DuPont™ Elvamide®

resins

Product and Properties Guide

The miracles of science™

Table of Contents

Introduction

Elvamide® resins are thermoplastic polyamides that combine the inherent toughness of nylon with ease of processing in solvent as well as melt systems. Elvamide® resins differ from conventional nylons in that they offer:

- Alcohol solubility
- Lower melt-processing temperatures
- High elongation
- Ability to cross-link with thermosetting resins

Elvamide® resins can be used singly or in a combination and can be further modified by formulating with plasticizer or other resins to meet specific end-use requirements. For most uses, they are applied from solvent solutions. They can also be melt compounded as, for example, in the manufacture of pigment concentrates or for extrusion into film adhesives for heat reactivation. Their relatively low melt-processing temperature allows use with heat-sensitive pigments and substrates.

Like Zytel® nylon resins, Elvamide® resins are suitable for molding and extrusion. They are tough, withstand impact and resist abrasion, but are softer and more flexible than conventional nylons. Melting points for Elvamide® multipolymer resins range from 115°C (239°F) to 160°C (320°F), compared with 265°C (509°F) for high temperature resistant 66 nylon homopolymer.

Features and Uses

The important features of Elvamide® resins are listed below:

- Abrasion resistance
- Impact resistance
- Resistance to most oils, solvents and gasolines
- Pigment dispersing ability
- Melting point
- High tensile strength
- Natural lubricity
- Toughness at high and low temperatures
- Alkali resistance
- Antioxidant ability

It is this combination of outstanding properties which results in benefits for a variety of uses.

Textiles

- ***Thread Bonding***—solutions of Elvamide® resins bond filaments into a strong thread that resists abrasion and high needle temperatures, preventing thread fraying and needle jamming at high sewing speeds.
- ***Salvage Bonding***—high melting point and tensile strength make Elvamide® a good bonding material for salvage edges, especially for knits, preventing unraveling and easing conversion operations.
- ***Fabric Bonding***—film adhesives of Elvamide®, which are reactivated by heat, provide strong fabric-to-fabric bonds that resist laundering and dry cleaning, especially on nylon fabrics.

Adhesives

Alone or in combination with epoxy, phenolic or other thermosetting resins, Elvamide® provides film adhesives with superior toughness, impact resistance and flexibility.

Adhesives based on Elvamide® resins are especially effective for bonding metal/metal laminates of similar or different metals.

Pre-impregnated glass fibers as well as carbon fibers can be formed into structural elements of fishing rods, sporting goods, antennas, etc. that are highly impact resistant.

Coatings

Coatings based on Elvamide® resins are relatively clear and non-tacky, and provide abrasion resistance and durability for fish and playpen netting, nylon seat belts, fabric screening, wire and cable, tennis racquet strings, and plastic films. Elvamide® provides a tough tie-coat for articles to be extrusion-coated with type 66 nylon. Because Elvamide® resins are highly resistant to most hydrocarbons, they offer excellent protection for articles such as conveyor belts and fuel tanks of rubber or other elastomers.

Color Concentrates

The compatibility of Elvamide® resins with other nylons such as types 6, 66, 610 or 612 make it an excellent color concentrate carrier resin for molded and extruded nylon articles.

Moldings and Extrusions

Elvamide® resins provide relatively soft, flexible, impact-resistant moldings and extrusions.

Binders

Elvamide® 8061 strength retention at elevated temperatures and low processing temperatures make it a preferred binder for rocket fuels, explosives, and lubricants.

Other Applications

Elvamide® resins offer toughness, flow characteristics, solvent resistance and quick set for hot-melt inks with improved printability.

Elvamide® resins serve as an antioxidant and nonmigratory stabilizer when blended in various plastics.

Physical Properties

Table 1 shows typical values for physical properties of Elvamide® resins. Elvamide® 8061 is often preferred for thread bonding applications and extruded products.

Elvamide® 8063 is more gel resistant than 8061 and is preferred for solutions which are stored for prolonged periods.

Elvamide® 8066 is a low melting point resin designed particularly for textile adhesive uses. It can also be combined with thermosetting resins in metal laminating adhesives, where it permits curing at lower temperatures than Elvamide® 8061. In addition, it has found application as a color concentrate carrier resin.

Table 1
Typical Physical Properties of Elvamide® Resins

Typical Properties[a]	ASTM Method	Units	Elvamide® 8061	Elvamide® 8063	Elvamide® 8023R	Elvamide® 8066
Form	—	—	3-mm (1/8 in) cubes	3-mm (1/8 in) spheres	3-mm (1/8 in) spheres	3-mm (1/8 in) spheres
Color	—	—	transparent to opaque	transparent to opaque	transparent to opaque	transparent to opaque
Moisture Content	D789	%	0–0.7	0–0.7	0–5.0	0–5.0
Melting Point	D3418	°C (°F)	156 (313)	158 (316)	154 (309)	115 (239)
Relative Viscosity	—	—	70–100	70–100	24–36	21–29
Specific Gravity 23/23°C (73/73°F)	D792	—	1.08	1.08	1.07	1.08
Water Absorption, % 24 hr immersion	D570	%	3.1	3.4	3.4	1.4
Rockwell Hardness	D785	R	71	71	65	—
Shore Hardness	D2240	D	75	75	70	72
Tensile Strength[b] 23°C (73°F)	D638	MPa (psi)	51.4 (7,500)	51.7 (7,500)	51.0 (7,400)	39.0 (5,700)
Elongation at Break[b] 23°C (73°F)	D638	%	320	315	370	370
Flexural Modulus[b] 23°C (73°F)	D790	MPa (psi)	952 (138,000)	903 (131,000)	490 (71,000)	—
Characteristics	—	—	General purpose; combines good solubility, abrasion resistance and toughness.	Greater gel resistance. Lower solution viscosity than 8061.	Low viscosity for special high solids solutions.	Softer resin with lower melting point for textile adhesives.

[a] These data describe Elvamide® resins but are not intended to serve as specifications.

[b] Samples conditioned in equilibrium with atmosphere and 50% RH.

Elvamide® 8023R offers the highest solids solution at a given temperature when compared with the other grades of Elvamide®.

The Elvamide® resins as packaged have a low moisture content. To protect against further moisture uptake these resins are shipped in moisture - barrier bags. If Elvamide® is to be used where moisture can be a problem, care should be taken once the bag is opened to avoid exposure to high humidity. On the other hand, moisture may contribute to ease of solution; in this case, the resin can be immersed in water overnight before dissolving. (See **Table 6**.)

Specifications

To ensure consistent solution or melt viscosity, DuPont controls relative viscosity for each grade of Elvamide® to the following specifications:

Grade	Relative Viscosity
8023R	24–36
8061	70–100
8063	70–100
8066	21–29

Test procedures for measuring relative viscosity are described on page 17.

Chemical Properties

Elvamide® resins are insoluble in water. They resist hot or cold aqueous alkali solutions and most salt solutions for weeks or months. Acetic acid attacks the resin slowly; stronger acids react more rapidly. Formic acid will dissolve Elvamide® resins. Most oxidizing agents react with Elvamide® but oxygen and oxygen-containing gases including ozone have little effect unless elevated extrusion temperatures are used.

The Elvamide® resins are highly resistant to petroleum-based products, showing little change after prolonged contact with lubricating oils and greases, or aliphatic and aromatic hydrocarbons.

The higher fatty acids, such as stearic acid have no appreciable effect on Elvamide® until a temperature of 150°C (302°F) is reached. The nylon resins are also resistant to most organic solvents including conventional lacquer solvents and diluents, carbon disulfide, esters, ethers, and amides.

Elvamide® resins contain carboxyl, amide and amine groups which react with thermosetting resins to form cross-linked structures. With epoxy resins, the amide groups along the nylon resin chain take part in the reaction.

Solution Technique

Solvent Selection

Selection of a solvent or solvent system for formulating and applying Elvamide® resin is very important and depends on the desired solids level and solution viscosity, solution stability requirements, nature of the substrate, processing equipment as well as the ultimate application technique.

The most popular solvents for Elvamide® resin are methanol, ethanol and 2-propanol, and mixtures of these with water. Other solvents for Elvamide® resin include benzyl alcohol, furfuryl alcohol, formic acid, phenol and m-cresol.

Anhydrous methanol is the most effective solvent and will dissolve up to 50% by weight of Elvamide® 8061 or 8063 with heating.

Typical Stability

On prolonged storage at room temperature or below, solutions of Elvamide® resin may show clouding or gelation; solution stability is increased as the temperature increases. Gelled solutions can be restored by gentle heating (no open flame) and stirring prior to use.

In alcohol-water solvent systems, the intermolecular nylon hydrogen bonding is reduced and thereby decreases solution time and the tendency for gel formation.

Stability of Elvamide® 8061 in alcohol/water mixtures can be improved by the addition of small amounts of benzyl alcohol or other high-boiling solvents. See **Table 4**. With multicomponent solvent systems the boiling point of any azeotrope should be considered.

As shown in **Tables 2** and **3**, Elvamide® 8063 gives lower viscosity for a given solids content than Elvamide® 8061 and is more gel resistant.

Methanol solutions containing 40 wt% Elvamide® 8061 should be used promptly as gelation occurs in less than 3 hr at 25°C (77°F). At 50% solids, the maximum stability is reduced to 30 min.

Elvamide® 8023R gives the lowest viscosity solutions and is preferred where high solids are required. At least 30% can be dissolved readily in alcohol/water mixtures by stirring at 45–60°C (113–140°F) for approximately 1 hr. **Table 5** shows typical solution viscosities. After two weeks at room temperature, the 30% solids solution increased in viscosity but had not gelled.

Table 2
Typical Solution Stability of Elvamide® 8061

Parts (wt)	Solvent Composition	Brookfield Viscosity, mPa·s (cP)[a] 10% Solids	Brookfield Viscosity, mPa·s (cP)[a] 20% Solids	Gelation, days[a] 10% Solids	Gelation, days[a] 20% Solids
100	Methanol	30	280	10[b]	3
85/15	Methanol/water	39	610	10–11	6
90/10	Ethanol/water	103	1860	10–11	6
80/20	Ethanol/water	111	1960	10–11	6
100	1 -Propanol	66	—	2	—
90/10	1 -Propanol/water	76	—	10	2

[a]Stability (gelation) tests and viscosity measurements were made at 25°C (77°F).
[b]Solution cloudy but still mobile.

Table 3
Typical Solution Stability of Elvamide® 8063

Parts (wt)	Solvent Composition	Brookfield Viscosity, mPa·s (cP) 10% Solids	Brookfield Viscosity, mPa·s (cP) 20% Solids	Gelation, days 10% Solids	Gelation, days 20% Solids
100	Methanol	14	155	30–31	<1
85/15	Methanol/water	21	253	30–31	25–26
90/10	Ethanol/water	37	—	<1	—
80/20	Ethanol/water	42	730	25–26	25–26[a]
100	SDA[b] #30 alcohol, 200 proof	28	gel	2–3	1 hr
100	SDA #2B, 190 proof	36	578	25–26	<1

[a] Solution cloudy but remains fluid.
[b] See Chemical Handbook for SDA (specially denatured alcohol) formulas.

Table 4
Typical Stability Improvement with High Boiling Solvents

High Boiling Solvent	Amount	15% Solids Elvamide® 8061 Nylon Multipolymer Resin 70/30 Ethanol/Water	15% Solids Elvamide® 8061 Nylon Multipolymer Resin 80/20 Ethanol/Water
		Time Before Gelation, Days (23°C, 73°F)	
None	—	1	7
Benzyl alcohol	5%	16	26
Furfuryl alcohol	5%	4	26
m-Cresol	5%	4	15

Table 5
Typical Solution Viscosity of Elvamide® 8023R

Methanol/Water Parts by Wt	% Solids	Brookfield Viscosity, mPa·s (cp)[a]
85/15	20	130
80/20	20	140
80/20	30	1,030

[a]Measured at 25°C (77°F) with model LVT, #1 spindle.

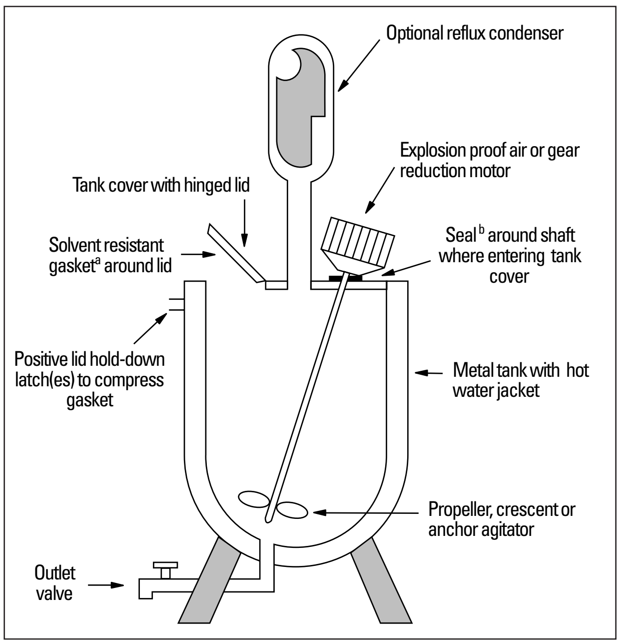
Preparation

For solutions of Elvamide® resins up to 20% solids, the resin pellets should be added to the solvent with continuous stirring. The mixture should then be heated (no open flame) with continued stirring to a temperature that is 5–10°C (9–18°F) below the reflux point of the solvent or solvent mixture. Usual temperatures are 54–60°C (130–140°F).

For suggested preparation equipment see **Figure 1**. The use of a reflux condenser is preferable for solution preparation. Explosion-proof electric or air motor agitator drives are adequate for most solution operations.

Heating and stirring should continue for at least one hour after solution appears complete in order to insure that all particles have dissolved. Solvent-swollen resin particles are colorless and transparent, and consequently are difficult to detect.

Figure 1. Equipment for Preparing Solutions



NOTE: Add ventilation over tanks as necessary to remove fumes from work areas. All metal parts should be grounded according to applicable codes and practices for handling flammable solvents.

[a] Suggested materials include Nordel® synthetic rubber or other materials recommended by gasket suppliers as suitable for use with methanol or other alcohol.

[b] Seals of Teflon® fluorocarbon resin or other materials recommended by their suppliers as suitable for use with methanol, etc.

Total time required depends on solvent type, resin concentration and type of agitation. Typical solution times are summarized in **Table 6**. Overnight steeping of the resin, preferably with periodic agitation, expedites dissolution. The time required for completing the solution depends on the solvent mixture used and the concentration resin particle size desired.

Table 6
Typical Solution Times

Solvent, wt%	Temperature, °C (°F)	Solution Time, hr
Elvamide® 8061		
100 methanol	57 (135)	2
100 methanol	39 (103)	4.5–5
80/20 methanol/water	42 (107)	3
70/30 methanol/water	44 (112)	3
100 2-propanol	71 (160)	Insoluble after 3 hr
80/20 2-propanol/water	71 (160)	2.75
Pre-wet[a] Elvamide® 8061		
100 methanol	39 (103)	4
Pre-dried[b] Elvamide® 8061		
100 methanol	39 (103)	5.5–6
Elvamide® 8063		
100 methanol	39 (103)	3

NOTE: All solutions contained 8% solids.
[a] Elvamide® 8061 was pre-wet by soaking in water at 39°C (103°F) for 16 hr.
[b] Elvamide® 8061 was pre-dried for 7 days in a vacuum dessicator.

When solvent solutions are stored or handled, adequate ventilation should be provided. See the section on Safety Precautions in this bulletin. Detailed information on safe handling of flammable liquids can be obtained from the National Fire Protection Association* or from your solvent supplier.

The above precautions are not intended to be all inclusive. They should be supplemented by good manufacturing procedures, prevailing industry standards and the recommendations of solvent suppliers.

* NFPA Std. No. 30, "Flammable Combustible Liquid Code," NFPA, Battery March Park, Quincy, MA 02269

Dispersions of Elvamide® 8063 in water at 10% solids are available from General Plastics Corp.* For information, contact your sales representative. (See back cover.)

Processing

Solutions of Elvamide® resins can be applied by dipping, brushing, spraying, or with conventional coaters designed to handle solvent-based systems.

Because of their relatively low melting temperature compared to molding grade nylon resins, Elvamide® resins also can be processed using standard melt compounding techniques.

Unless heat is used during drying, atmospheric moisture may cause a cloudy or opaque coating. Clear coatings can be obtained from anhydrous solvent systems if the drying temperature is sufficiently high to offset the cooling effect of evaporation and prevent condensation of atmospheric moisture on the surface. The required temperatures can be maintained with infrared heat or a circulating-air oven designed for use with flammable solvents.

To obtain a clear film using an aqueous solvent system (such as an alcohol/water mixture), a fusion treatment is recommended. By heating the coating above the resin melting point, optimum clarity, adhesion and physical properties can be developed.

Formulating Solutions

Grades of Elvamide® resins can be formulated with each other or with modifiers to produce a variety of properties. Generally modifiers are used with Elvamide® to improve adhesion to specific substrates, to vary blend toughness and flexibility, or for an optimum balance between cost and performance.

Typical modifiers for Elvamide® resins include plasticizers, thermosetting resins, thermoplastic resins and elastomers. See **Table 7** for a listing of modifiers compatible with Elvamide® resins.

One plasticizer commonly used with Elvamide® resin is 2-ethyl-1, 3 hexanediol at amounts up to 15 parts per hundred resin.

Thermosetting or cross-linking resins of the epoxy, phenolic or melamine formaldehyde type are frequently used as resin modifiers. Elvamide® resin reacts with these at curing temperatures to produce hybrid thermoset- thermoplastic compositions. See **Table 7** for examples.

Table 7
Typical Modifiers Compatible with Elvamide® Resins

Plasticizers	
Glycols	Ethylene glycol 2-Ethyl-1, 3-hexanediol
Phenols	Octyl phenol Resorcinol
Sulfonamides	Bisphenol A[a] NBBS[b]
Thermosetting Resins	
Epoxy	Araldite[c] Derakane[a] Epon[d]
Melamine/ Formaldehyde	Cymel[e] Resimene[f]
Phenol/ Formaldehyde	

[a] Dow Chemical Co.
[b] Unitex Corp. or Proviron Inc.
[c] Ciba-Geigy Corp.
[d] Resolution Performance Products
[e] Cytec Industries Inc.
[f] Solutia Inc.

In blends with epoxies or phenolics, 15–20% Elvamide® resin significantly improves the toughness and flexibility of the cured resin without impairing tensile strength or chemical resistance. The amine and carboxyl end groups on Elvamide® resins as well as the amide hydrogens along the chains enable Elvamide® resins to cross-link with thermosetting resins during the curing cycle. These blends with thermosetting resins are especially useful in high-strength structural adhesives discussed in more detail in the following section.

Combinations of Elvamide® resin and thermoplastic materials (**Table 7**) can be applied as resin solutions or hot melts.

*55 LaFrance Ave., Bloomfield, NJ 07003

Thermosetting Adhesive Uses

High-strength, fatigue-resistant polyamide/thermoset resin adhesives were initially developed to meet requirements set by aerospace engineers designing lightweight, smooth-surfaced, honeycomb structures of aluminum. (These developed into a range of uses mentioned on pages 1 and 2 under “Adhesives.”) They found adhesive bonded metal/metal laminates to have many advantages:

- no rivets to cause buckling of surfaces between points of contact
- no stress concentrations at isolated points of contact
- no high-temperature distortion of bonded parts
- no electrochemical corrosion between dissimilar metals
- simplification of design

Today, interest in adhesive bonding extends through wide segments of the metal-fabricating industry. Laminates of stainless steel to sheets of carbon steel for architectural panels, automotive trim, and window frames are examples of the cost-saving specialties possible. Adhesive bonding also permits the lamination of metal to other materials-such as glass and plastics.

Formulation requirements differ from one use to another. The development of high lap shear strengths may be the dominant need in one application; high peel strengths in another.

Although Elvamide® 8061 and 8066 can function as heat-activated adhesives (good shear and peel strength), the addition of a thermoset resin, e.g. 20%, which cross-links with polyamide during curing, eliminates creep and gives an adhesive of superior toughness and flexibility. The bonds formed during the curing of compositions of Elvamide® 8061 and thermoset resins are capable of withstanding severe deformation; they are also significantly stronger than the bonds developed in adhesives based on thermoset resins alone. Adhesives of Elvamide® 8061 and epoxy resin, for example, develop much higher peel strengths than the corresponding straight epoxy formulations.

Blends of Elvamide® 8061 and thermoset resin are useful in preparing postformable laminates as well as for other metal-to-metal bonding operations, for sandwiching honeycomb cores between metal sheets, and for bonding metals to various other substrates.

Formulating Adhesives

Structural adhesive formulations combine Elvamide® 8061 (65–90% of total resin) with a thermosetting resin (35–10%), a thermoset-curing agent, fillers (optional), and a solvent (evaporated if adhesive is used in film form). On heat-curing, the polyamide cross-links with the thermosetting resin to become an integral part of the cured adhesive. Elvamide® 8061 contributes toughness, flexibility, and good flexibility retention to the cured blend while giving bonds higher in both peel strength and shear strength than those obtained with the thermosetting resin alone. Application of Elvamide® 8061/thermoset adhesives can be from solution or as dry film.

Selection of Thermosetting Resins

Many thermosetting resins are sufficiently compatible with Elvamide® 8061 to permit their use in adhesive blends. Combinations of Elvamide® 8061 with epoxy resins of the bisphenol-A type and relatively high epoxy content are particularly effective in providing high-strength, flexible bonds. **Table 8** compares the shear strength of aluminum-to-aluminum bonds prepared in the laboratory using typical thermosetting resins in combination with Elvamide® 8061. Note the superior lap shear strengths given by the epoxy-type resin. (Peel strengths are likewise optimum.)

Table 8
Typical Adhesive Formulations Based on Elvamide® 8061 and Thermoset Resins
(Material bonded: unprimed 0.16 cm [0.064 in] Alclad 2024-T3 aluminum alloy sheet; 1.3 cm [0.5 in] lap)

Thermosetting Resin		Curing Agent		Zn Dust	Lap Shear Strength,
Trade Name	Type	Type	phr[a]	Filler, %[b]	mPa (psi)[c]
Epon 828[d]	epoxy	DICY[e]	10	0	42.7–45.5 (6200–6600)
Epon 828	epoxy	DICY	10	33.3	30.3–32.4 (4400–4700)
Resinox 410[f]	phenolic	TETA[g]	10	33.3	21.4–22.8 (3100–3300)
Aerotex 607[h]	melamine-formaldehyde	Phenol	50	33.3	14.5–20.7 (2100–3000)

[a] Parts (wt)/l00 parts thermosetting resin
[b] Based on total solids
[c] Ambient conditions
[d] Resolution Performance Products
[e] dicyandiamide, Cytec Industries
[f] Solutia Inc.
[g] triethylenetetramine, Dow Corp.
[h] Cytex Industries, Inc.

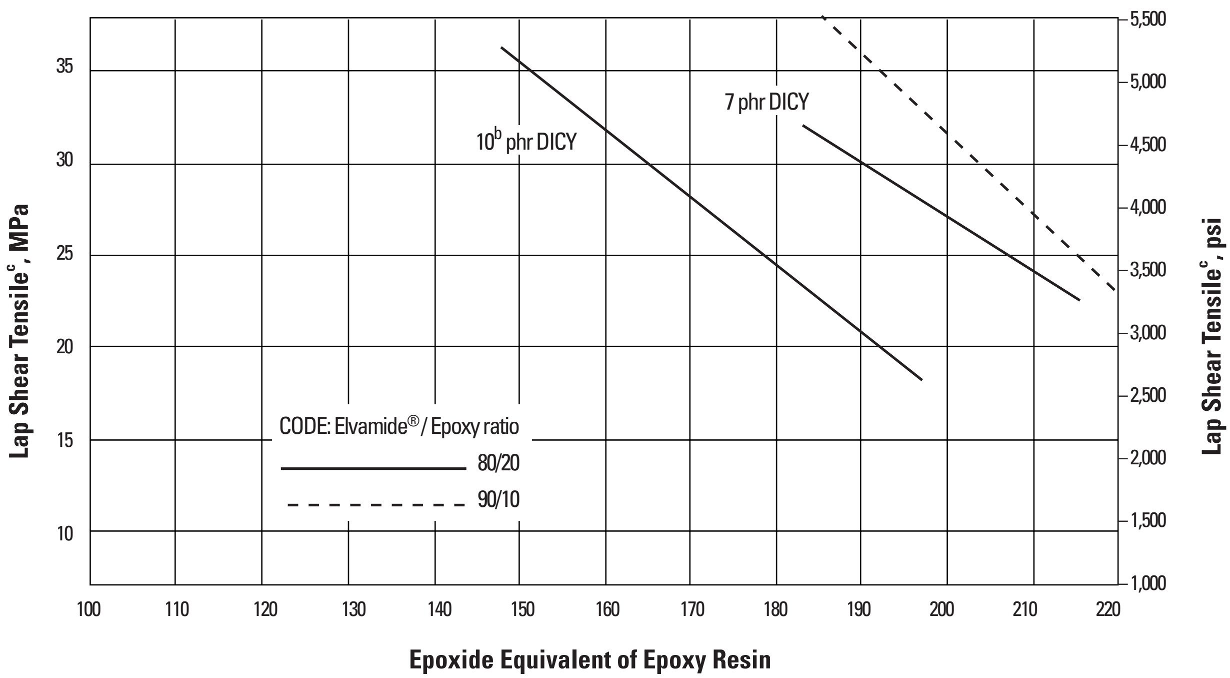
Ratio of Elvamide® 8061 to Thermosetting Resin

The optimum combination of bond strength and flexibility is generally achieved with blends containing 60–80% Elvamide® 8061, based on total resin content (see **Figure 2**). At concentrations of Elvamide® 8061 above this range, shear strength declines and the adhesive begins to assume the thermoplastic character of unmodified Elvamide® 8061. Adhesive blends containing less than 60% Elvamide® 8061 are less flexible, have lower peel strength and lower shear strength. However, as little as 20% Elvamide® 8061 significantly improves the flexibility of brittle thermosetting resins.

Curing Agents and Cure Schedules

The polyamide chains of Elvamide® 8061 resin contain carboxyl and amine end groups which react with thermosetting resins during cure to form cross-linked structures. With epoxy resins, the amide groups along the nylon resin chain also take part in the reaction. There is no specific epoxide equivalency of Elvamide® resins. Complete cure of an epoxy resin with Elvamide® 8061 takes place at high temperatures (e.g., 60 min at 232°C [450°F]) in the absence of a conventional curing agent. However, the addition of a curing agent for the

Figure 2. Typical Shear Strength[a] of Adhesives of Elvamide® 8061 and Epoxy Resin



[a] After 1-hr curing at 163°C (325°F) using dicyandiamide (DICY). Material bonded: unprimed 0.16-cm (0.064 in) Alclad 2024-T3 aluminum alloy sheet; 1.3-cm (0.5-in) lamp.
[b] Parts per hundred parts of total resin.
[c] Ambient conditions.

thermosetting resin in an adhesive based on Elvamide® 8061 gives a more practical curing cycle.

In formulations of Elvamide® and thermosetting resin, the curing agent concentration depends on the type and amount of thermosetting resin used. **Figure 2** shows the effect of both epoxide equivalency of the epoxy resin and curing agent concentration on the lap shear strength of adhesives of Elvamide® 8061 and epoxy resin.

In general, the resin manufacturer's recommendations should be followed with regard to type and amount of curing agent and cure schedules for the particular thermosetting resin used. To develop maximum bond strength, however, the glue line should be heated above the melting point of the Elvamide® nylon multipolymer resin, i.e., above 160°C (320°F) for adhesives based on Elvamide® 8061. Because of its lower melting point, Elvamide® 8066 permits curing at temperatures as much as 56°C (100°F) below those required using Elvamide® 8061.

With blends of Elvamide® 8061 and epoxy resin containing rapid curing agents, high peel strength bonds have been obtained in as short a time as 10–15 sec at 177–204°C (350–400°F). Longer cure schedules and suitable pretreatment of the substrate surface can increase the peel strength.

Examples of curing agents suitable for use in formulations of Elvamide® 8061 and epoxy resin are given in **Table 9**. Suggested concentrations for use with epoxy resins having an epoxide equivalent of 189 (e.g., "Epon 828," "Araldite 6005") are shown.

Effect of Fillers

Adding 20–40% of a suitable filler to a formulation of Elvamide® 8061 and thermosetting resin increases the peel strength of the adhesive, but usually at a sacrifice in shear strength. **Table 10** illustrates the effect of fillers on the peel and shear strengths of a typical blend of Elvamide® 8061 and epoxy.

Table 9
Curing Agents for Formulations of Elvamide® 8061 and Epoxy Resin

Curing Agent	phr[a]	Characteristics
Dicyandiamide[b] (DICY)	10	Latent curing agent requiring high temperature for cure; suggested for developing maximum bond strength.
Triethylenetetramine[c] (TETA)	10	Active curing agent for use where rapid cure is required; can be further accelerated by catalysts, e.g., 1 phr of phenol or resorcinol; gives high peel strength bonds in less than 1 min at 177°C (350°F).
Epon C-111[d] Curing Agent	100 (solution as supplied)	Active curing agent; chemically an amine adduct of an epoxy resin; slower than TETA but tends to develop higher bond strength.
DICY[a] + USB-110[e] Aminoborane	10 each	Rapid cure system; stable at 27°C (80°F); gives superior peel strengths in 60 sec or less at 232°C (450°F).

[a] Parts (wt) curing agent per 100 parts epoxy resin (epoxide equivalent, 189).
[b] Cytec Industries, Inc.
[c] Dow Corp.
[d] Resolution Performance Products
[e] U.S. Borax Inc.

Table 10
Effect of Fillers on Bond Strength

Filler	% Based on[a] Total Solids	Peel Strength[b] kN/m (lb/in)	Lap Shear Strength[c,d] mPa (psi)
None	—	10.5–14.0 (60–80)	42.7–45.5 (6200–6600)
Alumina	33.3	14.9–27.0 (85–154)	(not determined)
Glass, hammer-milled	33.3	10.5–14.0 (60–80)	(not determined)
Zinc dust	33.3	14.7–16.5 (84–94)	30.3–32.4 (4400–4700)

[a] Adhesive is 75/25/10 Elvamide® 8061/ Epon® 828/DICY. Curing conditions are 60 minutes at 163°C (325°F).
[b] Material bonded: 24 gauge Al foil to 0.16 cm (0.064 in) Alclad 2024-T3 sheet (unprimed). Peel strength of adhesive determined (ambient conditions) by climbing drum method, 180° angle.
[c] Material bonded: unprimed 0.16 cm (0.064 in) Alclad 2024-T3 sheet; 1.3 cm (0.5 in) lap.
[d] Ambient conditions.

Fillers assist in maintaining the desired glue line thickness, because filled compositions have less tendency than unfilled resin blends to exude from the glue line during heat-curing. With some thermosetting resins, addition of fillers may be necessary to prevent excessive bond shrinkage during cure.

Effect of Exposure on Bonds
The effect on bond strength of heating, exposure to ultraviolet light, and immersion in water and typical solvents is illustrated in **Table 11**. Adhesives of Elvamide® 8061 and epoxy resin lose approximately 50% of their bond strength at temperatures approaching 93°C (200°F), but show excellent strength at cryogenic temperatures.

Preparation of Adhesives

In preparing adhesives for application from solvent, the Elvamide® 8061 resin should be put into solution before adding the thermosetting resin. The most practical solvents for Elvamide® 8061 are the lower aliphatic alcohols and mixtures of these with water. Anhydrous methanol [b.p., approx. 64°C (148°F)], the most effective solvent of the series, will give hot mixtures containing up to 50 wt% Elvamide® 8061.

Preparing Liquid Adhesives

Adding the thermosetting resin to the solution of Elvamide® 8061, then stirring briskly, gives a solution which, for solids concentrations of 10–30%, will remain stable at room temperature over several months. Formulations containing latent catalysts designed for high temperature cure have also shown good stability at room temperature.

Systems containing active curing agents must be stored in tight containers in a cool location to prevent evaporation of the solvent. Loss of solvent results in rapid cure of the adhesive at room temperature.

When preparing a liquid adhesive for immediate use, one simply combines the solution of Elvamide® 8061 with the thermosetting resin, curing agent (if used), and filler (if used) at room temperature, stirs briskly for 15–30 min, then applies—e.g., by brush.

Preparing Adhesive Films

Adhesives for application in film form can be formulated using latent curing agents. The Elvamide® 8061 and thermosetting resin are first dissolved in a compatible solvent system just as in preparing solvent-type adhesives. Curing agent, fillers, and any other additives are then incorporated. The solution is cast on a release surface, dried at 93–121°C (200–250°F) or below, and stripped. Suitable casting surfaces include stainless steel, films of Elvanol® polyvinyl alcohol, and Teflon® fluorocarbon film.

Table 11
Effect of Exposure on Bond Strength
(Material bonded: unprimed 0.16 cm [0.064 in] Alclad 2024-T3 sheet; 1.3 cm [0.5 in] lap)

Exposure Test[a]		Lap Shear Strength[b], mPa (psi)	
Agent	**Time**	**Epoxy: Araldite® 6005[c]**	**Epon® 828[d]**
Control		33.8 (5200)	42.7 (6200)
Heat		(not determined)	20.7 (3000)
Ultraviolet light (Weatherometer)	60 hrs	29.0 (4200)	(not determined)
Tap Water	7 days	32.1 (4650)	43.8 (6360)
Salt Spray	10 days	(not determined)	41.4 (6000)
Isopropanol	7 days	35.0 (5080)	(not determined)
n-Hexane	7 days	33.1 (4800)	(not determined)
Transmission oil	7 days	31.7 (4600)	(not determined)

[a] All tests at 21° (70°F) except that for heat; to test effect of heat on bond, specimen was held at 82.2°C (180°F) during test procedure. Although the effect of low temperature has not been determined in DuPont laboratories, Elvamide® 8061 /epoxy adhesives are known to have excellent strength characteristics under cryogenic conditions.
[b] Adhesive is 75/25 Elvamide® 8061/Epoxy.
[c] Ciba Specialty Chemicals resin cured 60 min at 204°C (400°F); no curing agent.
[d] Resolution Peformance Products resin cured 60 min at 163°C (325°F); 10 phr dicyandiamide.

As with any coating operation, adhesion depends not only on the composition of the adhesive but also on the extent of contact of the adhesive with the substrate. Maximum bonding requires uniform contact and this, in turn, requires a clean substrate surface and an even coat of adhesive.

Application Techniques

Surface Preparation

Cleaning and etching the metal substrates before bonding insures maximum bond strength. In the work reported in **Tables 8**, **10**, and **11**, the aluminum alloy sheet or aluminum foil was vapor degreased, then immersed for 10 min at 66°C (150°F) in a pickling bath of the following composition:

	Parts by Weight
Sodium dichromate	31
Concentrated sulfuric acid	50
Water	170

The test specimens were rinsed in cold then hot tap water, dried in an oven at 60°C (140°F), and used immediately. Etching the solvent-cleaned surfaces increased bond strength by approximately 10%.

Adhesive Application

Whether the adhesive is applied from solution or in film form, the amount should be sufficient to give a final cured glue line at least 0.025 mm (1 mil) thick. Solution-type adhesives are evenly applied to one or preferably both of the surfaces to be joined and allowed to dry before the parts are assembled. Formulations containing active curing agents are unstable even at room temperature once the solvent has evaporated. Films deposited from adhesives of Elvamide® 8061 and epoxy resins formulated with active curing agents are no longer fusible after 24 hr at room temperature. To avoid premature cure, solvent should be driven off at or near room temperature, the parts assembled, then heat-cured promptly.

Bond Formation and Cure

In the bonding operation, surfaces previously coated with solution-type adhesive, or interleaved with film-form adhesive, are brought together under sufficient pressure to maintain good contact. Heat is then applied to bring the glue line to cure temperature. To develop maximum bond strength, the adhesive layer must be heated above the melting point of Elvamide® 8061. The optimum temperature will depend on the system-usually 177–191°C (350–375°F) for conventional curing schedules, 210–232°C (410–450°F) for quick cures. As discussed, Elvamide® 8066 permits lower curing temperatures than Elvamide® 8061. The objectives are to permit good wetting of the surfaces by the molten adhesive and to insure homogeneous interaction of the Elvamide® and thermosetting resin for maximum cross-linking during curing.

Adhesives containing active curing agents should be brought to flow-temperature rapidly, i.e., within 5 min or less. Otherwise, cure will have advanced too far by the time the prescribed temperature is reached to permit good flow and wetting, and bond strength will be poor.

The cure times specified in **Tables 10** and **11** and in the section on curing agents refer to duration of heating after the glue line has reached the temperature designated.

Textile Adhesive Uses

Elvamide® 8066, a low-melting resin, is designed particularly for textile adhesive uses such as embroidery and label attachment, heat sealable decorative tapes and fabric stiffening. The resin granules as supplied can be extruded into film or cryogenically ground to produce a fusible powder.

Because of its low moisture sensitivity and resistance to dry-cleaning solvents, Elvamide® 8066 can provide fabric-to-fabric bonds with excellent resistance to laundering and dry-cleaning. **Table 12** illustrates the strength of fabric-to-fabric seals attainable with Elvamide® 8066 and shows the effect of scaling temperature on bond strength.

Table 12
Heat Seal Strength[a] of Elvamide® 8066

Heat Seal Temperature, °C (°F)	Peel Strength, kN/m (gm/in) Elvamide® 8066	Type 12 Nylon
121 (250)	0.23–0.33 (600–850)	0.23 (600)
135 (275)	>0.77 (>2000)	0.58 (1500)
149 (300)	>0.77 (>2000)	>0.77 (>2000)

[a] 0.08 mm (0.003 in) films of resin sealed between two strips of 65/35 Dacron® polyester/cotton fabric for 2 sec at 138 kPa (20 psi).

Extrusion and Molding Uses

Elvamide® resins expand DuPont's family of nylon resins for specialty uses such as those mentioned on page 1.

Figure 3 shows the effect of temperature on melt viscosity of Elvamide® 8061.

Extruder Operation

Extrusion Conditions

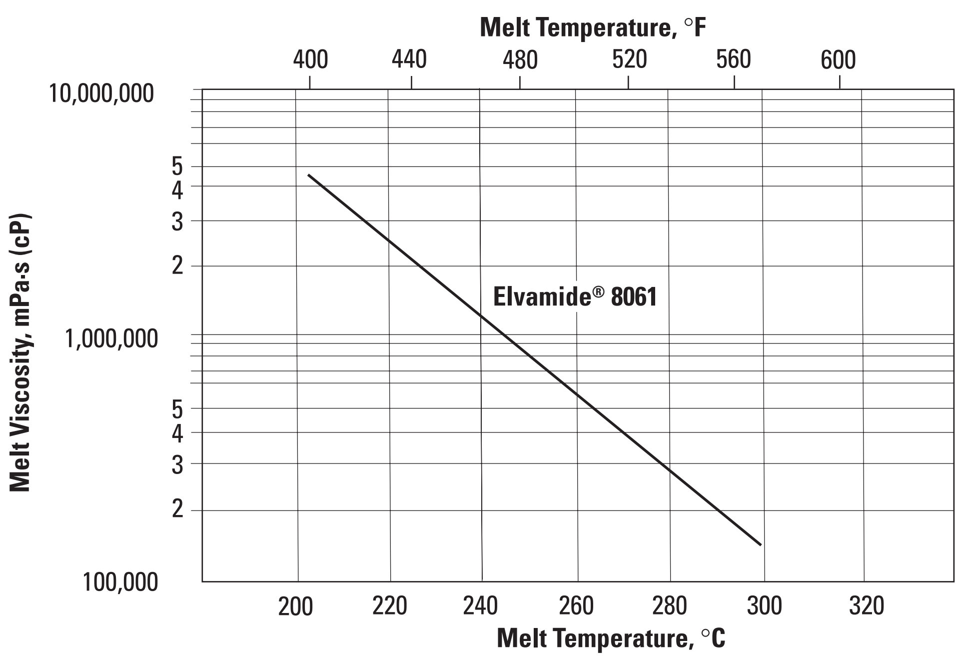
For Elvamide® 8061, a melt temperature of 218–232°C (425-450°F) is suggested. The temperatures of the die, adapter, neck, and front zones of the barrel should be controlled at the desired melt temperature. See **Table 13**, "Troubleshooting Guide."

Resin Handling

All nylon resins are hygroscopic and, therefore, readily absorb moisture from the atmosphere. For example, with 66 homopolymer nylon resin, as little as 0.05 wt% water gain in the resin can decrease the melt viscosity sufficiently to seriously impair an extrusion. If the total moisture content exceeds about 0.15–0.20 wt% then bubbling or splaying of the melt will occur.

DuPont Elvamide® resins for extrusion require drying to a moisture level less than 0.2 wt%.

Figure 3. Melt Viscosity vs. Melt Temperature (Shear Stress = 3 x 10^5 dynes/cm^2) L/D = 16



Based on resin moisture <0.10%

Table 13
Troubleshooting Guide-Extrusion Process

Issue	Possible Cause	Corrective Means
1. Bubbles in melt (constant bubbling or frothing)	a. Excessive moisture	a. Use resin directly from bag. b. Keep hopper covered. c. Use counter-current purge of nitrogen gas in hopper. d. Store resin at same temperature as around extruder.
	b. Overheating of melt	a. Lower controller settings. b. Check controller c. Check thermocouple. d. Use proper thermocouple location. e. Be sure thermocouple is properly seated. f. Increase the number of control zones. g. Reduce screw speed. h. Use barrel cooling. i. Use proper screw.
	c. Excessive hold-up	a. Increase the output—it may be too low for the extrusion temperature. b. Improve the streamlining of the system, particularly the die.
2. Erratic bubbles in the melt (e.g., periodic bubbling)	a. Entrapped air	a. Use proper screw. b. Lower barrel heats. c. Increase back pressure (screen pack, valve, or change temperature profile). d. Check controller units.
3. Surging	a. Inadequate reservoir of melt	a. Use a slower screw speed. b. Use proper screw. c. Change temperature profile—raising rear usually helps, especially for screw with short feed zone. d. Check for a temperature cycle. e. Increase back pressure by valving or by using a heavier screen pack. f. Increase land length of die. g. Reduce die slot opening.
	b. Bridging in feed section	a. Prevent bridging by starting up with rear zone set below melting point on nylon resin. b. Try increasing rear and center barrel temperatures. c. Use cooling water in the feed section of the screw. d. Calibrate temperature control units of feed zone.
	c. Bridging in transition zone	a. Increase rear and center rear barrel temperatures. b. Use screw with longer feed section.
	d. Slippage in belt drive	a. Tighten belts.
4. Bridging in feed zone of screw	a. Poor shutdown procedure	a. Turn heat off in rear and rear center zone and extrude at shutdown. b. Use cooling water on feed section of screw.
5. Overloading the extruder	a. Rear barrel temperature too low	a. Raise rear temperature. b. Check thermocouple and controller of rear zone.
	b. Wedging of cubes between flight land and barrel wall	a. Don't use undercut feed throat. b. Increase rear temperature.
	c. Degraded resin on screw land (after too many start-ups and shutdowns)	a. Use acrylic purge and clean extruder. b. Use high screw speed.

(continued)

Table 13 *(continued)*
Troubleshooting Guide-Extrusion Process

Issue	Possible Cause	Corrective Means
6. Carbon specks	a. Dirty equipment	a. Make sure extruder is clean. b. Use purge procedure.
	b. Extruder run dry at shutdown	a. Leave some resin in feed throat at shutdown. b. Change screen pack after purging at high speed.
7. Poor caliper control	a. Extruder surging	a. See issue #3. b. Lower rear barrel temperture.
	b. Variable take-off	a. Repair or rebuild take-off. b. Change to DC drive.
	c. Inadequate temperature	a. Insulate as much as possible. b. Calibrate control units for minimum on/off cycle.

Under normal operating conditions in areas of low humidity or in air-conditioned plants, hopper residence times of up to one hour can be tolerated without any noticeable moisture pickup. However, in areas of high humidity where long hopper residence times are required, it is good practice to provide a very slow purge of dry air or nitrogen into the base of the hopper to prevent moisture pickup. Under these conditions, a constant melt viscosity of the resin being processed will be ensured. A cover for the hopper should be used at all times to eliminate dirt.

Hopper driers may be used to insure the resin is maintained in a dry condition. The air supplied to the hopper should be passed through a molecular sieve or equivalent-type dehumidifier to eliminate moisture.

Start-up

The start-up technique is very important as it involves the safety of both operating personnel and machine. In addition, proper start-up of extrusion equipment will greatly facilitate smooth operation for extended periods without costly shutdowns. Start-up techniques will vary depending upon whether or not the machine is clean.

Clean Machine

For start-up with a clean machine, the temperature controllers of the die, neck, adapter, and barrel extension zones are set at operating temperatures for the particular resin and process. (As a rule of thumb, set temperatures 17°C [30°F] above the melting point of the nylon resin being processed.) This is a good opportunity to check the operation of controllers.

When these zones reach the operating temperature, the remaining barrel zones, except the rear, are heated to the same temperature. The rear zone is deliberately kept below the melting point of the nylon resin to prevent overheating and possible bridging problems during start-up. Feed throat cooling water is turned on. Cooling of the entire screw is not recommended in processing nylon; however, cooling of the feed zone (5 flights) is effective in solving some specific feeding problems like erratic or nonuniform feeding.

When all zones have been at the desired temperatures for 20–30 min, the resin may be fed into the hopper. The screw should be turned on at a slow speed (5–10 rpm). When it has been established that the screw is picking up the resin properly, the barrel rear zone is raised to the desired operating temperature.

Until one becomes familiar with the specific nylon resin being extruded, it is suggested that the resin be hand fed gradually until melt appears at the die. At this point, the melt should be clear and the melt temperature should have leveled out. It is desirable to use a pressure gauge and an ammeter to monitor the extruder performance at start-up. For maximum safety of the equipment, the pressure gauge should be located between the end of the screw and the breaker plate.

Full Machine

In the extrusion of nylon, the equipment usually has been shut down with resin remaining in the machine to prevent oxidation that might occur in a partially empty extruder. When possible, it is suggested that the machine be purged with a fairly low melting resin such as polyethylene before shutting down. This will insure the resin will be melted before the extruder is restarted again. Care must be exercised in starting a full machine to prevent bridging in the feed zone, localized overheating resulting in resin degradation, and cold spots (unmelted plugs in sections such as the adapter).

The following procedure will facilitate a smooth and safe start of a full machine:

Set all controllers from the front barrel section (metering zone) forward about 28°C (50°F) above the resin melting point. The other barrel controllers are left in the off position to prevent overheating the rear section of the screw. Bridging of the screw will then be prevented. When all the controllers have reached the set point, then the barrel controllers are turned on and set to the operating temperature. When all controllers reach the set point, the extruder is ready to be started. Feed throat cooling water is used during this start-up operation.

The screw is now set at a low or idle speed until smooth flow from the die is obtained. If melt flow is not observed, the screw is turned off and the barrel rear is raised 28°C (50°F). The machine is allowed to set under this condition for a few minutes and the screw is again turned to slow or idle speed until smooth flow is obtained. Once the flow from the die has been observed, the barrel rear is set to the desired operating temperature and safe extrusion can then be undertaken. Watch for any excessive melt pressure and amperage during the start-up—this indicates the presence of an unmelted plug.

Shutdown

For a brief shutdown of 30 min or less, no changes are required. However, certain procedures should be followed when the extruder containing nylon is to be shut down for periods longer than 30 min.

For subsequent extrusion operation with minimum loss of time and material, the following points should be observed:

- Continue to use feed throat cooling water.
- Drop the extruder temperature setting to 11°C (20°F) above the melting point of the nylon resin.
- Maintain extrusion at reduced speed.
- Continue to feed resin to the screw. This prevents the formation of air pockets or voids in the die which would cause the resin to oxidize, resulting in inferior melt in the next start-up.
- When all control, as well as melt temperatures have dropped below 5°C (9°F) over melting point, the screw power and heat can be turned off. At this temperature, the resin is sufficiently viscous to prevent material exuding from the die. The point at which extrusion should cease may also be determined by the amperage limit of the individual equipment. This limit should be established for each installation.

An alternative method shutdown involves purging the extruder with polyethylene. A medium-density polyethylene resin can be used to purge nylon from the extruder without changing the temperature profile. Screw speed may be varied, however, to help purge. When the melt appears clear, the die, adapter, and neck temperature settings are reduced below the nylon melting point. When the molten extrudate indicates that the purging has been completed, the normal polyethylene shutdown procedure is followed. The temperature of the die, neck piece adapter, and barrel is turned off. The screw power is turned off when the temperature of the barrel has dropped below the nylon melting point.

Film Casting

Since Elvamide® resins have lower melting points than conventional nylon molding and extrusion resins, lower chill-roll temperatures are required. The maximum chill-roll temperature to prevent sticking of Elvamide® 8061 is about 41°C (105°F).

By operating the chill roll at as high a temperature as possible, the rate of crystallization is increased, less post-crystallization occurs and roll conformation problems are minimized.

The processing conditions of melt temperature, quench temperature, air gap and rate influence the physical properties of cast nylon film. The following general statements indicate the more significant effects of these conditions. The degree of the effect depends on the specific resin being processed.

Effect of increasing melt temperature

- Transparency and gloss increase
- Haze decreases
- Impact strength increases

Effect of increasing quench temperature

- Yield strength increases
- Haze increases
- Transparency and gloss decrease
- Impact strength decreases

Effect of increasing air gap

- Haze increases
- Transparency and gloss decrease

Effect of increasing rate

- Haze decreases
- Transparency and gloss increase

Of the above variables, rate and air gap have the greater influence on properties.

Resin Drying

All Elvamide® resins go through a multiple-phase drying cycle with hot, dry air before packaging.

The equilibrium moisture content of the nylon decreases as the moisture content of the incoming air decreases. If the moisture content of the incoming air is too high, it is not possible to dry the nylon sufficiently at reasonable drying temperatures.

Hopper Dryers

A typical dehumidified hopper-dryer system consists of a filter, blower, dehumidifier, heater and a hopper. Air is circulated by the blower through the dehumidifier. The dehumidifier air is then heated and passed through the resin in the hopper and back to the dehumidifier via a filter. Pneumatic conveyers, or preferably vacuum systems, are used to feed resin into the hopper.

The rate of drying in a hopper dryer will be essentially the same as that in a tray oven for the same drying temperature and inlet air humidity. An advantage of the hopper-dryer system is the counter-current flow of polymer to air. The driest air contacts the driest polymer since the polymer is exiting at the bottom of the hopper and the dry air is entering at the bottom of the hopper.

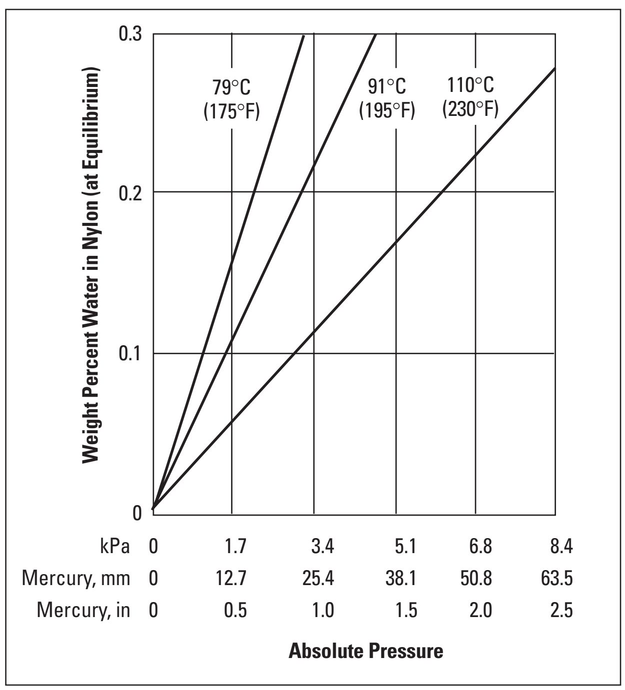
A number of potential problems associated with hopper dryers includes:

- **Incoming dry virgin resin subjected to unnecessary heating or air tends to discolor**. Separate drying of regrind can eliminate this problem.
- **Uneven flow of resin through the hopper**. This problem is most noticeable in the conical section above the throat of the hopper. It is possible that in a poorly designed hopper, the moisture level of the molding powder might vary enough to produce erratic molding conditions.
- Insufficient holdup time for drying wet nylon on a fast cycle.
- Inability to maintain a truly closed system.
- Inability to maintain a constant drying temperature. Insulation of the hopper minimizes this problem.

Vacuum Drying

Elvamide® resins can be dried in vacuum ovens or in rotary vacuum tumbler dryers. **Figure 4** shows the absolute pressure required to achieve a given equilibrium moisture content for nylon at various drying temperatures.

Figure 4. Vacuum Required to Dry Nylon Resins



The preferred way to operate a vacuum drying oven is as follows:

Charge the oven with the nylon resin to be dried. Apply vacuum to the drying vessel. Heat the vessel to the selected drying temperature. The drying process is complete when the oven pressure reading corresponds to the pressure required at the desired moisture level given in **Figure 4**. One precaution that must be taken in this case is to measure the vacuum in the drying vessel itself and not at the vacuum source. To minimize color formation, it is desirable to evacuate the vessel before heating the polymer.

Any leakage of room air into the oven will make the above-described drying technique invalid. This does not mean that nylon can not be dried in a vacuum vessel that has some leaks. In such cases, estimation of the final moisture content of the nylon is not possible unless the amount of leakage and the relative humidity of the air leaking into the oven are known.

Test Methods for Elvamide® Resins

Nylon resins can be distinguished from other plastics by a simple burning test. Place a small piece of the resin in a "Pyrex" tube and heat the end of the tube gently with a small flame until the polymer has partially melted and some decomposition has occurred. Scorched nylon gives off an unmistakable odor similar to that of burning hair.

Shown below are test methods for Elvamide® the most important of which is relative viscosity.

Relative Viscosity

Relative viscosity is a calculated value of the ratio of absolute solution viscosity to the absolute viscosity of the solvent. It is measured for an 8.4 wt% solution of Elvamide® resin in 90% formic acid solvent (0.11 g resin/mL formic acid). The absolute viscosity of formic acid is determined using a Cannon-Fenske size 75 viscometer. A Brookfield Viscometcr is used to determine the absolute viscosity of the Elvamide®/formic acid solution. The spindle and speed should be selected to give a viscosity highest on the 100 scale. Viscosities should be determined at 25°C (77°F).

Melting Point

DSC is used to determine the melting point of Elvamide® resins. Applicable test methods are ISO 3146 and ASTM D3418 using second melt points.

Special Safety Precautions

Solution Preparation

When preparing solutions of Elvamide® resins in flammable solvents, precautions must be taken to avoid ignition of flammable vapors by static electricity during the transfer of the resin to a dissolving kettle.

All metal parts of the mixing and processing equipment must be grounded. In addition, precautions must be taken to avoid discharging the static charges which may be generated within the bags of Elvamide® or on the operator during the transfer operation. It is not recommended that Elvamide® resin be transferred from the bag directly to the blend tank unless the resin has previously been wet down with water.

Some suggested alternatives for minimizing the hazard are:

- Transfer Elvamide® resin from the bag to an unlined metal container at a location away from the flammable vapor area. Ground the container to the blend tank. Then transfer Elvamide® resin from this container to the blend tank using a metal funnel which is grounded to the tank. The free fall distance for the resin should be minimized.
- Mount a grounded metal funnel or trough above the blend tank. The cubes of Elvamide® resin should travel for at least several feet along the metal surface. The point where Elvamide® is transferred from the bag to the funnel or trough should be well ventilated to reduce the concentration of flammable vapors. With floor-level tank openings, a grounded metal tray may be used.

After pouring Elvamide® resin from a bag, the operator should ground himself in a safe location before he approaches the potentially flammable environment near the opening of the blend tank.

Operations involving solvents must be adequately ventilated to limit operator exposure to permissible levels. Reference should be made to Section 1910.1000 of Title 29, Code of Federal Regulations, and to the Threshold Limit Values (TLV) published by the American Conference of Governmental Industrial Hygienists for guidance or acceptable concentrations of solvent vapors in the workplace atmosphere. Protect eyes and skin from contact with solvents by using goggles, gloves and other protective equipment.

These suggestions are not intended to be all inclusive. They should be supplemented by good manufacturing procedures, prevailing industry standards and the recommendations of the equipment manufacturers. In any operation that involves the handling of flammable solvents, the utmost care should be taken to avoid static accumulation and other possible ignition sources. Open flames should be prohibited, and nonsparking motors and tools should be used.

Molding and Extrusion

While the molding and extrusion of Elvamide® resins is ordinarily a safe operation, consideration should be given to the following:*

(A) Since Elvamide® resins are molded at high temperatures, the molten resin can inflict severe burns. Furthermore, above the melting point, moisture and other gases may generate pressure in the cylinder which, if suddenly released, can cause the molten polymer to be violently ejected through the nozzle.

To minimize the chance of an accident, the instructions given in this manual should be followed carefully. Potential hazards must be anticipated and either eliminated or guarded against by following established procedures—including the use of proper protective equipment and clothing.

Be particularly alert during purging and whenever the resin is held in the machine at higher than usual temperatures or for longer than usual periods of time—as in a cycle interruption.

In purging, be sure that the high volume (booster) pump is off and that a purge shield is in place. Reduce the injection pressure and "jog" the injection forward button a few times to minimize the possibility that trapped gas in the cylinder will cause "splattering" of the resin.

If there is any suspicion that gases are being formed in the cylinder, move the purge shield in place, back the nozzle away from the mold, turn off all heats except to the nozzle and the nozzle adaptor, and leave the machine until it cools below the melting point of the resin. Then, with purge shield still in place, reheat the cylinder to the minimum mold temperature. If jogging the injection or screw rotation buttons does not produce melt flow, a plug exists. In that case, shut off cylinder heats as before and follow your established safe practices for removing the nozzle. Always assume that gas may be trapped behind the nozzle. A face shield and protective long-sleeve gloves should be used.

In the event molten polymer does contact the skin, cool the affected area immediately with cold water or an ice pack and get medical attention for thermal burn. Do not attempt to peel the polymer from the skin.

(B) Small amounts of gases and particulate matter (i.e., oligomers) are released during the molding or extrusion of Elvamide® resin. As a general principle, we recommend adequate ventilation during the processing of all plastic resins. However, gaseous products are produced in much smaller quantities than is particulate matter and, as long as this is kept below the OSHA limit** for nuisance dusts, gases should be well below toxic levels.

Injection molding normally releases substantially less volatiles and, therefore, requires less ventilation. However, during purging, volatiles release is similar to that in extrusion.

(C) Granules of Elvamide® resin present a slipping hazard if spilled on the floor. They should be swept up immediately.

Epoxy Resins

Certain formulations utilize mixtures of Elvamide® resin and epoxy resins. Epoxy resins are combustible and must be kept away from heat and open flame. Avoid prolonged contact with skin and breathing vapor or spray mist. Keep container closed when not in use. Provide adequate ventilation when epoxy formulations are being prepared. Before proceeding with any compounding work, consult and follow label directions and handling precautions from suppliers of epoxy resins.

Packaging

Elvamide® resins are supplied as approximately 1/8 in colorless transparent cubes or beads. They are packaged in 25 kg (55 1b) net moisture barrier paper bags which maintain extremely low moisture levels. Pallet loads of 1000 kg (2,200 lb) are unitized.

---

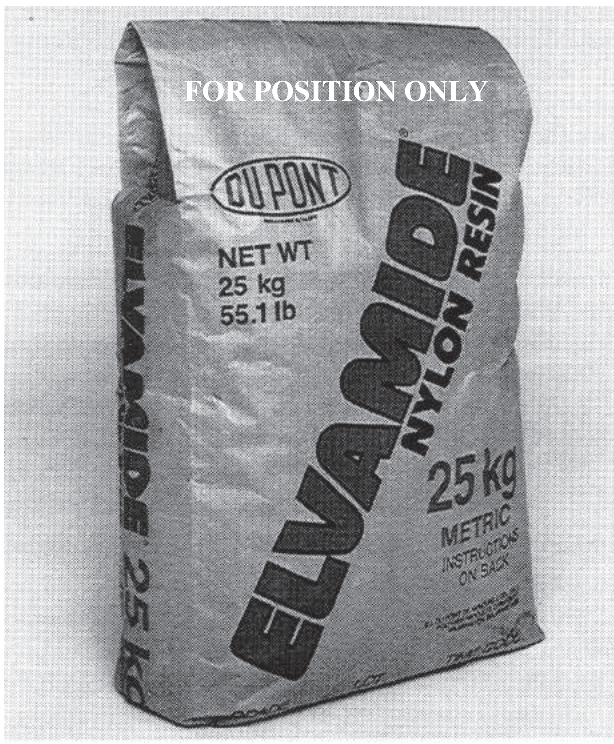
* Refer also to "Operator Safety Tips" leaflet published by the Society of Plastics Engineers, Inc., Greenwich, CT 06830.

**Title 29, CFR 1910.1000, Air Contaminants.

Bag Construction

The standard 25 kg (55 1b) bag for Elvamide® resins is pictured in **Figure 5**. Its multi-ply construction, shown schematically in **Figure 6**, is designed for extra strength, easy opening and excellent protection against moisture pickup. Grade identification, manufacturing lot number and time code are stenciled on the bottom of the bag, clearly visible in palletized loads.

Figure 5. Standard 25 kg (55.1 lb) Bag for Elvamide® Resins

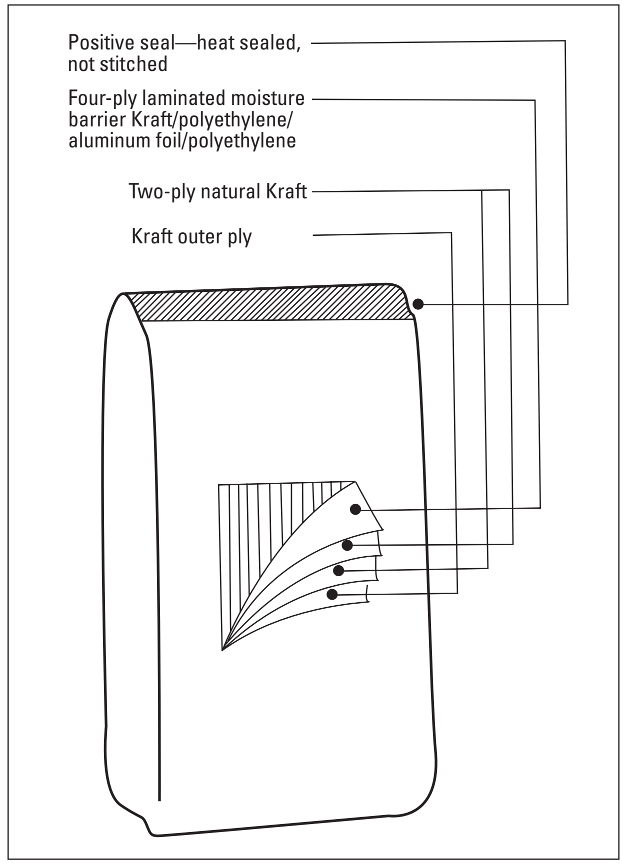


Precautions in Handling

Special safety precautions are printed on the back of each bag in English, French, German, Italian, Danish, and Dutch to help operators use Elvamide® resin safety. The precautions include among others:

- Avoid ignition of flammable vapors from such solvents by static electricity during the transfer of the resin to a dissolving kettle.
- Insure that work area is adequately ventilated to limit operator exposure to solvents to permissible levels.
- Protect eyes and skin from contact with solvents by using goggles, gloves, and other protective equipment.

Figure 6. Bag Construction



Also included on the bag is the following statement regarding moisture sensitivity:

Elvamide® resins readily absorb moisture. The resins, as packaged, have a low moisture content and the shipping bag protects against further uptake of moisture. In applications where moisture is detrimental, care should be exercised, if the bag is torn or opened, to prevent exposure to high humidities. If exposure occurs, the resin should be dried prior to use.

Opened bags should be folded down and taped securely to minimize moisture pickup. Remaining resin should be used as soon as possible.

Patent Status

The following U.S. Patents describe uses of Elvamide®:

U.S. Patent No.	Use
3,336,415	Nylon/epoxy adhesive blends
3,462,337	Nylon/epoxy adhesive blends
3,636,136	Powdering process for nylon
3,637,550	Silane-treated nylon adhesives

Regulatory Status

FDA Status

Elvamide® 8023R, 8061, and 8063 comply with FDA Regulation 21 CFR 178.2010, "Antioxidants and/or Stabilizers for Polymers," for use only at levels not to exceed 1.5% by weight of polyoxymethylene homopolymer as provided in paragraph (b) (1) of Regulation 177.2480 entitled "Polyoxymethylene Homopolymers." Elvamide® resin is not cleared for other uses at this time.

Results of animal studies with Elvamide® 8061 show there was no clinical, nutritional, biochemical, or pathological evidence of toxicity when animals were fed at a dietary level of 10%.

Toxic Substances Control Act

Elvamide® resins have been reported to the Environmental Protection Agency for inclusion in the Initial Inventory as required by the Toxic Substances Control Act, Title 40 CFR Part 710.

European Inventory of Existing Chemical Substances (EINECS)

The chemical constituents of Elvamide® resins are listed on the European Core Inventory (ECOIN) as published by the European Economic Community in 1981.

Waste Disposal

Elvamide® resins may be disposed of by incineration or burial but method must be in compliance with federal, state, and local regulations.

MSDS

Material Safety Data Sheets on Elvamide® resins are available from your DuPont Polymers representative.

Shipments

Elvamide® resins are not regulated by the Department of Transportation.

Freight Classifications

Truck: Plastic materials, synthetic O/T foam, pellets, expanded or sponge granules, NOIBN

NMFC Item: 156200

Rail: Plastic materials O/T liquid NOIBN

UFC Item: 77810

Export Classification

Schedule B Number 444.1210

Brussels nomenclature-none

IMCO: non-regulated

NOTES

For more information on Engineering Polymers: (800) 441-0575

http://www.plastics.dupont.com

For Automotive Inquiries: (800) 533-1313

U.S.A.

DuPont Engineering Polymers
Chestnut Run Plaza 713
P.O. Box 80713
Wilmington, DE 19880-0713
(302) 999-4592

Automotive

DuPont Engineering Polymers
Automotive Products
950 Stephenson Highway
Troy, MI 48007-7013
(313) 583-8000

Asia Pacific

DuPont Asia Pacific Ltd.
P.O. Box TST 98851
Tsim Sha Tsui
Kowloon, Hong Kong
852-3-734-5345

Canada

DuPont Canada, Inc.
DuPont Engineering Polymers
P.O. Box 2200
Streetsville, Mississauga
Ontario, Canada L5M 2H3
(905) 821-5953

Europe

DuPont de Nemours Int'l S.A.
2, chemin du Pavillon
P.O. Box 50
CH-1218 Le Grand-Saconnex
Geneva, Switzerland
Tel.: ##41 22 717 5111
Telefax: ##41 22 717 5200

Japan

DuPont Kabushiki Kaisha
Arco Tower
8-1, Shimomeguro 1-chome
Meguro-ku, Tokyo 153
Japan
(011) 81-3-5434-6100

Mexico

DuPont S.A. de C.V.
Homero 206
Col. Chapultepec Morales
11570 Mexico D.F.
(011 525) 722-1456

South America

DuPont America do Sul
Al. Itapecuru, 506
Alphaville—CEP: 06454-080
Barueri—São Paulo, Brasil
Tel.: (055-11) 7266.8182
Fax: (055-11) 7266.8513
Telex: (055-11) 71414 PONT BR

DuPont Argentina S.A.
Avda.Mitre y Calle 5
(1884) Berazategui-Bs.As.
Tel.: (54-1) 319-4484/85/86
Fax: (54-1) 319-4417

CAUTION: Do not use in medical applications involving permanent implantation in the human body. For other medical applications, see "DuPont Medical Caution Statement," H-50102.

The miracles of science™

(06/02) Printed in U.S.A.
Reorder No.: H-90236