

Polymer Blends and Alloys

GUIDEBOOK
TO COMMERCIAL
PRODUCTS

Polymer Blends and Alloys

GUIDEBOOK TO COMMERCIAL PRODUCTS

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藏书章



LANCASTER • BASEL

Published in the Western Hemisphere by
Technomic Publishing Company, Inc.
851 New Holland Avenue
Box 3535
Lancaster, Pennsylvania 17604 U.S.A.

Distributed in the Rest of the World by
Technomic Publishing AG

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Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

Main entry under title:
Polymer Blends and Alloys—Guidebook to Commercial Products

A Technomic Publishing Company book
Bibliography: p.
Includes index p. 557

Library of Congress Card No. 88-50188
ISBN No. 87762-566-2

Foreword

One of the rapidly emerging areas in polymer technology is that of polymer blends and alloys. While physical mixtures of polymers are not new ("Polyblends" have been around for a good many years), many advances have been made recently in the combining of two or more dissimilar polymers, and the use of these techniques is growing.

Simple blends generally show average properties of the components; "alloys" may show some synergism of properties as well as a single second order transition. Any number of combinations—and combinations of these—may be tailored to meet specific end-use demands by judicious choice of components and proportions. Questions of compatibility, partial miscibility, and immiscibility are best dealt with on a case-by-case basis and in consideration of end-uses.

While the number of combinations of "conventional" polymers has by no means been fully explored, the ongoing addition to polymer technology of new, highly

stable polymers with more and more unique characteristics guarantees that this is a field of increasing interest, growth and commercial development.

For this reason, Technomic Publishing Company has compiled this first Guidebook designed to provide practitioners with a somewhat broader overview, as this empirical technology continues to evolve from a new branch of polymer science to a wider realm of industrial applications.

The editors believe this book will be useful to processors seeking technical information about polymer blends and alloys. It is the desire of the editors that companies having commercial blend and alloy products will send information on these products to the Editor, *Polymer Blends and Alloys—Guidebook to Commercial Products*, for future editions. And finally, we invite your comments and suggestions so that future editions will be ever more useful to the plastics industry.

Acknowledgment

Technomic Publishing Company, Inc. is indebted to Mr. E. Melvin Sweeney, who served as the Editor for this first edition of *Polymer Blends and Alloys—Guidebook to Commercial Products*.

Mr. Sweeney's industrial experience includes 20 years of varied assignments with Armstrong World Industries' Research and Development Center; earlier he was product manager for Krauss-Maffei, GmbH. Currently a consultant specializing in polyurethane technology and

Reaction Injection Molding, in recent years he has consulted with the Soundesign Corporation in Jersey City, New Jersey, and the Dynasty Chemical Company in Lu Kang, Taiwan. Formerly a professor at the State University of New York/Morrisville College, where he taught in the plastics technology program, Mr. Sweeney has also conducted special programs for the New York State Private Industry Council and the New York State Education Foundation.

Introduction

POLYMER BLENDS AND ALLOYS: EXPANDING OPPORTUNITIES FOR PLASTICS

Sarah Y. Kienzle

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Plastics have enjoyed strong growth in demand, from less than 20 billion pounds in 1970 to nearly 50 billion pounds consumed in the United States in 1986, largely as a result of their substitution for traditional materials. Plastics have replaced metals, glass, ceramics, wood, paper, and natural fibers in a wide variety of industries including packaging, consumer products, automobiles, building and construction, electronics, electric equipment, appliances, furniture, piping and heavy industrial equipment. The success of various polymers in such a broad spectrum of applications is attributable to the wide range of properties available with plastic materials. These include light weight, breakage resistance, the ability to consolidate functional parts, inexpensive, automated production of complex components and, often, lower finished part cost by comparison to traditional materials.

Because of the reproducible properties and cost effectiveness of polymeric materials, much of the easy substitution for traditional materials has already been accomplished. With slow economic and population growth in the developed regions of the world, coupled with fewer substitution opportunities, polymer growth rates have begun to slow. Additionally, polymer downgrading has become a significant trend. As engineers and designers have gained familiarity with the use of plastics, over-engineered plastic components are increasingly being redesigned with less costly, lower propertyed polymer compounds. Thus, intercompetition among polymers has sharply increased and many suppliers suggest that the development risks of synthesizing a truly new polymer often outweigh the potential commercial rewards.

The combination of two or more commercially available polymers through alloying or blending, however, represents an inexpensive route to product differentiation for suppliers. Existing equipment may be utilized and the properties and chemical behavior of the constituents are generally well understood. For the processor and end user, alloying and blending technology permits tailoring of a polymer compound to their specific application requirements, often at a lower cost than the current material and over a short developmental period. Alloy and blend development, therefore, is typically market driven and requires an ongoing dialogue between supplier and customer to ensure commercial success.

ALLOY AND BLEND TECHNOLOGY

The terms alloy and blend are often used synonymously, yet the two material types differ in the level of thermodynamic compatibility between their components and the resulting effects on physical and mechanical properties. Some level of thermodynamic compatibility is necessary between components in all polymer combinations to prevent phase separation in processing and use. Beyond this level of compatibility, greater attractive forces between constituents serve to enhance the resultant property profile.

In general, two component polymer mixtures may be described by the following equation:

$$P = P_1C_1 + P_2C_2 + IP_1P_2$$

where P is a property value of the alloy or blend, P_1 and P_2 are the property values of the isolated components, and C_1 and C_2 are the concentrations of the two constituents. I is an interaction coefficient that describes the level of synergism, or thermodynamic compatibility, of the components in the mixture.

In mixtures where the interaction coefficient, I , has a positive value ($I > 0$), the resulting polymer combination exhibits better property values than the weighted arithmetic average of the components' properties and is termed synergistic. If I equals zero, the properties of the combination are equal to the weighted arithmetic average of the constituents' properties. In this case, an additive blend results. When I takes a negative value ($I < 0$), with resultant blend properties below those predicted by the components' weighted arithmetic property averages, a nonsynergistic blend results. The effects of various values of the interaction coefficient on polymer combinations are graphically depicted in Figure 1.

Alloys are synergistic polymer combinations with real property advantages derived from a high level of thermodynamic compatibility between components. Alloys exhibit strong intermolecular forces and form single-phase systems with unique glass transition temperatures. The most significant commercial alloys are the polystyrene-modified polyphenylene oxide and ether products developed by General Electric (NORYL) and Borg-Warner/Mitsubishi Gas Chemicals (PREVEX), respectively. Here the polymers are mutually soluble and the poly-

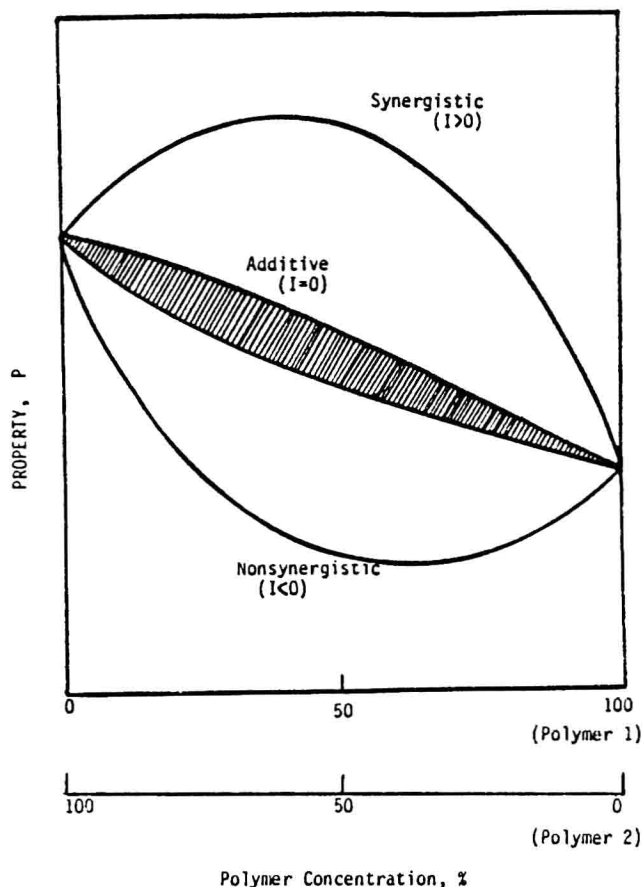


Figure 1. Property relationship in alloys and blends as a function of concentration.

styrene reduces the PPO or PPE melt viscosity sufficiently to allow ease of processing over a broad range of conditions. The phenylene-based constituent contributes strength, impact resistance, flame retardancy, and superior hydrolytic stability, which are minimally reduced by the presence of polystyrene.

Polymer blends, by comparison, have less intense thermodynamic compatibility than alloys. The blends exhibit discrete polymer phases and multiple glass transition temperatures. In general, the properties of a blend reflect the weighted arithmetic averages of the properties of its constituents ($I = 0$), as shown in Table 1. Here, commercially available blends of polycarbonate and ABS are compared with the theoretical "additive" property profile of a 50/50 PC/ABS blend. PC/ABS blends contain 50 percent or more polycarbonate, while ABS/PC blends contain less than 50 percent polycarbonate. Blends may also be nonsynergistic ($I < 0$), although this represents the least desirable outcome for the formulator.

Preparation of Alloys and Blends

Alloys and blends may be manufactured by a variety of means, including melt blending, solution blending, and latex or dispersion mixing. Melt blending, in intensive mixing extrusion equipment, is the predominant commercial method of alloy and blend preparation.

In melt blending, two or more polymers plus any

desired fillers, reinforcements, and additives are metered, by weight, into a shear intensive extruder. The constituents are mixed at elevated temperatures (i.e., above the melt points of the polymer constituents) by the extruder screw, which exerts mechanical shearing forces and ensures even distribution and thorough blending of the alloy and blend elements. Polymers may be blended in powder or pellet form, and the resulting alloy or blend is typically stranded, cooled, and chopped into pellets.

A compatibilizing agent may be incorporated in the alloy or blend to enhance the synergism of the mixture. By incorporating different functional groups in one chemical compound that can mate readily with the dissimilar polymers to be blended, the compatibilizing agent acts as a fastener, preventing phase separation and often enhancing the physical and mechanical properties of the resulting alloy or blend. Typical alloying and blending aids include block copolymers, graft copolymers, and polymeric plasticizers.

Melt blending has several advantages over solution blending and latex mixing. A liquid blending or dispersion agent is eliminated, thus negating costs associated with solvent removal, recovery, and losses. Additionally, by combining only those elements desired in the final mixture, melt blending reduces the likelihood of contamination in the alloy or blend. Also, polymer producers can use in-place equipment. For example, sharing extruders across product lines is possible and may reduce the capital investment necessary to introduce a new product line. The use of elevated temperatures in melt blending, however, poses the possibility of undesired cross-linking or grafting of the polymers. Additionally, polymer degradation, caused by chain scission, can result in color shifts and poor mechanical properties, if processing temperatures are not carefully controlled.

Solution blending reduces the likelihood of thermally or mechanically induced polymer degradation, since alloy or blend mixing occurs in a solvent, at relatively low temperature and with low shear forces. Contamination of the alloy or blend with residual solvent and the potential for phase separation or selective precipitation are hazards of this preparation method.

Latex or dispersion mixing uses coagulation to give an intimate alloy or blend mixture. Acrylonitrile butadiene styrene (ABS) polymers may be prepared by this method, which is also applicable for alloys and blends, in some cases. Dispersion mixing is followed with melt mixing (or compounding) to produce polymer strands for pelletizing.

Selecting a Polymer Combination

Polymers to be combined in alloys and blends are generally selected to complement each other in one or more of the following property categories: cost, processability, mechanical properties, warpage resistance, chemical resistance, and thermal performance. Blends are typically viewed as cost saving devices, whereby an expensive polymer may be combined with a less costly plastic to provide adequate performance at a significantly reduced price to the consumer. Although alloys may also represent cost reductions to prospective consumers, the driv-

Table 1. Properties of ABS and Polycarbonate Blends vs. Properties of Their Components

	Components		Theoretical Blend	Commercial Blends	
	ABS*	PC	50/50 ABS/PC	PC/ABS	ABS/PC
Specific gravity	1.07	1.2	1.14	1.12	1.10
Water absorption, 24 hr, %	0.32	0.15	0.24	0.21	—
Coeff. of thermal exp., 10 ⁻⁵ /°F	6.0	6.8	6.4	3.5	5.1
HDT at 264 psi, °F	230**	270	250	240	190
Tensile strength, psi	6,200	9,500	7,850	8,500	6,300
Flexural strength, psi	11,000	13,500	12,250	13,000	10,500
Flexural modulus, 10 ³ psi	350	340	345	350	330
Notched Izod impact, ft-lb/in.	4.3	16.0	10.2	10.5	8.5
Rockwell hardness	R112	M70	—	R117	R105

*Heat resistant.

**Annealed.

Table 2. Classification of Thermoplastic Polymers

Commodity	Transitional	Engineering	Performance
PET (unfilled) Polyethylene Polypropylene Polystyrene Polyvinylchloride	ABS/SAN Acrylics SMA copolymer	Modified PPO Nylon PBT PET Polyacetal Polycarbonate Alloys blends SMA terpolymer	Fluoropolymers Polyamide-imide Polyarylate Polyetheretherketone Polyetherimide Polyethersulfone Polyimide Polyphenylenesulfone Polysulfone
<div style="text-align: center;"> </div>			

Table 3. Crystalline and Amorphous Polymers

Crystalline Properties <ul style="list-style-type: none"> • Excellent chemical resistance • Sharp melting point • Low viscosity melt • Significant tensile flexural, and heat distortion improvement with reinforcement 	Amorphous Properties <ul style="list-style-type: none"> • Dimensional stability and warpage resistance • Maintenance of properties at elevated temperatures • Clarity • Generally good impact strength • Melting range
Polymers <ul style="list-style-type: none"> • Polypropylene • Polyacetal • Nylon 6/6 • Polybutylene terephthalate (PBT) 	Polymers <ul style="list-style-type: none"> • ABS • Polycarbonate • Polysulfone • Polyarylate

ing forces for their development and use are more typically the synergistic property profiles achievable.

Polymers can be segmented into four families, as described in Table 2. By combining polymers from two different families (e.g., commodity with transitional, transitional with engineering, engineering with performance), the property profile of the more costly polymer may be partially exploited, with the less costly polymer reducing overall compound cost. Many commercial blends, such as ABS/polycarbonate, ABS/polysulfone, and polyethersulfone/polyetheretherketone, have been developed for this reason.

A second common method of selecting polymers for combination into alloys or blends is the choice of one crystalline and one amorphous polymer. As described in Table 3, crystalline polymers have excellent chemical resistance, shown large improvements in mechanical properties with the addition of reinforcing agents (e.g., glass or carbon fiber), and exhibit low viscosity above their melting points, which aids in ease of melt processing. Amorphous polymers, such as polycarbonate, polyarylate, and polysulfone, provide dimensional stability, freedom from warpage, and excellent impact strength. When combining a crystalline and an amorphous polymer, the resulting blend or alloy provides good dimensional stability, ease of processing, and chemical resistance, as well as mechanical properties that can be tailored for a specific application.

Much of the current work in developing engineering thermoplastic blends and alloys for automotive body panels relies on crystalline/amorphous polymer combinations. Blends and alloys, such as nylon/PPO, PBT/polyarylate and PBT/polycarbonate, provide the combination of warpage resistance necessary for large part molding, chemical resistance to automotive and road chemicals, impact resistance, energy absorption characteristics, and stiffness necessary for body panel applications. This combination of properties is currently unobtainable with a single commercial polymer.

The combination of polymers with elastomers represents yet another group of alloys and blends. Typically, the polymer provides strength, stiffness, and thermal resistance, while an elastomer, such as polyurethane, the styrene block copolymers, copolyester elastomers, or EPDM, provides impact modification. The blending of polypropylene with EPDM for bumper covers and automotive fascia is a significant commercial example.

Alloy and Blend Supply

Several driving forces have prompted polymer suppliers to intensify their research and development efforts in alloy and blend technology. Increased interpolymer competition, with resultant losses in market share and margins, has caused polymer suppliers to focus their attention on providing polymer systems that offer a unique competitive advantage to their customers. The advantage may be solely a cost reduction from the previously specified material or the alloy or blend may provide a specific property advantage, such as improved impact strength or flame retardancy.

The development costs and risks for commercialization of a new base polymer are becoming nearly prohibitive for many suppliers. Chem Systems estimates that successful commercialization of a new polymer will require 15 to 20 years of development effort. By contrast, provision of an alloy or blend based on a supplier's commercial base polymers may require less than half that time for development and commercialization. Additionally, raw materials and manufacturing equipment for alloys and blends are readily available to suppliers from other product lines (e.g., an extruder is often used as the reactor), thus reducing procurement and capital investment risks.

Alloys and blends represent a route to portfolio diversification as well. For commodity plastic suppliers, engineering or transitional polymer alloys and blends offer a route to penetrate higher margin applications. For engineering plastic suppliers, alloys and blends may serve as product line extensions, to allow competition in new markets or represent a buffer against interpolymer competition losses in traditional product lines.

In general, it is important for the alloy and blend supplier to be basic in at least one of the alloy or blend components (preferably, the predominant one). As illustrated in Table 4, a supplier producing a blend based on market priced materials is at a significant cost disadvantage by comparison to a basic supplier with favorable material transfer costs. Blends are relatively easy to duplicate and patents are routinely circumnavigated by development of products with similar properties but compositions outside patent limits. Thus, a producer's cost position represents one of the few effective methods of deterring competition.

A second method of maintaining competitive dominance requires development of highly sophisticated blends and alloys through the use of proprietary technology. General Electric, DuPont and Monsanto, for example, have developed compatibilizing agents to achieve synergistic properties in a variety of polymer alloys. These additives, as well as the alloys containing them, may be patented and the property synergism derived is typically not simple for competitors to duplicate at comparable cost.

Custom compounders have established business based on production of proprietary polymer compositions. The compounder offers the advantage of being able to combine nearly any commercially available polymers with a plethora of fillers and additives. Proprietary technology and specialized, flexible manufacturing equipment allow the compounder to rapidly tailor formulations to meet specific application requirements. With smaller equipment, the compounder may be able to manufacture an alloy or blend more efficiently than larger suppliers, particularly for the small run sizes that characterize the alloy and blend business.

To assist their customers, successful alloy and blend suppliers provide a high level of technical service, in addition to tailoring the properties of the alloy or blend for specific applications. Market development activities of the suppliers include assisting the end user and fabricator with concept and design analysis, computer aided engineering and stress analysis, prototyping, tooling design, and manufacturing scale-up. Since many applications re-

Table 4. PC/ABS Cost of Production Economics, 1986
(10 Million Pounds per Year, U.S. Gulf Coast)

Capital summary	\$ million	
Inside battery limits	2.9	
Outside battery limits	0.7	
Total fixed investment	3.6	
Working capital	1.3	
Total investment	4.9	
	Market*	Transfer**
Cost of production	(¢/lb)	(¢/lb)
Raw materials		
ABS (@ 89¢/lb)	22.3	13.0
Polycarbonate (@ 145¢/lb)	108.7	65.3
Others	1.7	1.7
Total raw materials	132.7	80.0
Utilities	0.6	0.6
Operating costs	5.0	5.0
Overhead expenses	5.2	5.2
By-product credit	0	0
Cash cost of production	143.5	90.8
Depreciation	6.5	6.5
Net cost of production	150.0	97.3
Return @ 20% on investment	9.7	9.7
Cost plus 20% return	159.7	107.0
Market price	135.0	135.0
List price	146.0	146.0

*ABS at market price of 89¢/lb. PC at market price of 145¢/lb.

**ABS at transfer price of 52¢/lb. PC at transfer price of 87¢/lb.

Table 5. Alloy and Blend Programs of Several U.S. Suppliers

Amoco PSO/ABS PSO/Polyester Nylon/Polyarylate	Celanese PBT/PET Nylon/Elastomer PBT/Elastomer Polyester/Polyarylate Acetal/Elastomer	DuPont Nylon/Elastomer PET/Elastomer Acetal/Elastomer PBT/PET Nylon/Polyolefin Polyarylate/Polyester	ICI PEEK/PES
ARCO SMA/PC	Dow PC/ABS	General Electric PPO/PS PC/ASA PPO/Nylon PPO/Polyester PC/Polyester PBT/PET PVC/ASA	Mobay PC/ABS PBT/PET PC/Polyester PC/Polyester PC/TPU
Borg-Warner PPE/PS ABS/PC ABS/Nylon PPE/Nylon			Monsanto ABS/Nylon

quires material approval not only by the end user, but also by government, private, and trade regulatory bodies, suppliers also often assist in satisfying these requirements through development of polymer, and sometimes end product, performance data.

Since application requirements may not be well represented by standard material test data, it is incumbent on the blend supplier to simulate end-use tests and environments to ensure the end user of the viability of the polymeric material. Pin insertion in a connector is not well described by tensile strength or flexural modulus, just as dart impact strength is not representative of a polymeric bat hitting a baseball, for example. Thus, the material supplier may develop specific tests to simulate conditions encountered in product use and work with the end user to refine alloy or blend performance to meet these requirements.

Despite successful alloy and blend commercialization, suppliers are continually developing new alloy and blend products. Development of alloys and blends is a dynamic arena in which interpolymers substitution is a continued threat. Longevity of alloys and blends in specific applications appears to be somewhat shorter than with traditional polymers, largely, we believe, as a result of intense competition for the same target markets. Successful suppliers are following a pattern of product development, commercialization, and immediate new product development to provide consumers with state-of-the-art products and to forestall replacement with competitors' alloys and blends.

Commercial Significance of Alloys and Blends

Alloying and blending of polymers is not new. In 1986, engineering polymer alloys and blends, for example, represented nearly 300 million pounds of commercial sales in the United States. Chem Systems estimates that by 1995, U.S. consumption of engineering alloys and blends will reach approximately 700 million pounds. Alloy and blend demand growth will outstrip that for engineering base polymers by nearly two to one and will average at least 9 percent annually. Modified polyphenylene oxide and ether alloys enjoy the largest demand, but have begun to lose market share to other polymers and blends (e.g., ABS/PC) in a number of cost reduction programs.

Alloys and blends represent inexpensive routes to satisfy both end-user material requirements and suppliers' desires for competitive product differentiation. The high level of alloy and blend development activity is apparent from the list of products already commercially available, as described in Table 5. Polymer alloys and blends are well positioned for significant demand growth through the end of the century. As suppliers and consumers more fully understand the dynamics of alloy and blend development, including the necessity for rapid and continued grade modifications and detailed knowledge of end product performance requirements, product development times may be shortened and manufacturing competitiveness enhanced through the use of polymer blends and alloys.

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Engineering Resins
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Chicago, IL 60601

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TORLON 4203L

General Information:

TORLON engineering polymers are composites of polyamide-imide polymers alloyed with fluorocarbon polymers and reinforced with fillers to produce a family of high performance, high temperature molding resins. Products molded using TORLON have reliable performance at high temperature, and under high stress.

Product Information:

TORLON 4203L is formulated with ½% fluorocarbon and 3% TiO₂ as reinforcement. This molding resin has the best impact resistance and the most elongation for the TORLON family of resins. The resin's natural lubricity provides excellent release from the mold.

TORLON 4203 L has excellent electrical properties and molded products include parts for switches, relays, and other electrical products. The natural lubricity and excellent wear characteristics of TORLON 4203L moldings are important in such products as thrust washers, mechanical linkages, bushings, bearings, rollers, cams, and valve components. The high temperature performance is essential for thermal insulators and other applications in high temperature service.

Product Data:

TORLON 4203L

Property	ASTM Test Method	English Units	
Mechanical			
Tensile strength — 321°F 73°F 275°F 450°F	D1708	10 ³ psi	31.5 27.8 16.9 9.5
Tensile elongation — 321°F 73°F 275°F 450°F	D1708	%	6 15 21 22

(continued)

NOTE—Information provided in this book has been condensed. The publisher recommends that the product manufacturer be contacted, at the address or phone number provided, for more complete information on product safety, processing parameters, and applications not provided in this information sheet.

TORLON 4203L (continued)

Property	ASTM Test Method	English Units	
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Mechanical

Tensile modulus 73°F	D1708	10 ⁵ psi	7.0
Flexural strength – 321°F 73°F 275°F 450°F	D790	10 ³ psi	41.0 34.9 24.8 17.1
Flexural modulus – 321°F 73°F 275°F 450°F	D790	10 ⁵ psi	11.4 7.3 5.6 5.2
Compressive strength	D695	10 ³ psi	32.1
Compressive modulus	D695	10 ⁵ psi	
Shear strength 73°F	D732	10 ³ psi	18.5
Izod impact strength (1/8 in) notched unnotched	D256	ft-lb/in	2.7 20.0
Poisson's ratio			0.45

Thermal

Deflection temperature 264 psi	D648	°F	532
Coefficient of linear thermal expansion	D696	10 ⁻⁶ in/in·°F	17
Thermal conductivity	C177	Btu·in/hr·ft ² ·°F	1.8
Flammability Underwriters Laboratories			94 V-O
Limiting oxygen index	D2863	%	45

Electrical

Dielectric constant 10 ³ Hz 10 ⁵ Hz	D150		4.2 3.9
Dissipation factor 10 ³ Hz 10 ⁵ Hz	D150		0.026 0.031
Volume resistivity	D257	ohm·in	8 × 10 ¹⁶
Surface resistivity	D257	ohm	5 × 10 ¹⁵
Dielectric strength (0.40 in)	D149	V/mil	580

(continued)

TORLON 4203L (continued)

Property	ASTM Test Method	English Units	
General			
Density	D792	lb/in ³	0.050
Hardness, Rockwell E	D785		86
Water absorption	D570	%	0.33

TORLON 4203L

Property	ASTM Test Method	Metric Units	
Mechanical			
Tensile strength –196°C 23°C 135°C 232°C	D1708	N/mm ²	218 192 117 66
Tensile elongation –196°C 23°C 135°C 232°C	D1708	%	6 15 21 22
Tensile modulus 23°C	D1708	10 ³ N/mm ²	4.9
Flexural strength –196°C 23°C 135°C 232°C	D790	N/mm ²	287 244 174 120
Flexural modulus –196°C 23°C 135°C 232°C	D790	10 ³ N/mm ²	7.9 5.0 3.9 3.6
Compressive strength	D695	N/mm ²	220
Compressive modulus	D695	10 ³ N/mm ²	4.0
Shear strength 23°C	D732	N/mm ²	128
Izod impact strength (3.2 mm) notched unnotched	D256	J/m	142 1062
Poisson's ratio			0.45

(continued)

TORLON 4203L (continued)

Property	ASTM Test Method	Metric Units	
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Thermal

Deflection temperature 1.82 N/mm ²	D648	°C	278
Coefficient of linear thermal expansion	D696	μ·m/m·K	30.6
Thermal conductivity	C177	W/m·K	0.26
Flammability Underwriters Laboratories			94 V-O
Limiting oxygen index	D2863	%	45

Electrical

Dielectric constant 10 ³ Hz 10 ⁵ Hz	D150		4.2 3.9
Dissipation factor 10 ³ Hz 10 ⁵ Hz	D150		0.026 0.031
Volume resistivity	D257	ohm·m	2 × 10 ¹⁶
Surface resistivity	D257	ohm	5 × 10 ¹⁵
Dielectric strength (1.02 mm)	D149	kV/mm	23.6

General

Density	D792	g/cm ³	1.38
Hardness, Rockwell E	D785		86
Water absorption	D570	%	0.33

Amoco Chemicals Corp.

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Phone: 1 (800) 621-4557

TORLON 4275

General Information:

TORLON engineering polymers are composites of polyamide-imide polymers alloyed with fluorocarbon polymers and reinforced with fillers to produce a family of high performance, high temperature molding resins. Products molded using TORLON have reliable performance at high temperature, and under high stress.

Product Information:

TORLON 4275 has a polyamide-imide binder modified with 3 % fluorocarbon and 20 % graphite binder. Similar to TORLON 4301, the molded resin has better wear resistance at higher speeds. Applications include bearings, thrust washers, wear pads, guide strips, piston rings, seals, valve seats, etc.

Product Data:

TORLON 4275

Property	ASTM Test Method	English Units	
Mechanical			
Tensile strength	D1708	10 ³ psi	
– 321 °F			18.8
73 °F			22.0
275 °F			16.3
450 °F			8.1
Tensile elongation	D1708	%	
– 321 °F			3
73 °F			7
275 °F			15
450 °F			17
Tensile modulus	D1708	10 ⁵ psi	
73 °F			11.3

(continued)

NOTE—Information provided in this book has been condensed. The publisher recommends that the product manufacturer be contacted, at the address or phone number provided, for more complete information on product safety, processing parameters, and applications not provided in this information sheet.

TORLON 4275 (continued)

Property	ASTM Test Method	English Units	
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Mechanical

Flexural strength – 321°F 73°F 275°F 450°F	D790	10 ³ psi	29.0 30.2 22.4 15.8
Flexural modulus – 321°F 73°F 275°F 450°F	D790	10 ⁵ psi	13.9 10.6 8.1 7.4
Compressive strength	D695	10 ³ psi	17.8
Compressive modulus	D695	10 ⁵ psi	5.8
Shear strength 73°F	D732	10 ³ psi	11.1
Izod impact strength (1/8 in) notched unnotched	D256	ft-lb/in	1.6 4.7
Poisson's ratio			0.39

Thermal

Deflection temperature 264 psi	D648	°F	536
Coefficient of linear thermal expansion	D696	10 ⁻⁶ in/in·°F	14
Thermal conductivity	C177	Btu·in/hr·ft ² °F	
Flammability Underwriters Laboratories			94 V-O
Limiting oxygen index	D2863	%	45

Electrical

Dielectric constant 10 ³ Hz 10 ⁵ Hz	D150		7.3 6.6
Dissipation factor 10 ³ Hz 10 ⁵ Hz	D150		0.059 0.063
Volume resistivity	D257	ohm·in	3 × 10 ¹⁵
Surface resistivity	D257	ohm	4 × 10 ¹⁷
Dielectric strength (0.40 in)	D149	V/mil	

(continued)