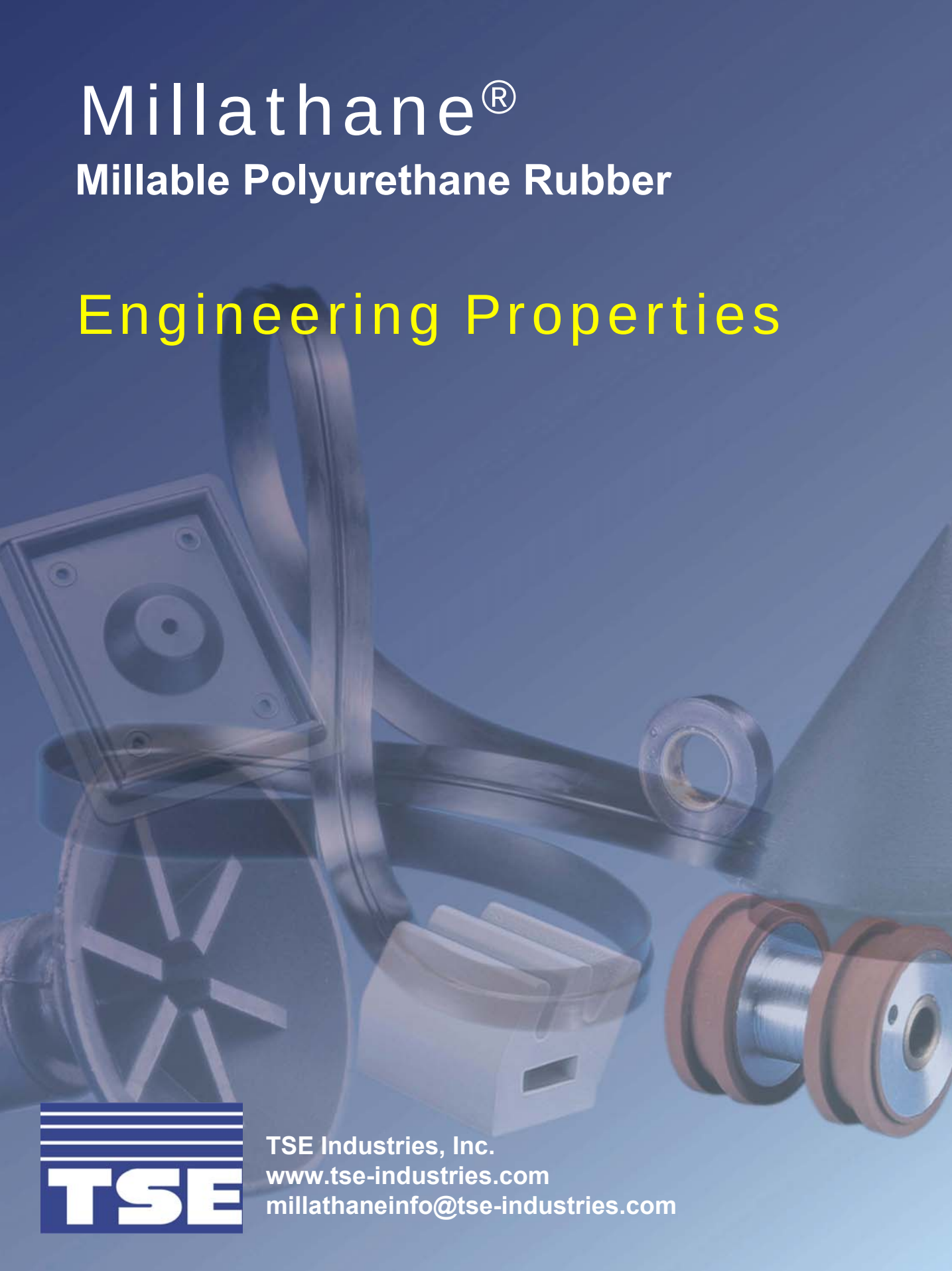
Millathane®

Millable Polyurethane Rubber

Engineering Properties



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Millathane® Millable Polyurethane

Engineering Properties Bulletin

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Millathane® Engineering Properties Bulletin

Millathane® Key Properties and Applications

TSE Industries Inc. has been working with millable polyurethanes since 1962 and is 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.

The key properties of a polyurethane rubber demanded by high performance applications include:

- abrasion resistance
- high strength properties
- low temperature flexibility
- ozone resistance
- load bearing ability
- outstanding oil resistance
- resistance to nitrogen permeability

Peroxide cured compounds, especially of polyester polyurethane grades, have good heat and compression set resistance, being able to withstand continuous temperatures up to 100ºC and intermittent temperatures up to 120º C. Sulfur cured compounds generally have higher strength properties, including abrasion resistance, versus peroxide cures. Isocyanate cured compounds have outstanding strength (tensile and tear) 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.

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

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 heat, oil and compression set 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 are Millathane E34, E40, CM, 55, 76 and HT.

	Key Properties	Typical applications
Polyether grades		
Millathane 26	Compliance with FDA regulation 21CFR177.2600	Rollers, belting and molded parts, for 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, and 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
Polyester grades		
Millathane 66	Excellent heat, oil and compression set resistance	Seals, gaskets, belts, 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 HT	Excellent frictional and low temperature properties	Belts, rollers, gaskets requiring excellent frictional characteristics
Millathane UV		
Polyether and polyester grades of Millathane UV can be used for continuously cured extrusions and calendered rubber, and also molded products, with compounds cured under UV curing lamps.		

Thanecure® Grades

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

Thanecure ZM	Thanecure ZM is a cure activator/accelerator for sulfur cured millable polyurethanes, typically used at a 1 part level.
Thanecure T9SF	Thanecure T9SF is dimerized TDI and is used as a vulcanization agent for isocyanate cured millable urethanes, typically along with HQEE and accelerator.

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 sulfur and peroxide curable. For Millathane 26, a comparison is made for compounds that are peroxide and isocyanate (Thanecure® T9SF/HQEE) cured.

The ratings are approximate, and may be different for different formulations of different hardnesses and properties.

Millathane® Grade	66	76		5004	HT		26		55		97	CM		E34		E40	
Type of Polyurethane	Polyester						Polyether										
Curing (P=Peroxide, S=Sulfur, I=Isocyanate)	P	S	P	P	S	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	+	++	+	++	+	o	+	++	+	+	+	++	+	+	+	+	+
Mechanical properties at high hardness	+	+	+	+	o	o	+	++	++	o	+	+	+	+	o	+	o
Mechanical properties at low hardness	o	++	+	+	+	o	+	—	+	+	o	+	+	+	+	+	+
Compression set -- at 70ºC	++	o	++	+	+	++	+	o	o	+	+	o	+	o	+	o	+
-- at 100ºC	++	o	++	+	+	+	+	—	o	+	o	o	+	o	+	o	+
Heat resistance	++	o	+	++	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]	o[2]	o[2]	++	+	++	++	++	++	++	++	++	++	++
Oil resistance	++	++	++	++	+	+	+	+	+	+	+	+	+	+	+	+	+
Diesel/biodiesel resistance	++	++	++	++	+	+	o	o	+	+	o	+	+	+	+	+	+
Gasoline resistance	++	++	++	++	+	+	—	—	—	—	—	—	—	—	—	—	—
Gasohol (gasoline/ethanol 90/10)	+	+	+	+	o	o	—	—	—	—	—	—	—	—	—	—	—
FDA applications (compliance w/177.2600)	—	—	—	—	—	—	++	—	—	—	—	—	—	—	—	—	—
Processing																	
Compression molding	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Transfer molding	++	+	++	++	++	++	++	—	++	++	++	++	++	++	++	++	++
Injection molding	++	+	++	++	+	++	++	—	+	++	++	+	++	+	++	+	++
Extrusion[3]	++	+	+	+	+	+	+	—	++	++	++	+	+	++	++	++	++
Steam vulcanization[4]	o	o	o	o	o	o	+	—	++	+	+	++	+	++	+	++	+
Hot air vulcanization[5]	o	++	o	o	+	o	+	—	++	+	+	++	+	++	+	++	+

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

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[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.

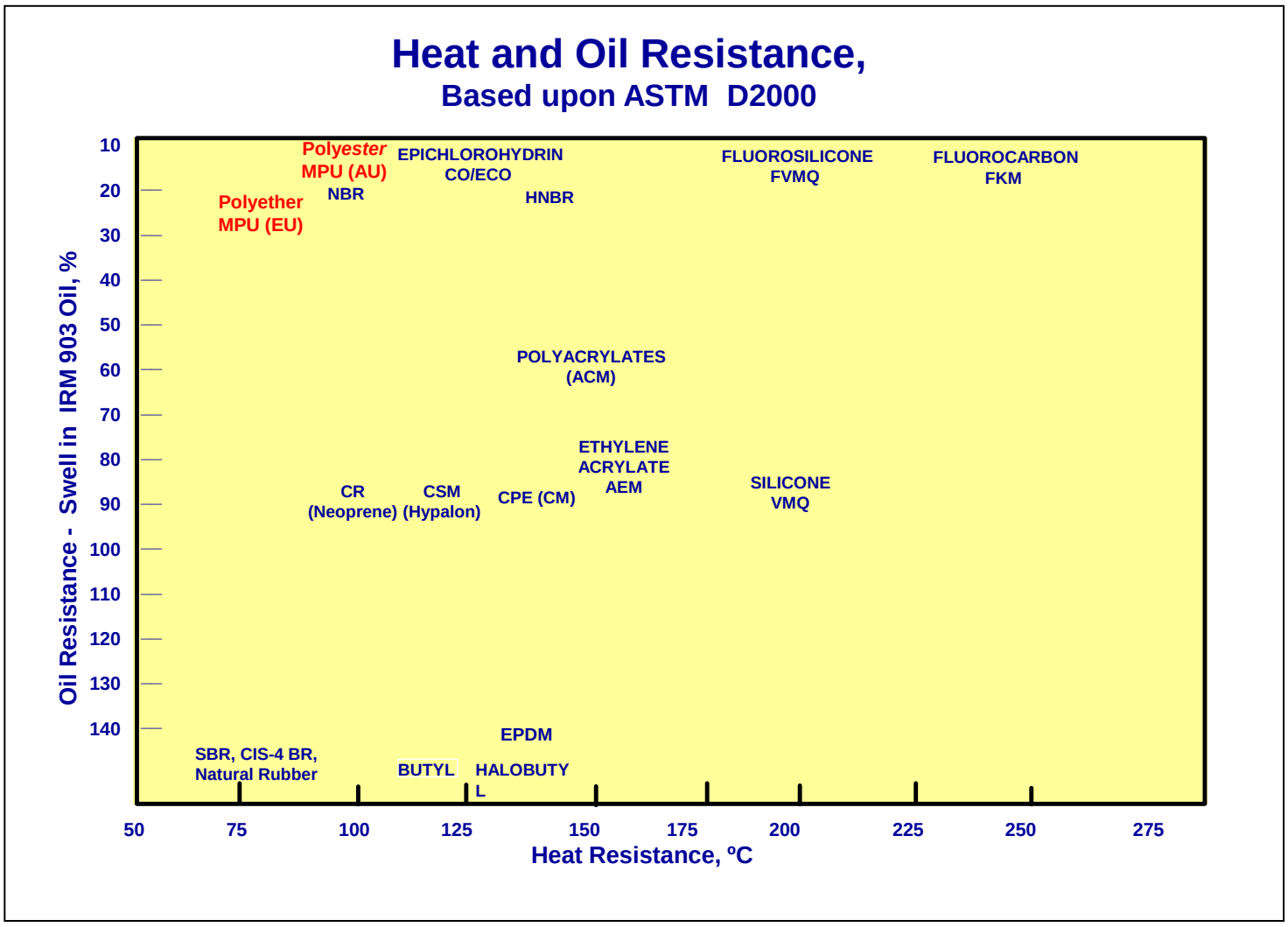
[3]For extrusion roll building or preforms only (Note: Millathane UV can be extruded and continuously cured with UV Curing lamps)

[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 resistance properties. The chart below, based upon ASTM D2000 requirements, shows that Millathane® millable urethanes have 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.



Millathane® Millable Polyurethane Rubber
Mechanical Properties

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 Strength 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 Millathane millable urethanes (isocyanate cures giving the highest properties), although products with properties lower than these values also perform excellently. 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). At moderate temperatures, compounds can have very good retention of properties, even better than polymers such as HNBR as shown in the following table.

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

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

Low Temperature Properties

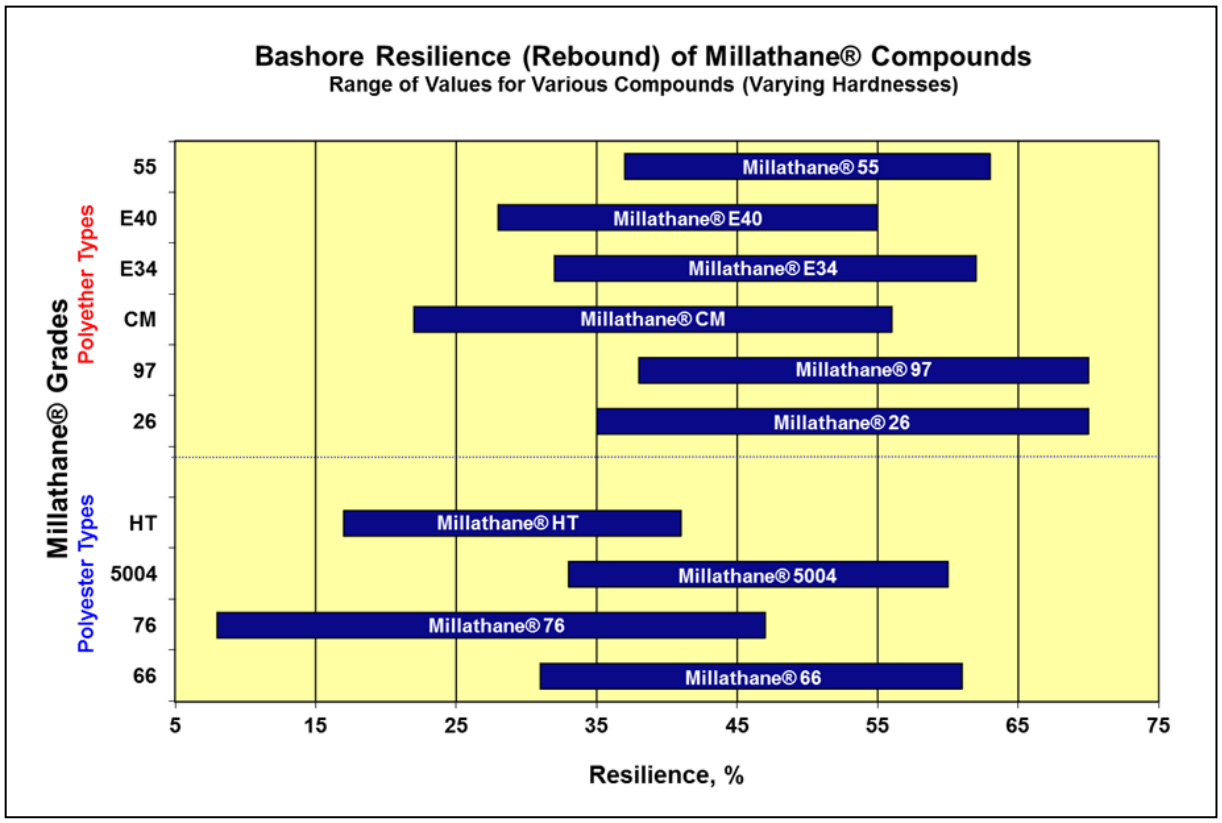
Millable urethanes, as a general category, have good low temperature properties, with compounds based upon polyether grades having brittle points down to as low as -68ºC (-90ºF) and compounds based upon polyester grades down to as low as -60ºC (-76ºC). Low temperature flexibility is important for applications 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. Millathane grades that are the most resistant to low temperature hardening are the polyether grades Millathane CM and Millathane E40 and the polyester grades Millathane HT and Millathane 66.

Resilience/Damping

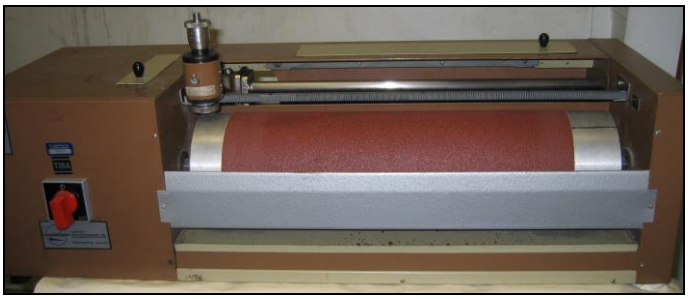
Resilience is a measure of the rebound characteristics of rubber. Bashore Resilience, tested per ASTM D2632, is a convenient test for measuring resilience. The test is run by dropping a plunger of specific mass and geometry from a set height onto the surface of the test sample. The ration of the distance 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 of Millathane millable urethanes. 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, and peroxide cures will tend to give higher resilience than sulfur cures. A chart showing the range of resilience values that compounds, based upon different Millathane grades, can achieve is shown below.

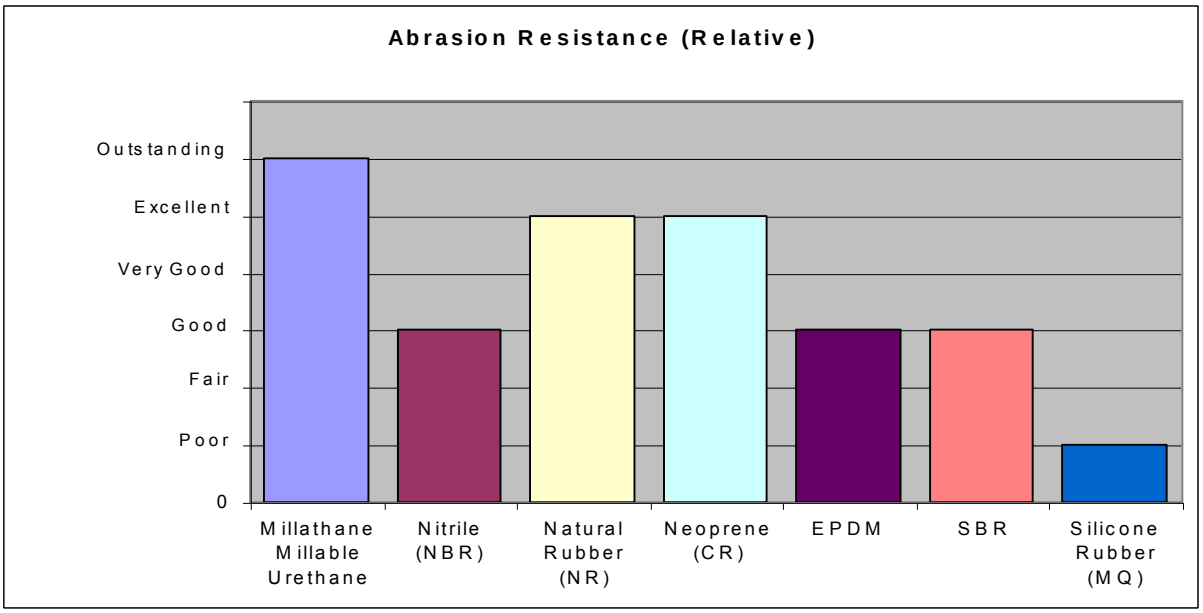


Abrasion Resistance

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 such as rollers, belting and helicopter dust covers. One of the most common tests for measuring abrasion resistance is the DIN Abrasion Test (ASTM D5963), 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 quality Millathane millable urethane compounds is 50-80 mm^3, although 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 Millathane millable urethane replaces a conventional rubber. A ranking of Millathane millable urethane vs. several other conventional rubbers is shown below:

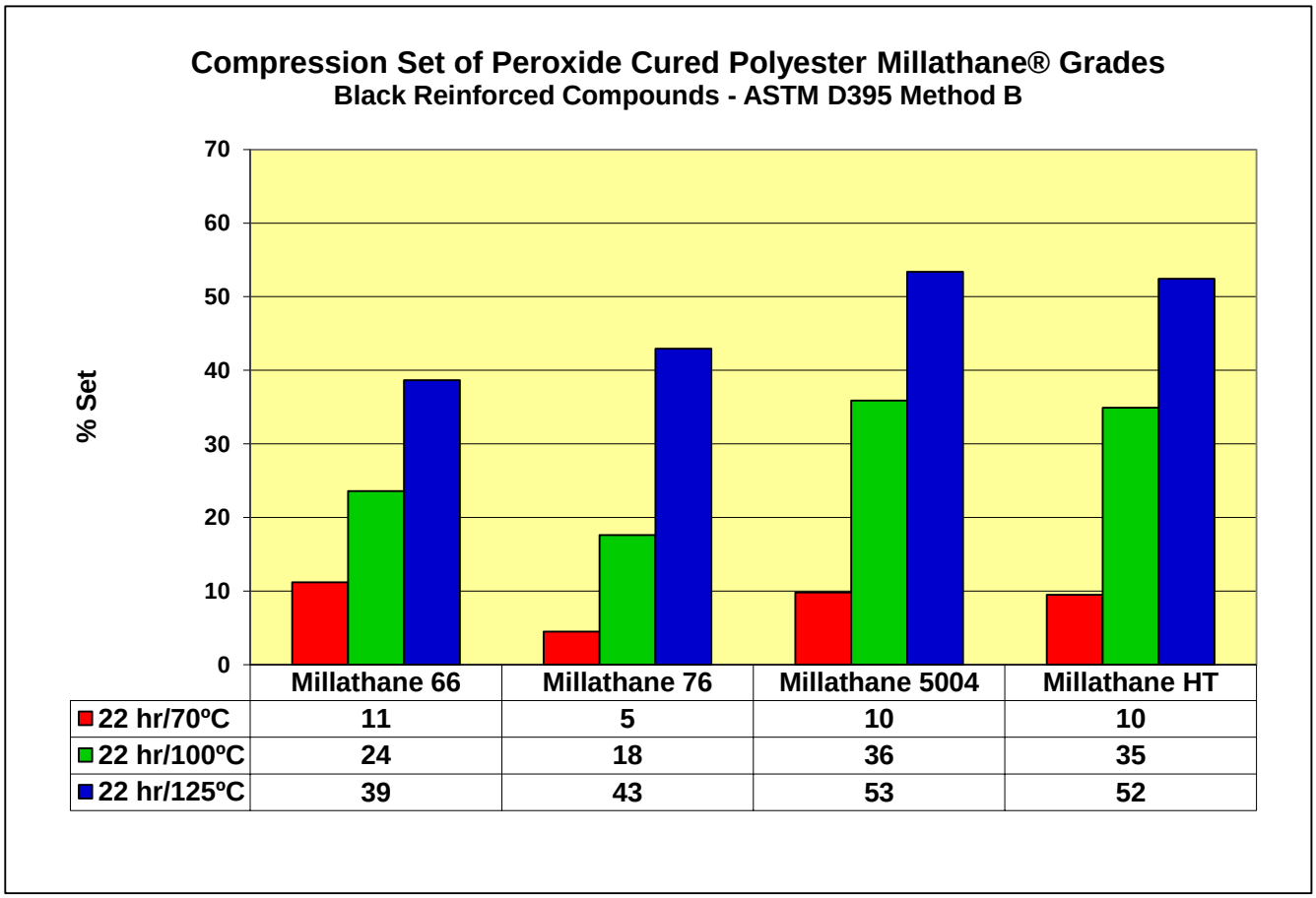


Compression Set

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.

Good resistance to compression set is an important property for applications such as rollers, o-rings and seals. Millathane millable urethanes, when peroxide cured, have very good compression set characteristics at temperatures up to 125ºC, with the set increasing as the temperature increases (as is typical for all rubbers). The chart below compares the compression set of four polyester Millathane grades at 70ºC, 100ºC and 125ºC. As seen in the data on Page 15, even lower compression sets can be achieved with Millathane compounds, with Millathane 66 generally giving the best (lowest) set at elevated temperatures.

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.



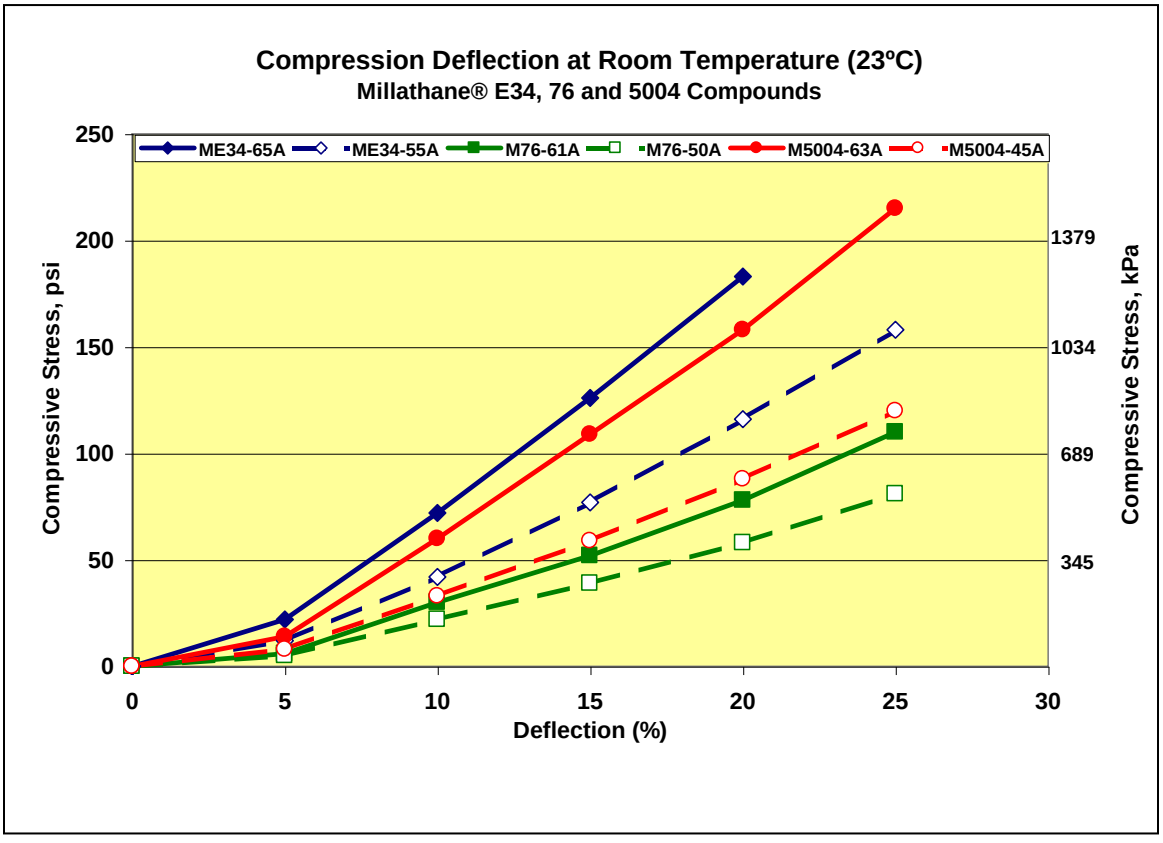
	Millathane 66	Millathane 76	Millathane 5004	Millathane HT
22 hr/70ºC	11	5	10	10
22 hr/100ºC	24	18	36	35
22 hr/125ºC	39	43	53	52

Compression/Deflection

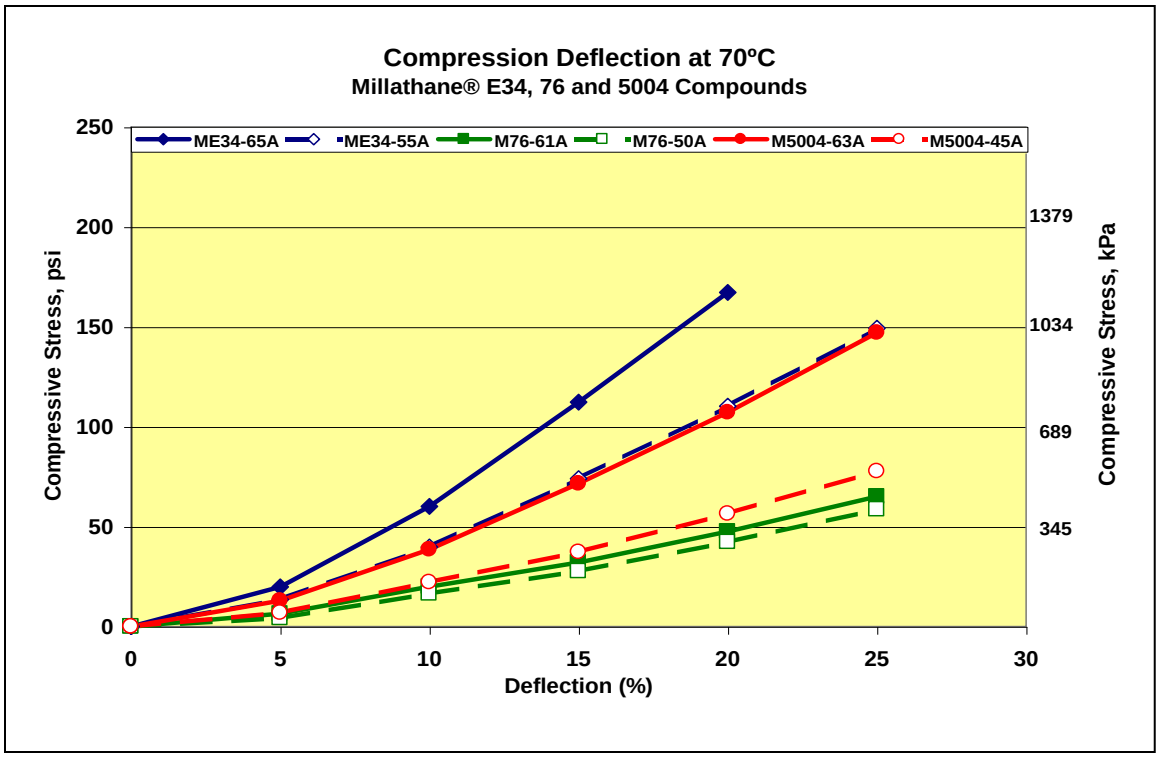
Several carbon black reinforced Millathane® millable polyurethane compounds, based upon three different polymers (Millathane® 76, Millathane E34 and Millathane 5004) were tested for compression deflection per ASTM D575 Method A. The Millathane 76 and E34 compounds were sulfur cured, while the Millathane 5004 compounds were peroxide cured, and there were two hardnesses of each compound 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 room temperature (23ºC), 50ºC and 70ºC.

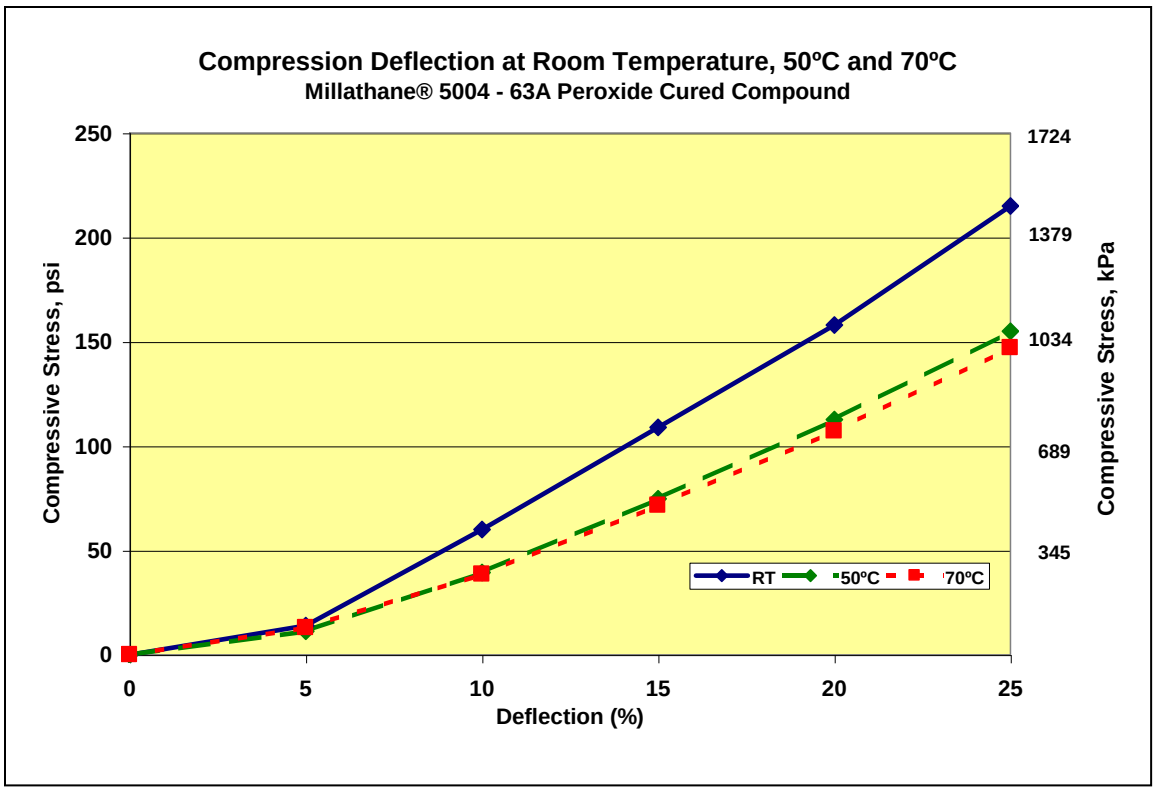
The data, plotted in the charts below and on the next page, show the softer compounds having lower compression deflection curves than harder compounds. Also, the Millathane 76 compounds show the lowest compression deflection values, while the Millathane E34 and Millathane 5004 compounds had somewhat similar compression deflection, when comparing the compounds at similar hardnesses.

The compression deflection results at **higher temperatures** show the expected trend of less stress required to deflect the samples. This is shown in the plotted 70ºC data for all compounds and the 63 Shore A Millathane 5004 compound data for all temperatures.



Compression/Deflection (continued)





Chemical Resistance

Urethanes generally 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

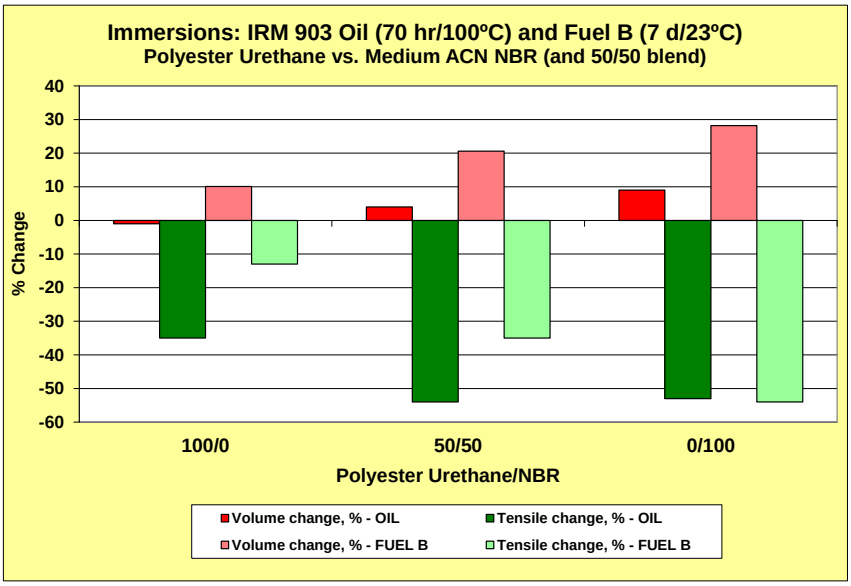
ACIDS	**%**
Hydrochloric acid, 10%	4
Nitric acid, 10%	25
Phosphoric acid, 10%	5
Sulfuric acid, 10%	3
ALCOHOLS	
Butyl alcohol	16
Ethyl alcohol	19
ALKALI	
Sodium hydroxide, 10%	2
ESTERS	
Cellosolve Acetate	302
Ethyl Acetate	104
HALOGENATED HYDROCARBONS	
Carbon tetrachloride	33
Tetrachloroethylene	21
Trichloroethylene	121

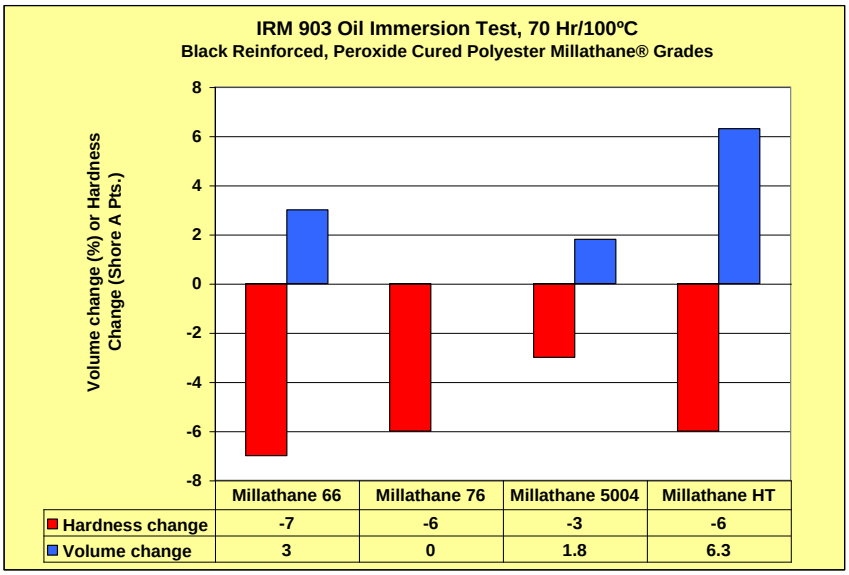
HYDROCARBONS	**%**
ASTM fuel B	16
ASTM oil #1	1
ASTM oil #1, 70 hr/100°C	-2
ASTM oil #3	1
ASTM oil #3, 70 hr/100ºC	-2
Benzene	100
Gasoline	9
Petroleum, crude, 70 hr/100°C	2
Toluene	59
Wax, petroleum, 70 hr/100ºC	-5
Xylene	36
KETONES	
Acetone	126
Methyl ethyl ketone (MEK)	119
OTHER MATERIALS	
Hydraulic Fluid (Skydrol)	59
Linseed oil	4
Water	5

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 (e.g., 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, with Millathane 5004 and Millathane 76 having the lowest volume changes, and Millathane 5004 having the least change in hardness.

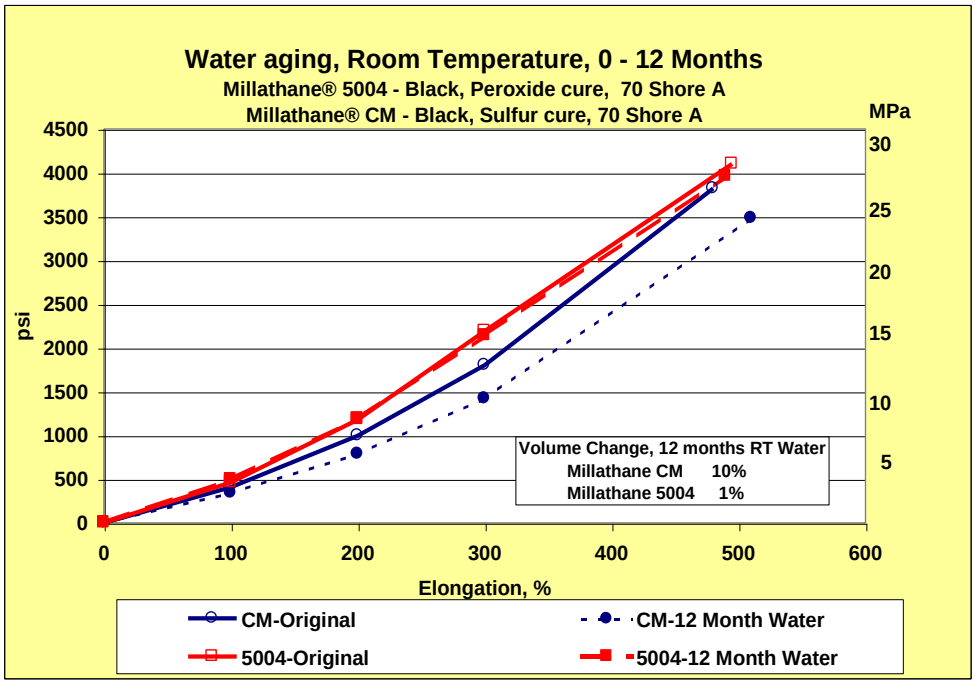




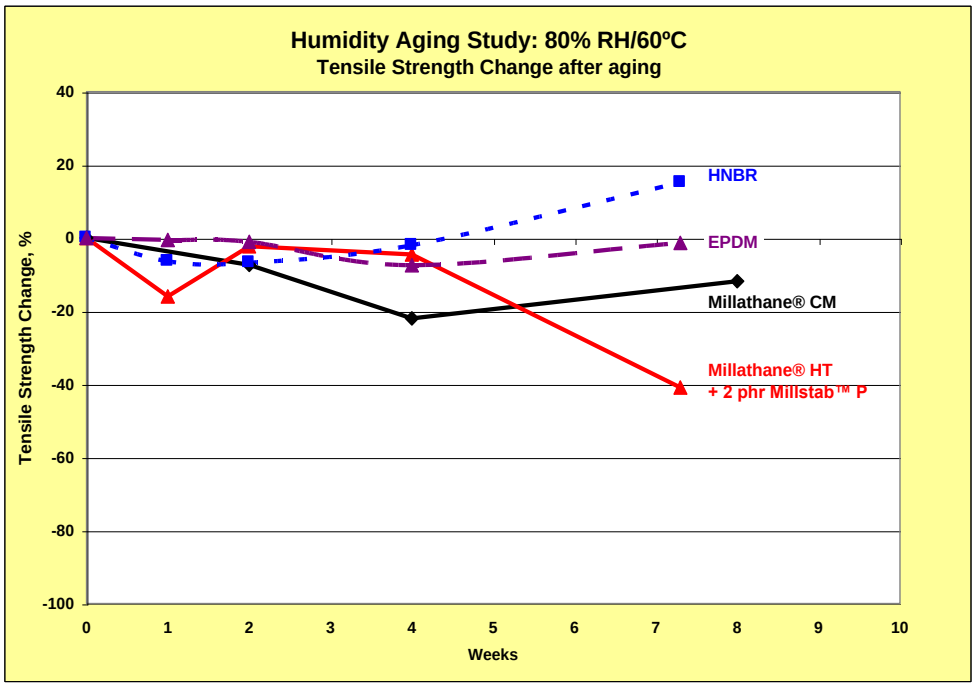
Water/Humidity Resistance

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 (although temporary) hydrolysis resistance by the addition of carbodiimide hydrolysis stabilizers, with the level and duration of the protection proportional to the amount of stabilizer (Millstab™ P) in the formulation.

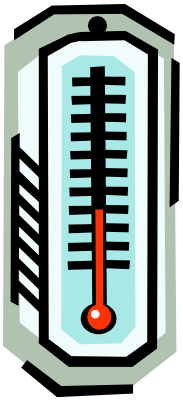
An example of the excellent hydrolysis resistance of the polyether millable urethane Millathane CM and the polyester millable urethane Millathane 5004 (with 5 parts of Millstab P) is shown in the chart below. After ***1 year*** continuous water immersion, both compounds had minimal changes in properties.



A comparison of Millathane CM and the polyester urethane Millathane HT (with 2 parts of Millstab P) to similar hardness HNBR and EPDM compounds tested under hot, humid conditions is shown in the lower chart. Millathane CM and the HNBR and EPDM compounds had minimal changes in tensile strength over the 7-8 week test, while the stabilized Millathane HT showed minimal tensile change for the first four weeks, then showed a significant decrease in tensile strength.



Heat Resistance



Millable polyurethane rubber is not particularly known for its high heat resistance, typically being used at temperatures less than 100ºC. Polyester grades of Millathane® millable urethane 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 Millathane 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	3550	3920	4120	2370	2750	3190
MPa	24.5	27.0	28.4	16.3	19.0	22.0
% Change	---	10	16	-33	-23	-10
Elongation, %	155	165	170	90	100	150
% Change	---	6	10	-42	-35	-3
		Compression Set Test Conditions				
		22 hr/70°C	**22 hr/100°C**	**22 hr/125°C**	**22 hr/140°C**	**22 hr/150°C**
Compression Set, %		4	5	22	35	74

The compound used Millathane 66 *Premilled*, which contains 1.5 parts of the hydrolysis stabilizer Millstab™ P. Millstab P is a polymeric carbodiimide which 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, similar to EPDM, due to the saturated backbone of the urethane polymer.

Black Millathane millable urethane compounds will have excellent resistance to the effects of UV (ultraviolet light). Light colored or transparent (using Millathane 97) articles can also have excellent UV resistance and resistance to yellowing, achieved by the addition of antidegradants such as antioxidants, ultraviolet absorbers (UVA) and Hindered Amine Light Stabilizers (HALS). Contact TSE for the best recommendation of antidegradants for your application.

The table below shows the minimal effect on properties of one year Florida exposure on three Millathane compounds.

	Millathane CM	**Millathane 5004***	**Millathane M97**
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)	3650 (25.2)	3200 (22.1)	2600 (17.9)
Elongation, %	335	490	475
Tear, Die C, lb/in (kN/m)	211 (36.9)	302 (52.9)	190 (33.3)
Surface Appearance	**No signs of cracking or crazing**		

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

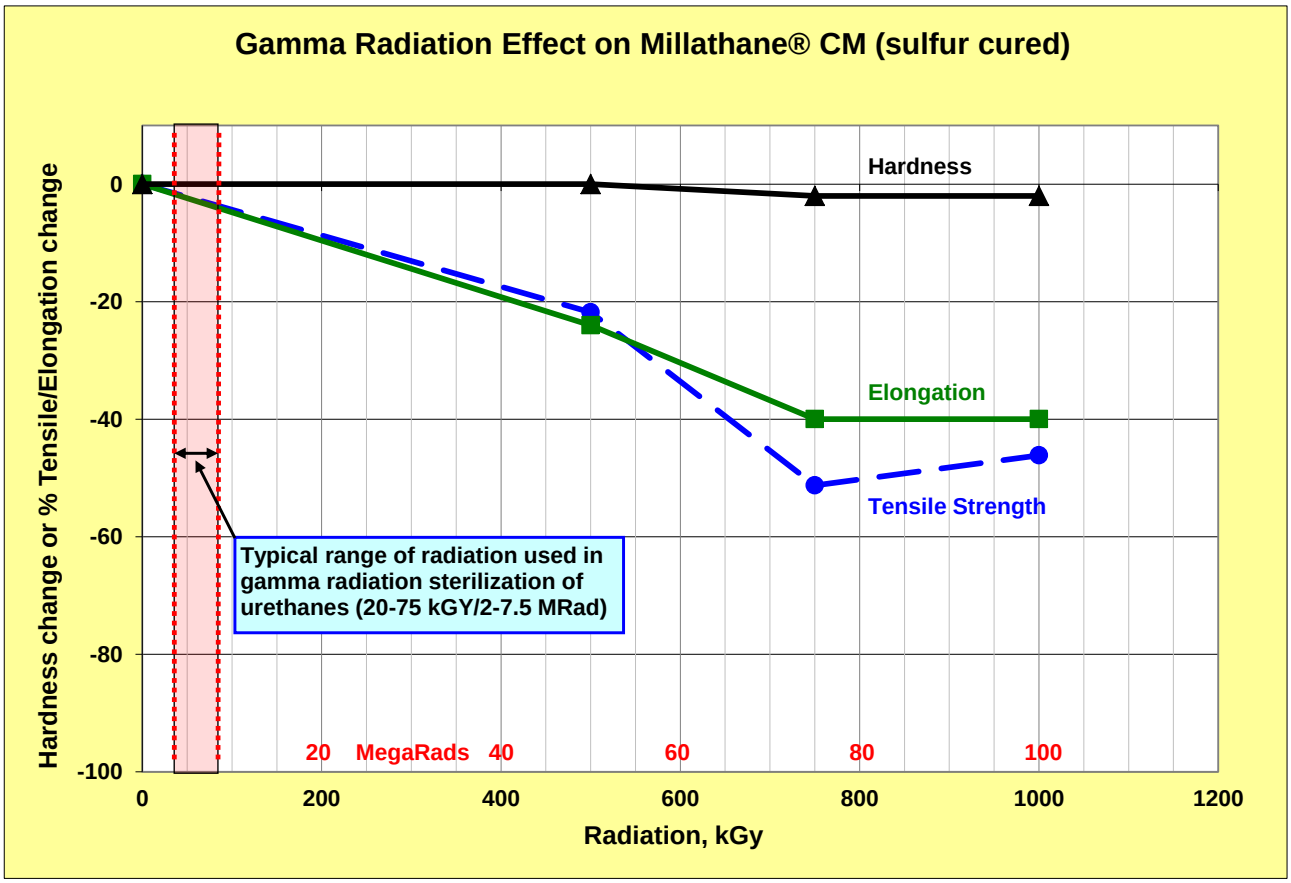
Flame Retardance

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 along 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 cure Millathane CM compound showed negligible changes in properties as shown in the chart below.

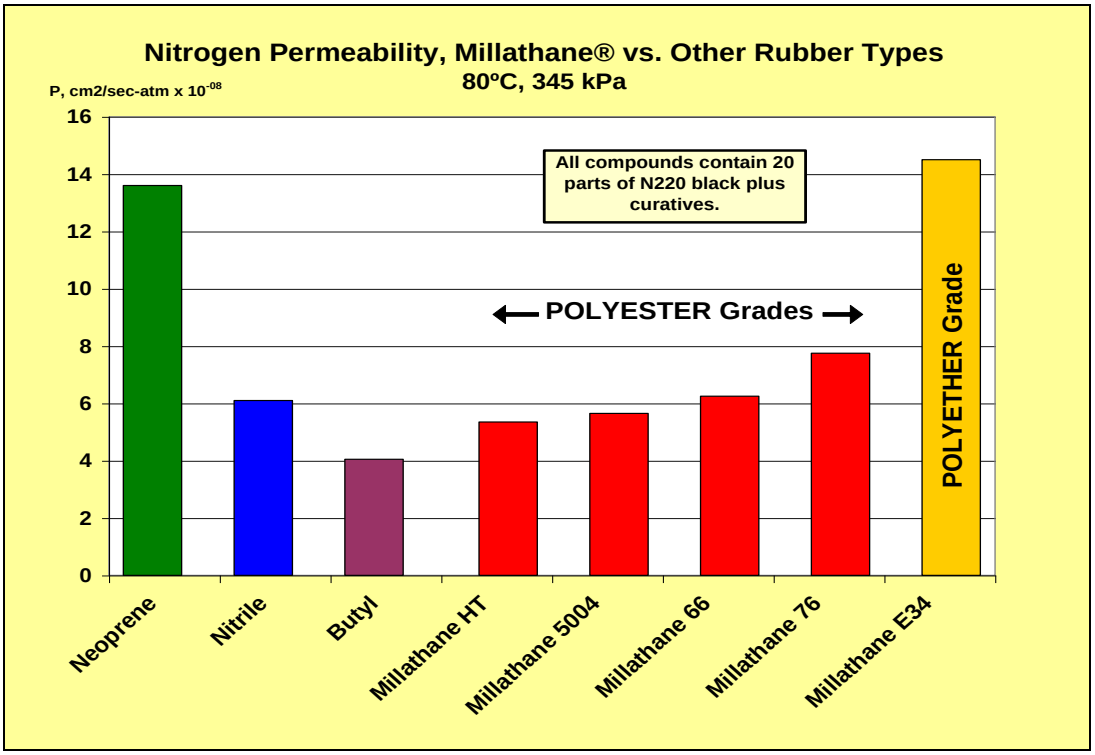
Even at the relatively large doses of 1000 kGy (100 Megarads), this Millathane CM compound still retained its good properties and would give satisfactory service. Peroxide cured compounds generally have good, but somewhat less, resistance to radiation than sulfur cured compounds.



Gas Permeability

Millathane® millable urethanes have very good resistance to permeability to gases, with the permeability of polyester Millathane 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-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.



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, and those with relatively high filler loadings may have slightly lower mold shrinkage. Peroxide cures generally give slightly lower mold shrinkages than sulfur cures.

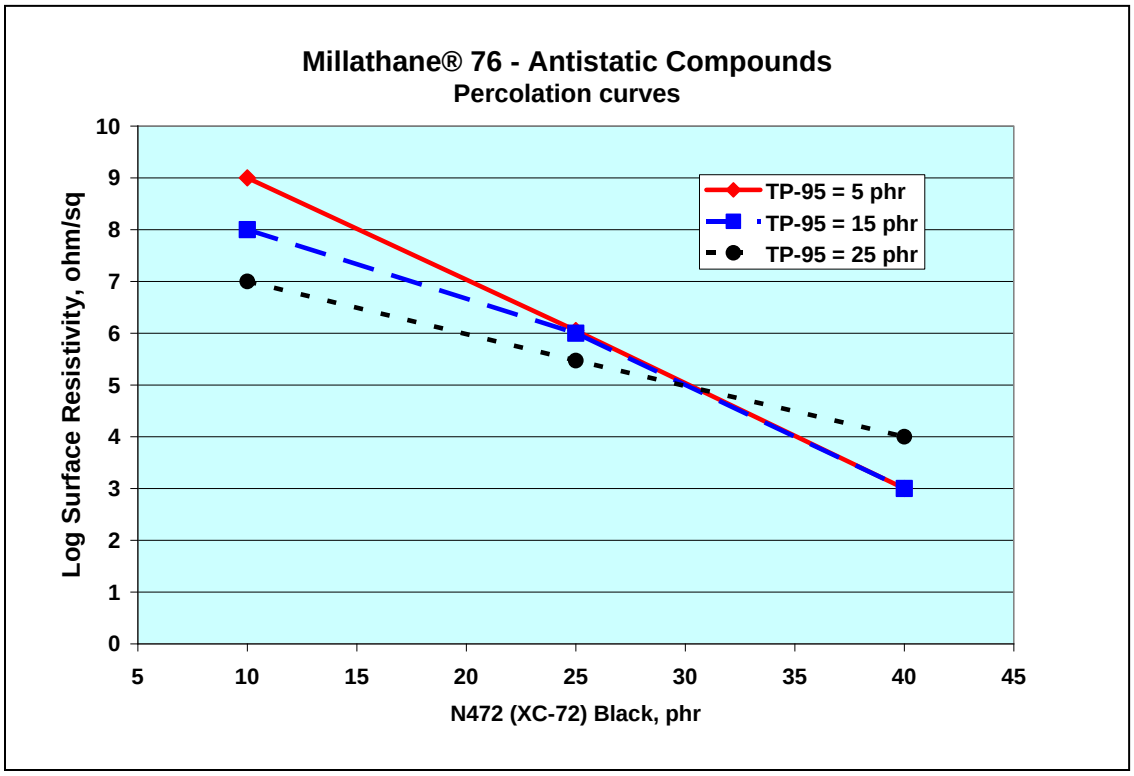
Electrical Properties

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

	Resistivity, ohm-cm	Specific Inductive Capacity (SIC) 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 in the chart below.



Colorability

As with other types of rubber, peroxide cured compounds will give brighter colors and better color retention than sulfur cured compounds, due to the discoloration (yellowing) that is associated with sulfur cures, especially with higher temperature cures.

For the best color compounds, we highly recommend Millathane 97, a peroxide curable, polyether millable urethane, compounded with small amounts of antioxidant and UV stabilizers (contact TSE for our best recommendation). Millathane 97 was developed for transparent applications such as sporting shoe soles, and can give, with proper compounding, clear or brightly colored parts.

Recyclability

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

Applications

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.

Summary

Millathane® millable urethanes have a wide range of excellent properties and seen in this bulletin. If you'd like to investigate how Millathane millable urethanes might be a good fit for your application, please feel free to contact us at any time.

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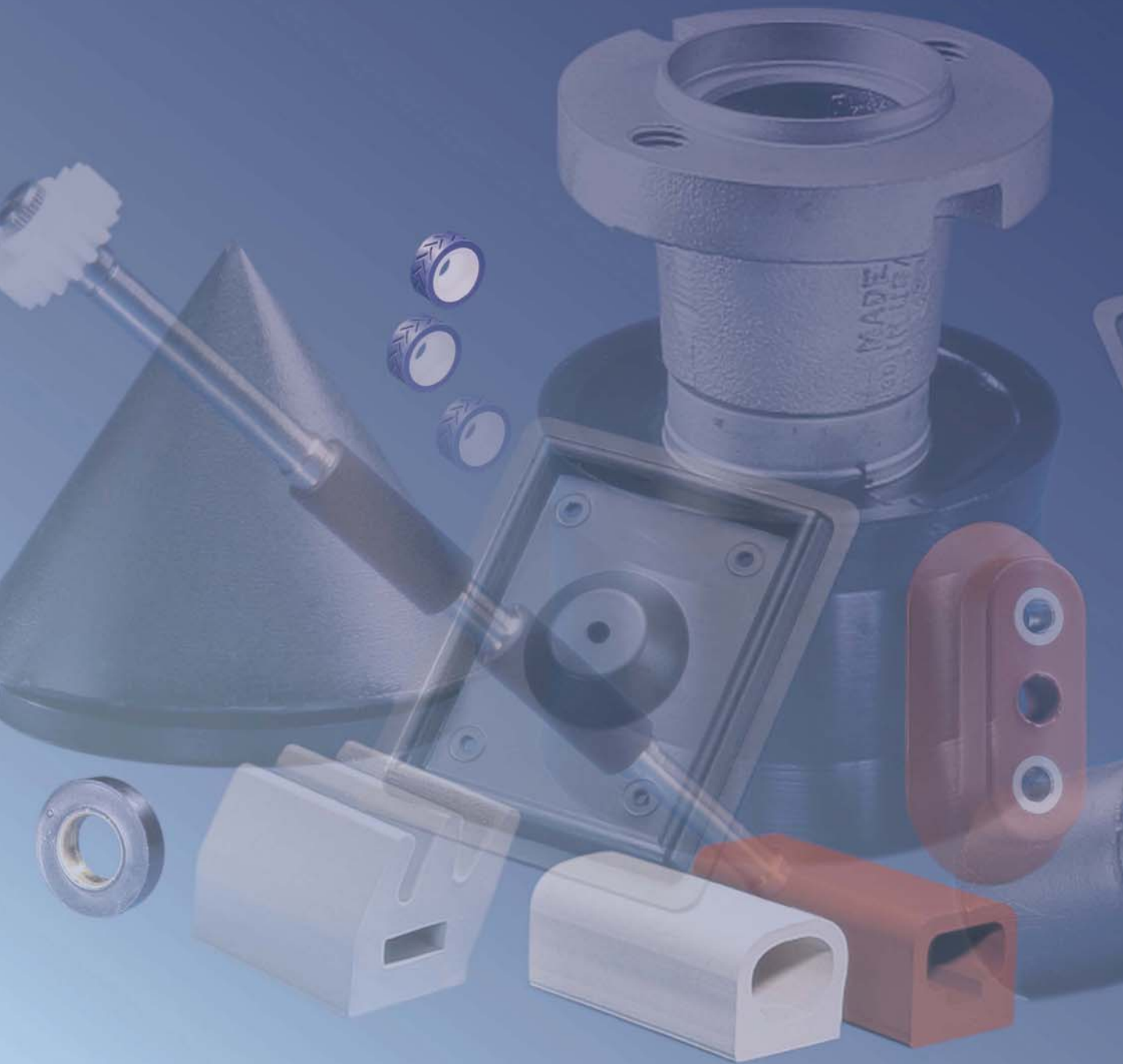

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