Poly-G® 55 Series Diols in High Performance Elastomers

Polytetramethylene glycols (PTMG) are premium-priced polyether diols that are often used for "high performance" polyurethane elastomers when optimum physical properties and resistance to hydrolysis are required. PTMGs are also used when lesser properties are needed, which results in over-engineered products and unnecessary expense.

The obvious solution is to replace a portion of the PTMG with a lower-priced diol. The least expensive polyether diol family, and the most common, is propoxylated diols. They are adequate for most elastomer applications, but, having only secondary hydroxyl groups, they are unequal to the demands of high performance elastomers. (PTMGs have 100% primary hydroxyls.)

Arch produces a line of ethylene-oxide capped diols with 70-85% primary hydroxyl groups called *Poly-G*®* 55 series Very High Primary (VHP) glycols. List prices of VHP glycols are approximately half the list prices of the PTMGs.

A study was therefore conducted to determine the feasibility of substitution for part of the PTMG in applications where full high performance properties are not required. The results demonstrate that when 25 to 50% of a PTMG is replaced with a *Poly-G* 55 VHP glycol, the elastomer retains much of the property profile imparted by the PTMGs alone, with significantly improved economics.

The study was conducted with prepolymer-based, castable elastomers. Prepolymers were prepared at both 6% and 9% free NCO levels. Glycol molecular weights of 650, 1,000 and 2,000 were studied, with 25, 50 and 75% substitutions of the less expensive diols.

Prepolymer Synthesis

Mondur M (flake, Mobay Chemical Co.) MDI was melted in a sealed can in a 55° to 60°C oven. The molten MDI was decanted from any dimerized solids into a clean, dry can, which was then capped with dry nitrogen and stored at 55° to 60°C.

The PTMGs were from duPont *(Terathane)* and Q.O. Chemicals. All polyols were vacuum stripped at 90° to 95°C, then cooled to 50° to 55°C. Molten MDI was added in a single charge, and the reaction mixture was rapidly agitated with the exotherm controlled so that 80°C was not exceeded. The reaction was continued at 75° to 80°C for two hours, when the prepolymer was canned under dry nitrogen. Free NCO determinations were conducted 24 hours later using the modified ASTM procedure described in Arch Data Sheet 15-15A.

Preparation of Cast Urethane Elastomers

All elastomers were cast between glass plates preheated to 115°C. The plates were treated with *E-115* mold release (SWS Silicones Corp.) and separated by *Teflon* (duPont) spacers, 0.075 inch thick.

The prepolymer was heated to 70 ± 2°C in a disposable beaker. To this, anhydrous grade 1,4-butanediol was added (calculated to achieve a 105 isocyanate index), with several drops of *SF-1080* silicone (General Electric) to aid degassing. Reactants were mixed 20 seconds, the sides of the beaker wiped, then mixed 10 seconds more. The beaker was then placed in a vacuum desiccator for degassing. All samples were oven-cured at 115°C for 16 hours.

Physical Property Testing

All samples were aged at standard laboratory conditions one week, die-cut, then conditioned an additional 72 hours at 22°C and 50% relative humidity. Tensile strength, elongation and flexural modulus were determined according to ASTM method D-412. Hardness was measured with a Shore A Durometer.

The key to high performance elastomers is the retention of good properties after aging at elevated temperatures or immersion in water. Accordingly, all samples were tested under these conditions as well.

Results

Complete details of the data collected are presented in Tables 1-10. General observations and conclusions may be drawn from the tests.

Reaction rates of the prepolymers formulated with 100% PTMG (and cured with 1,4-butanediol) were 2-3 minutes

faster than for those formulated with 100% *Poly-G* 55 series diols.

With 9% free NCO prepolymers, the loss of physical properties is minimal at the 25% *Poly-G* dilution level (Tables 1-4). At 50%, the 9% free NCO prepolymers produce elastomers with properties generally diminished by a maximum of 15-20% for the 1,000 and 2,000 MW polyols. Hardness and tensile strength are affected most. The majority of properties change less than 5% (Tables 1 and 3).

With 6% free NCO prepolymers, differences are more significant at the 25% diol substitution level (Tables 2 and 4). In all elastomers, particularly those formulated with the 650 MW polyols, dry heat aging increased tensile strength.

Dilution with *Poly-G* 55 diols reduces prepolymer viscosities. This results in easier processing and degassing (Tables 5-8).

Substitution of *Poly-G* 55 diols for 25 to 50% of PTMG can drastically change elastomer economics. At the time of this study the *Poly-G* diol list prices were approximately half the list price of PTMGS.

Table 1
Physical Properties of Elastomers
Prepared from 2000 MW Polyols
(9% Theoretical NCO Prepolymers)

Formulations			
***Poly-G* 55-56 Polyol (%)**	**0**	**25**	**50**
PTMG (%)	**100**	**75**	**50**
Actual NCO (%)	8.90	8.90	8.87
Room Temperature Properties			
Shore A Hardness	95	94	94
Bashore Resilience (%)	55	53	53
Tensile Strength (psi)	5100	4500	4000
Elongation (%)	500	450	500
Die C Tear (pli)	630	700	620
Split Tear (pli)	137	250	230
Dry Heat Aged Properties			
Shore A Hardness	93	93	93
Tensile Strength (psi)	5977	4431	3979
Elongation (%)	400	350	400
Water Immersed Properties			
Shore A Hardness	92	90	90
Tensile Strength (psi)	4847	3820	3820
Elongation (%)	450	500	550

Table 2
Physical Properties of Elastomers
Prepared from 2000 MW Polyols
(6% Theoretical NCO Prepolymers)

Formulations			
***Poly-G* 55-56 Polyol (%)**	**0**	**25**	**50**
PTMG (%)	**100**	**75**	**50**
Actual NCO (%)	5.94	5.90	5.91
Room Temperature Properties			
Shore A Hardness	87	85	82
Bashore Resilience (%)	60	52	56
Tensile Strength (psi)	4900	3600	2800
Elongation (%)	500	500	500
Die C Tear (pli)	648	440	398
Split Tear (pli)	81	124	92
Dry Heat Aged Properties			
Shore A Hardness	85	85	82
Tensile Strength (psi)	5470	3988	3558
Elongation (%)	400	400	450
Water Immersed Properties			
Shore A Hardness	82	77	75
Tensile Strength (psi)	4601	3507	2641
Elongation (%)	450	500	550

Table 3
Physical Properties of Elastomers
Prepared from 1000 MW Polyols
(9% Theoretical NCO Prepolymers)

Formulations			
***Poly-G* 55-112 Polyol (%)**	**0**	**25**	**50**
PTMG (%)	**100**	**75**	**50**
Actual NCO (%)	8.84	8.84	8.88
Room Temperature Properties			
Shore A Hardness	94	93	92
Bashore Resilience (%)	45	39	37
Tensile Strength (psi)	5500	4900	4700
Elongation (%)	300	300	350
Die C Tear (pli)	490	500	450
Split Tear (pli)	115	88	107
Dry Heat Aged Properties			
Shore A Hardness	93	94	93
Tensile Strength (psi)	5177	5487	5705
Elongation (%)	300	300	350
Water Immersed Properties			
Shore A Hardness	90	89	87
Tensile Strength (psi)	4891	4426	3681
Elongation (%)	350	350	400

Table 4
Physical Properties of Elastomers Prepared from 1000 MW Polyols (6% Theoretical NCO Prepolymers)

Formulations			
***Poly-G* 55-112 Polyol (%)**	**0**	**25**	**50**
PTMG (%)	**100**	**75**	**50**
Actual NCO (%)	5.90	5.84	5.88
Room Temperature Properties			
Shore A Hardness	87	83	80
Bashore Resilience (%)	48	40	34
Tensile Strength (psi)	4100	4100	3400
Elongation (%)	350	350	350
Die C Tear (pli)	386	327	280
Split Tear (pli)	79	90	45
Dry Heat Aged Properties			
Shore A Hardness	85	79	76
Tensile Strength (psi)	5051	5957	5717
Elongation (%)	400	450	350
Water Immersed Properties			
Shore A Hardness	81	70	65
Tensile Strength (psi)	4250	3362	2972
Elongation (%)	400	400	450

Table 5
Physical Properties of Elastomers Prepared from 650 MW Polyols (9% Theoretical NCO Prepolymers)

Formulations			
***Poly-G* 55-173 Polyol (%)**	**0**	**25**	**50**
PTMG (%)	**100**	**75**	**50**
Actual NCO (%)	8.97	8.75	8.73
Room Temperature Properties			
Shore A Hardness	96	95	92
Bashore Resilience (%)	29	24	22
Tensile Strength (psi)	6090	5030	5120
Elongation (%)	350	300	300
Die C Tear (pli)	580	485	435
Split Tear (pli)	140	120	135
Dry Heat Aged Properties			
Shore A Hardness	93	90	92
Tensile Strength (psi)	6275	6610	7075
Elongation (%)	300	310	310
Water Immersed Properties			
Shore A Hardness	91	86	82
Tensile Strength (psi)	4810	3475	3245
Elongation (%)	320	300	320
Prepolymer Viscosity (cps @ 25°C)	32,500	35,000	43,500

Table 6
Physical Properties of Elastomers Prepared from 650 MW Polyols (6% Theoretical NCO Prepolymers)

Formulations			
***Poly-G* 55-173 Polyol (%)**	**0**	**25**	**50**
PTMG (%)	**100**	**75**	**50**
Actual NCO (%)	5.75	5.76	5.79
Room Temperature Properties			
Shore A Hardness	90	83	80
Bashore Resilience (%)	17	11	9
Tensile Strength (psi)	5420	5350	3400
Elongation (%)	350	330	320
Die C Tear (pli)	400	330	290
Split Tear (pli)	110	100	90
Dry Heat Aged Properties			
Shore A Hardness	80	73	73
Tensile Strength (psi)	7760	6705	6960
Elongation (%)	350	350	350
Water Immersed Properties			
Shore A Hardness	72	64	62
Tensile Strength (psi)	3300	2280	1820
Elongation (%)	350	350	400
Prepolymer Viscosity (cps @ 25°C)	158,000	190,000	280,000

Table 7
Viscosities, 6% Free NCO Prepolymers

PTMG 2000 (%)	100	75	50
Poly-G 55-56 Polyol (%)	0	25	50
Viscosity (cps)	30,000	22,000	17,000

Table 8
Viscosities, 9% Free NCO Prepolymers

PTMG 2000 (%)	100	75	50
Poly-G 55-56 Polyol (%)	0	25	50
Viscosity (cps)	12,000	9,200	7,400

Table 9
Viscosities, 6% Free NCO Prepolymers

PTMG 1000 (%)	100	75	50
Poly-G 55-112 Polyol (%)	0	25	50
Viscosity (cps)	45,500	45,000	36,400

Table 10
Viscosities, 9% Free NCO Prepolymers

PTMG 1000 (%)	100	75	50
Poly-G 55-112 Polyol (%)	0	25	50
Viscosity (cps)	13,500	11,500	10,600

For More Information

Technical Service

Technical Service is available to facilitate further use of *Poly-G* 55 diols. If you have a specific question or need more information, please write or call: Urethane Technical Service, Arch Chemicals Plant, P.O. Box 547, Brandenburg, KY 40108-0547 (800) 370-9674.

How To Order

To place an order for delivery in the U.S. or Canada and to get fast answers on order status or product availabilities, call our toll-free number: 1-800-636-3786.

After your first order, you will be assigned your own personal Customer Service Representative. When you call back, simply ask for your Customer Service Representative by name. If you call evenings (after 5:00 pm Eastern Time) or on weekends or holidays, your message will be recorded and your representative will contact you at the beginning of the next business day.

Please refer to the Material Safety Data Sheet (MSDS) for complete information on Storage and Handling, Toxicological Properties, Personal Protection, First Aid, Spill and Leak Procedures, and Waste Disposal. To order an MSDS, call the customer service number listed above. Before using or handling this product, the MSDS should be thoroughly reviewed.

Sales Headquarters
Norwalk, CT 06851 – 501 Merritt 7, (203) 750-2951