TERRIN™

Technical Data Sheet

INVISTA TERRIN™ Polyols

Cost-Effective Alternative to Conventional Polyether and Polyester Polyols

Introduction

TERRIN™ polyols can be used in lieu of or in combination with conventional polyether or polyester polyols to formulate a variety of polyurethane products designed to be soft and flexible—or hard and stiff. These versatile, aliphatic, polyester polyols can be used in applications ranging from viscoelastic foam to spray coatings and adhesives to elastomeric resins. TERRIN™ Polyols:

- Are cost competitive in comparison to conventional polyols
- Contain a minimum of 50% recycled or renewable[1] content
- Have similar hydroxyl values to castor oil, and can be substituted on a nearly equal weight basis
- Are REACH and TSCA compliant

In addition, TERRIN™ polyols are an easily handled, low-viscosity liquid at room temperature. TERRIN™ product offerings—especially 168 and 168G—remain pourable liquids at -15°C/5°F and below[2]. TERRIN™ polyols do not crystallize and exhibit Tg in a range of approximately -60°C to -75°C.

Application

<u>High-Resilience Polyurethane Foam</u>

This This Technical Data Sheet is intended to illustrate how TERRIN™ polyols can be used in high-resilience (HR) polyurethane foam. HR foams are typically open-cell, flexible foams with relatively high resilience and rapid post-deformation recovery compared to low-resilience or viscoelastic foams. The formulations herein are not optimized for any specific application and aren't intended to cover the entire range of possibilities but are meant to provide the experienced polyurethane formulator with ideas, performance trends, and starting points for HR foam formulations. The information set forth herein is furnished free of charge and is based on technical data that INVISTA believes to be reliable, provided that INVISTA makes no representation or warranty as to the completeness or accuracy thereof. It is intended for use by persons having technical skill, at their own discretion and risk, who will make their own determination as to its suitability for their purposes prior to use. As with any material, evaluation of any compound under end-use conditions prior to specification is essential. Nothing herein is to be taken as a license to operate under or a recommendation to infringe any patents. In no event will INVISTA be responsible for damages of any nature whatsoever resulting from the use of or reliance upon the information contained herein or the product to which the information refers.Highlights of the results are summarized below, followed by full details of the formulations, testing and complete tabulated results.

[1]As defined by ISO 14021, Section 7.8; preliminary estimate based on small-scale production.
[2]Patents pending; consult the SDS for additional physical-chemical, safety and health information

Features

TERRIN™ 170 offers the polyurethane (PU) foam formulator several potential benefits when partially substituted for conventional polyols in high-resilience polyurethane foam. Benefits observed in lab-scale tests include:

- Increased strength and load-bearing capability
- 100% Renewable and recycled content[1]
- Potential to substitute for or use in combination with graft polyols
- Potential to reduce cost
- Similar reactivity to conventional polyols

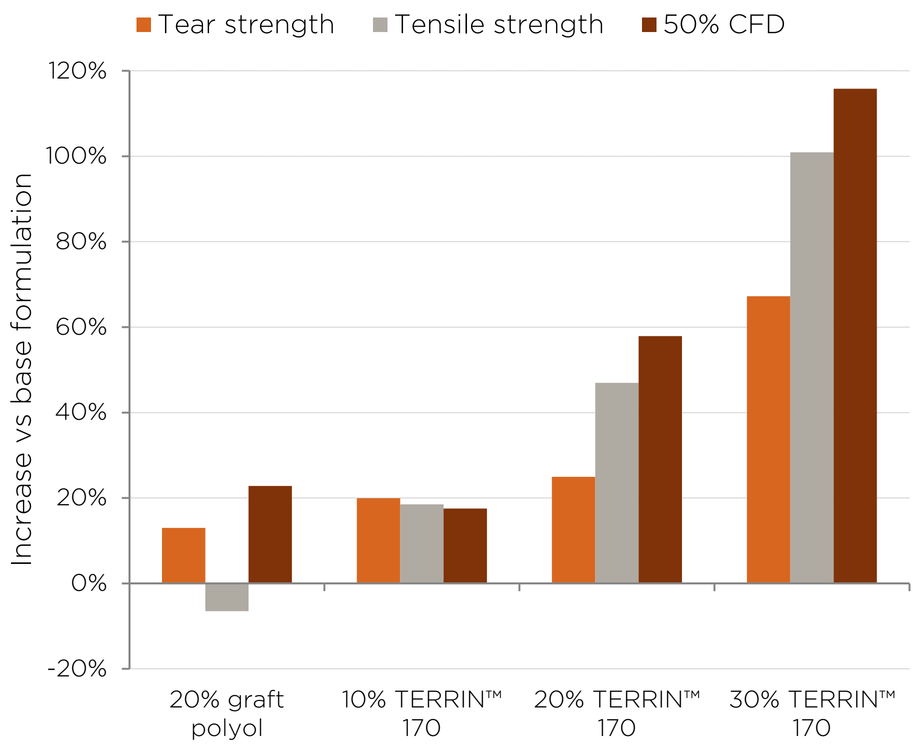

Figure 1: Comparison of high-resilience foams made using graft polyol or TERRIN™ 170 to the base formulation with no graft or TERRIN™ polyol (complete test data in Table).

Results

Strength and load-bearing properties

One main benefit from TERRIN™ 170 in HR foams is increased strength and load-bearing capability. In both free-rise and molded foams, tensile strength, tear resistance, and compression force deflection (CFD) values increased with addition of TERRIN™ 170 polyol in formulations with or without graft polyol (Figure 1). As expected, the reference foam with 20% graft polyol had higher tear strength and CFD than the reference foam without graft polyol. However, foams made using 10% and higher amounts of TERRIN™ 170 polyol prepared without a graft polyol exhibited tensile strength, tear resistance, and CFD values comparable or higher than the reference foam prepared with 20% graft polyol. These observations indicate that TERRIN™ 170 can improve mechanical strength and load-bearing properties of HR foams and have potential to replace graft polyols for this purpose.

Reactivity

Observations of reactivity indicate that TERRIN™ 170 can be incorporated into HR foams with little or no change in catalyst package and that the system responds as expected when catalyst changes are made. As can be seen from the free-rise foam cream, gel, and rise times in Table 4, addition of TERRIN™ 170 had only small effects on reactivity and density of foams without graft polyol. Density of foams containing graft polyol and 15 or 20% TERRIN™ 170 was higher than desired, but was easily adjusted back to the desired range by a small increase in diethanolamine, which is an expected response to that catalyst change. No issues were encountered in processing molded foams.

Burn Rate

For foams without graft polyol, the results in Table 4 indicate a trend of decreasing burn rate with increasing TERRIN™ 170 content. All foams containing graft polyol were self-extinguishing in the burn rate test.

Other Properties

Addition of increasing amounts of TERRIN™ 170 polyol reveals trends of decreasing resilience, increasing hysteresis, and increasing wet and dry compression set. However, resilience of foams prepared with 20% TERRIN™ polyol without graft polyol was still 55%, the minimum requirement for HR foam according to ASTM D 3770-91. Molded foams with 10% TERRIN™ 170 and no graft polyol exhibited hysteresis loss of 31%, which meets requirements of the Chrysler Material Standard for Type IV seating foam.2 Foams prepared with 10% TERRIN™ 170 polyol meet the wet compression set requirements for Type III and Type IV and those prepared with up to 25% TERRIN™ 170 polyol meet the requirements for Type IV seating foam of the Chrysler Material Standard.

As noted earlier, the formulations tested herein were not optimized nor targeted for any particular application. TERRIN™ polyols provide the formulator with cost effective alternatives to consider when optimizing a HR foam formulation to meet a balance of performance criteria while minimizing cost.

Preparation

A model high-resilience foam (HR foam) formulation based on toluene diisocyanate (TDI) was used to evaluate performance of TERRIN™ 170 polyol when substituted for polyether polyols in free-rise or molded HR foam. TERRIN™ 170 was also evaluated in comparison to and in combination with graft polyol as a means to improve strength and load-bearing properties of HR foam.

Polyols used in the formulations are described in Table 1, other materials in Table 2, formulations in Table 3, and foam properties in Table 4. As TERRIN™ 170 polyol was substituted into the base formulation, the two conventional polyether polyols were removed equally and proportionately to maintain constant weight of polyol. All foams used 3.6 parts by weight (pbw) water per 100 pbw polyols. Other ingredients including catalysts were held constant except that the amount of diethanolamine was increased in two formulations with graft polyol to maintain density of the resulting foam close to the reference foam (formulations TERRIN-NC-15DE and TERRIN-NC-20DE). Isocyanate was adjusted to maintain NCO index at 90.

Table 1: Polyols

Polyol	Description	Supplier	Equiv. wt.
TERRIN™ 170	Aliphatic polyester polyol	INVISTA	348.8
POLY-G® 85-29	Ethylene oxide-capped polyether triol	Monument	2141
VORANOL™ VORACTIV™ 6340	Catalytically active, high-functionality, Ethylene oxide-capped polyether polyol	Dow	1753
SPECFLEX™ NC 701	Grafted polyether polyol	Dow	2244
LUMULSE® POE 26	Ethoxylated glycerin, cell-opening polyol	Lambent Technologies	416.1

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Table 2: Other materials

Other materials	Description	Supplier	Equiv. wt.
TEGOSTAB® B4690	Polyether/Silicone Oil Mix - Surfactant	Evonik	1335.7
DABCO® 33LV	Triethylenediamine in dipropylene glycol - Catalyst	Air Products	105
Diethanolamine LFG 85%	Diethanolamine with 15% water - Catalyst, cross-linker	Huntsman	35.04
LUPRANATE® TD80	Toluene diisocyanate, 48.0% NCO	BASF	87.5

All foam preparations reported in Tables 3 and 4 were scaled to use a total of ~200 g polyol components. To prepare a foam, the polyols and other non-isocyanate components were combined, isocyanate added, and the formulation mixed for 5 or 7 seconds using a high-torque mixer. The mixture was transferred to an open polyethylene container and allowed to free rise or into a preheated aluminum mold (12x12x2 inches dimensions, preheated to 65°C). For free-rise foams, cream time, gel time, and rise time were noted then the foams were placed into a preheated 75°C air-circulating oven for 30 minutes to complete their cure. In the case of molded foams, de-molding time was 270 seconds.

Foam Testing

Foams were aged for at least one week at ambient room conditions before testing. Full evaluation was carried out on molded foams. The following properties were measured according to ASTM D 3574-08:

- Foam density (Test A)
- Resilience by ball rebound (Test H)
- Tensile strength at break (Test E)
- Elongation at break (Test E)
- Tear strength (Test F)
- Compression force deflection (CFD; Test C)
- Hysteresis (Procedure B – CFD hysteresis loss)
- Dry constant deflection compression set (Test D)
- Wet constant deflection compression set (Test D and Wet heat aging, Test L)
- Tensile strength and elongation after dry heat aging (Modified Heat Aging, Test K)

Horizontal burn rate was measured using an in-house method based on ASTM D 5132-04. Dripping was observed in all cases. Note that this test is for comparative purposes only within this study. Results should not be compared to results from other studies or results using different methods. Results of the above tests are given in Table 4.

Table 3: High-Resilience Foam Formulations

Sample designation	REFERENCE	TERRIN-5	TERRIN-10	TERRIN-15	TERRIN-20	TERRIN-25	TERRIN-30	TERRIN-40	TERRIN-50	REFERENCE-NC	TERRIN-NC-5	TERRIN-NC-10	TERRIN-NC-15	TERRIN-NC-15DE	TERRIN-NC-20	TERRIN-NC-20DE
% Graft polyol on total polyols	0	0	0	0	0	0	0	0	0	20	20	20	20	20	20	20
% TERRIN™ 170 polyol on total polyol	0	5	10	15	20	25	30	40	50	0	5	10	15	15	20	20
% TERRIN™ 170 polyol on total formulation	0	3.3	6.6	9.9	13.1	16.3	19.4	25.6	31.6	0	3.3	6.6	9.9	9.9	13.1	13.1
Polyol part																
POLY-G® 85-29 polyol	48.5	46	43.5	41	38.5	36	33.5	28.5	23.5	38.8	36.3	33.8	28.8	28.8	28.8	23.8
VORANOL™-VORACTIV™ 6340 polyol	48.5	46	43.5	41	38.5	36	33.5	28.5	23.5	38.8	36.3	33.8	33.8	33.8	28.8	33.8
SPECFLEX™ NC-701 polyol	0	0	0	0	0	0	0	0	0	19.4	19.4	19.4	19.4	19.4	19.4	19.4
TERRIN™ 170 polyol	0	5	10	15	20	25	30	40	50	-	5	10	15	15	20	20
LUMULSE® POE 26 cell opener	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Water, surfactant, catalyst																
Water added	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
TEGOSTAB® B 4690	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DABCO® 33LV	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Diethanolamine	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	1.5	2
Residual water	0.237	0.237	0.236	0.235	0.234	0.234	0.233	0.231	0.23	0.234	0.233	0.233	0.232	0.306	0.231	0.306
Isocyanate part																
LUPRANATE® TD80	41.8	42.72	43.64	44.56	45.47	46.39	47.31	49.15	50.98	41.66	42.58	43.5	44.44	46.4	45.34	46.98

Table 4: Reaction profiles and properties of free-rise and molded high-resilience foams

Sample designation	REFERENCE	TERRIN-5	TERRIN-10	TERRIN-15	TERRIN-20	TERRIN-25	TERRIN-30	TERRIN-40	TERRIN-50	REFERENCE-NC	TERRIN-NC-5	TERRIN-NC-10	TERRIN-NC-15	TERRIN-NC-15DE	TERRIN-NC-20	TERRIN-NC-20DE
% Graft polyol on total polyols	0	0	0	0	0	0	0	0	0	20	20	20	20	20	20	20
% TERRIN™ 170 on total polyol	0	5	10	15	20	25	30	40	50	0	5	10	15	15	20	20
Free-rise foams - reactivity and properties																
Cream time, sec.	9	9	9	9	9	9	9	8	8	9	9	9	8	8	8	8
Gel time, sec.	34	38	37	36	34	34	33	28	25	34	34	33	31	25	30	23
Off-gassing time										-		-	41	38	39	36
Rise time, sec.	52	52	51	51	49	47	47	41	36	44	43	43	-	-	-	-
Free-rise density, pcf	1.79	1.77	1.73	1.76	1.83	1.92	1.92	2.25	2.27	1.89	1.72	1.93	2.21	1.94	2.56	2.27
Resilience via Ball Rebound, %	59	58	57	55	51	46	42	35	28	61	57	53	-	47	-	45
Molded foams - properties																
Core density, pcf	2.95	3.12	2.94	3.11	2.95	3.07	2.92	2.88	3.05	2.77	2.9	2.92	-	3.34	-	2.99
Tensile strength at break, psi	12.5	11.1	14.8	15.4	18.3	18.1	25.1	25.7	28.0	11.7	19.3	16.7	-	17.3	-	21.4
Elongation at break, %	107	90	97	93	102	78	93	83	76	82	97	88	-	63	-	73
Tensile after dry heat aging, psi	20.1	14.4	18.6	18.9	20.5	22.3	21.3	25.3	21.7	19.3	20.7	21.0	-	18.8	-	20.3
Elongation after dry heat aging, %	186	125	144	128	124	102	93	84	58	124	119	95	-	74	-	80
Tear strength, Die C, pli	5.77	5.53	6.92	6.08	7.21	8.97	9.65	10.24	10.95	6.52	7.43	7.72	-	7.27	-	9.01
Compression force deflection (CFD)																
At 25% deflection, psi	0.4	0.45	0.46	0.55	0.64	0.85	0.9	1.15	1.58	0.48	0.63	0.65	-	0.89	-	0.98
At 50% deflection, psi	0.57	0.64	0.67	0.79	0.9	1.12	1.23	1.61	2.45	0.7	0.89	0.91	-	1.25	-	1.42
At 65% deflection, psi	0.85	0.95	1.02	1.18	1.37	1.63	1.9	2.37	3.76	1.04	1.29	1.33	-	1.99	-	2.26
Dry compression set, %	3.8	4.6	5.6	11.6	13.4	15.3	18.7	30.7	38.2	6.3	6.7	10.9	-	11.8	-	14.2
Wet compression set, %	14.7	15.5	19	20.2	20.6	21.5	31	39.6	45.1	12	16.2	22.2	-	24.9	-	27.1
Resilience via Ball Rebound, %	64	61	60	57	55	50	45	40	35	66	62	57	-	55	-	50
Hysteresis loss, %	23	29	31	48	48	60	68	73	67	30	56	69	-	82	-	87
Burn rate, mm/minute	73.1	70	68.3	67	62.9	58.7	56.8	55.4	53.9	self extinguished						

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