

## Table of Contents

<b>I. Introduction</b>	<b>2</b>
<b>II. Safety</b>	<b>2</b>
<b>III. Selection of Elvax® Resins</b>	<b>2</b>
<b>IV. Extrusion Processes</b>	<b>2</b>
<b>V. Pre-Extrusion Checklist</b>	<b>3</b>
<b>VI. Preparation of Elvax® Resins</b>	<b>3</b>
Raw Materials, Natural Elvax® resins, Pre-compounded Elvax® resins, Formulations via Concentrates, Dry Blending, Regrind, Formulations, Ultraviolet/Weather/Sunlight Resistant, Colors-Opaque and Transparent, Foam, Moisture and Drying, Rheology	
<b>VII. Extrusion Equipment</b>	<b>7</b>
Handling of Elvax® resins, Extruder, Typical Screw Design, Screw Cooling, Instrumentation, General, Adaptor and Die, Streamlining, Heating, Die Sizing, Typical Extrusion Dies, Forming and Cooling, Forming Methods, Forming/Cooling Tools, Water Cooling, Internal Air Pressure, Product Packing, Cutting/Trimming, Packing	
<b>VIII. Extrusion Operation</b>	<b>15</b>
Melt Temperature, Bridging, Cooling, General, Record Keeping, Startup Procedures, Shutdown Procedures, Purge Procedures, Barrel and Screw Cleaning	
<b>IX. Troubleshooting Guide</b>	<b>17</b>
<b>X. FDA Status</b>	<b>17</b>

## List of Tables

1 Elvax® Resin Grades for Extrusion and Compounding	2
2 Typical Extruder Temperature Profiles	15
3 Typical Production Operating Records	16
4 Troubleshooting Guide	18

## List of Figures

1 Typical Rheology Curves For Selected Elvax® Resins	6
2 Typical Metering Screw Design for Elvax® Resins	7
3 Screw Cooling	8
4 Adaptor and Die Streamlining	10
5 Profile Die vs. Part Configuration	11
6 Typical Extrusion Die Features and Assemblies	12
7 Water Cooling Ring	14
8 Manostat ("Bubbler") Assembly and Operation	14



## I. Introduction

DuPont™ Elvax® resins used for extrusion are copolymers of ethylene and vinyl acetate, generally ranging in vinyl acetate content from 9 to 40% and in melt index (MI) from 0.3 to 150. With no plasticizer to migrate and low odor, these resins offer advantages for use in many applications now served by plasticized polyvinyl chloride and compounded rubbers.

Extrusions of Elvax® resins have earned industry acceptance in many performance-demanding applications by offering these primary performance benefits:

- Outstanding toughness, especially at low temperature
- Flexibility
- Resilience
- Environmental stress crack resistance
- Clarity including weather resistant formulations
- Lightweight
- Favorable value-in-use and economics

Elvax® resins are relatively simple to extrude. They can be processed similar to polyethylene and other polyolefins. Processing characteristics which tend to be unique to Elvax® resins are covered in other sections of this guide.

## II. Safety

Safety hazards, common to all thermoplastic extrusion operations, apply to Elvax® resins and require standard, industry accepted, safety practice. Primary hazards relate to: high temperatures; high pressures; potential fume generation [especially over 220°C (428°F)]; and spills. Molten resin can easily stick to skin causing burns and this should be recognized as a specific hazard.

Recommended protective measures are:

- Use gloves and protective clothing, as necessary, when handling hot polymer or machine parts
- Wear approved safety glasses
- Use adequate ventilation
- Use accepted engineering designs and process controls
- Clean up spilled resin promptly to prevent slipping hazards.

Elvax® Material Safety Data Sheets are available at **www.dupont.com** or from your local DuPont representative.

## III. Selection of Elvax® Resins

Elvax® resins are available in a variety of grades. Selection of a grade for a particular application is typically based on consideration of the following properties:

- Melt Index (generally 8 or less for extrusion)
- Stiffness (available from flexural modulus of 7 to 83 MPa (1,000 to 12,000psi), in natural unmodified grades)
- Clarity: transparency, gloss and haze (a function of vinyl acetate content)
- Impact strength

A summary listing of DuPont™ Elvax® resins for extrusion and compounding is given in Table 1.

**Table 1 — Elvax® Resin Grades for Extrusion and Compounding**

Product Grade	% Vinyl Acetate	Melt Index
Elvax® 750	9.0	7.0
Elvax® 760	9.3	2.0
Elvax® 770	9.5	0.8
Elvax® 650Q	12.0	8.0
Elvax® 660	12.0	2.5
Elvax® 670	12.0	0.3
Elvax® 550	15.0	8.0
Elvax® 560	15.0	2.5
Elvax® 420	18.0	150
Elvax® 450	18.0	8.0
Elvax® 460	18.0	2.5
Elvax® 470	18.0	0.7
Elvax® 350	25.0	19
Elvax® 360	25.0	2.0
Elvax® 220W	28.0	150
Elvax® 240W	28.0	43
Elvax® 250	28.0	25
Elvax® 260	28.0	6.0
Elvax® 265	28.0	3.0
Elvax® 150	32.0	43
Elvax® 40W	40.0	57

## IV. Extrusion Processes

Industrial extrusion processes for DuPont™ Elvax® resins are all similar with respect to selection, handling and formulating of the resin. In addition, the extruder design and operation is basically common to the variety of extruded product configurations. Process differences begin with the extrusion die and continue through the cooling, haul-off, and product packing stages of the operation.

Extruded industrial products of Elvax® resins include:

- Profiles and shapes
- Tubing and pipe
- Sheet [generally defined as 0.25 mm (0.01 in.) thickness and greater]
- Coated wire and cable
- Blow molded articles
- Rod
- Coextrusions of each item above

This manual will cover, primarily, resin preparation and extruder considerations. Experience has demonstrated that these subjects are of highest priority to our customers and prospects. Information is included for cooling, haul-off, and product packing. However, it is beyond the scope of this manual to cover all details for these process steps for all of the potential extruded products.

An extrusion operation is conveniently divided into six steps. Identification and recognition of these individual steps is extremely beneficial and a clear understanding of these steps will assist in efficient problem solution.

#### **6 BASIC EXTRUSION STEPS:**

1. Blending and formulating Elvax® resins
2. Selection of extruder design
3. Selection of adaptor and die design
4. Forming and cooling
5. Haul-off
6. Product packing (typically rolls, coils or cut to length)

## **V. Pre-Extrusion Checklist**

### **IMPORTANT, PRE-EXTRUSION CHECKLIST:**

1. Elvax® resin from sealed, undamaged containers
2. Clean extruder preferred; extruder which still contains a polyolefin inventory (PE, E/MAA, EEA, PP, etc.), acceptable, if necessary
3. Polyolefin-type metering screw or equivalent in performance (confirm and document screw dimensions)
4. Metering screw compression ratio: 4/1 preferred; 3.511 acceptable (ratio of feed to metering channel depths)
5. Internal screw cooling-First 4-5 turns of feed section
6. Hopper feed throat jacket-water cooled
7. Rear barrel heat zone set low; (see Table 2 for specific setting)
8. Temperature profile dependent on % VA and melt index (see Section VIII, "Extrusion Operation"- "Melt Temperature")
9. Cooling tools, forming tools, chill rolls and water quench, all as cold as possible

During preparation for trials or production with Elvax® resins, several questions and concerns are typically of interest. These items are important for review during planning stages, prior to extrusion. This will assure that

the extrusion "set-up" will provide the best opportunity for trouble-free operation.

## **VI. Preparation Elvax® Resins**

### **RAW MATERIALS**

#### **Natural Elvax® Resins**

DuPont™ Elvax® resins are supplied in 500 kg (1,102 lb) boxes or 25 kg (55.1 lb) bags. Selected products are available in bulk hopper cars or hopper trucks. Many products are extruded from natural resin as supplied. Elvax® resins are not hygroscopic (will not absorb moisture).

#### **Pre-compounded Elvax® Resins**

Many finished products will require or will benefit from modification. UV stabilizers, colors, foaming agents, fillers or combinations can be easily incorporated in Elvax® resins.

The use of fully compounded product may be desirable depending on the additive system and the requirement for optimum mixing. For example, UV resistant formulations require a high degree of mixing (dispersion) to assure optimum end-use performance. Pre-compounded formulations can be prepared by commercial compounders or in-house, if the required compounding equipment is available.

#### **Formulations via Concentrates**

The types of formulations referred to under "Pre-Compounded" can also be prepared by use of a concentrate by the extruder. Concentrates are usually prepared by commercial compounders to assure optimum dispersion.

Typically, a concentrate will contain ten times the additive level desired in the "extended" or finished product. In this instance, nine parts of natural resin would be thoroughly mixed with one part of concentrate to produce ten parts of a resin pellet blend, to be fed into the extruder. This is commonly referred to as a 10/1 letdown ratio. Depending upon the formulation, letdown ratios range from 2/1 to 30/1.

Ideally, the base or carrier resin used to prepare the concentrate will be a natural EVA resin of an appropriate melt index to compensate for changes in melt viscosity, depending on the additives. For example, if high loadings of filler are required, then a higher melt index base would be recommended; if the additive is a liquid or plasticizer, then a lower melt index base would be recommended. Following these recommendations will assure that the final melt extension of the concentrate and natural resin will take place at nearly equal melt viscosities, thus achieving optimum melt shear mixing.

The concentrate carrier resin must be melt-compatible with Elvax® resin. Commercial compounders are generally familiar with these requirements.

The use of mixing type screws may be desirable when extending concentrates in a production extruder. This will depend upon the formulation and end use performance requirements.

## Dry Blending

Elvax® resins are recognized as good binders. They readily accept most additives, frequently at higher than anticipated loading levels for polyolefin resins. Therefore, it is not unusual for formulations to be prepared by dry blending at the extruder. This may offer economic incentive. However, the potential for cross-product contamination is great, and the dry blending technique is judged unacceptable by many processors.

Dry blend systems may be adequate for many applications. However, they will not have the dispersion quality of precompounded or concentrate systems. Consideration should be given to mixing type screws for production with dry blend systems. Dusting of dry blended additives can be minimized by addition of 0.1 weight % of mineral oil. Thorough dry mixing is very important.

## Regrind

Elvax® resins have good temperature stability, if extruded in the range of 95-220°C (203-428°F). Consequently, use of good quality regrind is acceptable. Regrind can be used at levels of up to 15-20%, provided that the regrind is:

- Clean and free of any contaminants
- Not degraded by excessive time/temperature exposure (for natural resins, no sign of yellowness; except for a natural resin containing, for example, an antioxidant with a yellow tint).

Generally, regrind can be cut with standard granulators, provided that the knives are sharp. Granulator settings for polyethylene with nominal 8 mm (5/16 in.) diameter screens are acceptable. Knives should be set for minimum clearance of 0.075-0.125 mm (0.003-0.005 in.). Stock to be granulated should be cool.

Exceptions to this may be resins with 28% or more vinyl acetate. They will require optimum grinding equipment, if not cryogenic grinding, for satisfactory grinding rates.

## FORMULATIONS

### Ultraviolet/Weather/Sunlight Resistant

A beneficial feature of Elvax® resins is that they can be stabilized to provide ultraviolet resistance (sunlight or weathering resistance), with little or no sacrifice of the inherent clarity of selected grades of Elvax® resins.

The preferred UV stabilizer system includes: a UV absorber, an energy quencher, an antioxidant and, optionally, a transparent blue or violet pigment. The preferred UV absorber imparts a slight yellow cast to the product. This can be masked by addition of a small amount of transparent blue or violet pigment. In any case, the blue, violet or yellow tints cannot be detected at nominal part thickness of 0.5 mm (0.02 in.), unless

compared to a control. As thickness increases, the tints will become progressively more apparent.

The predicted service life of the preferred clear UV stabilizer system is in the range of 3-5 years, depending upon the severity of exposure. This is a remarkable improvement when compared to unstabilized polyolefins or to some other stabilized polymers.

The preferred UV absorber and energy quencher both tend to volatilize at temperatures typical for compounding or extrusion. Therefore, these ingredients should be added at quantities which will compensate for volatilization losses (typically 33% loss or 50% excess in original material balance formula). Losses due to volatilization can be minimized by compounding and extruding at the lowest feasible temperatures.

Experience has shown that UV formulations, either precompounded or concentrates, are more prone to extruder screw bridging than natural resins. The tendency to bridge is minimized, if not eliminated, by specifying pellet size of the stabilized product (either concentrate or fully extended) to be nominally 3.2 mm (1/8 in.) diameter by 3.2 mm (1/8 in.) long. Smaller pellets are likely to cause bridging in UV stabilized formulations.

Optimum UV and weather resistance is achieved by incorporation of carbon black and antioxidant in resin of Elvax® ethylene-vinyl acetate copolymer. The carbon grade must be selected for UV protection and not simply as a pigment or colorant. In addition, the degree of carbon dispersion relates directly to service life. The carbon must be well dispersed. Elvax® resins, stabilized with carbon and antioxidant have been in continuous weathering service for over 20 years.

Carbon content should be at least 2.6 weight %; antioxidant content at least 0.1 weight %.

### Colors –Opaque and Transparent

DuPont™ Elvax® resins accept colorants to provide end use parts with high quality aesthetic appeal. Either transparent or opaque pigments can be used in grades of Elvax® with inherent clarity. Used separately or in combination, these pigments provide the opportunity to select a wide array of transparent colors, tints, and unique effects in addition to the more traditional opaque colors.

Pigments are generally preferred, rather than dyes. Pigments, typically, have better thermal stability at extrusion temperatures and better lightfastness. Improved dye systems are available and may be adequate for some colors.

### Foam

Foamed products offer economic incentives and the opportunity to design selective properties, such as resilience or weight reduction, into finished products. It should be noted that many strength properties are a direct function of density. However, because of the high toughness of many grades of Elvax®, adequate toughness remains after selected density reduction by foaming.

Elvax® resins can be foamed by release of gas within the molten polymer. This can be achieved by: (1) injection of a gas such as nitrogen; (2) injection of a liquid such as fluorocarbons; or by (3) addition of a chemical blowing agent (CBA) such as azodicarbonamide.

Introduction of nitrogen or fluorocarbons is usually by injection into the extruder barrel at the end of the screw transition zone or beginning of the metering zone. If facilities are not available for high pressure injection then CBA systems should be considered. Injection of Freon or nitrogen yields lower product densities, but requires minor equipment modification. CBA systems usually can be used with most standard extruders without equipment modification.

A typical CBA formulation includes a chemical blowing agent with an activation temperature in the range of 150-200°C (302-392°F); an activator which will reduce the temperature at which the CBA will evolve gas; a nucleator which will provide tiny sites for gas evolution, assuring uniform cell structure. In addition, mineral oil may be used to bind ingredients together if the formulation is prepared by dry blending.

The surface of foamed extruded products may be disrupted as a result of the blowing mechanism. If the surface is undesirable, a coextruded solid skin over the foam can be considered.

Elvax® resins with high melt viscosity (low melt index), are usually selected for foam formulations. In addition, they should be extruded at relatively low temperatures (125-150°C; 257-302°F), to provide high melt viscosity. High melt viscosity is mandatory to provide resistance to the evolved gas and to promote small, uniform cell structure.

All products cannot be produced in foam. Limitations relate to size, configuration and desired density. For example, low density, flat sheet cannot be produced using a flat die. Exit the die, expansion occurs in the machine and transverse directions and in thickness. The 3-dimensional expansion will result in a distorted, "wavy" sheet at low densities. Flat sheeting at low density can be made using a circular die. The "tube" is slit, opened, and wound flat.

Foamed products, by their nature, are insulators, due to the trapped gas in their structure. For this reason they are more difficult to cool than solid extrusions. Inadequate cooling will result in distortion and cell collapse.

## MOISTURE AND DRYING

Elvax® resins are not hygroscopic. They will not absorb moisture when exposed to the atmosphere. However, like most resins, they are subject to atmospheric condensation if cold resin is exposed to the atmosphere. Condensation of moisture on the resin in cold weather can be avoided by keeping about a one-shift supply of resin in the operating area. This allows the resin to warm above the condensation temperature (i.e., dew point), before the container is opened.

Defects will appear on the surface of the extrudate when excessive moisture is present. The defects usually appear as smeared, elongated surface bubbles. At very high moisture content, defects will appear as bubbles in the extrudate cross-section. However, bubbles may also be a result of a starve feeding condition (entrapped air), caused, for example, by extruder screw bridging.

Normally, Elvax® resins do not require drying. However, drying may be required as a result of condensation, use of regrind, or incorporation of hygroscopic additives.

The preferred method of drying is use of a dehumidified or vacuum tray-type oven. The oven temperature must be controlled accurately to avoid any cyclic increases in temperature. Most Elvax® resins should be dried at a maximum temperature of 60°C (140°F) to avoid potential caking of pellets. Softer products like the 100 and 200 series (33 and 28% vinyl acetate, respectively), should be dried at a lower temperature of 50°C (122°F). Generally, eight hours of drying time is adequate. Resin depth in the trays should be 50 mm (2 in.) or less.)

Hopper dryers are not recommended. At the required drying temperature, the weight of the resin in the hopper is liable to cause agglomeration of pellets, resulting in bridging in the hopper throat or feed zone. If drying temperature is reduced, then required drying time will be substantially increased.

## RHEOLOGY

Rheology data are shown in Figure 1 for several typical grades of Elvax® resins. The selected resins cover relatively constant melt index at various vinyl acetate contents and various melt indices at vinyl acetate content of 18 %. Rheology data for other grades of DuPont™ Elvax® are available on request.

FIGURE 1 NOTE:

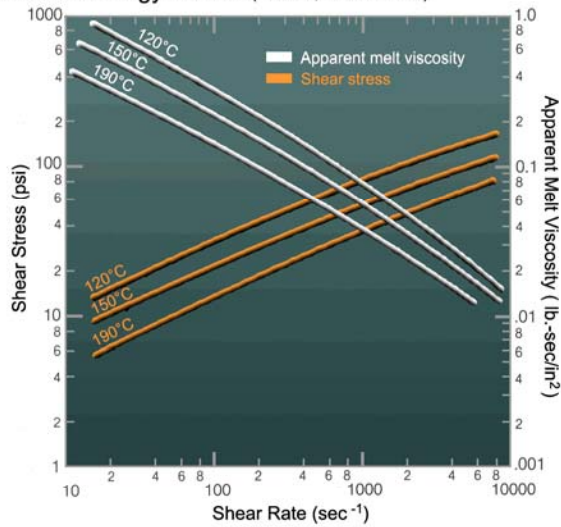
To convert psi (pounds per square inch) to Pa (Pascal), multiply psi by 6,895.

To convert lb.-sec/in<sup>2</sup> (pound-second per square inch) to Pa-s (Pascal second), multiply lb.-sec/in<sup>2</sup> by 6,895.

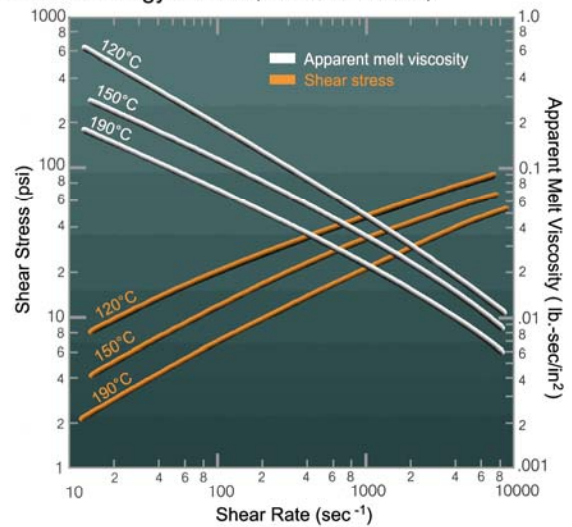


Figure 1 — Typical Rheology Curves for Selected Elvax® Resins

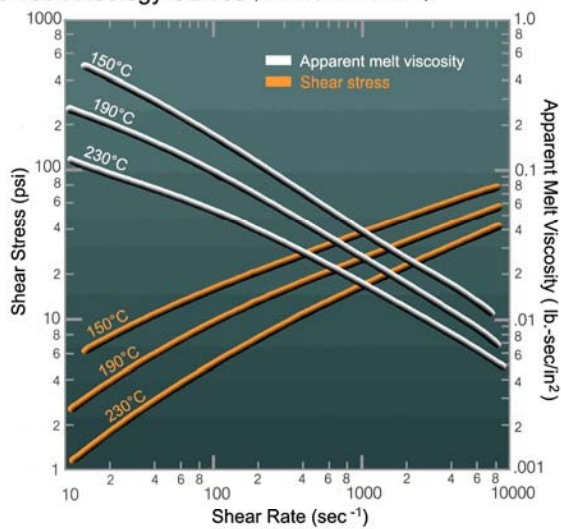
Elvax® 360 Rheology Curves (25% VA, melt index 2.0)



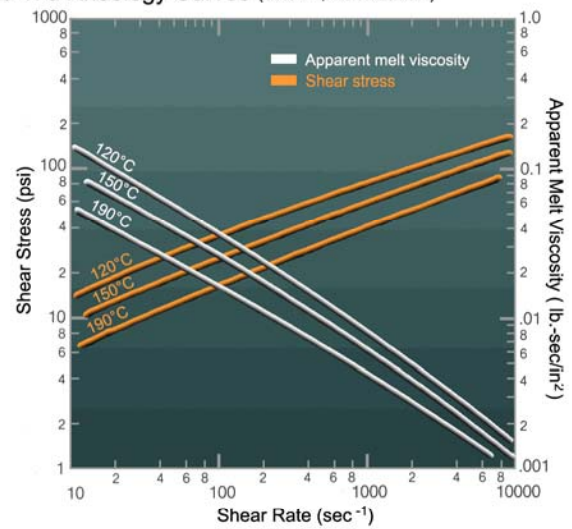
Elvax® 450 Rheology Curves (18% VA, melt index 8.0)



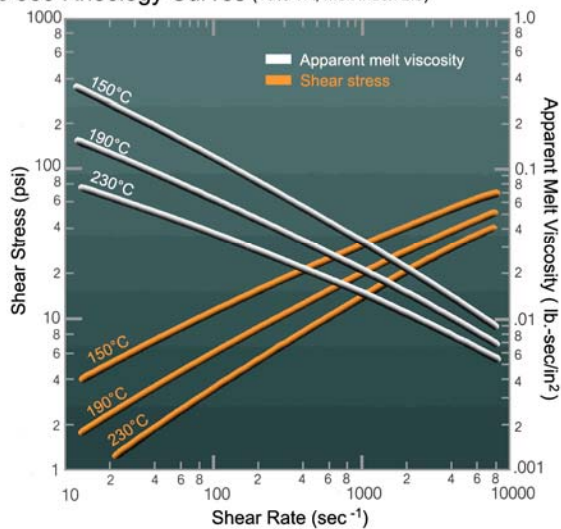
Elvax® 460 Rheology Curves (18% VA, melt index 2.5)



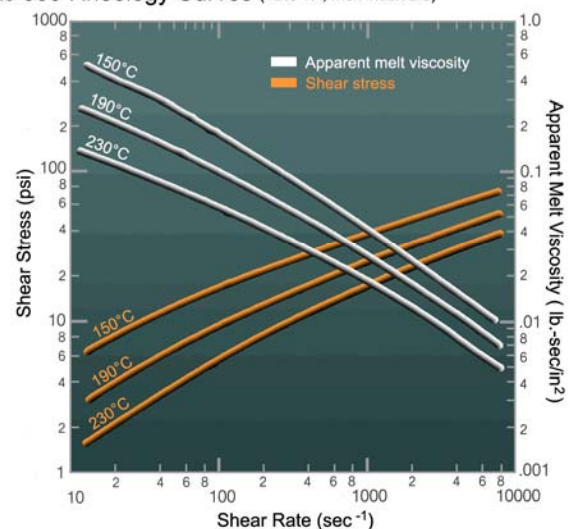
Elvax® 470 Rheology Curves (18% VA, melt index 0.7)



Elvax® 560 Rheology Curves (15% VA, melt index 2.5)



Elvax® 660 Rheology Curves (12% VA, melt index 2.5)



## VII. Extrusion Equipment

### HANDLING OF ELVAX® RESINS

Traditional resin handling equipment can be used for DuPont™ Elvax® resins, including pneumatic hopper loaders. Long distance pneumatic transport systems need to be carefully designed for these resins because of their low hardness and low softening temperature.

Feed hoppers should be covered to prevent contamination.

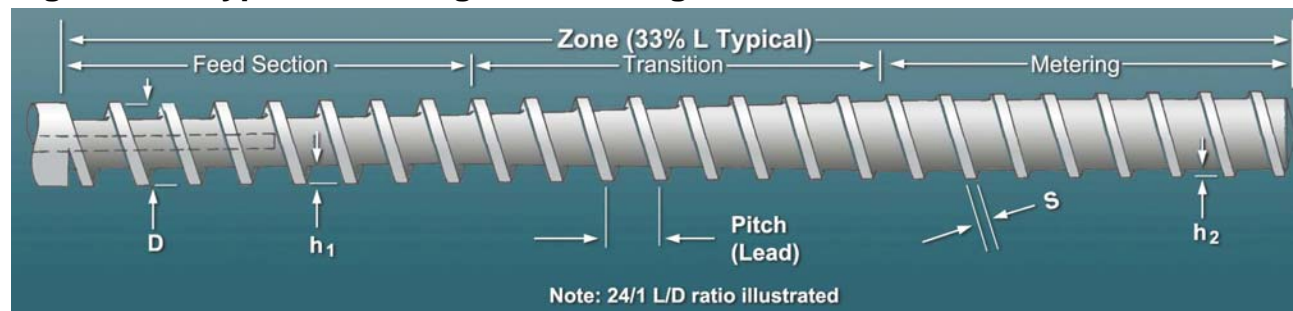
### EXTRUDER

#### Typical Screw Design

Metering type screws, common to polyolefins, generally perform satisfactorily with Elvax® resins. Typical metering screw design and dimensions are shown in Figure 2.

The minimum preferred length to diameter (L/D) ratio is 20/1. Ratios less than 20/1 will likely result in variations in output, delivery pressure, and melt temperature. UD ratios as high as 32/1 are used commercially. Ratios of 24/1 and 28/1 are perhaps most common.

**Figure 2 — Typical Metering Screw Design Dimensions**



Screw Diameter, mm (in.) (ref. figure, "D")	Feed Depth, mm (in.) (ref. figure, "h <sub>1</sub> ")	Metering Depth, mm (in.) (ref. figure, "h <sub>2</sub> ")	Flight Width, mm (in.) (ref. Figure 2, "S")	Radial Clearance
38 (1.5)	9.7 (0.380)	2.7 (0.110)	3.8 (0.15)	0.1 (0.004)
50 (2.0)	11.0 (0.432)	3.1 (0.125)	5.0 (0.20)	0.1 (0.004)
64 (2.5)	11.2 (0.440)	3.7 (0.145)	6.4 (0.25)	0.1 (0.004)
89 (3.5)	11.9 (0.468)	4.0 (0.155)	8.9 (0.35)	0.1 (0.005)
114 (4.5)	13.2 (0.520)	4.4 (0.175)	11.4 (0.45)	0.1 (0.005)
152 (6.0)	17.0 (0.670)	4.8 (0.190)	15.2 (0.60)	0.2 (0.006)

A screw compression ratio of 4/1 is preferred. This is the ratio of feed channel depth to metering channel depth. Compression ratios as low as 3.5/1 are satisfactory, especially in the larger diameter screws. If the compression ratio is too low, extruder screw bridging is likely.

A minimum feed channel depth of 9.5 mm (0.375 in.) is preferred. Smaller feed channel depths may likely interfere with uniform feeding and conveying of nominal 3.2 mm (1/8 in.) pellets and result in bridging and nonuniform extruder output.

The combination of preferred compression ratio; minimum feed channel depth; and requirement for internal screw cooling places significant limitations on the ability to design optimum performance screws at diameters less than 50 mm (2.0 in.). The design balance is very critical. It may be difficult to maintain adequate strength in the feed zone after cutting the feed channel and cooling bore due to minimum steel thickness remaining.

The nominal distribution of screw zone lengths (feed, transition and metering), is dependent upon the L/D ratio, for example:

L/D Ratio	Typical Zone Length, %		
	Feed	Transition	Metering
20/1	25	50	25
24/1 – 32/1	33	33	33

The feed zone length should never be less than 25% to minimize the tendency for bridging. Gradual transition in the range of 33-50% will improve uniformity of output, as compared to short or "sudden" transitions.

Given combinations of metering depth and length can result in an adiabatic melt temperature. This is a condition where the resin is heated internally by friction (shear), and no external heat from the barrel heaters is required. This adiabatic condition can result from a shallow channel depth over a long length. Reduction of extruder barrel temperatures will not reduce melt temperature when this condition exists. Lower melt temperatures can be achieved by reducing output or modifying the screw for a deeper metering depth and/or shorter metering length.

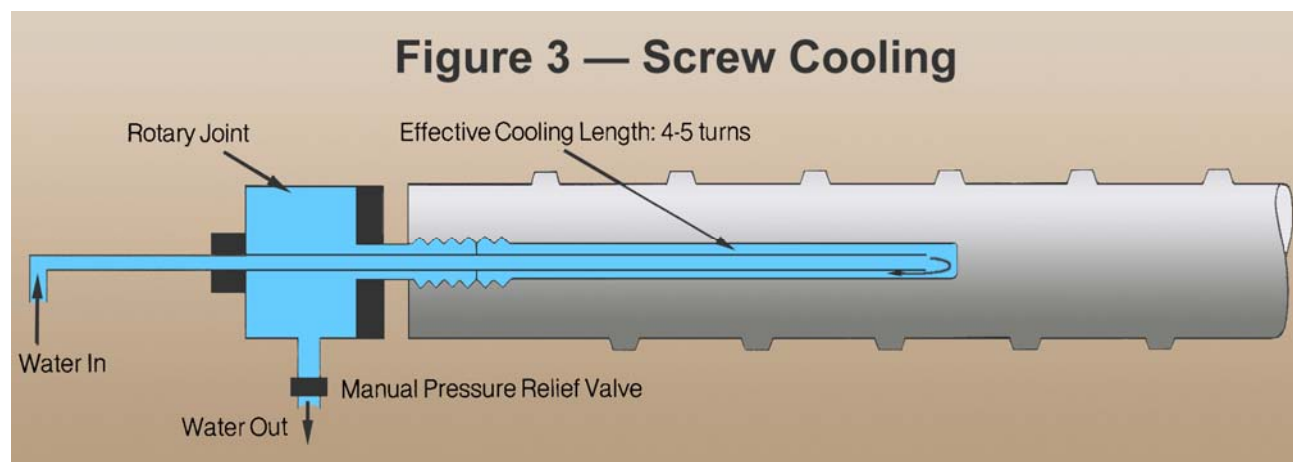
A variety of screw designs and configurations are available to meet specific requirements such as: (a) very high output; (b) precise control of melt temperature and pressure; and (c) mixing of ingredients. These high

performance designs should be considered for industrial extrusion operations which may be limited by the more general purpose metering type screw. (For example, heavy gauge sheeting at high output; or optimum mixing).

Screws designed for PVC are prevalent and, typically, have a constant pitch and uniformly increasing root diameter from the rear to the front. This type screw may cause variable output (surging) with Elvax® resins, especially as output is increased.

Vented (vacuum) type, 2-stage, screws can be used for DuPont™ Elvax® resins. However, their performance is critically dependent upon given resin viscosity and throughput rate. This type design should be considered only for operations where the same basic resin and extruder rate are both maintained for long production runs.

Screws which develop excessive localized heat or long holdup of hot resin are to be avoided.



### Screw Cooling

Internal cooling of the extruder screw is preferred with Elvax® resins. (See Figure 3.) The internal cooling should cover the first 4-5 turns of the feed zone of the screw. Cooling this zone will greatly reduce the tendency for bridging and unacceptable degrees of starve feeding.

Internal cooling of the metering zone should be avoided. Such cooling will alter the performance characteristics of a properly designed screw.

**CAUTION:** Screw cooling components (rotary joints, seals, connections, etc.), must be designed to withstand potential generation of steam pressure. A manual pressure relief valve should be activated prior to mechanical disassembly.

### Instrumentation

Instruments to monitor melt temperature and pressure are extremely important. Without these instruments only "guesses" can be made regarding the extruder performance. In addition, duplication of conditions from run to run may be impossible.

Melt temperature can conveniently be measured in the vicinity of the breakerplate (either up- or downstream). An exposed junction (for rapid response) melt thermocouple with 6.4 or 12.7 mm (1/4 or 1/2 in.) probe is preferred to avoid close proximity to the flow channel wall and to gain immersion into the melt stream. Probe lengths over 12.7 mm (1/2 in.) will frequently "bend over" against the flow channel wall due to the pressure of the polymer flow.

Melt pressure is best measured between the end of the screw and the breakerplate. (Pressure readings may show

"blips" at this location due to the passing of the screw flight with each revolution). Pressure can also be measured downstream of the breakerplate although this location will not effectively allow monitoring of screenpack condition. Either a pressure transducer or Bourdon type gauge can be used with the tip flush with the inside of the flow channel. The Bourdon type gauge requires a silicone "grease leg" to transmit pressure to the gauge and is subject to leaving a slight contamination on the surface of the extrusion. Therefore, direct reading transducers are preferred.

Standard instrument wells are used for both melt thermocouples and pressure gauges. Details are available on request.

### General

Extrusion of DuPont™ Elvax® resins requires a water cooled hopper feed throat. Virtually all modern extruders include this feature, which is necessary to prevent pellet agglomeration from heat in the feed throat. However, the cooling channel must be kept clean to provide efficient cooling.

The power requirement for extrusion of Elvax® resins has not been a demonstrated problem, probably because most commercial extruders have adequate drive power.

The extruder barrel should have at least four independently controlled heating zones (each 25% of the length). This will assure adequate control capability for optimum production. Many machines are equipped for barrel cooling. This feature may be of benefit to help prevent bridging in the first heat zone.



Standard extrusion operation should include a breakerplate and screen pack. The breakerplate will interrupt the spiral flow from the screw and the screen pack can prevent inadvertent debris from damaging die parts. The screen pack is not intended to develop back pressure- this is a function of a properly designed screw. A typical screen pack is 2-80 mesh and 1-40 mesh screens (40 mounted against the breakerplate). Streamlining of the breakerplate assembly is covered in the section following, "Adaptor and Die."

Elvax® resins can become unstable and degrade due to excessive time/temperature exposure. If this condition exists, then equipment components in contact with molten polymer can slowly corrode. Therefore, extruder, adaptor and die components, which come in contact with molten resin, should be constructed from corrosion resistant alloys or surfaced with durable chrome plating. Mild steel components may be attacked under certain conditions of time and temperature exposure to Elvax® resins.

## ADAPTOR AND DIE

### Streamlining

Streamlining of the polymer flow paths in the adaptor and die assembly is extremely important. Resin flow in these components is laminar and not "plug flow." This means that flow velocity is highest in the center of the flow channel and, at least in theory, is at zero velocity on the walls of the flow channel. Therefore, resin near the walls has an appreciably longer holdup time than resin toward the center of the channel.

While DuPont™ Elvax® resins are reasonably heat stable, they are, like any polymer, subject to degradation when exposed to high temperatures for a long time - commonly referred to as time/temperature exposure. The temperature is dictated by the extrusion process. The time factor, by definition, is increased for resin near the channel wall in systems with good streamlining design. Poor streamlining or, in effect, "unnatural flow paths" can result in areas of total stagnation and no flow. Resin will degrade and slough off into the extruded product, causing defects. Examples of "Right" and "Wrong" streamlining designs are illustrated in Figure 4.

### Heating

The adaptor and die assembly should be totally heated to maintain a uniform melt temperature. Generally, this assembly is not intended to either remove or add heat to the melt; but rather to maintain the melt temperature, pre-established by the screw. All possible areas of the adaptor and die should be covered by heater bands or equipped with internal heaters. An exception would be over the area of a melt flow seal, which could possibly leak. In this case a heater band could conceal the leak until significant cleanup would be required.

Some designs do not permit effective placement of heaters-for example, massive head clamps or swing gates. In these cases, the non-heated areas should be insulated. This will allow adjacent heated zones to more

Doc. Ref. K-25776 rev.1 November 2011, page 9  
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effectively heat these areas and also will minimize heat loss from the non-heated area.

Each adaptor and die heat zone should have about the same geometry throughout the zone. An undesirable situation would be combining a massive die zone with a small diameter neck piece (common to sheeting dies), and controlling both by a thermocouple in the massive zone. The neck piece can be subject to severe overheating. Conversely, if the controlling thermocouple is in the neck piece, the massive die zone would not come up to heat.

### Die Sizing

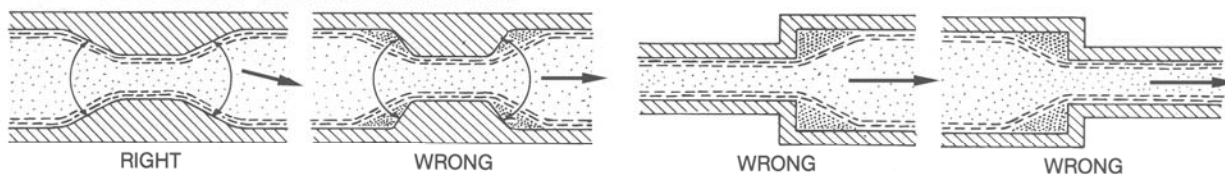
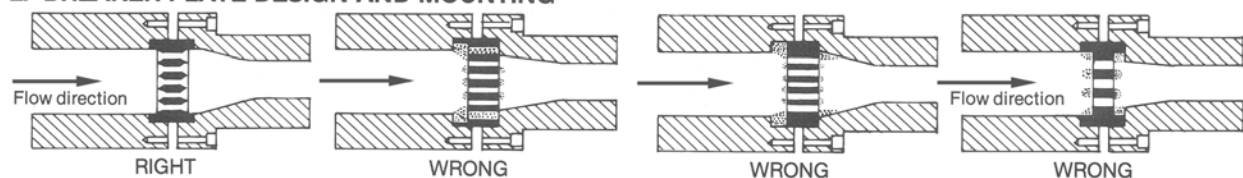
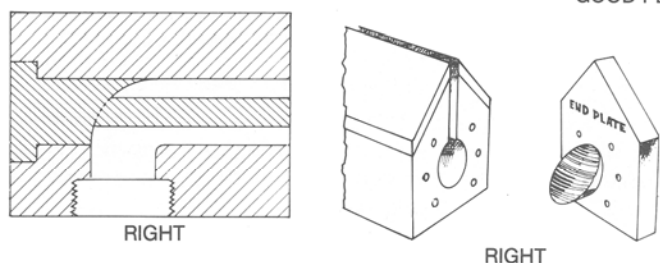
The area of the die face opening is typically larger than the area of the finished product. The comparison of these cross-sectional areas is defined as drawdown. For example, for tubular products the drawdown ratio is:

$$\text{Cross-sectional Area Drawdown Ratio} = \frac{(\text{Die diameter})^2 - (\text{Mandrel diameter})^2}{(\text{Tube OD})^2 - (\text{Tube ID})^2}$$

Drawdown ratios for Elvax® resins are typically in the range of 1.5/1 to 4/1. Drawdown is desirable because it provides tension in the melt and makes the melt easier to handle. Simple, symmetrical extrusions such as tubing, pipe, and sheeting rarely require drawdown over 3/1. More complex parts may have differential drawdown ratios throughout their cross-section.

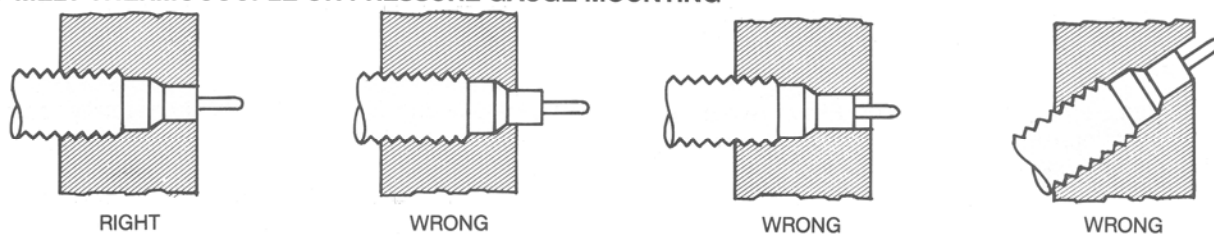
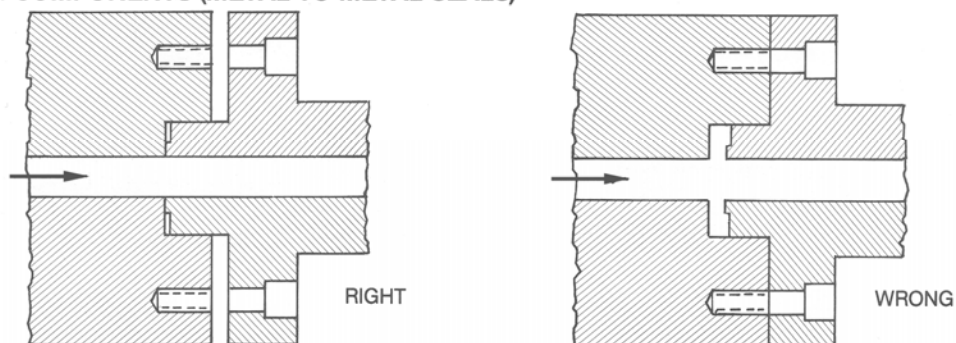
The melt strength of DuPont™ Elvax® resins is good, and it will tolerate high drawdown ratios without tearing or breaking. However, as drawdown ratio increases, the balance of machine and transverse direction properties can be affected. Therefore, it is best to minimize drawdown ratio unless product testing shows no detrimental loss of properties.

Die sizing for profile extrusions is predominately an "art" and not a science. It is heavily dependent upon experience and is not easily reduced to guidelines, due to the almost infinite variety of profiles which can be extruded. It is not unusual to modify profile dies several times before an acceptable part is produced. Therefore, it may be helpful to make trials with any similar dies available before fabricating a die for a new part.

**Figure 4 — Adaptor and Die Streamlining****1. CHANGE IN FLOW CHANNEL DIAMETER****2. BREAKER PLATE DESIGN AND MOUNTING****3. CHANGE IN FLOW DIRECTION**

LEGEND

GOOD FLOW	INTERMEDIATE FLOW	NO FLOW

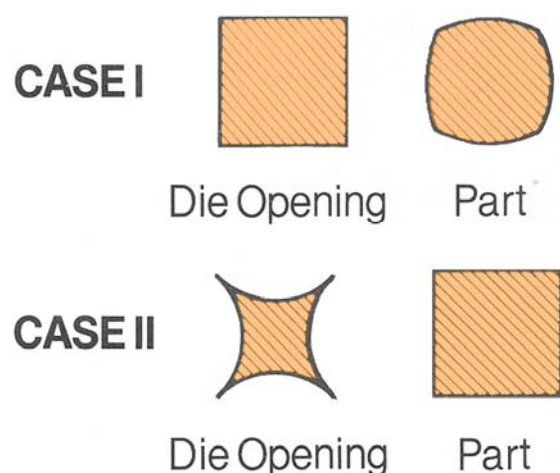
**4. MELT THERMOCOUPLE OR PRESSURE GAUGE MOUNTING****5. MATING COMPONENTS (METAL TO METAL SEALS)**

"Streamlining of Extrusion Dies," P.N. Richardson, SPE Journal, Vol. 14, Number 8. Reprinted with permission.

Profile dies are typically flat plates (thickness of 3.2-12.7 mm; 1/8-1/2 in.), mounted on the die body. Practicality dictates this technique even though it is not optimum with respect to streamlining and resin holdup. The flow channel feeding the flat plate die is frequently circular. The diameter of the flow channel face should be approximately equal to the major dimensions of the die opening. If the major and minor dimensions of the die opening are remarkably different-then entry contouring is required. Contouring of the flow channel entry to the flat plate die is preferred in all cases.

A simple example of die vs. part configuration is shown in Figure 5. The part configuration is significantly different than the die opening. Additional differences would result from changes in land length, die temperature variation, melt viscosity, melt swell, etc.

**Figure 5 — Profile Die vs Part Configuration**



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### Typical Extrusion Dies

A variety of typical extrusion die features and assemblies are illustrated in Figure 6. Also included is typical die component nomenclature.

## FORMING AND COOLING

### Forming Methods

There are several basic forming techniques which are used in combination with the initial cooling of extruded products. Each has many variations as they have been adapted to meet particular requirements.

The forming techniques include:

- Free extrusion
- Sizing ring
- Sizing plate or shoe
- Vacuum sizing
- Internal forming mandrel
- Chill roll
- 3-roll finisher

**Free extrusion** is perhaps the most simple method. The extrusion is formed by entry into a water quench tank with a guide plate to control water flow and rollers to keep the product submerged. This method is generally used for small diameter tubing and rod, and other uncomplicated cross-sections. The inside of tubing must be vented to the atmosphere or provided with low positive pressure to prevent collapsing.

**Sizing ring** forming applies to circular products (tubing and pipe) and **sizing plate** or **shoe forming** (profiles or shapes) is similar, except that the products are not circular and, in most cases, are non-symmetrical. These extrusions are formed by drawdown against the ring or plate at the entry to the water quench tank or by introduction of low pressure air, if the section is hollow. Most operations require multiple sizing plates, progressively smaller in size and located downstream, as required, until final form stability is achieved.

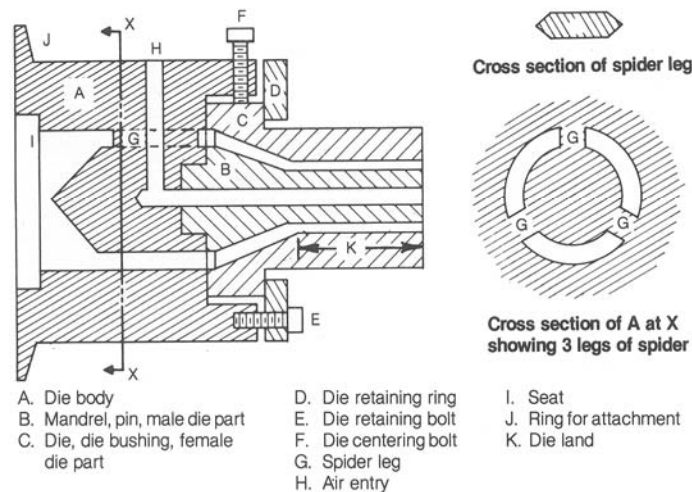
Hollow products will accommodate the **vacuum sizing** technique (sometimes called differential pressure sizing). It does not require positive internal air pressure. The initial section of the water quench tank is sealed to permit a vacuum to be applied. As the product enters this vacuum section it passes through a series of sizing plates, usually placed very close together. With vacuum applied, and the inside of the section vented to the atmosphere, the differential pressure "pushes" the extrusion against the sizing plates for forming during cooling. Seals must be provided at the entry and exit of the vacuum tank in order to maintain uniform vacuum.

The **internal forming mandrel** method is used for hollow products, traditionally pipe and tubing. However, it may be considered for non-circular, hollow sections. The method involves the attachment of an extended mandrel with capability for internal water coolant circulation, in-line with the hot mandrel (pin or male die part) in the die assembly. As the product is drawn over the internal forming mandrel it is cooled and shaped. Additional cooling is provided by a water quench tank. The downstream end of the product must be kept open to the atmosphere, otherwise the product will collapse. The cold mandrel is normally tapered to prevent seizure. A cross head or offset die is preferred to allow coolant circulation from the rear of the die assembly to the cold mandrel. (Coolant entry in an inline die must be through a spider leg and is very likely to upset the temperature uniformity in the die and result in weak weld lines).

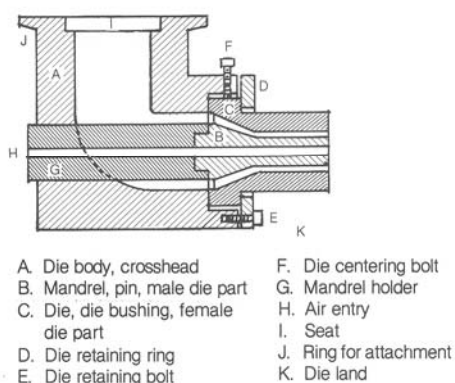


## Figure 6 — Typical Extrusion Die Features and Assemblies

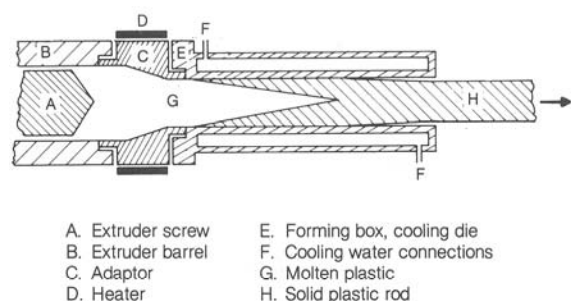
### PIPE OR TUBING DIE FOR INLINE EXTRUSION



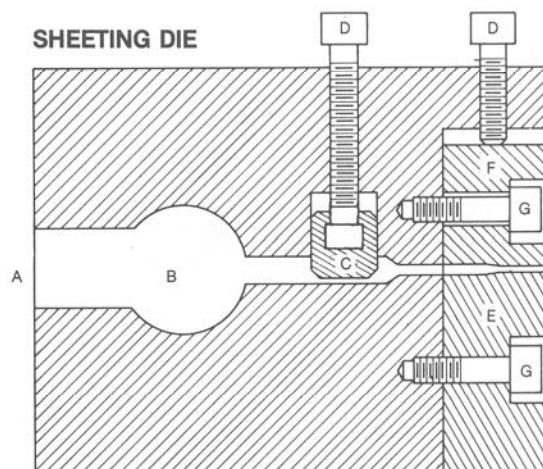
### PIPE OR TUBING DIE FOR CROSSHEAD EXTRUSION



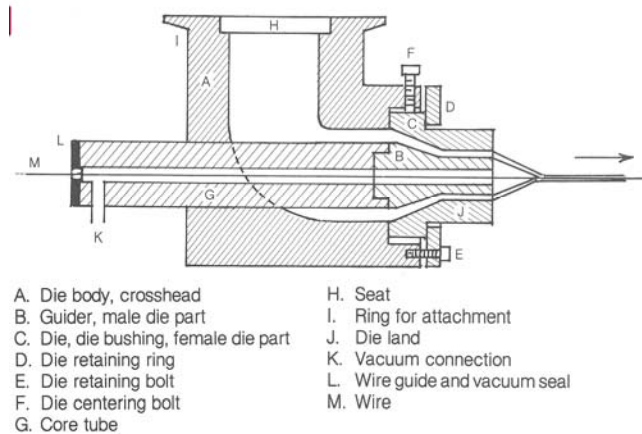
### ROD DIE AND COOLING



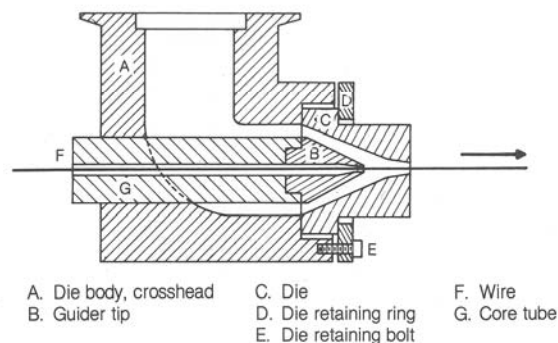
### SHEETING DIE



### WIRE COATING TUBING DIE



### WIRE COATING PRESSURE DIE



'Introduction to Extrusion,' P.N. Richardson, SPE Processing Series. Reprinted with permission.

Some relatively flat, but simply formed, profiles can be extruded onto an internally cooled **chill roll** to accomplish initial or complete cooling. Use of a chill roll alone depends on thin sections and rates may be limited. A chill roll can be followed by a water quench tank. Within limits the chill roll finish can be modified to achieve various finishes on the extruded product.

Sheeting is typically produced using a **3-roll finisher** stack. Sizing is accomplished by controlling the initial nip opening. Cooling is achieved on both sides by an "S" wrap around the rolls. However, the center roll must remove adequate heat to allow the sheet to release from the roll. Therefore, roll diameters may be 61 cm (24 in.), or larger, and should be chilled to a temperature at or near the dew point.

### Forming/Cooling Tools

The above forming methods involve a wide variety of specific forming and cooling tools (plates, rings, shoes, rolls, etc.). A general and important rule in the extrusion of Elvax® resins is that: **All these forming and cooling tools should be kept as cold as possible.** The molten resins are prone to stick to metal parts. The most effective means of eliminating sticking is good cooling. Most often this is accomplished by minimizing metal mass to be chilled; and designing and operating for good circulation of cold water on the tooling, particularly in the area adjacent to the hot polymer contact.

Forming and cooling tools are typically fabricated of brass or aluminum. A roughening of the surfaces which contact the polymer will help reduce sticking. This can be accomplished by sandblasting or sanding with emory cloth at a right angle to the product travel. The entry side of cooling devices should have a radius.

Another technique helpful in eliminating sticking is to lubricate the melt, with careful control, just prior to contact with the forming device. Lubricants can be water or a water soluble oil. Some consideration has been given to the use of porous bronze components to allow a controlled "weeping" of lubricant.

It is common practice to direct "jets" of cooling air onto selected portions of many extrusions between the die and the forming/cooling tools. Care should be taken to prevent these air jets from cooling the die. This technique is useful to help cool thin fins and give them more strength before entering the forming tool.

Depending upon part configuration, pairs of rollers can be placed in the early stages of the quench tank to modify surface finish. One roller would be used for support; the other to "emboss" the desired finish.

### Water Cooling

DuPont™ Elvax® resins have melting and freezing temperatures toward the lower end of the scale for polyolefins. Therefore, they must be cooled to lower temperatures before form stability is achieved. This can result in potentially longer cooling facilities. However, very few water quench tanks are operated with good efficiency in cooling. If simple, high efficiency cooling techniques are used, Elvax® resins can be adequately cooled in most existing installations.

Typical quench tanks have only one or two water inlets and drains. This arrangement is most likely very inefficient. Frequently, the water flow path does not intersect the product to be cooled as the water flows from inlet to drain. In practice, the only water capable of cooling the product efficiently is the water "skin" directly in contact with the product. Therefore, **it is critical that quench water be circulated directly on and around the product to be cooled.** This can be accomplished by selective positioning of inlets and drains, or by introduction of water through submerged copper tubes aimed directly at the extrusion throughout the length of the tank. Mechanical stirring devices can also be considered (air operation preferred).

DuPont has developed a device called a water cooling ring. It was initially intended for cooling pipe but can also be used for many other sections. The cooling ring delivers a "cone" of high pressure water onto the extruded product. When the "cone" strikes the product a "sheet" of water flows downstream, as far as 1-2 m (39-78 in.), before any water falls away. This represents highly efficient use of cooling water. The cooling rings can be installed over splash pans or in sections of the quench tank which have been baffled to remove normal water inventory. The rings can also be used in series.

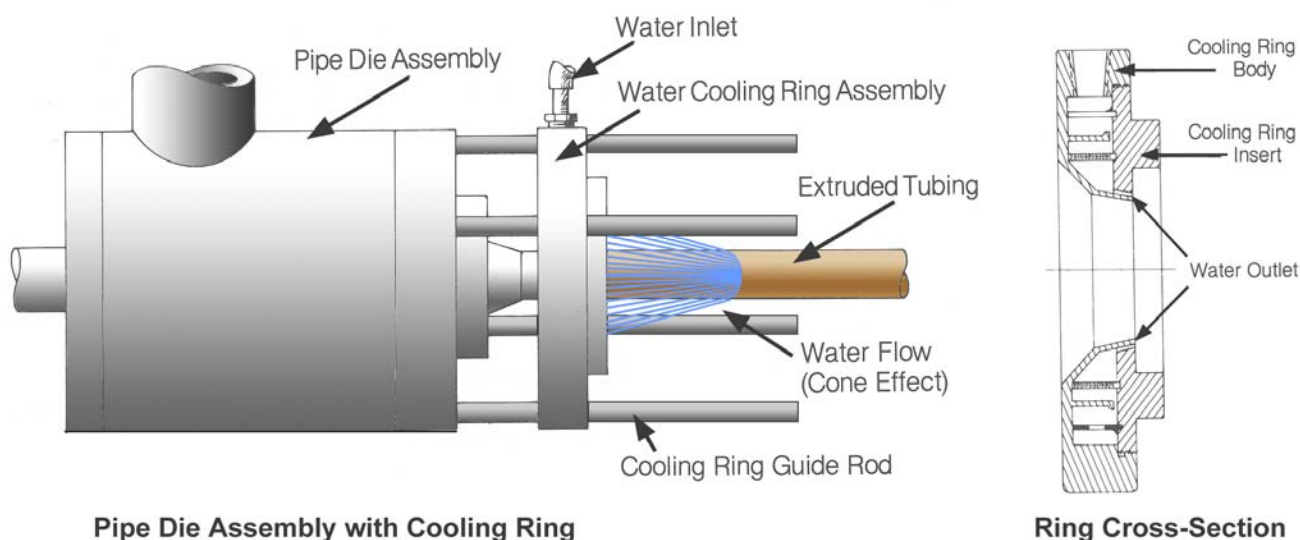
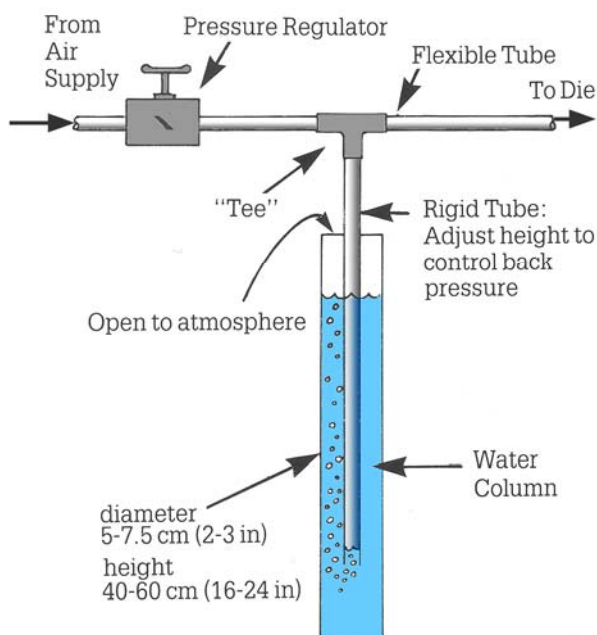
The water cooling ring is illustrated in Figure 7. It is shown installed on a pipe die with internal forming mandrel. Also shown is a cross-section of the cooling ring assembly. The ring can be used for initial cooling with the internal forming mandrel method. In most other methods it would be used for efficient cooling after forming is complete.

A modified version of the ring combines the functions of sizing and cooling. It can be used for circular products and would replace the initial sizing plate. It is called a water sizing ring.

### Internal Air Pressure

Several of the forming methods for hollow products require introduction of low pressure air inside the product. This air must be delivered at a very uniform rate in order to produce parts without dimensional variation. Frequently standard pressure regulators result in unacceptable variations in air delivery. A simple manostat, or "bubbler," can be assembled from storeroom items and will permit uniform air delivery. The manostat assembly and operation is illustrated in Figure 8:



**Figure 7 — Water Cooling Ring****Figure 8 — Manostat ("Bubbler") Assembly and Operation****PRODUCT PACKING****Cutting/Trimming**

Elvax® resins may be difficult to cut or trim at the end of the extrusion line due to their inherent toughness. It is mandatory that all cutting tools be sharp. In addition, if the frequency of cutting is high, the cutting tools may get hot causing the polymer to stick. If so, it may be necessary to either cool or lubricate the cutters.

**Packing**

Parts made of DuPont™ Elvax® resins are softer and more flexible immediately after extrusion than they will be about a day later. Aging causes an increase in stiffness, due to crystalline growth, following the heat treatment and cooling involved in extrusion. Care should be taken to preserve the part shape until completely cooled and form stability has been achieved. Any bends or dents introduced during this period may be difficult to remove. If the utility of the part is destroyed by such distortions, additional care must be taken to handle and store the parts.

## VIII. Extrusion Operation

### Melt Temperature

Melt temperature for industrial extrusions of Elvax® resins is, generally, in the overall range of 95-205°C (203-401°F). The melt temperature depends upon the melt index of the resin, the % vinyl acetate and the part configuration.

Melt temperatures are nominally as follows, depending on melt index (MI):

Melt Index (MI)	Nominal Melt Temperature °C (°F)
<1	205 (401)
1-5	175 (347)
5-10	150 (302)
10-30	120 (248)
30	95 (203)

NOTE: Melt temperatures should never exceed 220°C (428°F) as a precaution against resin degradation.

**Table 2 — Typical Extruder Temperature Profiles, °C (°F)**

Barrel zones					Head and Adaptor	Die	Desired Nominal Melt Temperature
Rear*	Rear Center*	Center	Front Center	Front			
80 (175)	95 (200)	95 (200)	95 (200)	95 (200)	95 (200)	95 (200)	95 (200°F)
90 (195)	120 (250)	120 (250)	120 (250)	120 (250)	120 (250)	120 (250)	120 (250°F)
90 (195)	150 (300)	150 (300)	150 (300)	150 (300)	150 (300)	150 (300)	150 (300°F)
90 (195)	150 (300)	175 (350)	175 (350)	175 (350)	175 (350)	175 (350)	175 (350°F)
90 (195)	150 (300)	205 (400)	205 (400)	205 (400)	205 (400)	205 (400)	205 (400°F)

\*May need to be adjusted.

### Bridging

A bridge is defined as a flow interruption in the channel of the extruder screw, usually in the feed zone. It can be a partial or total flow interruption. The cause of a bridge is pellets sticking to the root of the feed channel, frequently followed by a buildup of pellets sticking to one another until the flow channel is totally restricted. A bridging condition will result in (a) entrapped air and bubbles in the melt; (b) reduction of head pressure and drive motor amperage due to the starve feeding of the screw metering zone; (c) variations in motor amperage, head pressure, and die output; and (d) in severe cases, complete loss of die output, with no head pressure and minimum amperage.

DuPont™ Elvax® resins are sensitive to bridging because they have relatively low melting points and an affinity for metal when molten.

Potential bridging can be eliminated by use of the preferred screw designs and the following operating procedures:

1. Maintain the rear barrel heat zone at 90°C (194°F) or less.
2. Use internal screw cooling for the first 4-5 turns of the feed zone.
3. Use water cooling for the hopper feed throat jacket.

These procedures, with good screw design, should eliminate virtually all bridging. In the event that a bridge does develop, a number of operational techniques can be used to overcome the problem:

1. Rapidly increase the screw speed to maximum and maintain for 1-3 minutes. The increased delivery of pellets and higher

pressure of the pellets as they are conveyed forward may dislodge the bridge. Return to a moderate screw speed for 1-3 minutes and repeat this procedure as necessary.

2. Reduce the resin inventory to the feed throat over the screw. Force feed a rod of polyethylene into the screw channel, allowing large chunks be bitten off and conveyed forward.  
**CAUTION: Do not place hands or fingers in hopper feed throat.** These larger pieces will melt more slowly and may mechanically dislodge the bridge. A purge to polyethylene pellets is optional before reintroducing ethylene-vinyl acetate resin to the hopper.
3. If a rod of polyethylene is not available, then a purge to polyethylene may be helpful. The alternate high and moderate screw speed in item No. 1, above, should be used during the purge and subsequent operation with polyethylene.
4. Should all these techniques fail to dislodge the bridge, then screw removal and cleaning will be required. Therefore, design and operation to avoid bridging is very worthwhile to avoid a tear-down procedure.

## Cooling

Cooling of extruded products deserves special consideration because this process step is most frequently the limiting factor in production rate. Attention is redirected to Section VII "Extrusion Equipment-Forming and Cooling".

Certain product defects can develop during cooling. They include:

- Raised, circular defects can be formed by water droplets splashing on the product in the air gap. The water droplet chills the surface it strikes and prevents the small area from further drawdown, leaving a raised defect.
- Depressed, circular defects can be formed by air bubbles attaching themselves to the extruded product as it travels through the quench tank. The air bubble "insulates" the product surface and slows the local cooling rate. The slow cooling permits more shrinkage and a subsequent depression (sink) in the surface.
- 0 "Stick release" patterns (fine lines across the sheet), can be formed on sheeting as a result of sticking to the chill roll.

## General

Specific product quality requirements can be influenced by adjustment of operating conditions. For example, surface gloss is predominantly influenced by melt temperature. Higher temperatures provide more gloss. Conversely, a styling interest in a "dry look" or dull finish can be achieved by using lower melt temperatures and lower melt index grades of DuPont™ Elvax® resins. Gloss is also influenced by length of air gap. Longer air gaps will improve gloss.

Many die configurations require recombining of melt streams; for example, dies with spiders or crossheads with mandrels. The area of recombination is referred to as a weld line. Adequate temperature must be maintained in this area to assure that the weld line is as strong as the adjacent material in the finished product. A common cause of poor weld line strength can be contamination with previous polymers that have not been fully purged from the flow paths. Poor streamlining will accentuate this problem.

## Record Keeping

The maintenance of a production log or data sheet is extremely important and is frequently overlooked. Such records document production and allow retrieval of data when problems are encountered. Examples of the type of information which should be routinely recorded are given in Table 3.

(DuPont permits copying and reuse of this Operating Record.)

**Table 3 — Typical Production Operating Records**

<b>Job Name or Number</b>	
<b>Date</b>	
<b>Names of Operators</b>	
<b>Elvax® Resin Grade and Lot</b> Concentrates, additives, etc.	
<b>Extruder Screw Designation</b>	
<b>Die-Part No. and Size</b>	
<b>Screens</b>	
<b>Cooling and Haul-off Equipment</b>	
<b>Extruder conditions</b>	
Temperatures	
Barrel, Adaptor, Die (Set/Actual)	
Cooling	
Screw, Barrel, Hopper Feed Throat	
Screw Speed	
Motor Power	
Melt Temperature Melt Pressure	
Rate, kg (lbs)/hour	
<b>Water or Roll Temperatures</b>	
<b>Haul-off Rate</b>	
<b>Product</b>	
Thickness	
Width	
Length	
Appearance	
From "Introduction to Extrusion," P.N. Richardson, SPE Processing series. Used with permission.	

## Startup Procedures

Prior to startup, the information in Sections II, "Safety," and "Pre-Extrusion Checklist," should be specifically reviewed.

Ideally, startup will be with an entirely clean extruder, adaptor, and die assembly, although this is not necessarily a requirement. Most often, experience and individual plant policy dictate whether machines are cleaned or purged prior to startup with a new resin. The following startup procedure assumes: (a) startup from room temperature; and (b) startup with a clean and empty barrel and screw (or the screw has been run "dry" from a previous shutdown with Elvax® resins or polyethylene resins).

1. Machine heats should be turned on one to two hours prior to introduction of resin. This will assure a total heat-up and prevent excessive pressures and drive power during startup. Less time may be acceptable with some machines if experience has shown that excessive pressure and power consumption does not result. Cooling water to the screw and hopper feed throat jacket should be on during this period.
2. Machine temperatures should be set to provide melt temperatures as suggested in Section VIII, "Extrusion Operation," "Melt Temperature," depending upon the resin of interest. This assumes that experience has not demonstrated other acceptable temperatures. It is likely that,

once the operation is established, temperatures can be lowered. However, for safety reasons, (primarily excessive head pressure or torque), it is preferred that initial temperatures be higher than necessary rather than lower.

3. Resins should be introduced to the screw at full feed (not starve feed), and the screw speed should be moderate (30-40% of maximum rpm). Full feed and moderate rpm will help establish good conveying without bridging. Once the extruder output is established the screw speed can be reduced. If production is off-line or down, it is best to maintain the screw speed at 5-10 rpm, unless experience has shown that a stopped screw will not cause a bridge.
4. Situations requiring resin change purging are covered at right.

### Shutdown Procedures

These procedures apply to shutdown with a given Elvax® resin, and subsequent startup (overnight or over a week-end), with the same or similar melt index resin. It is also assumed that preferred screw designs and operating conditions have been used.

1. The melt temperature at shutdown should be 25-50°C (45-90°F) below the operating melt temperature. During the period of "cool down" the screw speed should be set at 5-10 rpm, with the temperature settings reduced or temperature controllers turned off, if carefully monitored. When the melt temperature reaches 25-50°C (45-90°F) below the operating temperature, polymer feed to the screw is stopped and the screw is run dry. When polymer delivery at the die ceases, the screw is shut off. Screw cooling and hopper feed throat jacket cooling water should be left on until the machine has reached room temperature. The machine is then ready for startup as outlined above.
2. An alternate shutdown procedure is to purge the Elvax® resin from the machine with polyethylene. Normal shutdown procedures for polyethylene are then followed.

### Purge Procedures

Purging from other polyolefins to DuPont™ Elvax® resin or vice versa, is relatively simple if the viscosity of the new resin is higher (lower flow), or if the viscosity of the two resins is similar. If the viscosity of the new resin is lower (higher flow), then the following steps may be helpful. High viscosity is low melt index-, low viscosity is high melt index):

1. Use an intermediate polyolefin purge resin which has a viscosity intermediate between the initial and final resins.
2. Allow the machine temperature to decrease during entry of the new lower viscosity resin. This will cause it to gain viscosity and displace the hotter inventory in the machine.

The effectiveness of purging can be improved by varying the screw speed during the purge procedure. Increase the

screw speed to maximum for one to three minutes; then decrease to 5-10 rpm for four to five minutes; and repeat. This procedure will upset the laminar flow patterns in the adaptor and die and result in faster, more effective purging.

Do not purge directly from heat-sensitive materials to Elvax® resins. Use pre-established methods to remove heat sensitive materials based on individual plant experience. Purging of non-polyolefin and non-heat sensitive materials is usually accomplished by use of an intermediate purge resin such as polyethylene.

### Barrel and Screw Cleaning

On occasion it is necessary, or helpful, to thoroughly clean the extruder barrel and screw. A procedure for cleaning with acrylic purge compound has been developed at our Technical Services Laboratory. The procedure is intended for the barrel and screw and must be used only after the breakerplate, adaptor and die assemblies have been removed. After using this procedure, removal of the screw from the barrel is accomplished with ease. A Technical Release is available on request.

## IX. Troubleshooting Guide

Table 4 lists some of the problems that may occur in the extrusion operation. For each problem possible causes and remedies are suggested.

## X. FDA Status

FDA Regulation 177.1350 ethylene-vinyl acetate copolymers sanctions the use of Elvax® resins for uses in food packaging applications, provided that extraction of the finished food contact article using food-simulating solvents specified in the regulation does not exceed 0.5 mg. of extractives per square inch of surface area. The extraction requirements (solvent, time and temperature) are a function of the end-use conditions, e.g., type of food, fill, and use temperatures.

DuPont™ Elvax® 40W is not included in 177.1350. It complies with the following FDA regulations subject to the limitations specified therein:

175.105	Adhesives
176.170	Components of paper and paperboard in contact with aqueous and fatty food.
176.180	Components of paper and paperboard in contact with dry food.
177.1200	Cellophane

**Table 4 — Troubleshooting Guide**

<b>PROBLEM</b>	<b>POSSIBLE CAUSE</b>	<b>REMEDY</b>
<b>I. No extruder output</b>	A. Hopper empty B. Hopper feed throat bridge  C. Complete screw bridge	1. Fill hopper  1. Cool hopper feed throat jacket. 2. Clean feed throat coolant channel 3. Do not use hopper dryer.  1. Cool rear barrel heat zone to 90°C (194°F) or less. 2. Internal screw cooling—first 4-5 turns of feed section. 3. Cool hopper feed throat jacket. 4. Select metering type screw with compression ratio of 3.5:1 or more and recommended feed zone depth. 5. Calibrate rear barrel heat zone controller.
<b>II. Excessive extruder drive power requirement</b>	A. Rear barrel heat zone too low  B. Barrel heat zone over screw transition zone too low  C. Melt temperature too low	1. Increase rear barrel temperature.  1. Increase temperature of barrel heat zone over screw transition zone.  1. Increase barrel temperatures. 2. Increase screw rpm to increase shear working.
<b>III. Surging</b>	A. Screw design   B. Partial screw bridge C. Extruder drive variation D. Stick-Slip in forming tools   E. Variation in haul-off unit	1. Select screw with: • metering zone • compression ratio 3.5/1 or more • more shallow metering depth • feed zone at least 25% of length • gradual transition  1. See Section I-C-1 through 5.  1. Check drive performance.  1. Chill forming tools. 2. Lubricate forming tools. 3. Reduce mass of forming tool to be cooled. 4. Sandblast or sand polymer contact area. 5. Contour entry into tool. 6. Provide uniform internal air pressure.  1. Set belts for positive grip. 2. Check unit-mechanical/electrical.
<b>IV. Bubbles in melt</b>	A. Partial screw bridging- starve feed (entrapped air) B. Excessive moisture	1. See Section I-C-1 through 5.  1. Use resin from sealed, undamaged containers. 2. Condition resin container in operating area before opening. 3. Dry natural resin, concentrate, or regrind, as necessary, in dehumidified tray oven.
<b>V. Surface defects</b>	A. Water splashing in air gap B. Air bubbles in quench water C. Stick-Slip in forming tools	1. Eliminate splash or shield splash  1. Improve quench water circulation.  1. See Section III-D-1 through 6.
<b>VI. Smeared, elongated surface bubbles (rough surface)</b>	A. Excessive moisture	1. See Section IV-B-1 through 3.
<b>VII. Dull surface</b>	A. Resin melt index too low B. Melt temperature too low. C. Short air gap	1. Select resin with higher melt index  1. Increase melt temperature.  1. Increase air gap.
<b>VIII. Poor caliper control</b>	A. Surging	1. See Section III
<b>IX. Distortion</b>	A. Inadequate cooling	1. Use colder quench water. 2. Circulate quench water efficiently. 3. Consider use of water cooling ring, 4. Reduce melt temperature.



<b>X. Poor weld line strength</b>	A. Poor purge from previous resin	1. Use variable speed purge procedure. 2. Streamline to allow effective purging.
	B. Melt temperature too low	1. Increase melt temperature.
	C. Poor in-line die spider design	1. Streamline spider design.
	D. Concentrate base resin not compatible with Elvax® resins.	1. Select concentrate base resin of Elvax® or similar ethylene copolymer resins.
<b>XI. Excessive shrinkage</b>	A. Excessive cross-sectional area drawdown	1. Decrease drawdown.
	B. Melt temperature too low	1. Increase melt temperature.
	C. Resin melt index too low	1. Select resin with higher melt index.
<b>XII. Degradation</b>	A. Excessive resin holdup	1. Increase extruder output. 2. Streamline flow paths in adaptor and die.
	B. Poor shutdown procedure	1. Reduce temperatures before shutdown. 2. Purge to clear degradation.
	C. Excessive temperature	1. Check temperature control systems.
	D. Poor purge from previous heat sensitive resin	1. See Section X-A-1 and 2.
<b>XIII. Carbon specks</b>	A. Excessive resin holdup	1. Streamline flow paths in adaptor and die.
	B. Dirty equipment	1. Extruder/adaptor/die cleaning. 2. Avoid shutdown with high temperature.
	C. Excessive temperature	1. Check temperature control systems.

The technical data contained herein are guides to the use of DuPont resins. The advice contained herein is based upon tests and information believed to be reliable, but users should not rely upon it absolutely for specific applications because performance properties will vary with processing conditions. It is given and accepted at user's risk and confirmation of its validity and suitability in particular cases should be obtained independently. The DuPont Company makes no guarantees of results and assumes no obligations or liability in connection with its advice. This publication is not to be taken as a license to operate under, or recommendation to infringe, any patents.

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