MILLATHANE®

Millable Polyurethane Rubber

Engineering Properties

Table of Contents

Millathane® Key Properties

TSE Industries has been working with millable polyurethanes since 1962. We are the world's largest manufacturer of a complete line of millable polyurethane rubber called Millathane. It possesses a combination of physical properties not found in natural or other synthetic rubbers and makes a significant contribution to the high performance rubber market.

Key properties of Millathane that is demanded by high performance applications:

- OUTSTANDING ABRASION RESISTANCE
- EXCELLENT OIL, OXYGEN, OZONE RESISTANCE
- LOW TEMP FLEXIBILITY, WITHSTANDS TEMP UP TO 120°
- DYNAMIC LOAD BEARING ABILITY
- EXCELLENT RESISTANCE TO COMPRESSION SET
- EXCELLENT RESISTANCE TO GAS PERMEABILITY

Peroxide-cured compounds, especially polyester polyurethane grades, have good heat and compression-set resistance, being able to withstand continuous temperatures up to 100°C and intermittent temperatures up to 120°C. Sulfur-cured compounds generally have higher strength properties, including abrasion resistance, versus peroxide cures. Isocyanate-cured compounds have outstanding tensile and tear strength and abrasion resistance in higher hardness compounds (75-99 Shore A to 65 Shore D).

Polyester types of polyurethane rubber feature excellent resistance to oil and moderate temperatures. Polyester urethanes are also better in sliding abrasion resistance. Polyether types are more hydrolytically stable and are resistant to impingement abrasion due to their high resilience.

Applications

Millathane millable polyurethane rubber is used in many industrial markets such as business machines, automotive, textile, and footwear. Typical high-performance applications include roller coverings, belts, o-rings, gaskets, diaphragms, seals, vibration isolators, bumpers, impellers, shoe soles, and hose tubes and covers.

Some of the applications that take advantage of the broad design potential of Millathane millable urethanes are solid tires, rubber covered rollers, bushings, bearings, suction cups, medical devices, diaphragms, gaskets, tester pads, athletic footwear, belting, military dust covers, airplane deicing bladders, and shock absorbing bumpers.

Millathane Millable Polyurethane Grades

TSE produces Millathane millable urethanes in both polyester and polyether grades. Polyether grades have better water and hydrolysis resistance than polyester grades, while polyester grades have better compression-set, heat, and oil resistance than polyether grades.

Most Millathane grades are available in a range of viscosities and are available as dense bales or Premilled sheets. Premilled polyester grades contain 1.5 phr of polycarbodiimide hydrolysis stabilizer. All grades are peroxide curable. Sulfur curable grades include Millathane E34, E40, CM, 55, and 76.

	Key Properties	Typical Applications
Millathane 26	Compliance with FDA regulation 21CFR177.2600	Rollers, belting, and molded parts. Food and non-food handling applications.
Millathane 55	Lower viscosity and higher hardness vs. Millathane E34	Rollers and molded parts.
Millathane 97	Transparency and high abrasion resistance	Transparent shoe soles and shoe components. Brightly colored parts.
Millathane CM	Excellent strength and low-temperature properties	Military and aerospace parts requiring excellent strength and low-temperature resistance
Millathane E34	Abrasion and hydrolysis resistance	Rubber covered rollers for paper and printing industries, footwear
Millathane E40	Outstanding low-temperature properties	Military and aerospace parts requiring the optimum in low-temperature properties
Millathane 66R	Excellent heat, oil, compression-set resistance	Seals, gaskets, belts, and rollers needing optimum heat and compression-set resistance
Millathane 76	Excellent oil and abrasion resistance	Rollers, O-rings, gaskets, suction cups, vibration isolators, wheels
Millathane 5004	Oil and solvent resistance	Suction cups, diaphragms, rollers for printing and paper handling
Millathane UV	A UV-curing technology that can be used with Millathane polymers. This technology provides a low-temperature curing system that can be useful for continuously-cured extrusions, calendared sheets, and molded products. Uses UV light to achieve cured properties similar to peroxide systems.	

Thanecure® Grades

TSE produces two Thanecure products that are used for vulcanization of millable urethane rubbers.

Thanecure ZM	Thanecure T9SF
Cure activator/accelerator for sulfur-cured millable polyurethanes, typically used at a 1 part level.	Dimerized TDI used as a vulcanization agent for isocyanate-cured millable urethanes, typically along with HQEE and accelerator. Also used as an adhesion promoter for rubber to textile bonding.

Choosing the Right Millathane® Millable Polyurethane

The chart below shows a comparison of the properties of the available grades of Millathane, including a comparison of sulfur and peroxide-cured compounds for those Millathane grades that are both. For Millathane 26, a comparison is made for compounds that are peroxide and isocyanate-cured (Thanecure® T9SF/HQEE). The ratings are approximate, and may be different for different formulations of different hardnesses and properties.

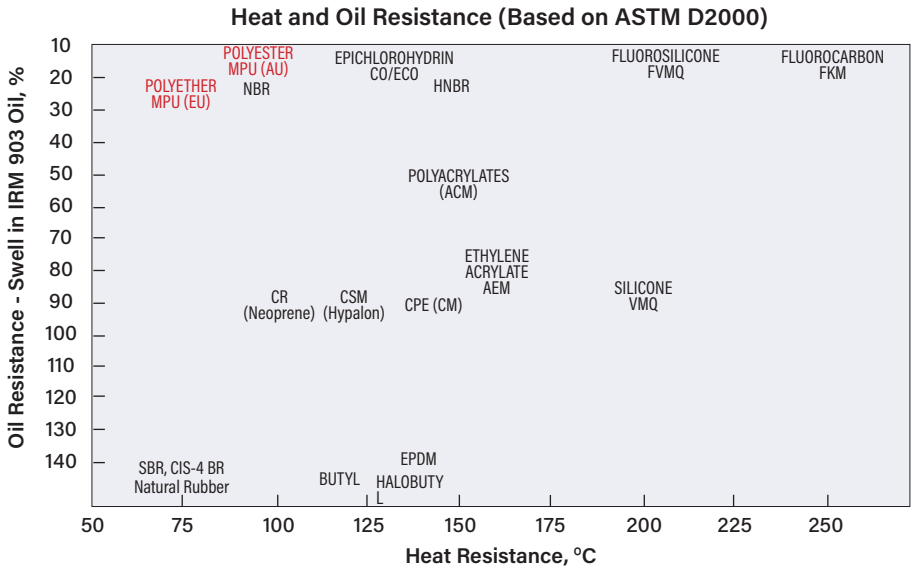
Millathane Grade	**66**	**76**		**5004**	**26**		**55**		**97**	**CM**		**E34**		**E40**	
Polyurethane Type	**Polyester**				**Polyether**										
Curing *(P=Peroxide, S=Sulfur, I=Isocyanate)*	P	S	P	P	P	I	S	P	P	S	P	S	P	S	P
Physical Properties[1]															
Tensile Strength	++	++	+	+	+	++	++	+	+	++	+	++	+	++	+
Rebound Resilience	+	O	O	+	++	++	++	++	++	++	++	++	++	++	++
Abrasion Resistance	+	+	+	+	+	++	++	+	+	++	+	++	+	++	+
Tear Resistance	+	++	+	++	+	++	+	+	+	++	+	+	+	+	+
Mechanical Properties (High Hardness)	+	+	+	+	+	++	++	O	+	+	+	+	O	+	O
Mechanical Properties (Low Hardness)	O	++	+	+	+	—	+	O	+	+	+	+	+	+	+
Compression Set at 70°C	++	O	++	+	+	O	O	+	+	O	+	O	+	O	+
Compression Set at 100°C	++	O	++	+	+	—	O	+	O	O	+	O	+	O	+
Heat Resistance	++	O	+	++	O	O	O	+	O	O	+	O	+	O	+
Low Temperature Performance	++	O	O	+	+	+	O	O	+	++	++	O	O	++	++
Gas Impermeability	+	+	+	++	+	+	+	+	+	+	+	+	+	+	+
Transparency (Cured Articles)	O	—	O	O	O	—	—	O	++	—	—	—	O	—	O
Hydrolysis (Water) Resistance[2]	O[2]	O[2]	O[2]	O[2]	++	+	++	++	++	++	++	++	++	++	++
Oil Resistance	++	++	++	++	+	+	+	+	+	+	+	+	+	+	+
Diesel/Biodiesel Resistance	++	++	++	++	O	O	+	+	O	+	+	+	+	+	+
Gasoline Resistance	++	++	++	++	—	—	—	—	—	—	—	—	—	—	—
Gasohol (Gasoline/Ethanol 90/10)	+	+	+	+	—	—	—	—	—	—	—	—	—	—	—
FDA Use (177.2600 Compliant)	—	—	—	—	++	—	—	—	—	—	—	—	—	—	—
Processing															
Compression Molding	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Transfer Molding	++	+	++	++	++	—	++	++	++	++	++	++	++	++	++
Injection Molding	++	+	++	++	++	—	+	++	++	+	++	+	++	+	++
Extrusion[3]	++	+	+	+	+	—	++	++	++	+	+	++	++	++	++
Steam Vulcanization[4]	O	O	O	O	+	—	++	+	+	++	+	++	+	++	+
Hot Air Vulcanization[5]	O	++	O	O	+	—	++	+	+	++	+	++	+	++	+

++ = Excellent, + = Good, o = Fair, — = N/A or insufficient data

[1]Relative properties (to other Millathane polymers/compounds).
[2]The hydrolysis resistance of polyester urethanes can be significantly improved by the addition of carbodiimide hydrolysis stabilizers. Premilled grades contain 1.5 phr of Millstab™ P, a polymeric carbodiimide hydrolysis stabilizer.
[3]For extrusion roll building or preforms only (Note: Millathane UV can be extruded and continuously cured with UV Curing lamps).
[4]Compound must be completely protected from direct steam contact.
[5]Peroxide cured compounds can be cured in hot air (with pressure) if protected from air/oxygen contact.

ASTM D2000 Chart

A common way to compare different rubber types is by their heat-aging and oil-resistant properties. Based upon ASTM D2000 requirements, the chart below shows Millathane having very good oil resistance, similar to NBR and HNBR, and moderate heat resistance (up to 100ºC - 125ºC), similar to that of neoprene and NBR rubbers.



Hardness

Millathane millable urethanes can be compounded to make products in the hardness range of 30 to 99 Shore A and up to 65 Shore D durometer, although most useful products are in the range of 50 to 80 Shore A durometer.

Tensile and Tear Strength

Values as high as 51 MPa (7500 psi) tensile strength and 157 kN/m (900 lb/in) tear strength are obtainable, with isocyanate cures giving the highest properties. Products with properties lower than these values also perform excellently as well. Mechanical parts made from rubber are rarely used close to their ultimate breaking strength, typically within 20% elongation or compression.

Strength at High Temperatures

Good retention of properties at high temperatures is important for applications such as seals, gaskets, and belting that see elevated temperatures during use. Urethane rubber compounds are not known for their high temperature resistance, as they tend to soften significantly at temperature over 150ºC (302ºF). Compounds can have very good retention of properties at moderate temperatures, even better than polymers such as HNBR.

Physical Properties			Millathane 5004		HNBR	
Test at 23ºC	Hardness, Shore A	TSE-100*, MPa	75	5.2	73	3.7
Test at 52ºC	TSE-100*, MPa	% Change	4.3	-16	2.8	-24
Test at 107ºC	TSE-100*, MPa	% Change	4.1	-21	2.7	-28
Test at 135ºC	TSE-100*, MPa	% Change	3.9	-25	2.6	-30

**TSE-100 = Tensile Stress (Modulus) at 100% Elongation*

Low Temperature Properties

As a general rule, Millathane® Millable urethanes have good low temperature properties. Compounds based upon polyether grades having brittle points down to as low as -68ºC (-90ºF), and compounds based upon polyester grades down to as low as -60ºC (-76ºC). Low temperature flexibility is important for applications such as airplane deicing bladders, automotive parts, and hose for cold temperature use.

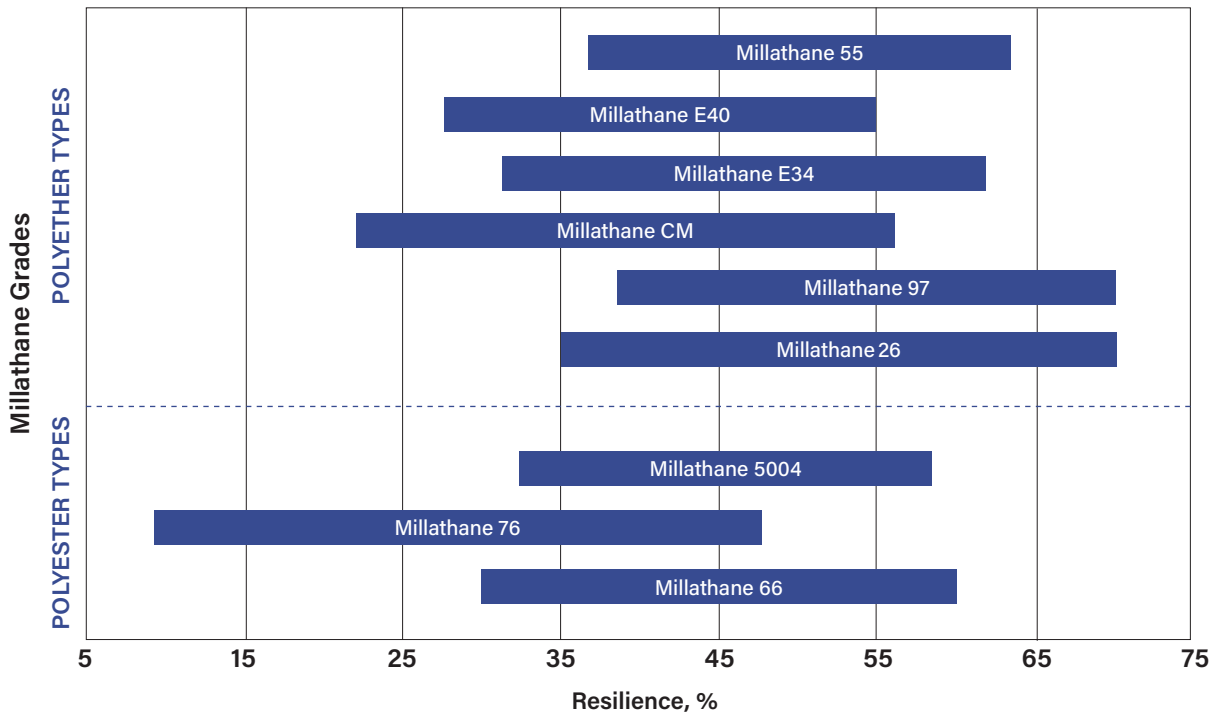
Some grades of both polyether and polyester millable urethanes can stiffen considerably at low temperatures due to crystallization of the polymer. (See Crystallization, page 8.) Grades that are the most resistant to low temperature hardening are the polyether grades Millathane CM and E40 and the polyester grade Millathane 66.

Resilience/Damping

Resilience is a measure of the rebound characteristics of rubber. Bashore Resilience, tested per ASTM D2632, is a convenient resilience test. The test is run by dropping a plunger of specific mass and geometry from a set height onto the surface of the test sample. The ratio of the distance the plunger rebounds to the distance the plunger traveled before impact is the Bashore Resilience, expressed as a percentage.

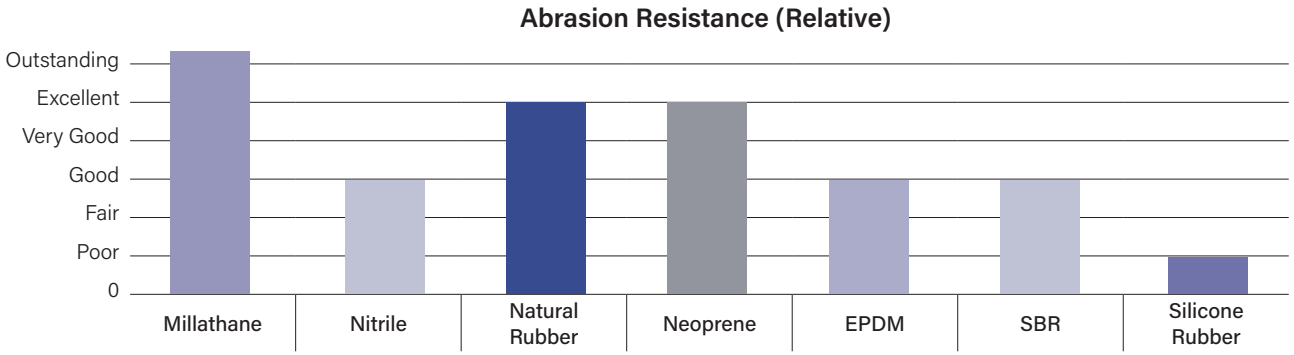
Millathane millable urethanes can have resilience (rebound) values varying from below 10%, as seen with some Millathane 76 compounds, to over 60%, as seen with several polyether grades. Low resilience compounds generally have excellent vibration damping characteristics and are used in instrument packaging and other vibration damping applications. High resilience compounds tend to have lower heat build-up in dynamic applications such as rubber covered rollers. Generally, resilience will be higher with low filler loadings than with higher filler loadings. Peroxide cures will tend to give higher resilience than sulfur cures. Based on different Millathane grades, the chart below show the range of resilience values that compounds can achieve.

Bashore Resilience (Rebound) of Millathane Compounds
Range of Various Compounds (Varying Hardnesses)



Abrasion Resistance

Abrasion resistance is the ability of a surface to resist wearing due to contact with another surface moving with respect to it. High resistance to abrasion is important in applications like rollers, belting, and helicopter dust covers. The DIN Abrasion Test (ASTM D5963) is one of the most common tests for measuring abrasion resistance. It's where a rotating cylindrical sample is passed across a rotating drum of abrasive and the amount of sample volume lost is measured. Typical abrasion resistance values for Millathane millable urethane compounds is 50-80 mm^3. Some compounds can have abrasion resistance values as low as 25 mm^3, depending on the polymer, cure system, and formulation. Polyurethane rubber provides the highest abrasion resistance of any rubber, synthetic or natural. Laboratory tests do not always predict the advantage of Millathane compounds over other rubbers, but field experience often shows a tremendous improvement in product lifetime when millable urethane replaces a conventional rubber.

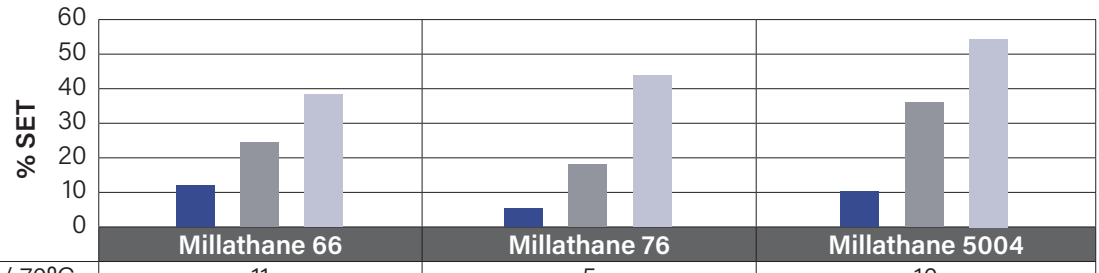


Compression Set

Compression set is the resistance to permanent deformation after the application of a load or deformation for a specific time and temperature. A typical test method is ASTM D395 Method B, where a 1" diameter x 0.5" high sample is compressed 25%, and then placed into an oven for the time and temperature specified. Upon removal from the oven and fixture, the sample is allowed to relax for 30 minutes and the amount of permanent set is measured.

Peroxide-cured Millathanes have very good compression-set characteristics at temperatures up to 125°C, with the set increasing as the temperature increases (as is typical for all rubbers). The chart below compares the compression set of three polyester Millathane grades at 70°C, 100°C, and 125°C. Even lower compression sets can be achieved with compounds, with Millathane 66 giving the best (lowest) set at elevated temperatures (See Heat Aging, pg 11). Generally, polyester urethanes will have improved compression set compared to polyether grades. Peroxide-cured millable urethane compounds will have much better (lower) compression set compared with sulfur-cured compounds, especially when coagents are included along with the peroxides.

Compression Set Peroxide Cured Polyester Grade Millathane, Black Reinforced Compounds (ASTM D395 Method B)



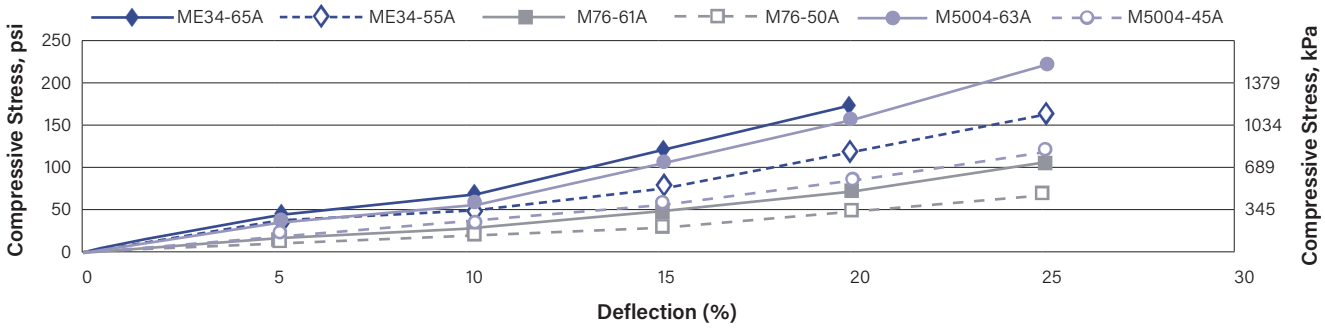
	Millathane 66	Millathane 76	Millathane 5004
22 hr / 70°C	11	5	10
22 hr / 100°C	24	18	36
22 hr / 125°C	39	43	53

Compression Deflection

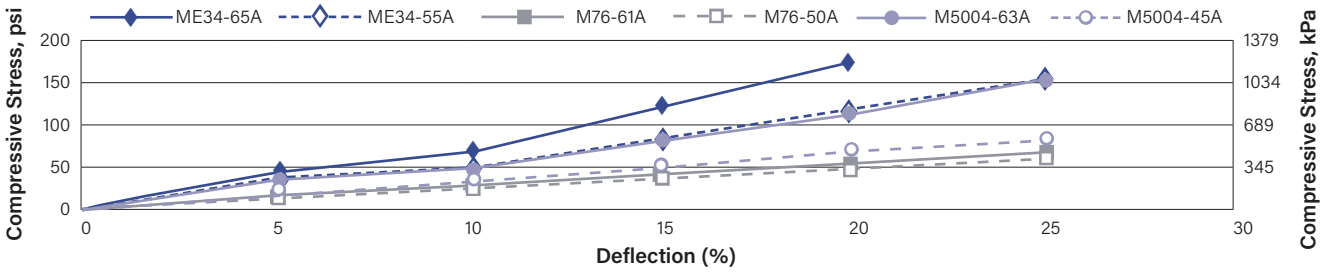
Three different carbon black reinforced Millathane® millable polyurethane compounds (76, E34, and 5004) were tested for compression deflection per ASTM D575 Method A. The Millathane 76 and E34 compounds were sulfur cured, and the Millathane 5004 compounds were peroxide cured. Two hardnesses of each compound were tested. The samples had a shape factor of 0.5 (cylinders 1 inch (25.4 mm) in diameter and 0.5 inch (12.7 mm high). Compression deflection was tested at 23ºC (room temperature), 50ºC, and 70ºC.

The data shows the softer compounds having lower compression deflection curves than harder compounds. When comparing the compounds at similar hardnesses, Millathane 76 shows the lowest compression deflection values, while the Millathane E34 and 5004 compounds had somewhat similar compression deflection. The compression deflection results at **higher temperatures** show the expected trend of less stress required to deflect the samples, as shown in the 70ºC data for all compounds and the 63 Shore A Millathane 5004 compound data for all temperatures.

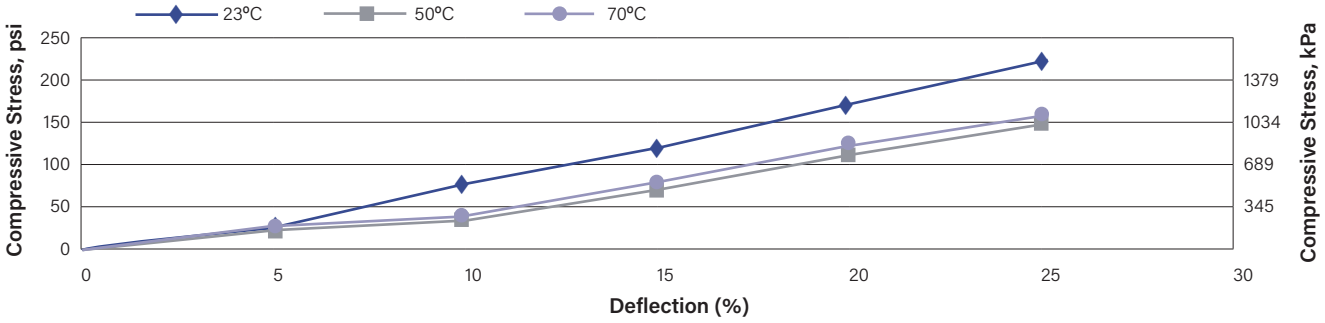
Compression Deflection at Room Temperature 23ºC (Millathane E34, 76, 5004 Compounds)



Compression Deflection at 70ºC (Millathane E34, 76, 5004 Compounds)



Compression Deflection at 23ºC, 50ºC, and 70ºC (Millathane 5004-63A Peroxide-Cured Compound)



Chemical Resistance

Generally, urethanes have very good resistance to oils and fuels but poor resistance to chlorinated hydrocarbons and ketones. Urethanes are not known for their resistance to acids and bases, and they are somewhat affected by water, especially at elevated temperatures. Polyester urethanes are especially affected by these materials as they can undergo hydrolysis where the polymer is degraded. Stabilizers can protect polyester urethanes from hydrolysis to a limited, but non-permanent, extent. Below is a chart of the resistance of a Millathane 76 test compound (black reinforced, sulfur cured) to various chemicals, showing the percent volume swell after immersion for one week at room temperature or as otherwise noted.

Volume Swell of Millathane 76 in Various Chemicals			
Acids	**%**	**Hydrocarbons**	**%**
Hydrochloric Acid, 10%	4	ASTM Fuel B	16
Nitric Acid, 10%	25	ASTM Oil #1	1
Phosphoric Acid, 10%	5	ASTM Oil #1, 70 hr/100°C	-2
Sulfuric Acid, 10%	3	ASTM Oil #3	1
		ASTM Oil #3, 70 hr/100°C	-2
Alcohols	**%**	Benzene	100
Butyl Alcohol	16	Gasoline	9
Ethyl Alcohol	19	Petroleum, Crude, 70 hr/100°C	2
		Toluene	59
Alkali	**%**	Wax, Petroleum, 70 hr/100°C	-5
Sodium Hydroxide, 10%	2	Xylene	36
Esters	**%**	**Ketones**	**%**
Cellosolve Acetate	302	Acetone	126
Ethyl Acetate	104	Methyl Ethyl Ketone (MEK)	119
Halogenated Hydrocarbons	**%**	**Other Materials**	**%**
Carbon Tetrachloride	33	Hydraulic Fluid (Skydrol)	59
Tetrachloroethylene	21	Linseed Oil	4
Trichloroethylene	121	Water	5

Crystallization

Millable urethanes can undergo crystallization when stored for long periods at room temperature or for shorter periods when stored below room temperature. Polymers that are crystallized become hard and milky in color compared to the usual softer, transparent, or translucent material.

The quality of the Millathane millable polyurethane rubber is not adversely affected by crystallization. It is completely reversible by warming at 70° - 100°C (158° - 212°F) until the polymer returns to its original color.

It is important to note that mixing crystallized or partially crystallized rubber can damage equipment or result in poor polymer dispersion.

Millathane E34

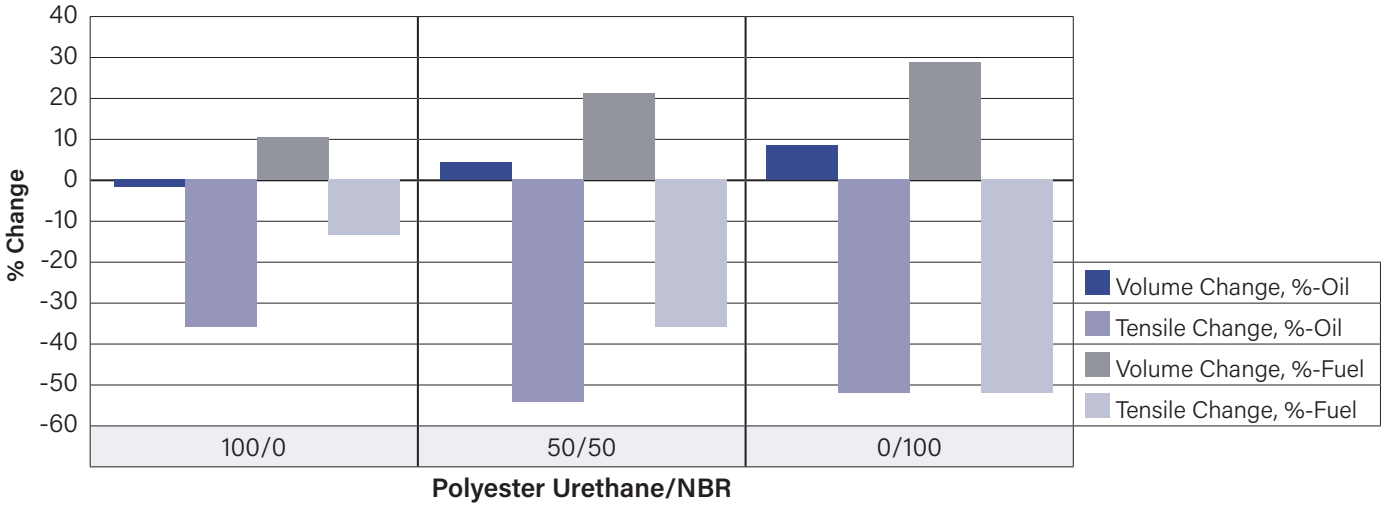
Normal Crystallized

Oil, Fuel, and Solvent Resistance

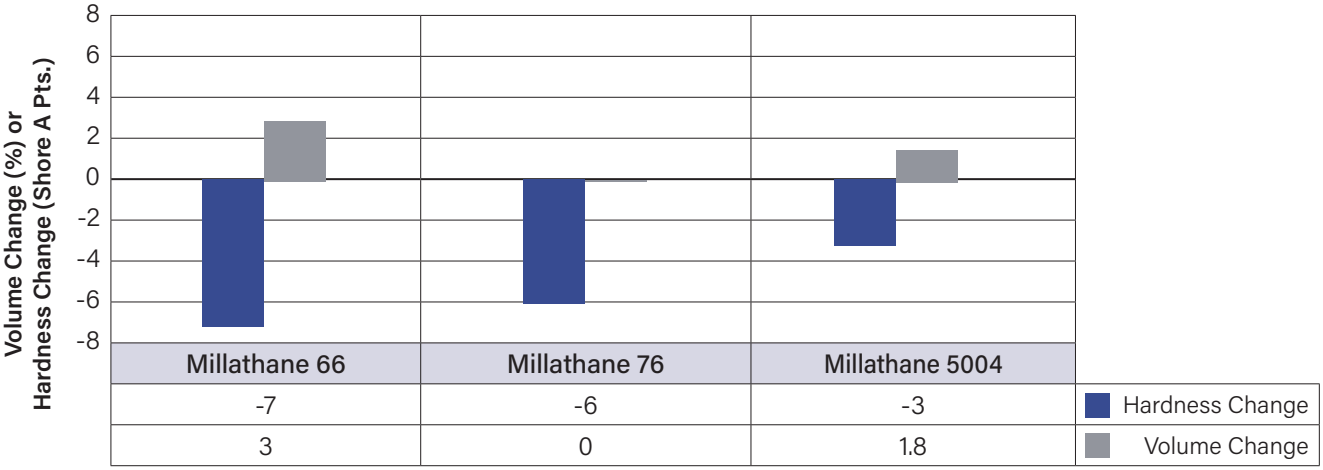
Millable polyurethanes generally have excellent oil resistance, similar to that of a medium ACN nitrile (NBR) or HNBR rubbers. Solvent and fuel (gasoline or gasohol) resistance is also similar, and in some cases better, compared to a medium ACN nitrile rubber. The chart below shows a Millathane® polyester urethane to have better resistance (less change in volume and tensile strength) to oil and Fuel B than a medium ACN nitrile compound. IRM 903 is a test oil which is similar to lubricating oil that has an aniline point of 70ºC. Fuel B is 70:30 mixture of isooctane and toluene.

Polyester grades will have significantly better resistance to oil and solvents than polyether grades. Polyester grades should be chosen for applications requiring optimum resistance to these materials, such as printing rollers and seals. The chart below compares four polyester Millathane grades for their resistance to IRM 903 Oil. All of the compounds showed minor hardness and volume changes after the elevated temperature oil exposure. Millathane 5004 and 76 had the lowest volume changes, and Millathane 5004 had the least change in hardness.

Immersions: IRM 903 Oil (70 hr/100ºC) and Fuel B (7 d/23ºC)
Polyester Urethane vs. Medium ACN NBR (and 50/50 Blend)



Immersions: IRM 903 Oil Immersion Test (70 hr/100ºC)
Black Reinforced, Peroxide Cured Polyester Millathane® Grades



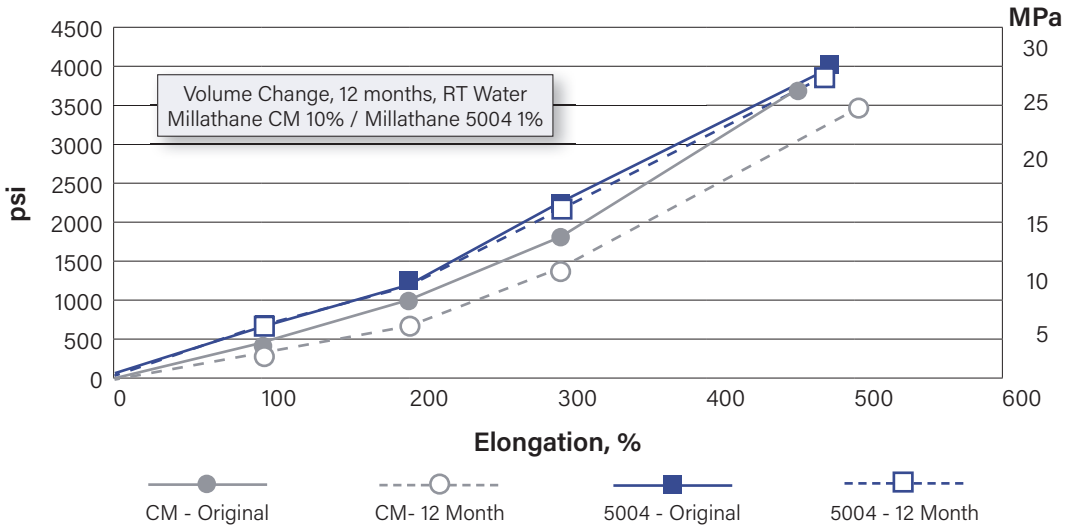
Water and Humidity Resistance

Polyether millable urethanes have good water and humidity resistance and are recommended for applications where long-term hydrolysis resistance is important. Polyester urethanes are much less resistant to hydrolysis but can achieve excellent temporary hydrolysis resistance with the addition of carbodiimide hydrolysis stabilizers and the level and duration of the protection proportional to the amount of Millstab™ P stabilizer in the formulation.

An example of the excellent hydrolysis resistance of the polyether millable urethane Millathane CM and the polyester millable urethane Millathane 5004 (with 5 parts of Millstab P) is shown in the chart below. After one year continuous water immersion, both compounds had minimal changes in properties.

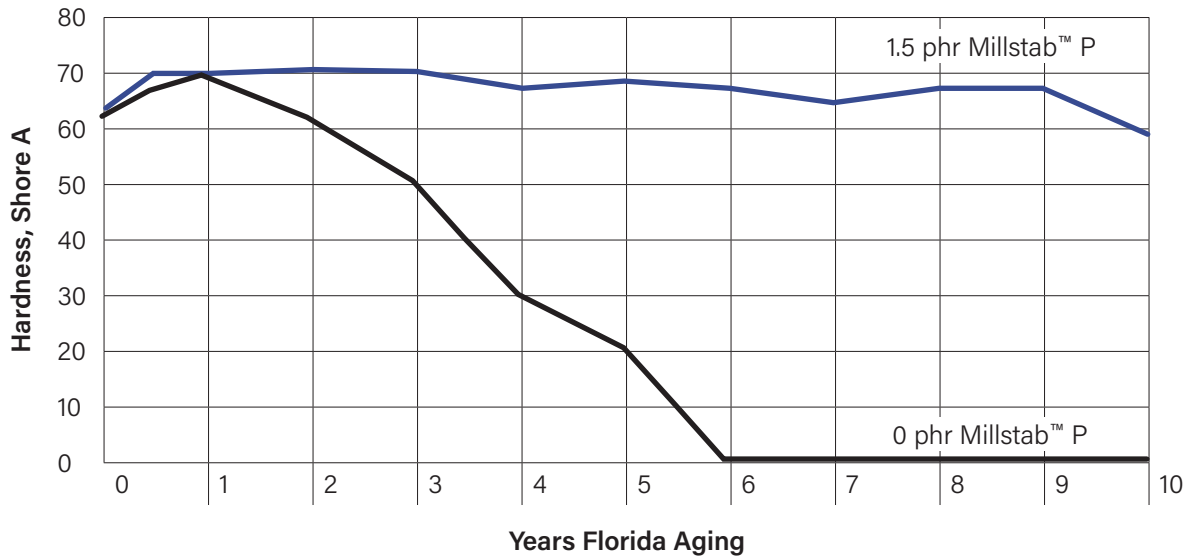
Water Aging, Room Temp, 0-12 Months

Millathane 5004 (Black, Peroxide Cure, 70 Shore A) / Millathane CM (Black, Sulfur Cure, 70 Shore A)



The chart below shows the benefit of 1.5 phr Millstab P to the Florida aging of a Millathane 5004 compound. The compound with Millstab P didn't soften at all, while the compound without Millstab P softened considerably at 3+ years, and fell apart after 5 years.

Millstab™ P in Millathane 5004 Florida (Tampa Region) Heat & Humidity Aging



Heat Resistance

Millable polyurethane rubber is not known for its high-heat resistance, typically being used at temperatures less than 100ºC. Polyester grades of Millathane® have significantly better heat resistance than polyether grades, and peroxide cures will have better heat resistance than sulfur cures. For applications that need non-continuous exposure to temperatures up to 150ºC, peroxide-cured polyester millable urethanes such as Millathane 66 and 5004 can have very good utility because of their excellent retention of properties.

The table below shows the excellent heat resistance of a black reinforced, peroxide-cured Millathane 66 compound. The physical properties tested showed no hardness change and minor changes in tensile strength and elongation for heat agings conducted from 70ºC to 150ºC. Compression set showed excellent results up to 140ºC; the high value of set at 150ºC would make it unsuitable for applications at this temperature.

Heat Aging Conditions						
	Original	70 hr/70ºC	70 hr/100ºC	70 hr/125ºC	70 hr/140ºC	70 hr/150ºC
Hardness, Shore A	88	88	88	88	88	88
Points Change	—	0	0	0	0	0
Tensile Strength, psi (MPa)	3550 (24.5)	3920 (27.0)	4120 (28.4)	2370 (16.3)	2750 (19.0)	3190 (22.0)
% Change	—	10	16	-33	-23	-10
Elongation, %	155	165	170	90	100	150
% Change	—	6	10	-42	-35	-3
Compression Set Conditions						
		22 hr/70ºC	22 hr/100ºC	22 hr/125ºC	22 hr/140ºC	22 hr/150ºC
Compression Set, %		4	5	22	35	74

Millathane 66 Premilled contains 1.5 parts of the hydrolysis stabilizer Millstab™ P, which is a polymeric carbodiimide. This is beneficial primarily to hydrolysis resistance but also benefits heat aging and compression-set resistance.

Ozone and Weather Resistance

Millathane millable urethanes have excellent ozone resistance due to the saturated backbone of the urethane polymer. Black compounds will have excellent resistance to the effects of UV light. Light colored or transparent compounds like Millathane 97 can also have excellent UV resistance and resistance to yellowing with the addition of antidegradants such as antioxidants, ultraviolet absorbers (UVA) and Hindered Amine Light Stabilizers (HALS). The table below shows the minimal effect on properties of one year Florida exposure on three Millathane compounds.

		Millathane CM		**Millathane 5004***		**Millathane 97**	
Compound Reinforcement		Carbon Black		Carbon Black		Fumed Silica	
Compound Color		Black		Black		Clear/Transparent	
Original Properties							
Hardness, Shore A		70		70		72	
TSE-100** psi	MPa	405	2.8	460	3.2	317	2.2
Tensile Strength, psi	MPa	3820	26.3	4100	28.3	3905	26.9
Elongation, %		480		495		560	
Tear, Die C, lb/in	kN/m	269	47.1	284	49.7	219	38.4
Properties after 1 year outdoor Florida exposure (unstressed samples)							
Hardness, Shore A		75		68		66	
TSE-100** psi	MPa	695	4.8	530	3.7	310	2.1
Tensile Strength, psi	MPa	365	25.2	3200	22.1	2600	17.9
Elongation, %		335		490		475	
Tear, Die C, lb/in	kN/m	211	36.9	30	52.9	190	33.3
Surface Appearance		**No Signs of Cracking or Crazing**					

**Contains 5 parts Millstab P, a carbodiimide hydrolysis stabilizer* ***TSE-100 = Tensile Stress at 100% elongation*

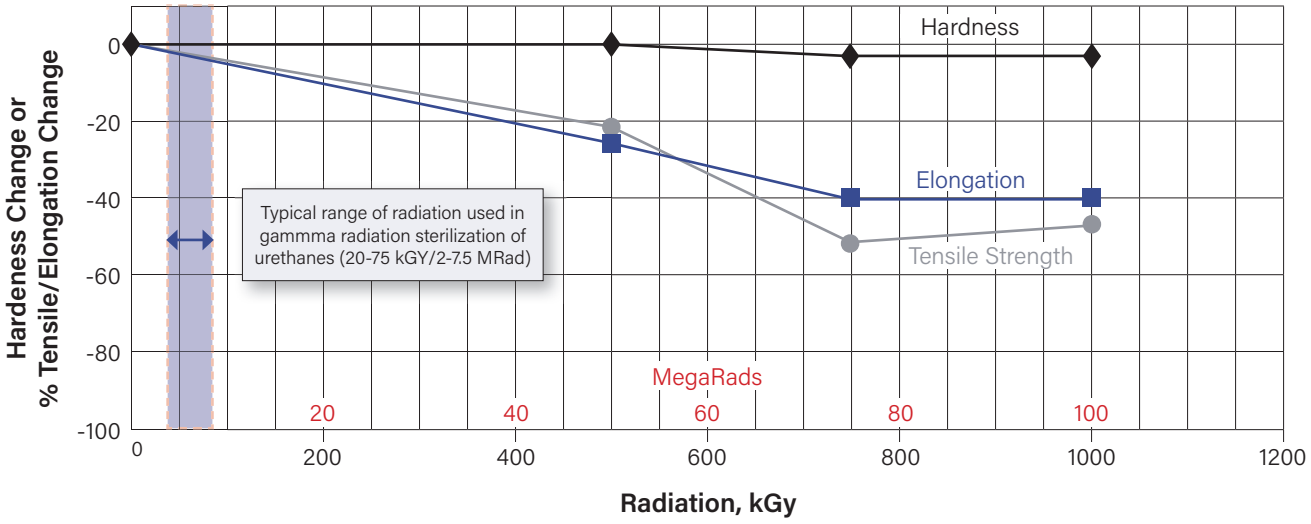
Flame Retardence

Millathane millable urethanes are not inherently resistant to burning but can be compounded with flame-retardant additives to improve fire resistance, similar to other rubbers. Compounds containing antimony oxide with halogenated materials have been tested and comply with UL94 V-0 requirements. Halogen-free, flame-retardant compounds can be prepared by using high levels of alumina trihydrate and/or magnesium hydroxide in the compound.

Radiation and Sterilization Resistance

Millathane millable polyurethanes generally provide good resistance to gamma ray radiation compared with other elastomers. In the typical range of radiation used for gamma ray sterilization of medical products (up to 75 kGy), a sulfur-cured Millathane CM compound showed negligible changes in properties as shown in the chart below. Even at relatively large doses of 1000 kGy (100 Megarads), the Millathane CM compound still retained its good properties and would give satisfactory service. Peroxide-cured compounds are somewhat less resistant to radiation than sulfur-cured compounds.

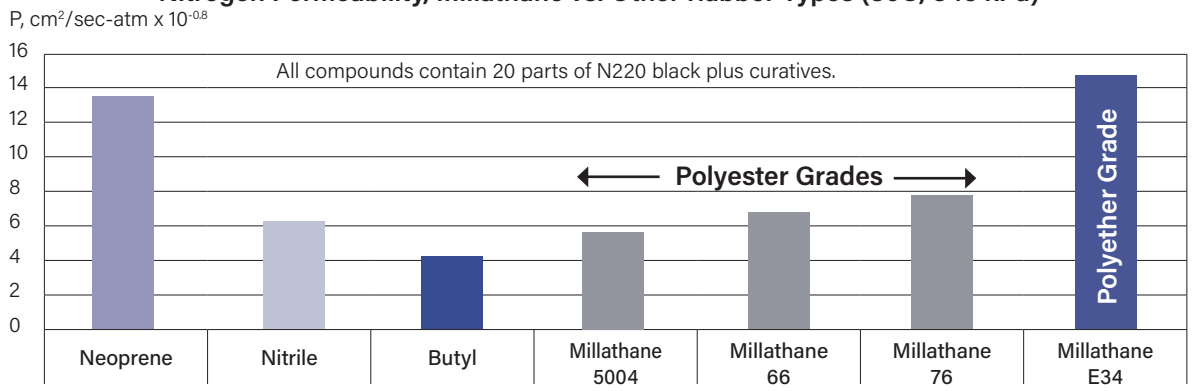
Gamma Radiation Effect on Millathane CM (Sulfur-Cured)



Gas Permeability

Millathane millable urethanes have very good resistance to gas permeability, with polyester grades approaching that of butyl rubber. A comparison of the nitrogen permeability of several Millathane grades vs. neoprene (CR), nitrile (NBR) and butyl (IIR) rubber is shown in the chart below. Polyester millable urethanes have very low gas permeability, comparable to or slightly better than nitrile rubber and slightly defensive to butyl rubber. Millathane E34, a polyether polyurethane, had higher (poorer) nitrogen permeability, similar to that of neoprene rubber.

Nitrogen Permeability, Millathane vs. Other Rubber Types (80C, 345 kPa)



Mold Shrinkage

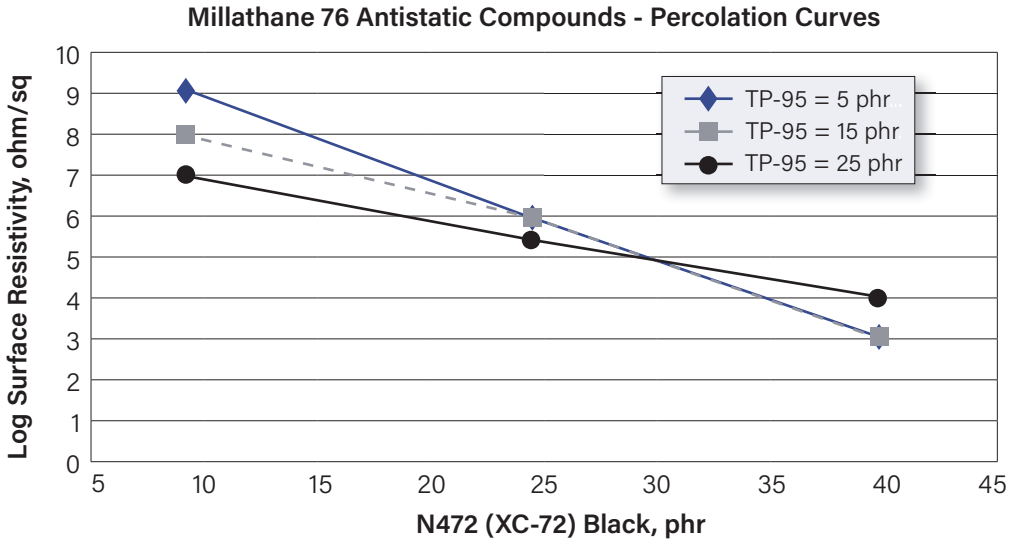
Mold shrinkage for Millathane® millable urethane compounds is generally between 2.2 and 2.5%. Gum compounds and those with low filler loadings may have slightly higher mold shrinkage. Those with relatively high filler loadings may have slightly lower mold shrinkage. Peroxide cures generally give slightly lower mold shrinkages than sulfur cures.

Electrical Properties

Millable urethanes are not typically used for electrical applications due to the relatively poor electrical properties of the polar urethane polymers. Below is a comparison of insulation-type compounds based upon Millathane CM, natural rubber, and neoprene.

	Resistivity, ohm-cm	Specific Inductive Capacity at 1000 cps	Power Factor at 100 cps
Natural Rubber	10^{15}	2.5	0.005
Neoprene	10^{12}	6.7	0.025
Millathane CM	10^{10}	10.2	0.080

Millathane compounds can be formulated to be antistatic or semi-conductive by the addition of conductive carbon. Antistatic compounds are important for static dissipative rollers and belting, typically for use in business machines where paper products are conveyed. Sulfur-cured Millathane 76 compounds, which varied in conductive black from 10 to 40 parts and plasticizer from 5 to 25 parts, had electrical resistivity values from 10^8 down to 10^3, as seen below.



Colorability

As with other types of rubber, peroxide-cured compounds will give brighter colors and better color retention than sulfur-cured ones. This is due to the discoloration (yellowing) that is associated with sulfur cures, especially with higher temperature cures. For the best color compounds, we recommend the peroxide-cured Millathane 97 polyether compound with small amounts of antioxidant and UV stabilizers. This grade was developed for transparent applications such as athletic shoe soles. With proper compounding, it can produce clear or brightly colored parts.

Recyclability

Cured products of Millathane millable urethanes can be ground to a fine powder via cryogenic techniques and added back into the same compound at low levels with minimal effect on properties.

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