

Introduction

The purpose of this guide is to present the latest information concerning the extrusion and coextrusion of *Alcryn*[®] melt-processible rubber. The material contained in this guide is based on Advanced Polymer Alloys' technical experience in our laboratory and practical knowledge gained in the field. If you have any questions after reading this guide, or if you need any more assistance, please contact Advanced Polymer Alloys or visit our web site at WWW.APAINFO.COM

Alcryn[®] melt-processible rubber can be processed on a wide range of plastic extruders. Parts made of *Alcryn*[®] will look, feel and perform like rubber while providing outstanding oil, heat and weather resistance.

Alcryn[®] is a partially cross-linked, chlorinated olefin interpolymer alloy. It is supplied fully compounded, in a ready-to-use pelletized form. Available grades range in hardness from 50 to 80 Shore A and unfilled formulations. The latter two can be colored with standard color concentrates. For more information on properties and for assistance in grade selection, please refer to the *Alcryn*[®] Product and Properties Guide.

This guide provides information on extrusion of *Alcryn*[®]. It reviews the type of equipment as well as the extrusion conditions required for obtaining the highest quality parts at optimum rates. The information is applicable to all grades of *Alcryn*[®] (1000, 2000, 3000 and 4000 series).

Rheology of *Alcryn*[®]

Viscosity Relationships

The rheology of *Alcryn*[®] differs from that of conventional thermoplastic materials because of its partially cross-linked structure. The polymer has no crystalline melting point and is essentially amorphous. Flow can only be induced by the application of shear. The viscosity is very high, especially at low shear rates such as those commonly found in extrusion. It is more sensitive to changes in shear rate than to temperature changes (Figure 1).

Influence of temperature on viscosity differs. For example:

- Temperature has some influence on the 2000 and 4000 series but little effect on the 1000 and 3000 series (Figure 2).
- The 1000 series has the highest viscosity and the 2000 series has the lowest. The 3000 and 4000 series has intermediate viscosity (Figure 3).
- In the same series, the softer grades have lower viscosity than the harder ones.

Figure 1. Viscosity vs. Shear Rate
Alcryn[®] 1070-BK

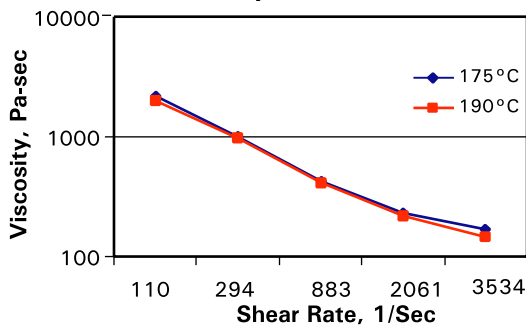


Figure 2. Viscosity vs. Temperature
Alcryn[®] 1070-BK, 2070-BK and 4070BK

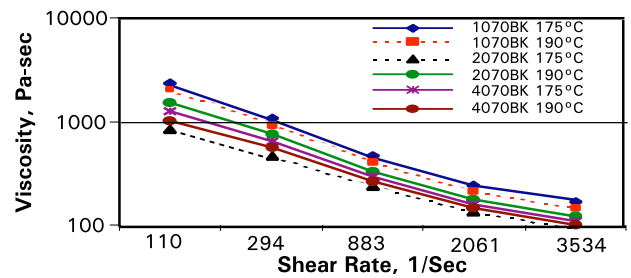
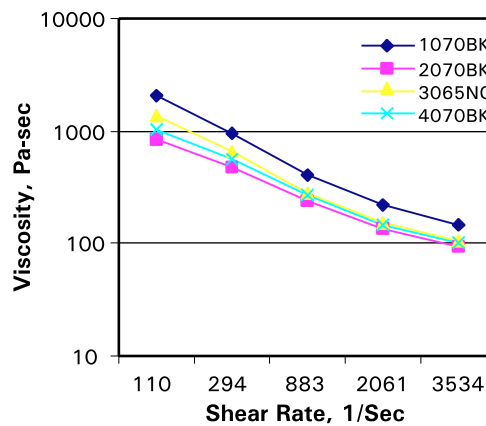


Figure 3. Viscosity of *Alcryn*[®] vs Shear Rate



Effect on Extrusion

The polymer is brought to the melt stage more through shear than heat. Heat generated through shearing of the material has to be removed to avoid degradation of the material. Therefore, it is necessary to provide medium shear and an efficient cooling to avoid overheating of the polymer melt.

On the other hand the heat should be designed to give maximum pressure at the die and to ensure equal flow rate across all sections.

Safety and Handling Precautions

All safety practices normally followed in the handling and processing of melted thermoplastics should be followed for *Alcryn*[®] melt-processible rubber. The material is not hazardous under normal shipping and storage conditions.

Alcryn[®] is a partially cross-linked, chlorinated olefin interpolymers alloy. If suggested processing temperatures or holdup time are exceeded during processing, *Alcryn*[®] can degrade with evolution of gaseous products, including hydrogen chloride (HCl). Polymer degradation is avoided when processing melt temperatures are kept at or below 375°F (190°C). The working time before the onset of degradation decreases as the melt temperature increases beyond 385°F. Evolution of HCl may occur if the melt temperature exceeds 400°F (204°C) for more than 30 minutes.

Cross contamination of the *Alcryn*[®] and polyacetals (Delrin^{®*}, Celcon^{®**}) must be avoided because acetals react with halogenated polymers, liberating significant quantities of formaldehyde gas and HCl.

Extruders should be thoroughly purged before processing *Alcryn*[®].

For further information, please refer to the *Alcryn*[®] Toxicity and Handling Guide and the MSDS sheets for these grades.

Basic Extrusion Equipment

Experience has shown that the best results have been obtained with plastics extruders. Good results have also been obtained with some modified rubber equipment. However, it is recommended this equipment be used only as a last resort, since it does not provide optimum conditions for the extrusion of *Alcryn*[®].

General Design

Materials of Construction

Corrosion resistant materials such as those typically used for PVC are suggested for use with *Alcryn*[®] to maximize life of equipment. For example, chromium or nickel screws and bimetallic extruder barrels can be considered.

Extruder Drive

D.C. motors with SCR drives are recommended, since they provide good speed control and infinitely variable adjustment of speed over a large range. Such drives normally provide automatic current limitation to prevent screw breakage as a result of excessive torque. Whatever type of drive is used, it is essential that some form of overload safety device is incorporated in the drive system. Additional protection should be provided by means of a rupture disc installed in the zone between the extruder screw and the breaker plate/screen pack, or a pressure transducer with high pressure cut-out interlocked to the extruder drive.

Hopper and Feed Throat

Overhead or tangential-type feed throats, as normally provided on single screw-extruders, work well with *Alcryn*[®]. Water cooling of the throat is recommended to prevent excessive heating of the resin entering the screw and to serve as a protection for the drive bearings.

Hopper drying is not required for *Alcryn*[®]; however, please refer to page 7 for information on when drying of the pellets may become necessary.

* Delrin[®] is a registered trademark of E. I. DuPont de Nemours & Co., Inc.

** Celcon[®] is a registered trademark of Hoechst Celanese Corporation.

Extruder Barrel

Extruder barrels which are suitable for use with common thermoplastics such as plasticized nylon, PVC or polyolefins are often, though not always, suitable for extrusion of *Alcryn*®. Length to diameter ratios of at least 20:1, and preferably around 24:1, provide the best quality.

Alcryn® has been extruded on extruders with diameters up to 152 mm (6 in). However, the bigger the diameter, the more difficult is the control of the melt temperature. In our work, the best results for mono extrusion have been obtained using barrel diameters of 64 mm (2.5 in) or lower.

It is recommended that the barrel is equipped with at least four heat control zones, and the temperature controlled by a separate thermocouple and proportional control instrument.

Efficient cooling is essential to obtain high productivity. As mentioned earlier, one of the key points in extrusion of *Alcryn*® is the removal of the heat generated by shearing of the material.

Therefore, an efficient cooling system by means of air blowers, or even better by water, helps to keep the temperature under control. A good cooling system is even more important with large diameter extruders.

Screw Design

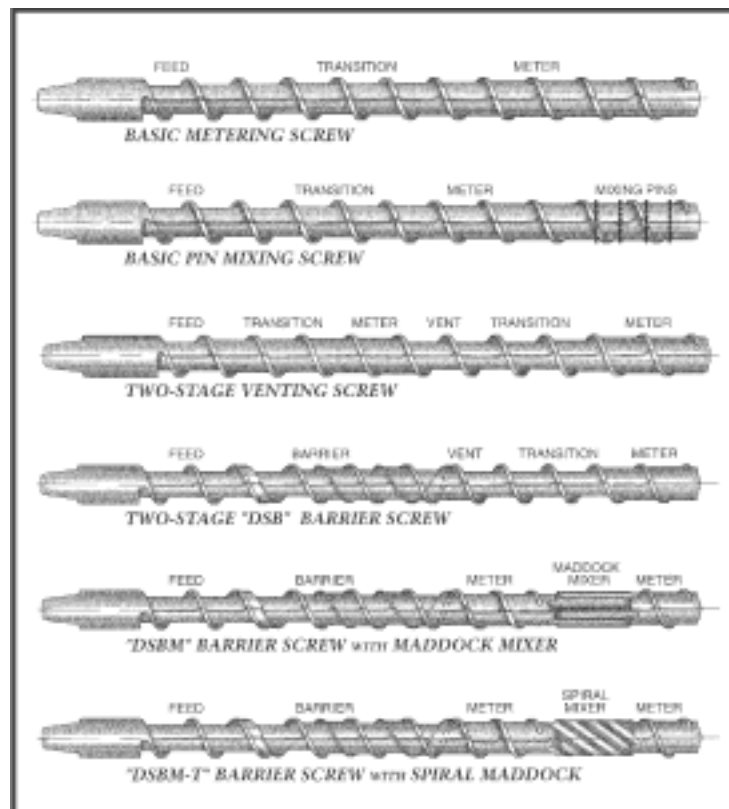
The most important element of an extruder is the screw. Its design can mean the difference between successful and troublesome extrusion, and *Alcryn*® is no exception.

The key of the success in extrusion of *Alcryn*® is to obtain a good homogeneous melt through shear action.

Screw shear should be moderate but as constant as possible. For most *Alcryn*® extrusion purposes, good results are obtained with simple 3 zone screws, having a transition (compression) zone of at least one third of the screw length (Figure 4). The longer the transition zone, the better it is. Short compression zones should be avoided as they result in high localized shear which causes overheating in the material.

The length of diameter (L/D) ratio should be a minimum of 20:1 and ideally around 24:1 for good uniformity of the extrudate.

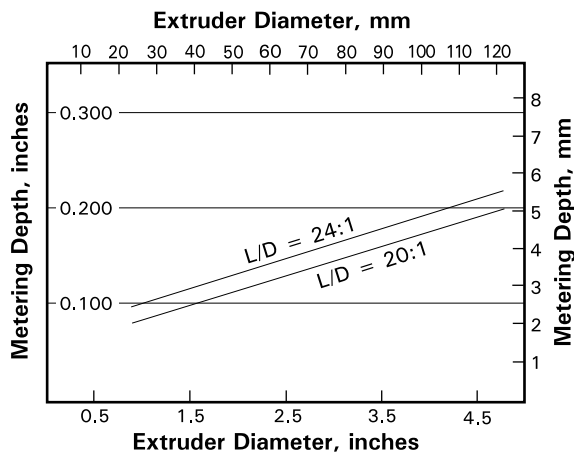
Figure 4. Screw Configuration for *Alcryn*®



Compression ratios should be between 2.0:1 and 3.0:1, as determined by the depth of the feed zone channel divided by the depth of the metering zone channel. Higher compression ratio (up to 3.5:1) should be used with the soft grades of the 1000 and 3000 series and with all 2000 and 4000 series grades in order to provide good mixing. The depth of the channel in the metering section is also important. If it is too shallow, it causes poor mixing. Figure 5 gives some suggested depths for different extruder sizes. Figure 6 shows the effect of screw flight depth on extruder output. The screw should have an offset rounded or conical tip to avoid "dead spots" in front of the screw where degradation of polymer can occur. Certain designs of "barrier" screw have been found to be useful with *Alcryn*[®]. Figure 4 gives an example of such a screw.

On some occasions where good mixing is required, such as incorporation of color concentrates, it is recommended to use a mixing element based on the division of flow and not on intensive shear. In Figure 4, an example of such a device is shown. Internal screw cooling is not normally desirable for *Alcryn*[®] as it causes additional shearing of the material due to the temperature difference between the wall of the extruder and the screw. For further details of screw design for *Alcryn*[®], please contact Advanced Polymer Alloys, or Davis Standard Corporation.

Figure 5. Design of Metering Screws with a Compression Ratio of 3:1



Screen and Breaker Plate

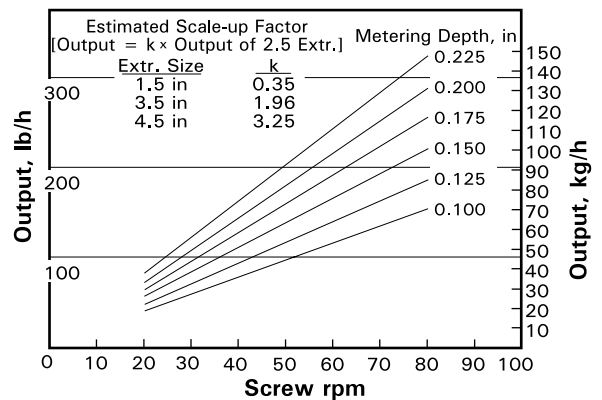
A breaker plate of streamlined design, e.g., counterbored on both sides (Figure 7), is usually placed between the end of the screw and the adapter to support a screen pack when used. For extrusion of *Alcryn*[®], it is normally only required to break the flow and remove any impurities from the melt stream but not to increase the back pressure at this level.

It has been shown that the higher the back pressure the higher is the heat generated by the screw.

Consequently, no screen pack or very coarse ones (below 80 mesh) are recommended. Finer screen pack should only be used in combination with low compression ratio screws to improve mixing. If screen packs are used, they should be regularly replaced in order to avoid excessive pressure drops developing across the screen pack, and consequent loss of flow.

Good external heating is also necessary in the breaker plate area of the extruder, as this is usually where a large amount of heat is lost to the surrounding air.

Figure 6. Typical Output of 2.5-inch Extruder (L/D: 24/1) Equipped with Metering Screws with Compression Ratio of 3:1



Adapter and Head Design

Both the adapter and the head must be of streamlined design to avoid any "dead spots" in the material flow. They should also have minimal volume with gradually decreasing cross sections. This ensures there is no sudden reduction in polymer shear rate, which would cause local increase in viscosity and irregular flow. It also provides a gradient of pressure which ensures regular flow of the material. Long and narrow channels should also be avoided as this causes additional pressure build up inside the adapter, which is undesirable.

"Wrong" and "right" designs are shown in Figure 7. As already mentioned, adequate heater capacity must be provided for the adapter since it is generally a heavy piece of metal. It is important to control the temperature of the head and the adapter separately, since they usually differ greatly in size and energy requirements.

Die Design

Die design is critical to achieve high quality profiles especially for complex shapes. It is recommended to prototype each die under the final conditions of use. *Alcryn*[®] grade, extruder size, and extrusion speed all influence the output and the die swell.

Entrance

The die should be tapered to increase the flow velocity on the wall of the die and avoid bad definitions of the corners. It also helps to balance the die by opening the section in front of the thin sections of profile.

The taper angle should be between 30 and 60 degrees.

Land Length

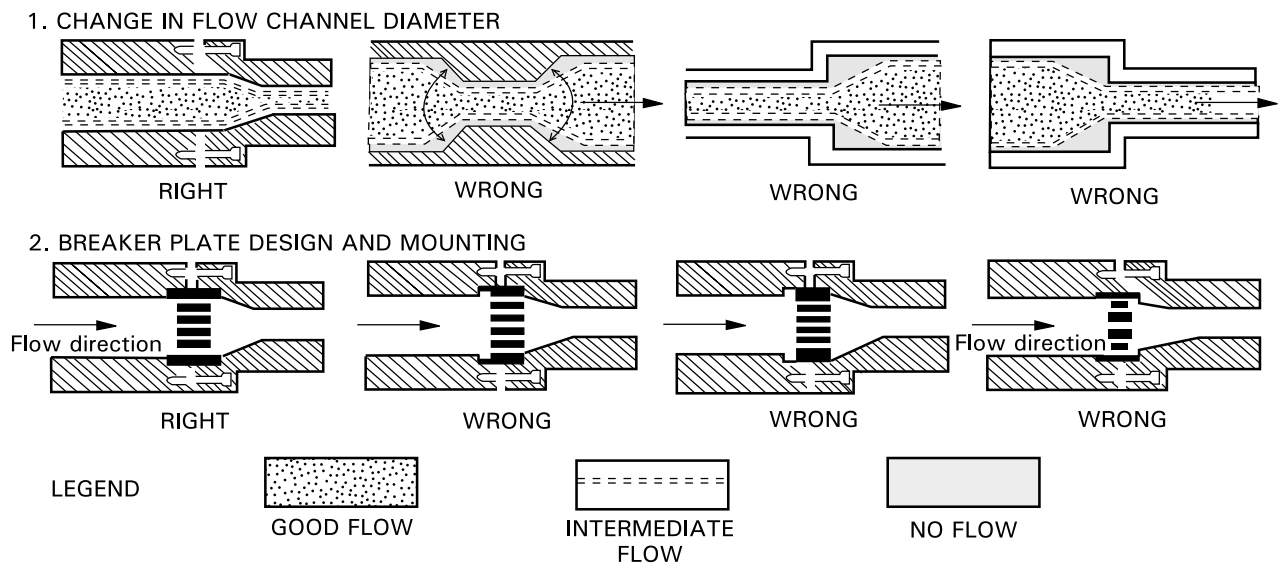
The die must be streamlined and well balanced.

It is essential to have shorter land lengths in the thin sections to prevent preferential flow through the large sections of the profile.

The ratio of land length to thickness should be around 5:1. As a guideline, the soft grades usually require a slightly higher ratio than the hard grades.

Furthermore, it is recommended to avoid sharp edges and sharp corners of 90 degrees. A minimum radius of 0.3 mm (0.12 in) is recommended.

Figure 7. Adapter and Die Streamlining



Die Swell

Dimensioning of the die is a function of the die swell and of the relative output of each section of the profile. *Alcryn*® die swell can vary from 10% to much higher values, depending on the die design. The following rules can apply:

- Soft grades give high die swell
- Thin sections cause higher swell
- Long land lengths reduce die swell
- High outputs increase die swell especially if combined with short land length.

Since flow through large cross sections will be higher than small, flow must be balanced by sizing the associated land lengths to equalize pressure drop. Because it is difficult to calculate and/or predict the flow patterns in complex profiles, it is highly recommended that the dies be prototyped before final cuts are made.

Draw Down

Due to the high melt viscosity of *Alcryn*®, it is not recommended to apply a draw down ratio higher than 1.5 to the profiles, as it induces residual stresses inside the polymer and causes high post shrinkage.

Temperature Control

If the die extends beyond the extruder head, it should have its own thermocouple and temperature controller.

For further details on die design for *Alcryn*®, please contact your Advanced Polymer Alloys representative.

Instrumentation

The function of an extruder is to pump molten thermoplastic material at a constant rate and temperature. Some instrumentation is therefore a prerequisite for quality production. To gauge extruder performance it is important to determine the pressure and temperature of the melt, as well as to provide adequate methods of control.

Pressure Gauges

Melt pressure should be monitored during extrusion and also during start-up. Recording and monitoring during start-up will indicate if there is proper flow of the material or a freeze-off situation. During production, pressure changes will also indicate output and viscosity changes of the molten plastic. For accurate measurement and rapid response, a diaphragm-type transducer with electronic indicator is recommended. Fluctuations may influence the quality and uniformity of the product; therefore, it may be beneficial to continuously monitor melt pressure by linking the transducer output to a chart recorder or other type of data storage equipment.

Melt Temperature

Thermocouples that indicate the actual melt temperature of the extrudate are useful when extruding *Alcryn*®. For rapid response they should be of the unshielded variety and located either in the adaptor plate or, preferably, as close as possible to the die, but not in it. Otherwise the flows may be disturbed.

In addition, the use of a hand-held pyrometer to check the actual melt temperature before startup is recommended. Measurements should be made at normal running screw speed, after purging for sufficient time to allow temperatures to stabilize.

Material Handling

Alcryn® is supplied in pellet form and is packaged in 25 kg (55.1 lb) polyethylene bags.

Drying

Usually *Alcryn*® can be used directly from the bag without predrying.

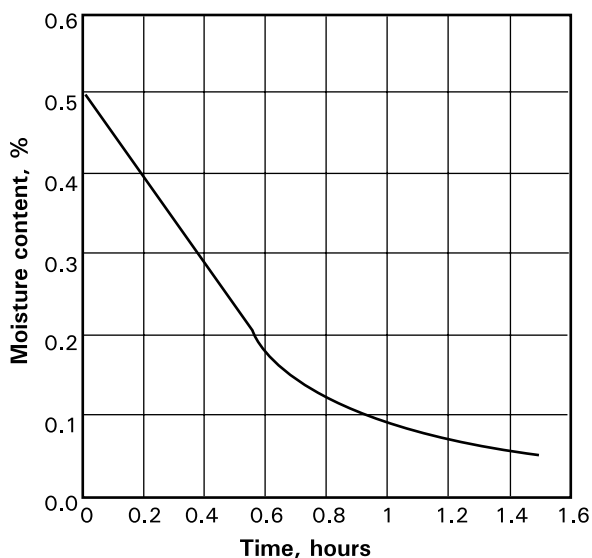
However, if bags are left open for an extended period of time, *Alcryn*® pellets may pick up surface moisture and pre-drying maybe necessary.

Figure 8 shows a drying curve for *Alcryn*®. Two hours at 176°F (80°C) is in most cases sufficient to obtain moisture level below 0.1%.

Moisture levels above 0.1% may cause porosity inside the profile and rough surfaces.

Porosity may occur at lower moisture level if high extrusion speed is used.

Figure 8. Drying Curve at 100°C
for *Alcryn*® 2070 BK



Regrind

Clean, dry scrap from any processing operation can be recycled several times with little change in either processing characteristics or properties of fabricated products, provided that the scrap resin has been properly handled. Scrap can be granulated for hopper-fed equipment or recycled through the internal mixer or hot mill for strip feed operations. Dry extruded scrap can also be reused directly as strip feed. Although scrap can be recycled as 100% of the equipment feed, blending with 10 to 15% virgin material is advisable to ensure consistent processing and finished product performance.

Purging

Brief shutdowns of up to 30 minutes require no special precautions, provided the measured melt temperature is not greater than 365°F (185°C). If the extruder is to be shut down for longer periods, *Alcryn*® should be purged from the extruder and the heaters turned off.

During the next start-up, the initial material coming from the extruder should be discarded.

The extruder can be purged with low density, low viscosity polyethylene, EPDM, or highly filled and stabilized PVC cleaning compounds.

Extrusion Conditions

A combination of heat and shear is necessary to transform *Alcryn*® into a properly fluxed, uniform melt. Melt temperature should be 356 ± 18°F (180 ± 10°C) for the 1000 and 3000 series and 365 ± 9°F (185 ± 5°C) for the 2000 and 4000 series.

Temperature Settings

The temperature profile depends on the type of screw and the grade of *Alcryn*®.

Die temperature has some influence on the surface finish of the 2000 and 4000 series: high die temperature gives a glossy surface and low die temperature gives a matt surface. Both 1000 and 3000 series give matt finish regardless of die temperature.

Screw Speed

Screw speed can be adjusted to achieve the desired output. Increasing screw speed with a screw suitable for *Alcryn*® will cause an increase in melt temperature due to shear heating. Barrel temperature set points must be adjusted to maintain the suggested melt temperature. This effect of shear is most noticeable with a high shear screw, and it may even limit the screw speed due to overheating of the material.

Quenching

Quenching should be as rapid as possible to avoid porosity, especially in thick section. Quenching can be accomplished by shower spray or water trough.

Usually, *Alcryn*® has high enough melt strength to avoid the need for any post forming equipment. However, in the case of thin hollow shapes (wall thickness below 1 mm [0.04 in]), it is necessary to have some air injection through the die to support the section.

Table 1
Extrusion Grades of *Alcryn*® (1000 and 3000 Series) Temperature Profile*

Length/Diameter	Compression Ratio	Type of Profile	Feed	Transition/Meter	Adapter/Die
Long	High	Increasing	300 °F (150 °C)	320--340 °F (160--171 °C)	325 °F (163 °C)
		Flat	325 °F (163 °C)	325 °F (163 °C)	325 °F (163 °C)
Short	Low	Reverse	350 °F (177 °C)	340--320 °F (171--160 °C)	325 °F (163 °C)

*Temperature should be increased 18°--27°F (10°--15°C) when extruding the 2000 series *Alcryn*® grades.

Extrusion Guidelines Summary

Materials of construction	Corrosion resistant materials
Extruder	L/D > 20/1 (24/1 preferred)
Barrel set points	See Table 1
Melt temperature	1000 and 3000 series: 180 ± 10 °C 2000 series: 185 ± 5 °C
Screw Barrier	screw preferred: 3 zones screw, with transition zone longer than one third of the screw
Screen pack	Streamlined breaker plate. No mesh or 80 and below

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Alcryn®