WHITE PAPER:

POLYURETHANE

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There is a lot of talk about what type of polyurethane is used in casters wheels. The goal of this white paper is to discuss the various types of polyurethane and examine the reasoning behind why RWM Casters chose Polytetramethylene Ether Glycol, or PTMEG for short, as its material of choice.

To begin, there are three main types of polyurethane. The types are differentiated by the core molecules that make up the links in their polymer chains. These polymer chains are what give the material their strength. Generally speaking, the longer the chain is, the stronger the material will be. When it comes to polyurethane, these links are known as "polyols." The three main types are polyester, polyether, and polycaprolactone. For the purposes of this discussion, we will ignore polycaprolactone, which is really a sub-group of the polyester family, as it is primarily used to make O-rings and seals. Of the three types, polyester is the most widely used type of polyol. Ester-type urethane offers good tear and abrasion resistance, oil resistance and long-term heat damage resistance. The downside of ester- based urethanes is that when confronted by both heat and moisture, they begin to break down because the moisture attacks and breaks the polymer chains, thus making them shorter and the material much weaker. Depending on the amount of humidity in the air and how hot the climate is, this can take two years or longer to occur. If used in an extremely hot and humid area, this breakdown could take as little as a few weeks. It should also be noted that polyester-based urethanes can also be affected by bacteria and fungi.

On the flip side you have polyether-based materials. Inside of the polyether family, you have two distinct groups, which will be discussed next. As a family of materials, polyether-based urethanes are not as effected by water as polyesters, but cannot match polyesters when it comes to oils and solvents. Ethers are also better at dealing with low temperate environments, but the trade-off is that it cannot stand up to long term heat as well as an ester can. Ethers are also better when it comes to rebound, heat build-up, microbe resistance, and resistance to deformation.

	Ester	Ether
Tensile & Tear Strength	+	–
Abrasion Resistance	+	–
Water Resistance	–	+
Fuel/Oil/Grease Resistance	+	–
Compression Set, 250C (770F)	=	=
Compression Set, 700C (1580F)	+	–
Density	–	+
Clarity	+	–
Low Temperature Flexibility	–	+
Microbe Resistance	–	+
Moisture Vapor Transmission	–	+

Figure 1. General Property Comparison of Esters and Ethers

Now, we need to discuss the two different groups of polyether polyurethanes. These two groups are known as Polypropylene Ether Glycol (PPG) and Polytetramethylene Ether Glycol (PTMEG). In general, PPG does not possess the same level of mechanical properties that an ester-based urethane does. However, PTMEG does to a greater degree. In fact, in durometers over 80A, PTMEG exhibits mechanical properties very similar to those of polyesters. Also, PTMEG has dynamic properties better than any other common urethane type which makes them very good in motion applications such as a wheel. The table below will illustrate the difference between PPG urethane and PTMEG urethane. Explanations of the various terms have been included.

Tensile Strength (psi)	4510	7500
100% Modulus (psi)	1705	2200
300% Modulus (psi)	3560	5000
Elongation at Break (%)	335	350
Die C Tear (pli)	385	400
Split Tear (pli)	134	130
Compression Set (%)	29	32
Bashore Rebound (%)	37	48

Figure 2. Property Comparison of PPG and PTMEG

100% Modulus – The force required to stretch the material to twice its original length

300% Modulus – The force required to stretch the material to 300% of its original length

Elongation at Break – The amount you can stretch the material before it breaks

Die C Tear and Split Tear– These properties are measures of the material's resistance to tearing. Two different test methods are used to obtain this information.

Compression Set – This value measures the material's resistance to permanent deformation.

Bashore Rebound – This is how well the material absorbs a shock such as a bump in the ground.

Tensile Strength – A general accounting of the strength of the material

As you can see, the PTMEG simply outclasses the PPG product. PTMEG successfully combines the tearing and abrasion resistance of polyester urethanes with top shelf dynamic properties. What does this mean for the consumer? A wheel that lasts longer, takes higher loads, absorbs shocks better, resists tearing and abrading, and does not flat spot.

Chemical, Oil And Solvent Resistance

Samples of both PTMG-Ether and polyester-based elastomers were immersed for seven days at 75°F in various chemicals. Samples were then removed, dried and measured for volume swell.

Ratings were given based on the following key:

1 = Excellent (0 – 3%)
2 = Good (4 – 15%)
3 = Fair (16 – 35%)
4 = Poor (36% & up)

CHEMICAL	ETHER	ESTER
Acetaldehyde	4	4
Acetic Acid	4-3	4-3
Acetic Anhydride	4	4
Acetone	4	4
Acetyl Bromide	3-4	4
Acetyl Chloride	3-4	4
Acetylene	2-3	3
Adipic Acid	1	2
Aluminum Chloride	2	2
Aluminum Sulfate	2	2
Aluminum Sulfide	2	2
Ammonia	2	2-3
Ammonium Acetate	3-4	3-4
Ammonium Carbonate	2	2
Ammonium Hydroxide	1-2	2
Ammonium Nitrate	2	2-3
Ammonium Persulfate	2	2
Ammonium Sulfate	2	2
Ammonium Sulfide	2	2
Ammonium Thiocyanate	2	2
Amyl Acetate	4	4
Amyl Alcohol	3	3-4
Amyl Chloride	3	3
Aniline	4	4
Aniline Hydrochloride	4	4
Animal Fats & Oils	2-3	2-3
Antimony Salts	2	2
Aqua Regia	4	4
Arsenic Salts	2-1	2
ASTM Oil #1	1-2	1
ASTM Oil #2	2	1
ASTM Oil #3	2	1

CHEMICAL	ETHER	ESTER
ASTM Reference Fuel A	1	1-2
ASTM Reference Fuel B	2	2
Atlantic Oil	1	1-2
Barium Carbonate	2	2
Barium Hydroxide	1	2
Benzaldehyde	3-2	4
Benzene	4	4
Benzene (Gasoline) (aromatic)	2-3	3
Benzoic Acid	2-3	3-4
Boric Acid	1	2
Bromine	2-3	2-3
Bunker Oil	1-2	2
Butane	1	2-3
Butyl Acetate	4	4
Butyl Alcohol	2	3
Calcium Carbonate	2	2
Calcium Chloride	1	2
Calcium Hydroxide	1	2
Calcium Nitrate	2	2
Calcium Sulfate	2	2
Carbon Dioxide	1	1
Carbon Disulfide	2-3	2-3
Carbon Monoxide	1	1
Carbon Tetrachloride	3	4
Chloroacetic Acid	3-4	4
Chloroform	4	4
Chromic Acid	3-4	4
Chromium Potassium Sulfate	2	2
Citric Acid	2	2
Cottonseed Oil	1	2

CHEMICAL	ETHER	ESTER
Cresol (meta)	4	4
Cupric Chloride	1	2
Cupric Nitrate	2	2
Cupric Sulfate	2	2
Cyclohexanone	4	4
Cyclohexane	2	2
Dibutyl Phthalate	3-4	4
Dibutyl Ether	2	2
Dichlorobenzene (Ortho)	3	3
Dodecyl Mercaptan	2-3	2
Diester Oil	2	2
Dimethyl Acetamide	4	4
Dimethyl Formamide	4	4
DTE Oil (heave, medium)	2	2-3
Ether	2-3	2-3
Ethyl Acetate	4	4
Ethyl Alcohol (Ethanol)	3	2-3
Ethyl Bromide	3	3-4
Ethyl Chloride	3	3-4
Ethylene Glycol	2	2-3
Esso #90 Lub. Oil	1	2
Ferric Chloride	2	2
Ferric Nitrate	2	2
Ferrous Chloride	2	2
Ferrous Sulfate	2	2
Formaldehyde	3	2
Formic Aci	3-4	4
Freon, 12 or 113	1	2
Fuel Oil	2	2
Gasoline	2	2-3
Glycerine (Glycerol)	1	2
Glycolic Acid	2	2-3
Greases	1-2	2
Heptane	1	2
Hexane	1	2
Hydrazine	4	4

CHEMICAL	ETHER	ESTER
Hydrobromic Acid	2	2
Hydrocarbon Oil	1	2
Hydrochloric Acid, 20%	2	2-3
Hydrofluoric Acid	2-3	3
Hydrogen	1-2	2
Hydrogen Peroxide	2	2
Hydrogen Sulfide	3-4	4
Hydrolodic Acid	2	2
Iodine Solution	1	2
Isooctane	2	2
Isopropyl Alcohol (Isopropanol)	2-3	3
Isopropyl Ether	2	2-3
JP-4 oil	2-3	3
JP-5 & 6	4	4
Kerosene	2	2-3
Lactic Acid	2	2
Lead Acetate	2	2
Linseed Oil	2	2-3
Lubricating Oil	2	2-3
Magnesium Hydroxide	1	1-2
Magnesium Salts	2	2
Malaic Acid	3-4	4
Mercury	1-2	2
Methyl Alcohol (methanol)	4	3
Methyl Ethyl Ketone	4	4
Methylene Chloride	4	4
MIL-D-5606 Oil	3	3-4
MIL-L-7808	1-2	2-3
Mineral Oil	1	1
Mobil Artic Oil	1	2
Naphthalene	2	2-3
Natural Gas	2	2
Nickel Salts	3	3-4
Nitric Acid	4	4
Nitrobenzene	4	4

CHEMICAL	ETHER	ESTER
Nitrogen	1	1
Oleic Acid	1-2	2
Oxalic Acid (5%)	1	1-2
Oxygen	1	1
Ozone	1	1
Palmitic Acid	1	2
Paints	1-2	2
Perchloric Acid	4	4
Perchloroethylene	3-4	4
Petroleum	1-2	2
Phenol (carbolic acid)	4	4
Phosphoric Acid (dil.)	2-3	3
Phosphoric Acid (conc.)	3	4
Potassium Cyanide	1	2
Potassium Salts	2	2
Propane	2	2
Propyl Alcohol	2-3	3
Propylene Glycol	2	2
Pydraul Oil	4	4
SAE #10 Oil	1	1
Seawater	1-2	2
Silicic Acid	2-1	2
Skydrol Oil (500)	4	3
Silver Nitrate	2	2
Soap	2-3	2-3
Sodium Acetate	1-2	2
Sodium Bicarbonate	2	2
Sodium Bisulfate	2	2
Sodium Borate	2	2
Sodium Carbonate	2	2
Sodium Chlorate	2	2
Sodium Chloride	2 2	
Sodium Cyanide	2	2
Sodium Dichromate	2	2
Sodium Ferrocyanide	2	2
Sodium Fluoride	2	2-3
Sodium Hydrosulfite	2	2

CHEMICAL	ETHER	ESTER
Sodium Hydroxide, 45%	2	2
Sodium Nitrate	2	2
Sodium Silicate	1-2	2
Sodium Sulfate	2	2
Sodium Sulfide	2	2
Sodium Hypochlorite, 5%	4	4
Sperry Oil	2	2-3
Steam	4	4
Stoddard Solvent	1	2
Styrene	2	2
Sulfur Dioxide	2	2-3
Sulfuric Acid, 10-50%	3-4	4
Tannic Acid, 10%	1	2
Tartaric Acid	1	2-3
Tin Salts	2	2
Titanium Salts	2	2
Toluene	4	4
Transformer Oil	2-3	3
Trichloroacetic Acid	4	4
Trichloroethylene	4	4
Tricresyl Phosphate	3-4	4
Triethanol Amine	2	2
Trisodium Phosphate	2	2
Turpentine	3	2
Urea	2	2
Varnish	2	2-3
Vegetable	1	2
Water	2	2
Xylene	3	3-4
Xylol	3-4	4
Zinc Chloride	2	2
Zinc Sulfate	2	2

Data courtesy of Chemtura Corp.