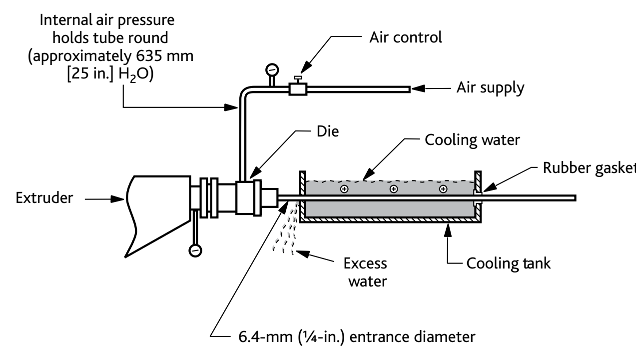
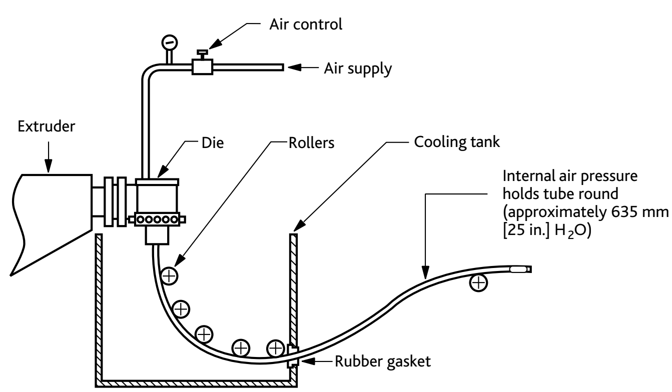


Figure 9 **Free vertical extrusion into water**



The die orifice used in the free-extrusion process is usually oversized, allowing for higher drawdown. Some very low internal air pressure is usually introduced into the tube through the inside die ring to more accurately control dimensions.

Pullout equipment

A rubber-wheel or belt-type pullout apparatus is used to pull the tube through the sizing equipment. The pullout must operate at a uniform speed because variations in line speed produce an uneven wall thickness in the extruded tube. The pullout is driven by a variable-speed drive so that it can be used for a wide range of line speeds and product sizes.

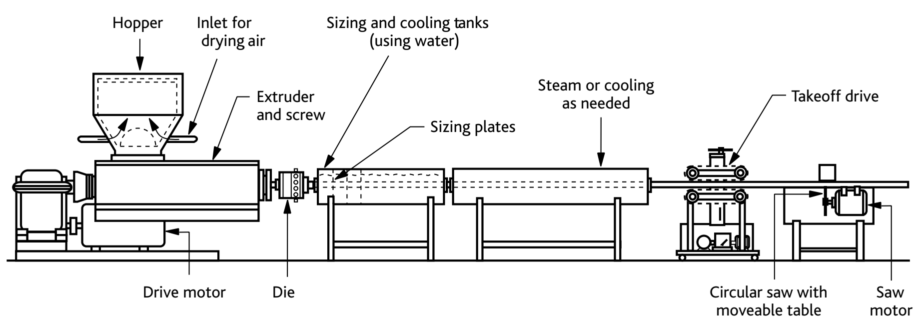
Cutting

Heavy-wall tubing is often cut into predetermined lengths. A number of automatic, moving-table saws are available commercially for this type of cutting operation. Each saw can accommodate a wide range of tube sizes. Fly-knife cutters are normally used for thin-wall tubing. Postsizing heating may be required to eliminate breakage in high-speed cutting. Curved blades are often used on fly-knife cutters to provide a "slicing" versus "chopping" action. Lubricants and heated blades can be used to help get a cleaner cut and reduce fines and/or burrs on the edge of the cut.

Profile extrusion

The extrusion process produces a plastic part that has a uniform cross-sectional profile throughout its length. Extruded profiles may serve decorative and mechanical functions. For example, extruded profiles may be used as decorative, colored trim around a table edge or may provide meshing edges to align and seal the mating halves of a briefcase when it is closed. Figure 10 shows a typical profile extrusion line.

Figure 10 **Profile extrusion line**



The continuous extrusion of profiles from Tenite™ cellulosics is similar in some respects to the extrusion of tubing. The differences are in die design, methods of sizing, and cooling. Some hollow profiles and profiles that can be cut from a hollow profile can be made by the vacuum-sizing method using the same techniques as those used in tubing extrusion. Most profiles, however, are too complicated to be made in this manner and must be extruded through a profile die and cooled in a water bath.

A profile extrusion line employs an extruder that has adequate output to meet line speed requirements. A 25-, 38-, or 64-mm (1-, 1½-, or 2½-in.) extruder is usually adequate for profile extrusions. The use of multiple-head dies (more than one die for one extruder) for profile extrusion is complicated and, therefore, not usually suggested.

Extruder position

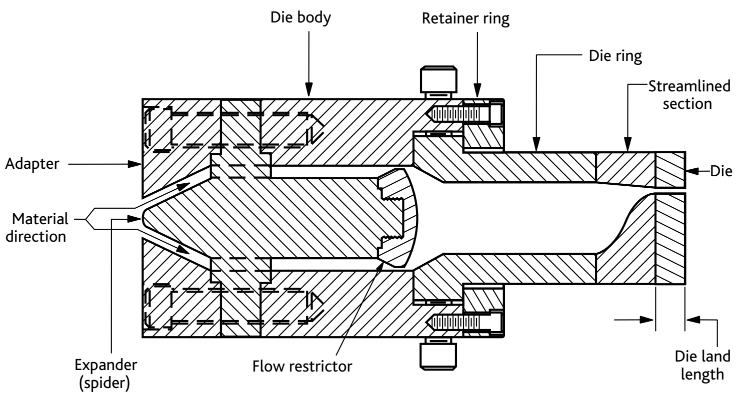
For profile extrusion, the extruder may be placed either in line with or perpendicular to the direction of extrusion.

If the profile is to contain wire or metal reinforcement, perpendicular placement of the extruder is required. This type of die is usually referred to as a crosshead design. If the profile does not have other material introduced into it during extrusion, the extruder is usually positioned in line with the extrusion direction.

Die design

Die bodies similar to those used to retain tubing die rings can be used to hold profile dies. Figure 11 shows one type of profile die using a straight-die body.

Figure 11 **Typical profile die**



Depending on the wall thickness of the profiles, the straight-die body may require a simple type of restriction similar to that used in tubing dies. Other designs are possible, but downstream restriction may be necessary to provide a uniform flow of material to the profile die. The land length of the die depends on the thickness of the profile. The land length allowance is about the same as that used for tubing, a length-to-thickness ratio in the range of 10:1 or 12:1 being normal. However, this may vary for some profile configurations and thin cross sections.

Figure 12 shows a die with a streamlined section to eliminate material stagnation points and permit a uniform flow of material through the die. A smooth die surface imparts a good surface finish to the extruded profile.

A die that is not streamlined will likely have stagnation points (Figure 13) where there is essentially no flow of material. During a long operating period, this stagnation can cause the material to degrade and discolor the extruded part. If this happens, the die may need to be removed from the machine and cleaned. Dies that have not been streamlined may be suitable for small runs, but for long-term operations, a streamlined die is recommended.

Figure 12 **Streamlined die**

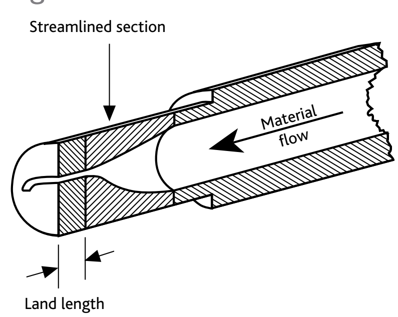
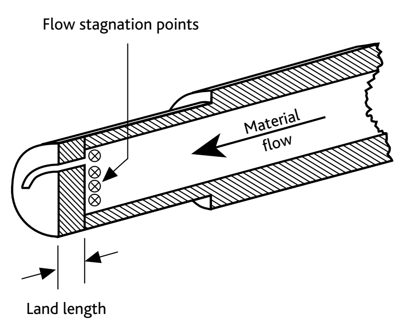


Figure 13 **Unstreamlined die**



Sizing

After the profile extrudate leaves the die, it is held to size by a series of sizing plates mounted in the water bath used to cool the extrudate. Control of the water bath temperature may be necessary for some operations, but in most instances, it is not. The design of the sizing plates depends on the complexity of the profile. The plates are usually slightly larger than the profile but fit close enough to prevent the cooling water from dripping from the plates onto the emerging extrudate.

As with tubing sizing plates and sleeves, profile sizing tooling should be fabricated of materials that have good heat transfer characteristics but are somewhat impervious to water. Brass and bronze are commonly used metals for sizing plates and sleeves. Aluminum transfers heat better than brass or bronze but will oxidize when in contact with water for extended periods of time. If using aluminum, keep it dry when not in use and wipe and dry completely after each use. The use of low-heat transfer materials (such as steel) is not recommended.

Drawdown

The profile die is normally made 15%–25% larger in all dimensions than the final profile desired. The amount of drawdown will vary somewhat with changes in either extruder output or line speed.

Pullout equipment

The pullout equipment used for profile extrusion can be the same as that used for tubing extrusion.

A wide variety of pullout equipment is commercially available from Conair, Novatec, and Goodman, as well as others.

Secondary operations

Profiles made from Tenite™ cellulosics can be machined in subsequent operations if necessary. Tenite cellulosic materials can also be polished either by mechanical methods or by solvent polishing. A profile may also be formed into various curvatures by heating the part and bending it on a forming mandrel that has a cross section similar to that of the extruded profile. A following arm is used to help maintain the cross-sectional configuration while the profile is being bent.

Safety precautions

Users of Eastman products should review applicable Safety Data Sheets (SDS) before handling or storing any Eastman products including those products identified herein. Safety Data Sheets for Eastman products are available at www.eastman.com on request.

The information contained herein is based on current knowledge and experience; no responsibility is accepted that the information is sufficient or correct in all cases. Users should follow all instructions for their manufacturing operations and should consider the information contained herein only as a supplement to other information. Users should make independent determinations of the suitability and completeness of information from all sources to assure proper use and disposal of these materials, the safety and health of employees and customers, and the protection of the environment.

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