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Focus on the Future

The Plastics Industry Trade Association

PRIPRO
X-Link POLYMERS

Presented By:
Pijush Dewanjee
John Guard

Introduction

PriPro Polymers, Inc. was established in 2005 with the Mission and Vision to:

- **Enhance the performance of existing polymers by chemical Cross-Linking**
- **Process these Cross-Linked polymers economically by Injection Molding and/or Extrusion methods**
- **Focus on Injection Moldable/Extrudable Polyurethanes with mechanical properties better than Castable Polyurethane products**

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Presentation Overview

Part I: Polymer Morphology and Benefits of Chemical Cross-linking

Part II: Physical Properties of "*X*-Link Polymer TPUs"

Part III: Current and Potential Applications of "*X*-Link Polymer TPUs"

Part IV: Conclusion

Part V: Acknowledgements

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Part I

Polymer Morphology and Benefits of Cross-Linking

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Three Main Types of Polymers:

- **Linear Polymers**
- **Branched Chain Polymers**
- **Cross-Linked Polymers**

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Linear Polymers

Equivalent to strings of polymers which are not tied together

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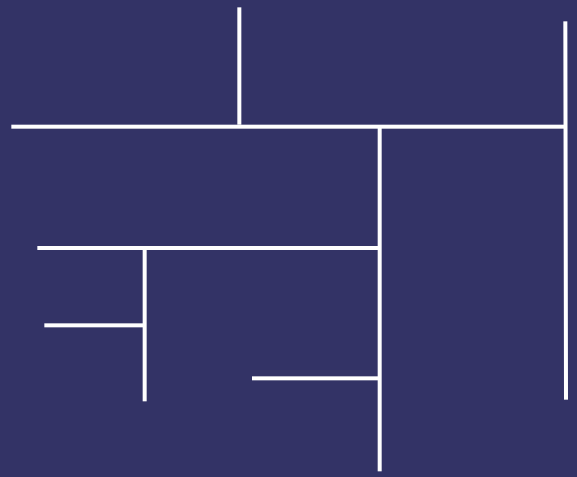
Branched Polymers

Equivalent to tying the same pieces of string together, without tying the ends to form closed loops



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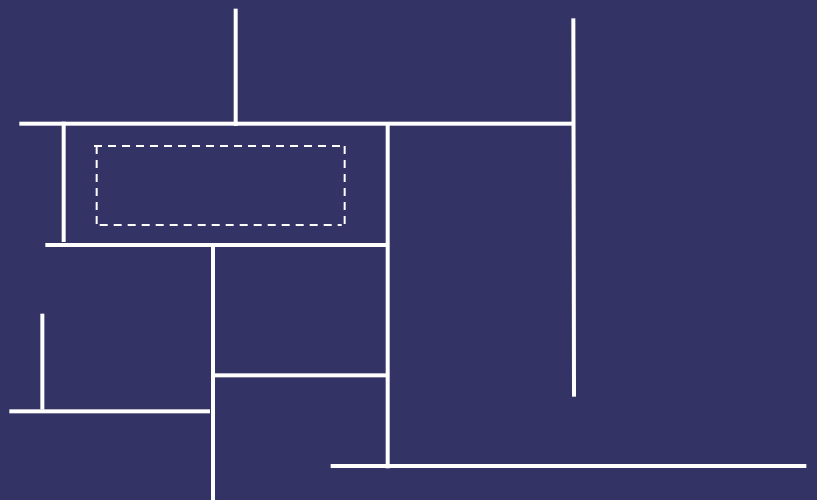
Cross-Linked Polymers

Equivalent to tying the ends of the strings together to form closed loop Networks, which include the polymer class of "Thermosets"



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Improved Properties of Cross-Linked Polymers

- **Tensile Strength**
- **Abrasion Resistance**
- **Compression Set**
- **Tear Strength**
- **Chemical Resistance**
- **Glass Transition Temperature (Tg)**

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Why Polyurethanes?

Polyurethanes are types of polymers that:

- **Form Hydrogen Bonds easily**
- **Make Block copolymers with other types of soft rubbery polymers**
- **Make Block copolymers by cross-linking effectively with the linkages of Urethanes and Ureas**
- **Meet most of the requirements of "Engineering" polymers when combined with the right choice of Ester or Ether Links**

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Castable Polyurethane Systems

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Offer Superior Mechanical Properties over Injection-Moldable Polyurethane Systems in both Abrasion Resistance and Compression Set

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Injection Moldable Polyurethane Systems

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Offer Superior Manufacturability over Castable Polyurethane Systems in high throughput applications

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Injection Moldable *X*-Link Polymer TPU Systems

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Offer the best of both Castable and Injection Moldable Systems

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X-Link Polymer TPUs

PriPro's Patent Pending Cross-Linked Thermoplastic Polyurethanes (TPUs) offer benefits in the key areas of:

- **Tensile Strength**
- **Abrasion Resistance**
- **Compression Tolerance**
- **Tear Strength**
- **Chemical Resistance**
- **Manufacturability**

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Part II

Physical Properties of "*X*-Link Polymer TPUs"

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Background of "*X*-Link Polymer TPUs"

_X_-Link Polymer TPUs can be formulated with:

- **Any commercially available TPUs**
- **Hardness in the range of 60A to 70D**
- **Either Ester or Ether Backbones**

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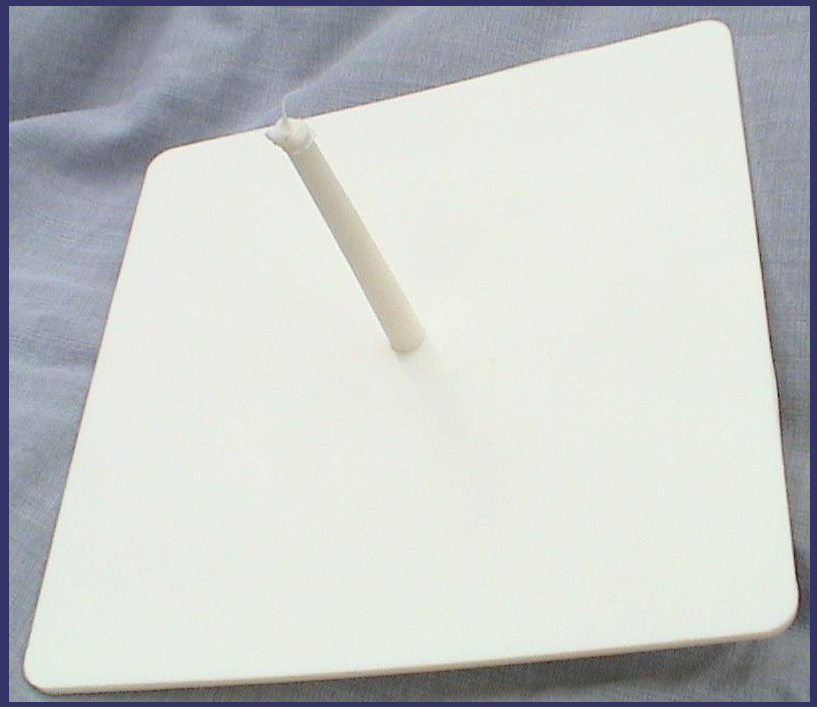
Molded Test Specimens

Dimension: (1/8 inch)X(6 inches)X(6 inches)

Gating: Center-gated (Fan-gated)



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Post Curing of *X*-Link Polymer TPUs

All *X*-Link Polymer TPUs must be Post Cured and Aged for two weeks to achieve full Mechanical Properties.

Typical Post Curing Range Requirements:

8 - 12 hours at 180 - 240°F

Based On Part Size and Thickness

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Huntsman's Irogran A95P4021 (Ether)

Material Tested by Huntsman

Properties	Methods	A95P4021 As molded and tested by Huntsman (End Gated Part)	A95P4021 Tested at 100% (Center Gated)	Casted B836 Chemtura Corp. From Data Sheet (MDI/Polyether, 95A)	A95P4021 X-Linked (Center Gated)	
Abrasion (mm^3)	DIN 53516	**48**	**80.6**		**37.8**	↓
Shore Hardness	ASTM D-2240	50 -52 D	50 - 52 D	95 A	57-58 D	
Compression (Set 70 hrs@70°C)	ASTM D-395	**63%**	**64%**	**30% (Set 22 hrs@70°C)**	**52%**	↓
Compression (Set 70 hrs@100°C)	ASTM D-395	**93%**	**85%**		**79%**	↓
Tensile Strength (psi)	ASTM D-412	3662	2952	5470	3658	
Ultimate Elongation (%)	ASTM D-412	515	441	460	373	
100% Tensile Mod. (psi)	ASTM D-412	**1725**	**1605**	**1345**	**1905**	↑
300% Tensile Mod. (psi)	ASTM D-412	**2598**	**2364**	**2635**	**3093**	↑
Specific gravity	ASTM D-792	1.13	1.10	1.11	1.10	
Tear Strength (pli)	ASTM D-624	697	571	700	663	
Manufactuing Process		Inject. Molded	Inject. Molded	Casted	Inject. Molded	
Cycle Time		**35 Secs.**	**35 Secs.**	**720 Secs.**	**35 Secs**	↓

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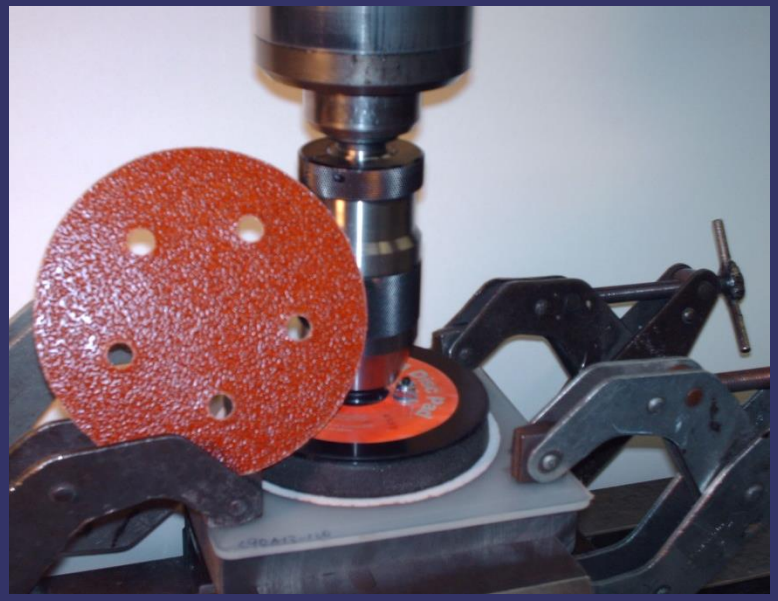
PriPro's Disc Durability Testing

Using GatorGrit Ø5.0 inch 40 grit (5 Hole) sanding disc with 2.55 PSI of pressure at 1000 RPM for 60 seconds. Softer Grades (60-70A) are tested for 30 seconds. A new disc is used for every test.



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Disc Durability Testing Data

Base Material Supplier	Materials Tested	RPM	Time Length (Sec.)	Average Loss (Gram)	% Increase Over Control
Huntsman	A95P4021 100%	1000	60	4.11	
	A95P4021 X-Link	1000	60	2.02	104%
Huntsman	A98H4661 100%	1000	60	2.92 (**)	
	A98H4661 X-Link	1000	60	2.12	38%
BASF	C95A10 100%	1000	60	4.41 (*)	
	C95A10 X-Link	1000	60	2.43	81%
BASF	C90A13 100%	1000	60	3.44 (**)	
	C90A10 X-Link	1000	60	1.89	82%

Note:
Tested Plaques Marked (*) Showed Significant Melting
Tested Plaques Marked (**) Showed Partial Melting

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Disc Durability Testing Data (cont'd)

Base Material Supplier	Materials Tested	RPM	Time Length (Sec.)	Average Loss (Gram)	% Increase Over Control
Bayer	TP 6045DU 100%	1000	30	2.33 (*)	
	TP 6045DU X-Link	1000	30	1.04	124%
Bayer	Texin 985 100%	1000	30	4.10 (**)	
	Texin 985 X-Link	1000	30	1.60	157%
Huntsman	A65P4324 100%	1000	30	1.61 (*)	
	A65P4324 X-Link	1000	30	0.45	258%
BASF	C60A10W 100%	1000	30	1.02 (*)	
	C60A10W X-Link	1000	30	0.78	31%

Note:
Tested Plaques Marked (*) Showed Significant Melting
Tested Plaques Marked (**) Showed Partial Melting

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Disc Durability Testing
Bayer: TP 6045 DU
(Plaque Photos)

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X-Linked

100% (Control)

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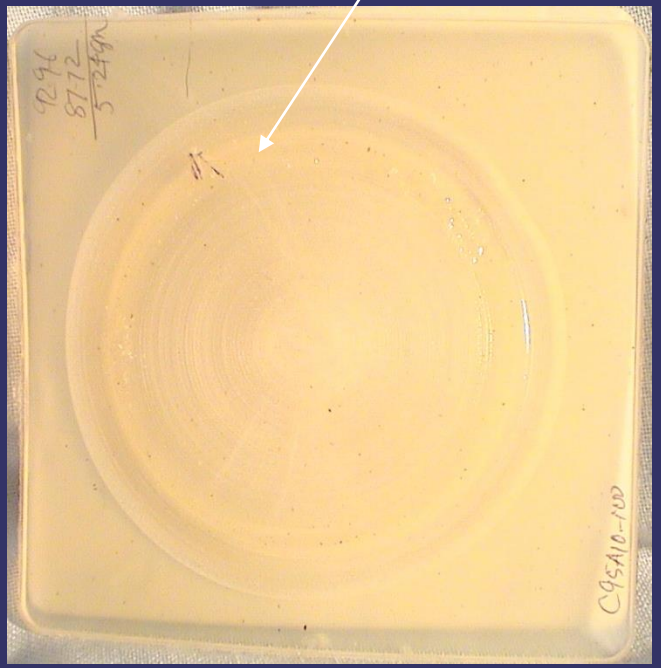
Disc Durability Testing
BASF: C95A10
(Plaque Photos)

Melting



X-Linked **100% (Control)**

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Huntsman's Irogran A60E4902DP (Ester)

Material Tested by Huntsman

Properties	Methods	A60E4902DP 100% As Tested	Casted CPA 600 Tandem Products (MDI/Polyester, 60 A)	A60E4902DP *X*-Linked	
Abrasion (mm^3)	DIN 53516	**60.4**		**48.3**	↓
Shore Hardness	ASTM D-2240	68 A	60 A	75 A	
Compression (Set 22 hrs@32°C)	ASTM D-395	27%		31%	
Compression (Set 22 hrs@70°C)	ASTM D-395	78%		84%	
Tensile Strength (psi)	ASTM D-412	819	926	1089	
Ultimate Elongation	ASTM D-412	769%	328%	878%	
100% Tensile Mod. (psi)	ASTM D-412	148	169	188	
300% Tensile Mod. (psi)	ASTM D-412	**250**		**303**	↑
Specific gravity	ASTM D-792				
Tear Strength (pli)	ASTM D-624	**181**	**180**	**236**	↑
Manufacturing Process		Inject. Molded	Casted	Inject. Molded	
Cycle Time		**50 Secs.**	**900 Secs.**	**50 Secs.**	↓

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BASF Elastollan C60A10W (Ester)

Material Tested by Third Party

Properties	Methods	C60A10W Tested at 100%	Casted CPA 600 Tandem Products (MDI/Polyester, 60 A)	C60A10W *X*-Linked.	
Abrasion (mm^3)	DIN 53516	**60.4**		**48.3**	↓
Shore Hardness	ASTM D-2240	60 A	60 A	65-68A	
Compression (Set 70 hrs@70°C)	ASTM D-395	46%		34%	
Compression (Set 70 hrs@100°C)	ASTM D-395	62%		58%	
Tensile Strength (psi)	ASTM D-412	**2701**	**926**	**3674**	↑
Ultimate Elongation	ASTM D-412	879%	328%	663%	
100% Tensile Mod. (psi)	ASTM D-412	317	469	430	
300% Tensile Mod. (psi)	ASTM D-412	**638**		**835**	↑
Specific gravity	ASTM D-792	1.15		1.15	
Tear Strength (pli)	ASTM D-624	**299**	**180**	**344**	↑
Manufacturing Process		Inject. Molded	Casted	Inject. Molded	
Cycle Time		**50 Secs.**	**900 Secs.**	**50 Secs.**	↓

PRIPRO X-Link POLYMERS

Bayer Material Science Texin 985 (Ether)

Material Tested by Bayer Material Science

Properties	Methods	Texin 985 Tested at 100%	Casted Chemtura Corp. From Data Sheet (MDI/Polyether, 83 A)	Texin 985 X-Linked	
Taber Abrasion, mg loss H-18 Wheel, 1000 g Load, 1000 Cycles	ASTM D-3489	**13**	**3.6**	**3.5**	↓
Shore Hardness	ASTM D-2240	83	83	85	
Bayshore Resilience, %	ASTM D-2632	47.8	42	49	
Compression Set, post cued (22 Hours @ 23°C)	ASTM D-395-B	10.80%		3%	
Compression Set, post cued (22 Hours @ 70°C)	ASTM D-395-B	**24.6%**	**30%**	**14%**	↑
Tensile Strength, psi	ASTM D-412	4084	4500	4500	
Tensile Stress @ 100% Elongation, psi	ASTM D-412	770		875	
Tensile Stress @ 300% Elongation, psi	ASTM D-412	**1258**		**1675**	↑
Ultimate Elongation, %	ASTM D-412	661%	600%	475%	
Manufacturing Process		Inject. Molded	Casted	Inject. Molded	
Cycle Time		**35 Secs.**	**720 Secs.**	**35 Secs.**	↓

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Huntsman's Irogran A85P4394 (Ether)

Material Tested by Huntsman

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Properties	Methods	A85P4394 From Data Sheet	Casted B625 Chemtura Corp. From Data Sheet (MDI/Polyether, 85 A)	A85P4394 *X*-Linked
Abrasion (mm^3)	DIN 53516	35.0		26.5
Shore Hardness	ASTM D-2240	85 A	85 A	88 - 90 A
Compression (Set 70 hrs@70°C)	ASTM D-395	**45% (Set 24 hrs@70°C)**	**29% (Set 22 hrs@70°C)**	**32% (Set 70 hrs@70°C)**
Compression (Set 70 hrs@100°C)	ASTM D-395			64%
Tensile Strength (psi)	ASTM D-412	5500	5400	5407
Ultimate Elongation	ASTM D-412	610%	460%	484%
100% Tensile Mod. (psi)	ASTM D-412	940	820	959
300% Tensile Mod. (psi)	ASTM D-412	1690	1900	2026
Specific gravity	ASTM D-792	1.12	1.09	1.11
Tear Strength (pli)	ASTM D-624	**400**	**540**	**518**
Manufacturing Process		Inject. Molded	Inject. Molded	Inject. Molded
Cycle Time		**35 Secs.**	**720 Secs.**	**35 Secs.**

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BASF Elastollan C90A13 (Ester)

Material Tested by Third Party

Properties	Methods	C90A13 Tested at 100%	Casted 8090 Crompton Uniroyal Chemical (MDI/Polyester, 90 A)	C90A13 *X*-Linked	
Abrasion (mm^3)	DIN 53516	38.8		35.8	
Shore Hardness	ASTM D-2240	90 A		95-97 A	
Compression (Set 70 hrs@70°C)	ASTM D-395	**78%**	**30% (Set 22 hrs@70°C)**	**37%**	↓
Compression (Set 70 hrs@100°C)	ASTM D-395	**96%**		**76%**	↓
Tensile Strength (psi)	ASTM D-412	4984	6000	6067	
Ultimate Elongation	ASTM D-412	538%	510%	519%	
100% Tensile Mod. (psi)	ASTM D-412	1141	1100	1259	
300% Tensile Mod. (psi)	ASTM D-412	**2038**	**2050**	**2362**	↑
Specific gravity	ASTM D-792	1.17	1.25	1.19	
Tear Strength (pli)	ASTM D-624	659	610	680	
Manufacturing Process		Inject. Molded	Casted	Inject. Molded	
Cycle Time		**35 Secs.**	**720 Secs.**	**35 Secs.**	↓

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BASF Elastollan C95A10 (Ester)

Material Tested by Third Party

Properties	Methods	C95A10 Tested at 100%	Casted 8010 Chemtura Corp. From Data Sheet (MDI/Polyester)	C95A10 *X*-Linked	
Abrasion (mm^3)	DIN 53516	42.3		45.2	
Shore Hardness	ASTM D-2240	95 A	95 A	57-58 D	
Compression (Set 70 hrs@70°C)	ASTM D-395	**75%**	**35% (Set 22 hrs@70°C)**	**38%**	↓
Compression (Set 70 hrs@100°C)	ASTM D-395	91%		80%	
Tensile Strength (psi)	ASTM D-412	5774	6500	5420	
Ultimate Elongation	ASTM D-412	525%	450%	447%	
100% Tensile Mod. (psi)	ASTM D-412	1417	2000	1644	
300% Tensile Mod. (psi)	ASTM D-412	**2635**	**3900**	**3258**	↑
Specific gravity	ASTM D-792	1.18	1.25	1.19	
Tear Strength (pli)	ASTM D-624	757	800	784	
Manufacturing Process		Inject. Molded	Casted	Inject. Molded	
Cycle Time		**35 Secs.**	**720 Secs.**	**35 Secs.**	↓

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Huntsman's Irogran A98H4661 (Ester)

Material Tested by Huntsman

Properties	Methods	A98H4661 Tested at 100%	Casted CPT-1550 Rhino Hyde Products (MDI/Polyester)	A98H4661 *X*-Linked
Abrasion (mm^3)	DIN 53516	37.7		32.6
Shore Hardness	ASTM D-2240	54 - 55 D	55 D	58-60 D
Compression (Set 70 hrs@70°C)	ASTM D-395	58%		53%
Compression (Set 70 hrs@100°C)	ASTM D-395	81%		78%
Tensile Strength (psi)	ASTM D-412	5336	5500	4670
Ultimate Elongation	ASTM D-412	604%	300%	489%
100% Tensile Mod. (psi)	ASTM D-412	1912		2239
300% Tensile Mod. (psi)	ASTM D-412	**3019**		**3314**
Specific gravity	ASTM D-792	1.19		1.22
Tear Strength (pli)	ASTM D-624	923	950	969
Manufacturing Process		Inject. Molded	Casted	Inject. Molded
Cycle Time		**35 Secs.**	**900 Secs.**	**35 Secs.**

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Chemical Resistance Testing

Huntsman's Irogran A95P4021 (Ether, 95 A)

Material Tested by Huntsman

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3 Day MEK Resistance				
Property	**A95P4021-100% (control)**	**A95P4021 *X*-Link (+)**	**A95P4021 *X*-Link**	**% Increase Over Control**
Tensile	284 ± 308	955 ± 395	1281 ± 44	**351%**
% Elongation	25 ± 31	192 ± 64	228 ± 18	**812%**
100% Modulus, psi	--	623 ± 74	750 ± 51	--
300% Modulus, psi	--	--	--	--

3 Day Acetone Resistance				
Property	**A95P4021-100% (control)**	**A95P4021 *X*-Link (+)**	**A95P4021 *X*-Link**	**% Increase Over Control**
Tensile	467 ± 183	875 ± 56	1506 ± 83	**222%**
% Elongation	47 ± 32	254 ± 18	297 ± 21	**532%**
100% Modulus, psi	--	490 ± 7	675 ± 34	--
300% Modulus, psi	--	--	730 ± 894	--

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Part III

Current and Potential Applications of *X*-Link Polymer TPUs

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Current Application: Skateboard Wheels

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PriPro's Abrasion Testing

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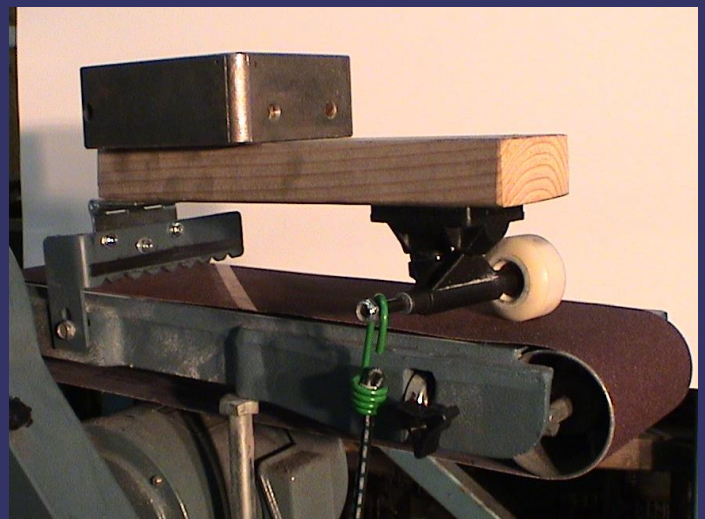
Wheels mounted at a 10º angle to belt (Aluminum oxide, A120 grit) under a force of 15 lb, were abraded for 30 seconds. The final Abrasion loss amount was an average of 3 runs.



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PriPro's Rebound Testing

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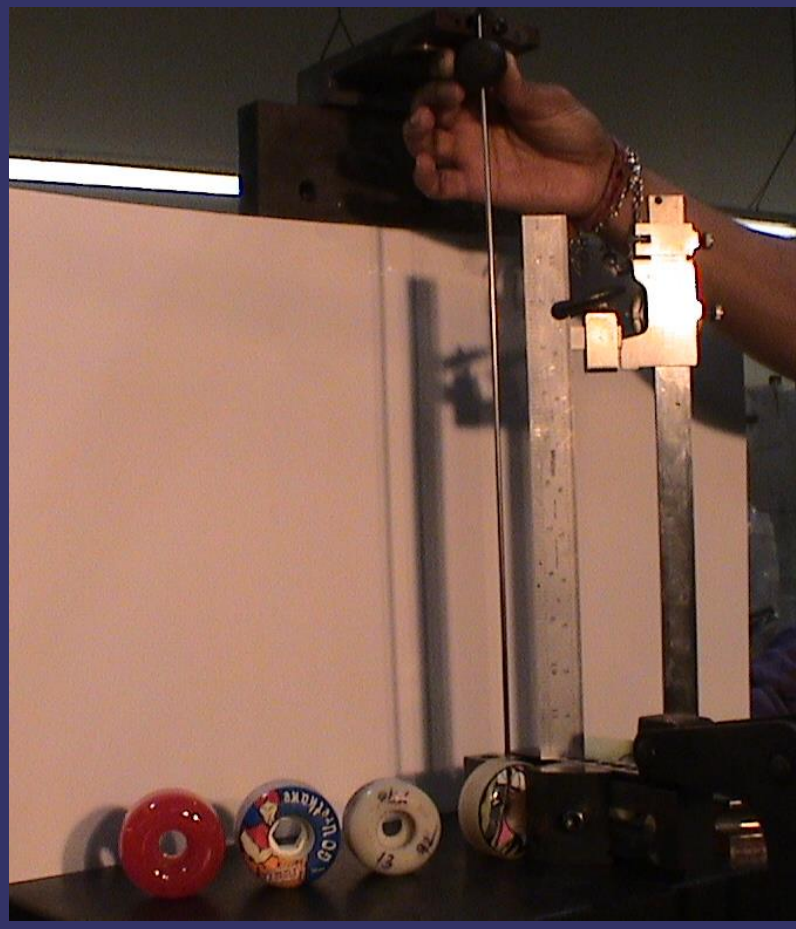
Sphere of one inch diameter (104.4 gm) guided by a 0.125 inch diameter rod, is dropped from a height of 16 inches. The final Rebound number was an average of 6 drops.



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Competitive Wheel Test Results

Head to Head Comparison for Abrasion and Rebound

Material Type	Durometer (D Scale)	Wheel PSI / Material Loss (Mid. PSI / Delta Gram)	Difference over Go-Urethane (Abrasion)	Rebound (Inches)	Difference over Spit-Fire (Rebound)
Current Market Wheels					
Go-Urethane	59	1.864	0%	6.250	-14%
Finesse	59	2.120	14%	6.375	-12%
Spit-Fire	54	1.282	-31%	7.250	0%
PriPro's Wheel					
X-Linked Wheel	**59**	2.254	**21%**	7.375	**2%**

<u>*X*-Linked Wheels</u> Offer Overall Better Performance Than Castable Wheels.

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Potential Applications of *X*-Link TPUs

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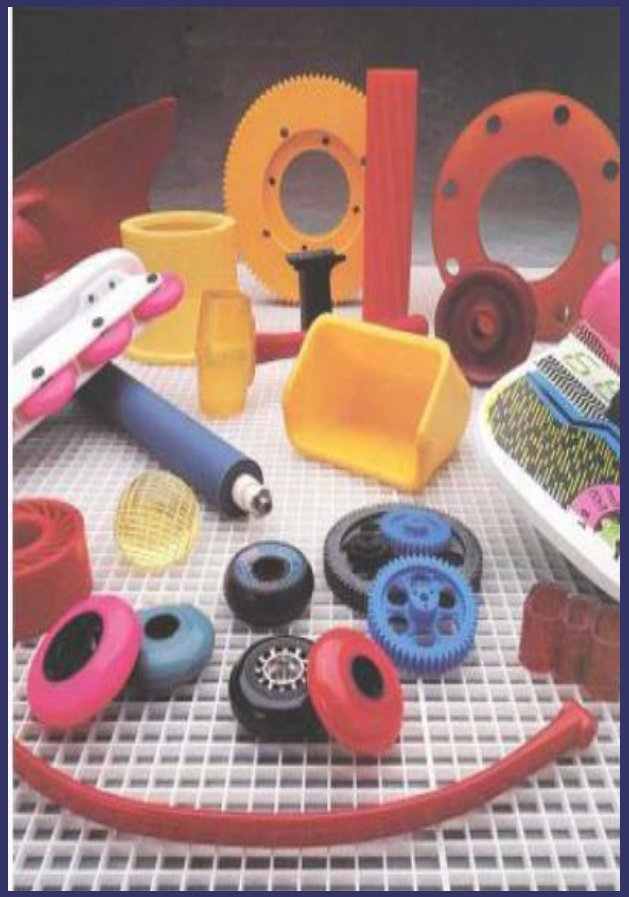
- **Recreational Wheels:**
  Inline Skates, Skateboards
- **Automotive Parts:**
  Seals, O-Rings, Gaskets, Bushings, CV-Joint Covers, and Wiper Blades



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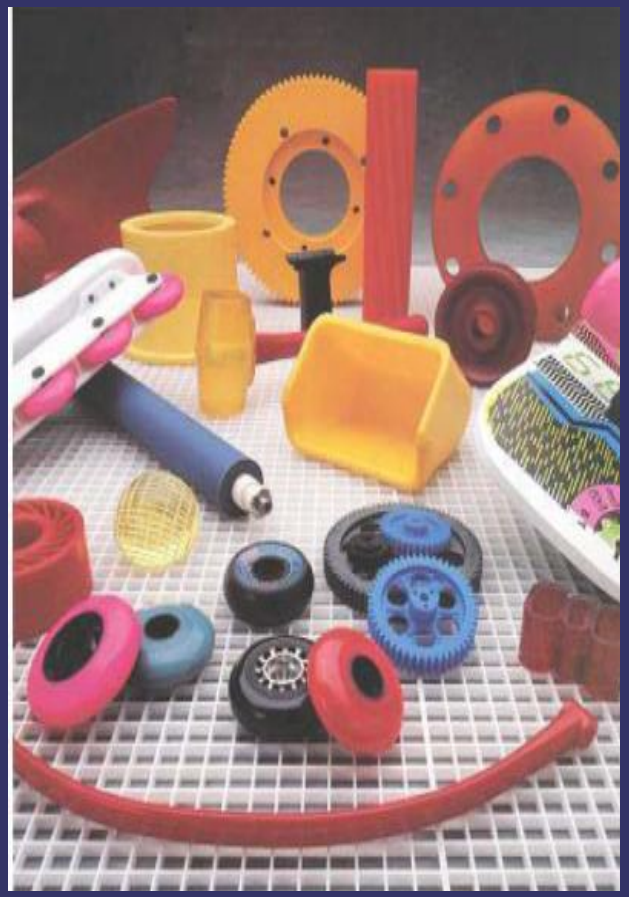
Potential Applications of *X*-Link TPUs (Cont'd)

- **Agriculture:**
  Silo Liners (Sheets), Plow Parts, Pipes, Pipe Liners, and Conveyor Buckets
- **Footwear:**
  Shoe Soles & Top Pieces of Women's Designer Shoes



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Part IV

Conclusion

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John Guard

Conclusion

Compared to Castable Polyurethanes PriPro's Innovative *X*-Link Polymeric TPUs Provide:

- **Greater or Equal Compression Set**
- **Greater or Equal Abrasion Resistance**
- **Porosity and Void-Free Products**

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Conclusion (cont'd)

Flexibility and Cost Benefits of *X*-Link TPUs:

- **Can be Master Batched and Vacuum Sealed for an acceptable Shelf Life**
- **Master Batches can be used as a "Drop-In" for standard Injection Molding and Extrusion processes without any equipment modifications**
- **Commercially available TPUs can be *X*-Linked as an "Inline" process using a standard Gravimetric Blender**

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Conclusion (cont'd)

X-Link Polymer TPUs Open a World of Novel Materials for New Markets in a Cost-Effective Manner

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Part V:

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John Guard

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John Guard

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John Guard

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