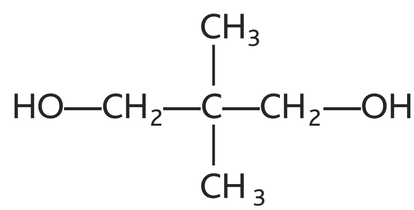
Designing high-performance gel coats with Eastman NPG™ glycol

- Excellent weatherability
- Excellent boiling water resistance
- Excellent stain resistance



CAS: 126-30-7

Introduction

Eastman NPG™ glycol is the glycol of choice for premium-quality gel coats. It reacts rapidly with Eastman™ purified isophthalic acid (PIA) to produce low-color gel coat resins. Gel coats based on the combination of NPG glycol with PIA provide a unique balance of properties including excellent weatherability, hydrolytic stability, and stain resistance.

These performance benefits are shown by direct comparison of a gel coat resin based on NPG glycol with a similar resin based on propylene glycol (PG). Instructions for preparing a typical gel coat and clear casting are presented along with mechanical properties determined from the clear castings.

Polyester resin formulations

Table 1 summarizes the composition of the gel coat resins used in this study. Constants in the resins include the glycol-to-diacid molar ratio and the saturated diacid-to-maleic anhydride (MA) molar ratio. Table 2 gives pertinent physical properties of these resins.

Table 1 **Molar compositions of polyester resins**

	Resin formulations	
Reactants	NPG/PIA/MA	PG/PIA/MA
Eastman NPG™ glycol	2.1	—
Propylene glycol	—	2.1
Eastman™ PIA	1.0	1.0
Maleic anhydride[a]	1.0	1.0

[a]*Reactant charged in second stage*

Table 2 **Physical properties**

	Resin system	
Properties measured	NPG/PIA/MA	PG/PIA/MA
Acid value[a]	17	27
ICI viscosity, poise[b]	9.2	10.2
Molecular wt, number average[c]	2,281	2,189
Molecular wt, weight average[c]	5,563	5,509

[a]*Acid value is expressed in milliliter equivalents of potassium hydroxide per gram resin.*

[b]*ICI™ Cone and Plate viscometer, 0–40 spindle @ 175°C*

[c]*Determined by gel permeation chromatography*

Synthesis apparatus and procedure

Conventional laboratory processing techniques were used to synthesize all resins.

The NPG glycol/PIA-based polyester was synthesized by a two-stage process. Variables such as up-heat time, reaction temperature (max. 200°C), and inert gas flow were held constant for the polyester resins being evaluated.

On completion of the polyesterification, the reaction product was cooled to approximately 130°C and blended with 30 wt% styrene monomer and 100 ppm hydroquinone (HQ), both based on total solution weight.

Preparation of gel coat laminates

Gel coat laminates were prepared to compare the performance of the Eastman NPG™ glycol versus PG-based resins. Table 3 shows the gel coat formulation. Titanium dioxide was dispersed in a portion of the resin to a Hegman™ fineness of 5–6 units. Fumed silica (thixotropic agent) was blended into the resin (vehicle blend) followed by the cobalt promoter. Finally, enough of the pigment grind was mixed with the vehicle blend so that the finished gel coat contained 20 wt% titanium dioxide.

Test laminates 3.18 mm (0.125 inch) thick were prepared by pouring gel coat catalyzed with 1 wt% methyl ethyl ketone peroxide (MEKP) on a polished glass plate and using a drawdown applicator to obtain an 18- to 20-mil cured coating. After gelation, the coating was allowed to cure at room temperature until almost tack-free. A general-purpose laminating resin was then poured onto the gel coat film and reinforced with three plies of 42.5-g (1.5-ounce) chopped-strand fiberglass mat. On a weight basis, a resin:fiberglass ratio of 70:30 was maintained for each of the laminates. The laminates were cured at room temperature until the exotherm subsided, then postcured for 2 hours at 66°C (150°F). Test specimens cut from the laminates were evaluated by conventional test methods. Since each part of the composite influences gel coat performance, the same amount and type of laminating resin and fiberglass were used in preparing each laminate.

Evaluation of gel coat laminates

Gel coats based on the polyester resins shown in Table 1 were evaluated for performance using commonly accepted tests. Results of these tests (Tables 4–6) show that the Eastman NPG™ glycol-based gel coat provided better weatherability, hydrolytic stability, and stain resistance than the propylene glycol-based gel coat.

Table 3 **Pigmented gel coat formulation**

Composition		Wt, grams
Pigment grind	Polyester resin (55 wt% solids in styrene)	48.00
	Titanium dioxide R-902[a]	72.00
Vehicle blend	Polyester resin (55 wt% solids in styrene)	130.40
	Cab-O-Sil™ M-5 silica[b]	30.00
	Pigment grind (above)	66.60
Additives[c]	Hydroquinone, 100 ppm[c]	0.02
	Cobalt octoate (6% Co metal), 0.3%	0.47
	Eastman™ DMAA, 0.4%	0.63
	Lupersol™ DDM-9,[d] methyl ethyl ketone peroxide,1.0%	1.57
Total		229.69

[a]*DuPont*
[b]*Cabot*
[c]*Based on weight of polyester resin and styrene*
[d]*Elf Atochem*

Weatherability

One vitally important characteristic of premium-quality gel coats is their ability to maintain a desirable appearance after extended exposure to natural sunlight in a variety of humidity conditions. Eastman NPG™ glycol has a proven record of prolonged durability in a number of thermoset coatings applications. Table 4 further demonstrates this resistance to adverse effects of weathering.

Gel-coated panels based on Eastman NPG™ glycol and propylene glycols were prepared and exposed in Florida for one year. The gloss retention for gel coats based on NPG glycol was significantly greater than for those based on propylene glycol. In addition, the yellowing produced was substantially less for the NPG glycol-based gel coats. These important elements of weathering show that NPG is the glycol of choice for gel coat applications.

Table 4 One-year Florida weathering results[a]

	Resin system			
	NPG/PIA/MA		PG/PIA/MA	
	Exposure time, months			
Properties measured	0	12	0	12
20° Gloss[b]	96	28	94	2
60° Gloss[b]	101	50	100	11
b-color[c]	1.12	2.42	1.28	3.44

[a]*Test panels were exposed in Florida, facing south at a 5° angle, ASTM D4141-87.*

[b]*Specular gloss, ASTM D523-89. Values determined on Gardner™ Glossmeter (Gardner Laboratories)*

[c]*HunterLab Ultrascan, ASTM D2244-89 and ASTM E308-90.*

Boiling water resistance

Table 5 summarizes the responses of gel coat laminates exposed to distilled boiling water for 100 hours. Laminates based on NPG glycol displayed fewer blisters and less fiber prominence than those based on propylene glycol.

Table 5 Boiling water resistance[a]

	Resin system	
Performance areas	NPG/PIA/MA	PG/PIA/MA
Blisters	2	4
Cracks	0	0
Fiber prominence	0	1
Loss of gloss	0	0
Color change	1	1
Total	3	6

[a]*Low numbers denote best performance; ANSI Z124.1-5.1.*

Stain resistance

After being subjected to a variety of stains, the gel coat laminates were evaluated for resistance to those reagents. The results, summarized in Table 6, reveal that the predominant variable in reducing staining is the choice of glycol. Again, Eastman NPG™ glycol proved to be superior to propylene glycol.

Table 6 **Stain resistance**[a]

	Resin system	
Performance areas	NPG/PIA/MA	PG/PIA/MA
Black shoe polish	1	2
Gentian violet	2	5
Iodine (30 min.)	2	3
Total	5	10

[a]*ANSI Z124.1; lowest values indicate best performance*

Preparation of clear castings

The mechanical properties of the resins were evaluated using clear castings. Castings 3.18 mm (0.125 in.) thick were prepared by dispersing the additives listed in Table 7 into the polyester resin, adding the MEKP last. Each component was slowly stirred in before the next was added. A mold was prepared for the clear casting using 2 tempered glass plates 25.4 x 30.5 cm (10 x 12 in.), 2 pieces of 5-mil Mylar™ 25.4 x 30.5 cm (10 x 12 in.), 3 pieces of rubber gasket material 1.3 x 30.5 x 0.3 cm (0.5 x 12 x 0.125 in.), and 12 large clamps or equivalent. The glass plates were cleaned with acetone and a piece of Mylar placed on top. A strip of rubber gasket material was placed along the outer edge of 3 sides of the glass, and the pieces butted together to ensure a leakproof seal. A second piece of Mylar was placed on top of the rubber gasket and the second glass plate placed on top. Next, 2-in.-wide masking tape was used to seal the 3 sides fitted with gasket material. The sides and bottom were then secured using clamps to prevent leakage.

The mold was placed in a vertical position and the solution slowly poured into it to avoid air entrapment. The resin solution was permitted to gel overnight. The clamps, tape, and rubber gaskets were then removed. With the casting still between the glass plates, it was placed in an oven at 120°C for 2 hours to postcure. The mold was removed from the oven and allowed to cool to room temperature (about 4 hours). The mold was removed by pulling the glass and Mylar™ from the casting.

Table 7 **Clear casting formulation**

Composition	Wt, grams
Polyester resin (55 wt% solids in styrene)	225.00
Cobalt octoate (6% Co metal), 0.3%[a]	0.68
Eastman™ DMAA, 0.25%[a]	0.56
Eastman™ HQ, 175 ppm[a]	0.04
Lupersol DDM-9,[b] methyl ethyl ketone peroxide, 1.0%[a]	2.25
Total	228.53

[a]*Percentage based on weight of polyester resin and styrene*
[b]*Elf Atochem*

Evaluation of clear castings

Clear castings were prepared from both of the resin formulations listed in Table 1. A summary of the initial mechanical properties and the changes that resulted from exposure of the castings to 5 wt% sodium hydroxide (NaOH) solution at 66°C is provided in Table 8. The retention of mechanical properties after exposure to this corrosive environment was superior for the castings based on Eastman NPG™ glycol compared with those based on propylene glycol.

Table 8 **Changes in mechanical properties of clear castings exposed to 5 wt% NaOH @ 60°C**

	Resin system					
	NPG/PIA/MA			PG/PIA/MA		
	Exposure time, weeks					
Mechanical properties	0	6	12	0	6	12
Tensile strength @ fracture,[a] MPa (psi)	67 (9,710)	63 (9,155)	67 (9,680)	56 (8,050)	41 (5,975)	38 (5,495)
Elongation @ fracture,[a] %	2.2	1.9	2.1	1.7	1.1	1.1
Tensile modulus of elasticity,[a] MPa (10^5 psi)	3,792 (5.50)	3,840 (5.57)	3,585 (5.20)	3,585 (5.20)	3,903 (5.66)	3,654 (5.30)
Flexural modulus of elasticity,[b] MPa (10^5 psi)	3,558 (5.16)	3,682 (5.34)	3,634 (5.27)	3,716 (5.39)	3,723 (5.40)	3,634 (5.27)
Flexural strength,[b] MPa (psi)	131 (18,930)	109 (15,800)	110 (16,000)	130 (18,790)	102 (14,800)	82 (11,900)

[a]*ASTM D638*
[b]*ASTM D790*

Summary

The selection of Eastman NPG™ glycol is important for the preparation of a premium-quality gel coat resin. In this study based on the combination of a single glycol with a single saturated diacid and maleic anhydride, results clearly demonstrate that NPG glycol provides several performance advantages (improved hydrolytic stability, better weathering, and superior stain resistance) over propylene glycol in gel coat applications.

Eastman publication reference

GN-396 *Eastman™ copromoters for effective polyester cure*

GN-407 *Eastman™ inhibitors for the fiberglass reinforced plastics market*

GN-417 *Eastman™ products for the unsaturated polyester resin market*

N-307 *Eastman™ resin intermediates and their performance characteristics*

Eastman Chemical Company
Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

Telephone:
U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations, (1) 423-229-2000
Fax: (1) 423-229-1193

Eastman Chemical Latin America
9155 South Dadeland Blvd.
Suite 1116
Miami, FL 33156 U.S.A.

Telephone: (1) 305-671-2800
Fax: (1) 305-671-2805

Eastman Chemical B.V.
Fascinatio Boulevard 602-614
2909 VA Capelle aan den IJssel
The Netherlands

Telephone: (31) 10 2402 111
Fax: (31) 10 2402 100

Eastman (Shanghai) Chemical
Commercial Company, Ltd. Jingan Branch
1206, CITIC Square
No. 1168 Nanjing Road (W)
Shanghai 200041, P.R. China

Telephone: (86) 21 6120-8700
Fax: (86) 21 5213-5255

Eastman Chemical Japan Ltd.
MetLife Aoyama Building 5F
2-11-16 Minami Aoyama
Minato-ku, Tokyo 107-0062 Japan

Telephone: (81) 3-3475-9510
Fax: (81) 3-3475-9515

Eastman Chemical Asia Pacific Pte. Ltd.
#05-04 Winsland House
3 Killiney Road
Singapore 239519

Telephone: (65) 6831-3100
Fax: (65) 6732-4930

www.eastman.com