# Nourybond® Adhesion Promoters
## for Automotive Plastisol Applications

EVONIK
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# Contents

# Introduction

Evonik offers a full line of high-quality, performance-oriented Nourybond® adhesion promoters for automotive plastisol applications. When properly used in PVC or acrylic plastisol formulations, these products can improve the adhesion of plastisols to many automotive-grade primed metal surfaces.

Plastisols are often used as an automobile underbody coating and seam sealant. They are applied on electrodeposition primed (E-coat primed) metals and exposed to high temperatures in a body shop or paint shop, usually ranging between 120 °C and 160 °C. During this exposure, the diffusion of PVC or acrylic resin in a plasticizer forms a continuous adhesive film.

Nourybond adhesion promoters are either polyamide-based or blocked isocyanate-based. Both types are summarized at right.

Polyamide-based adhesion promoters are typically used in PVC plastisol formulations at 0.5 to 1.5 parts by weight. There are nine varieties of polyamide-based Nourybond adhesion promoters. These adhesion promoters have different compositions and therefore deliver a variety of handling and performance properties. **Table 1** summarizes their handling properties.

Blocked isocyanate-based adhesion promoters are typically used in PVC and acrylic plastisol formulations at 2.0 to 5.0 parts by weight. These adhesion promoters can be used with or without a polyamide-based adhesion promoter, depending on the application, required properties and chemistry of the plastisol.

There are five varieties of blocked isocyanate-based Nourybond adhesion promoters. These adhesion promoters differ in composition in terms of basic polymer, blocking agent and plasticizer and therefore deliver different handling and performance properties. **Table 2** summarizes their handling properties. **Table 3** references their performance properties.

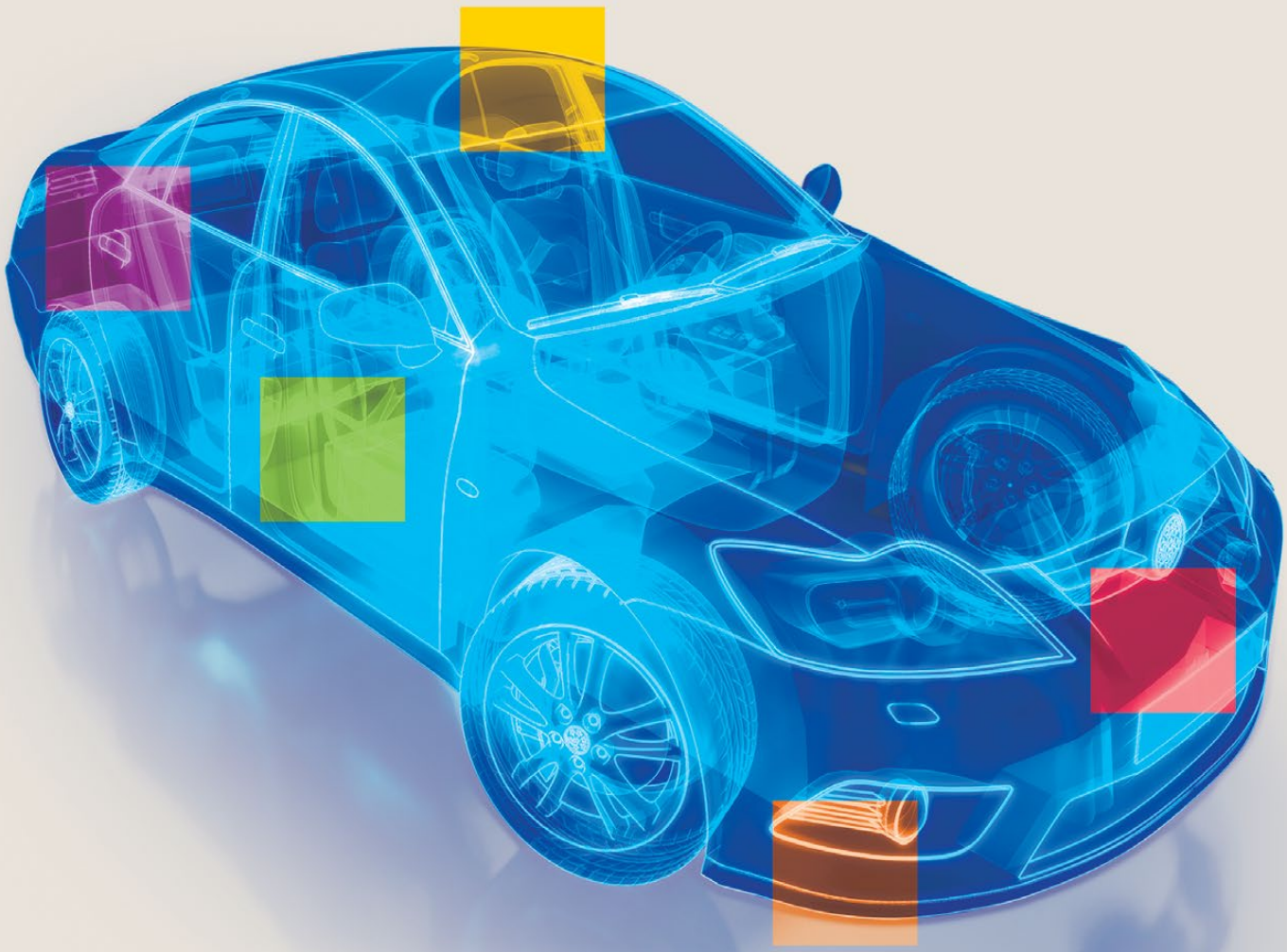
**Table 1** Summary of Polyamide-Based Nourybond Adhesion Promoters

| Adhesion Promoter | Color (Gardner) | Viscosity [mPa·s] | Amine Value (mg KOH/g) | Comments |
|---|---|---|---|---|
| **Nourybond® 272** | max. 10 | 15,000 - 35,000 @ 25 °C | 185 - 250 | Good overall balance of properties. |
| **Nourybond® 276** | max. 10 | 8,000 - 28,000 @ 25 °C | 110 - 130 | Excellent rheological properties and high strength. Best color stability. |
| **Nourybond® 301** | max. 12 | 1,000 - 1,500 @ 75 °C | 380 - 400 | Plasticizer free (100% solids). Improves coatability of plastisols. |
| **Nourybond® 308** | max. 12 | 12,500 - 22,500 @ 25 °C | 180 - 210 | Non-phthalate plasticizer. Good humidity resistance. |
| **Nourybond® 312** | max. 12 | 2,000 - 4,000 @ 75 °C | 440 - 500 | Plasticizer free (100% solids). Excellent adhesion. Good humidity resistance. |
| **Nourybond® 316** | max. 14 | 1,000 - 2,000 @ 75 °C | 260 - 310 | Non-phthalate plasticizer. Excellent adhesion and good rheology. |
| **Nourybond® 346** | max. 12 | 1,000 - 3,000 @ 25 °C | 280 - 330 | Non-phthalate plasticizer, good handling properties. |
| **Nourybond® 356** | max. 12 | 1,000 - 4,000 @ 25 °C | 185 - 200 | Non-phthalate plasticizer, good handling properties. |
| **Nourybond® 368** | max. 12 | 2,000 - 8,000 @ 25 °C | 225 - 245 | Non-phthalate plasticizer, good handling properties. |

**Table 2** Summary of Blocked Isocyanate-Based Nourybond Adhesion Promoters

| Adhesion Promoter | Color (Gardner) | Viscosity [mPa·s] @ 25 °C | Type of Isocyanate | % Blocked Isocyanate | Comments |
|---|---|---|---|---|---|
| **Nourybond® 289** | max. 2 | 30,000 - 50,000 | Toluene Diisocyanate | 1.8 - 2.1 | Recommended for acrylic and PVC plastisols. Excellent color stability, superior plastisol rheology and wet-onwet paint capability. Must be used without a polyamidebased adhesion promoter. |
| **Nourybond® 290** | max. 2 | 2,000 - 6,000 | Toluene Diisocyanate | 1.6 - 3.2 | Recommended for acrylic and PVC plastisols. Used in conjunction with a small amount of polyamidoamine adhesion promoter. |
| **Nourybond® 291** | max. 4 | 20,000 - 80,000 | Toluene Diisocyanate | 3.0 - 3.6 | Recommended for acrylic plastisols only. Solvent-free version. |
| **Nourybond® 292** | max. 5 | 1,000 - 2,200 | Toluene Diisocyanate | 3.0 - 3.7 | Recommended for acrylic and PVC plastisols. Strong film strength, excellent low-temperature properties. |
| **Nourybond® 293** | max. 4 | 5,000 - 12,500 | Hydrogenated Methylene Diisocyanate | 4.1 - 4.9 | Recommended for acrylic and PVC plastisols. Strong resin strength, excellent adhesion. |

**Figure 1** Nourybond Adhesion Promoter Application Recommendations



### VISIBLE SEALERS

- Hem flange areas
- Color stable
- Paintable
- Sag resistant

Nourybond 276
Nourybond 289
Nourybond 292
Nourybond 293

### NON-VISABLE SEALERS

- Interior applications
- Sag resistant
- Stable viscosity

Nourybond 272
Nourybond 308
Nourybond 346
Nourybond 368

### HIGH BAKE SYSTEM

- General applications
- 140-160 °C bake
- Physical properties

Nourybond 272
Nourybond 276
Nourybond 308
Nourybond 316
Nourybond 346
Nourybond 368

### UNDERBODY COATINGS

- 120-130 °C bake
- High physical strength
- Tough
- Flexible

Nourybond 276
Nourybond 290
Nourybond 308
Nourybond 312
Nourybond 316
Nourybond 368

### ANTI-CHIP COATINGS

- Color stable
- Paintable
- Tough and flexible
- Low viscosity

Nourybond 276
Nourybond 290
Nourybond 289
Nourybond 292
Nourybond 293

**Table 3** Nourybond Adhesion Promoter Property Performance

| Adhesion Promoter | Adhesion | Rheology | Tensile Properties | Color Stability | Viscosity Stability |
|---|---|---|---|---|---|
| **Nourybond 272** | ++ | ++ | ++ | ++ | ++ |
| **Nourybond 276** | ++ | +++ | +++ | +++ | + |
| **Nourybond 301** | ++ | + | ++ | ++ | ++ |
| **Nourybond 308** | ++ | ++ | +++ | ++ | ++ |
| **Nourybond 312** | +++ | + | +++ | + | ++ |
| **Nourybond 316** | ++ | ++ | +++ | + | ++ |
| **Nourybond 346** | ++ | ++ | ++ | ++ | +++ |
| **Nourybond 356** | ++ | ++ | ++ | ++ | ++ |
| **Nourybond 368** | ++ | ++ | +++ | ++ | +++ |
| **Nourybond 289** | +++ | +++ | ++ | +++ | +++ |
| **Nourybond 290** | + | +++ | +++ | + | +++ |
| **Nourybond 292** | +++ | ++ | ++ | + | ++ |
| **Nourybond 293** | ++ | ++ | ++ | + | ++ |

+++ = Excellent ++ = Good + = Moderate

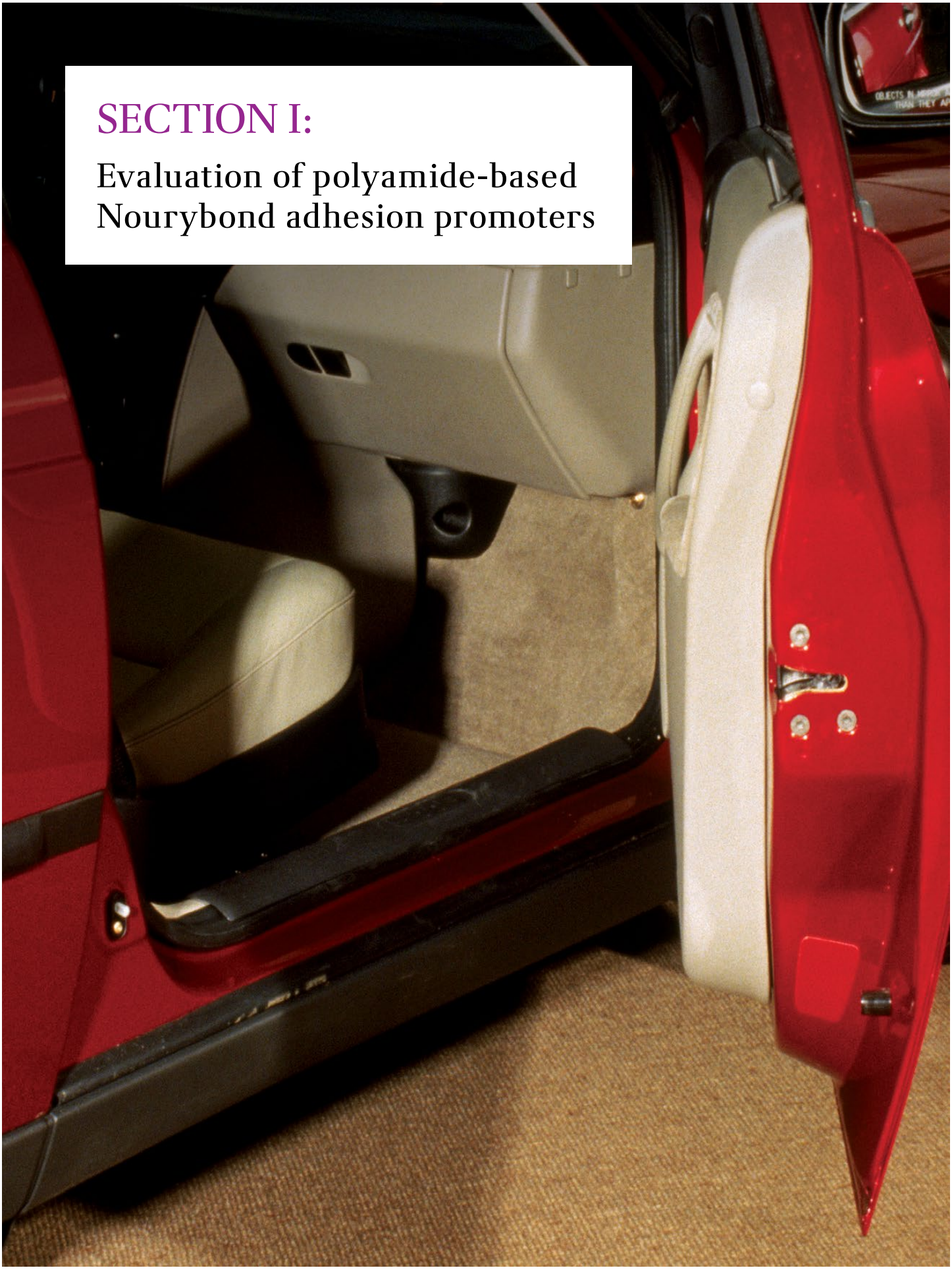
**The Nourybond adhesion promoters were incorporated into model PVC plastisol formulations to evaluate their performance. The model formulations, test methods, results and conclusions are presented in this brochure as follows:**

Section I: Evaluation of polyamide-based Nourybond adhesion promoters

1. Adhesion
2. Rheology
3. Tensile properties
4. Viscosity stability
5. Color stability

Section II: Evaluation of blocked isocyanate-based Nourybond adhesion promoters

1. Adhesion
2. Rheology
3. Tensile properties
4. Color stability



# SECTION I:

## Evaluation of polyamide-based Nourybond adhesion promoters

The following comparative evaluations of polyamide-based Nourybond adhesion promoters use a model PVC plastisol formulation. While we recognize this formulation cannot approximate every type of application or performance requirement in the marketplace, it is useful and necessary to demonstrate the general capabilities of our products for automotive applications.

**Table 4** describes the components and composition of the model formulation. It is neither our intention nor recommendation that this formulation be used in actual commercial applications.

Sample preparation was carried out as follows: A carefully measured amount of adhesion promoter (0.5, 1.0 or 1.5 parts) was added to a plasticizer and then mixed by hand using a spatula. Next, three types of PVC resins, two grades of $CaCO_3$, fumed silica, CaO and ZnO were introduced, followed by the addition of solvent. Once the solid materials were sufficiently wet, the plastisol was mixed under medium shear at room temperature until completely homogeneous. Additional dispersion followed using a three-roll mill. Finally, the plastisol was degassed under vacuum to remove any entrapped air.

Model plastisol formulations were evaluated for the key properties mentioned earlier.

**Table 4** Model PVC Plastisol Formulation

| Component | Function | Parts by weight | Supplier** |
|---|---|---|---|
| **Diisononylphthalate** | Plasticizer | 30 | BASF |
| **PVC - VESTOLIT® 1353 K** | PVC-homopolymer | 7.5 | Vestolit GmbH & Co. KG |
| **PVC - Lacovyl® PA 1384** | PVC - copolymer | 5 | ARKEMA |
| **PVC - Vinnolit® SA 1062/7** | PVC - copolymer | 17.5 | Vinnolit GmbH & Co. KG |
| **Socal® 312** | Coated chalk | 16 | Solvay Chemicals |
| **Ulmer Weiss XM** | Natural chalk | 16 | Eduard Merkle GmbH |
| **AEROSIL® 200** | **Thixotropic agent** | **0.5** | **Evonik Corporation** |
| **CaO Precal® 30S** | Drying agent | 2 | Schaefer Kalk |
| **Zinc Oxide** | Stabilizer | 0.2 | AppliChem GmbH |
| **ExxsolTM D 80** | Solvent | 4.3 | Exxon Mobil Chemical |
| **Nourybond** | **Adhesion Promoter** | **Varies*** | **Evonik Corporation** |

* Three different loading levels of Nourybond adhesion promoters were used: 0.5, 1.0 and 1.5 parts by weight.

** Suppliers of PVC resins in North America are Formosa Plastics Corporation and Kaneka Corporation. In Asia, Nippon Zeon Corporation, Tosoh Corporation, and Kaneka Corporation.

# 1. Adhesion

Adhesion to E-coat primed metals was evaluated by a manual adhesion test and a single lap shear test. Both tests used the following five E-coat primed metals and three bake cycles.

E-coat primers used on steel substrates: BASF CathoGuard® 520, BASF U32 AD350 V, PPG-6060C, DuPont EC-3000AM® and DuPont CorMax® VI

Bake time in oven and temperature: 30 minutes at 130 °C, 140 °C or 160 °C

**MANUAL ADHESION:**

The manual adhesion test examines the adhesion of model plastisols to E-coat primed substrates. This test provides a preliminary evaluation of the efficiency and effectiveness of Nourybond adhesion promoters. Adhesion was evaluated as a function of adhesion promoter loading level, bake temperature and substrate.

## Test Method:

Each model plastisol formulation is applied to a clean E-coat primed substrate in a continuous ribbon measuring 8 cm long, 15 mm wide, and gradually increasing in thickness from 0 to 3 mm. The samples are baked in a convection oven for 30 minutes at 130 ˚C, 140 ˚C or 160 ˚C. After baking, the samples are returned to ambient temperature and two manual adhesion tests are performed: the first after 1 hour and the second after 24 hours.

The adhesion measurement technique is somewhat complicated and subjective. First, two parallel strips are cut at the thick (3 mm) side of the plastisol ribbon. The strips are 1.5 cm apart. A scraper is inserted underneath the cut strip, cleanly separating the first 0.5 - 1 cm of the strip from the substrate. The loose hanging edge of the plastisol strip is then pulled away from the substrate. The first strip is pulled quickly, and the second is pulled slowly. Manual adhesion is subjectively evaluated in three categories based on the degree of force required to pull the plastisol strip from the substrate: excellent adhesion, acceptable adhesion or unacceptable adhesion.

**Table 5** presents the results of the manual adhesion test.

## Conclusions:

- Adhesion is impacted by bake temperature, E-coat primer and the loading level of the adhesion promoter.
- In general, adhesion is improved by increasing both the loading level of Nourybond adhesion promoter and the bake temperature.
- Increasing the adhesion promoter's loading level from 0.5 to 1.0 parts significantly improves adhesion. A further increase to 1.5 parts produces a minor improvement in adhesion.
- Except when paired with BASF CathoGuard 520 primed substrate, an adhesion promoter loading level of 0.5 parts does not produce acceptable adhesion at 130 °C.
- Adhesion is impacted by substrate selection. Substrates primed with DuPont CorMax VI show the least plastisol adhesion at a loading level of 0.5 parts.
- Nourybond 312 adhesion promoter produces the best plastisol adhesion across all substrates, bake temperatures and loading levels, followed by Nourybond 301 adhesion promoter.
- Nourybond 316 adhesion promoter offers very good adhesion at loading levels of 1.0 and 1.5 parts.

**Table 5** Manual Adhesion Results

| Bake Cycle | Adhesion Promoter | BASF CATHOGUARD 520 | | | BASF U32 AD350 V | | | PPG 6060 | | | DUPONT EC-3000AM | | | DUPONT CORMAX VI | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 parts | 1.0 parts | 1.5 parts | 0.5 parts | 1.0 parts | 1.5 parts | 0.5 parts | 1.0 parts | 1.5 parts | 0.5 parts | 1.0 parts | 1.5 parts | 0.5 parts | 1.0 parts | 1.5 parts |
| 30 minutes at 130 °C | Nourybond 272 | | +++ | +++ | | + | +++ | | + | +++ | | +++ | + | | +++ | + |
| | Nourybond 276 | | +++ | + | | + | + | | +++ | +++ | | | + | | + | + |
| | Nourybond 301 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | + | +++ | +++ | | +++ | +++ |
| | Nourybond 308 | +++ | +++ | +++ | | +++ | +++ | + | + | +++ | + | + | +++ | | + | + |
| | Nourybond 312 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | + | +++ |
| | Nourybond 316 | +++ | +++ | +++ | + | +++ | +++ | + | +++ | +++ | | +++ | +++ | | + | +++ |
| | Nourybond 346 | +++ | +++ | +++ | +++ | + | +++ | + | +++ | +++ | | +++ | +++ | | +++ | + |
| | Nourybond 356 | + | +++ | +++ | | + | + | | +++ | +++ | | + | +++ | | +++ | +++ |
| | Nourybond 368 | +++ | +++ | +++ | +++ | +++ | +++ | | + | + | | + | +++ | | +++ | +++ |
| 30 minutes at 140 °C | Nourybond 272 | +++ | +++ | +++ | | + | + | | + | +++ | | + | +++ | | + | + |
| | Nourybond 276 | + | + | +++ | | + | + | | + | + | | | | | + | |
| | Nourybond 301 | +++ | +++ | +++ | + | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| | Nourybond 308 | +++ | +++ | +++ | + | + | +++ | +++ | +++ | + | | + | +++ | +++ | +++ | +++ |
| | Nourybond 312 | +++ | +++ | +++ | + | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| | Nourybond 316 | +++ | +++ | +++ | +++ | +++ | +++ | + | +++ | +++ | + | +++ | +++ | | + | +++ |
| | Nourybond 346 | +++ | +++ | +++ | +++ | | +++ | +++ | + | +++ | + | +++ | +++ | | +++ | + |
| | Nourybond 356 | +++ | +++ | +++ | + | + | + | + | + | + | | + | + | | + | + |
| | Nourybond 368 | +++ | +++ | +++ | + | + | +++ | + | + | + | + | +++ | +++ | | + | + |
| 30 minutes at 160 °C | Nourybond 272 | +++ | +++ | +++ | + | | +++ | +++ | + | +++ | + | +++ | +++ | | + | +++ |
| | Nourybond 276 | +++ | +++ | +++ | + | | | +++ | | + | + | | | | | |
| | Nourybond 301 | +++ | +++ | +++ | + | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| | Nourybond 308 | +++ | +++ | +++ | + | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | + | +++ | +++ |
| | Nourybond 312 | +++ | +++ | +++ | + | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| | Nourybond 316 | +++ | +++ | +++ | + | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | | +++ | +++ |
| | Nourybond 346 | +++ | +++ | +++ | + | + | +++ | +++ | +++ | +++ | +++ | +++ | +++ | + | + | +++ |
| | Nourybond 356 | +++ | +++ | +++ | | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | | +++ | +++ |
| | Nourybond 368 | +++ | +++ | +++ | | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | | +++ | +++ |

+++ Excellent adhesion + Acceptable adhesion (Blank) Unacceptable adhesion

## LAP SHEAR ADHESION:

The most important parameters controlled by adhesion promoters are plastisol adhesion to primed metals and mode of failure. The following information presents the shear adhesion properties of formulations containing polyamide-based Nourybond adhesion promoters.

## Test Method:

25 mm x 100 mm (W x L) lap coupons of E-coat primed metal were bonded by model plastisol formulations to form a 25 mm overlap and a 3 mm bond line thickness. These bonded lap shears were baked for 30 minutes at 130 °C, 140 °C or 160 °C. When the samples cooled to ambient temperature, lap shear strength was evaluated by pulling apart the bonded metals at 50 mm/min crosshead speed until failure. Afterward, the joints were examined for their mode of failure.

## Results:

**Table 6** presents lap shear strengths in $N/mm^2$ and mode of failure.

## Conclusions:

- Higher lap shear strength and percent cohesive failure can be achieved through higher bake temperatures (140 °C and 160 °C, as tested).
- Increasing the loading level of Nourybond adhesion promoters from 0.5 to 1.0 parts significantly increases adhesion strength and percent cohesive failure. Increasing the loading level from 1.0 to 1.5 parts demonstrates some positive impact on lap shear strength.
- Shear adhesion and mode of failure depend on the substrate's E-coat primer. Model plastisols showed lower adhesive strength when applied to DuPont CorMax VI and EC-3000AM versus other E-coat primed substrates, especially at a loading level of 0.5 parts.
- For formulations with a loading level of 0.5 parts and a bake temperature of 130 °C, Nourybond 312 adhesion promoter demonstrates the best adhesive performance.
- Nourybond 312-based formulations show cohesive failure across all substrates, loading levels and bake temperatures. Formulations containing other Nourybond adhesion promoters show adhesive failure on at least one substrate when tested at 0.5 parts loading level and 130 °C bake temperature. When Nourybond adhesion promoters are tested under all other conditions, their mode of failure is predominantly cohesive.

**Table 6** Lap Shear Strength in N/mm$^2$ and Mode of Failure*

| | Adhesion Promoter | BAKE TEMPERATURE AND LOADING LEVEL | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 30 MINUTES AT 130 °C STRENGTH / MODE OF FAILURE | | | 30 MINUTES AT 140 °C STRENGTH / MODE OF FAILURE | | | 30 MINUTES AT 160 °C STRENGTH / MODE OF FAILURE | | |
| | | 0.5 parts | 1.0 parts | 1.5 parts | 0.5 parts | 1.0 parts | 1.5 parts | 0.5 parts | 1.0 parts | 1.5 parts |
| BASF U32 AD350 V Primed Substrate | Nourybond 272 | 1.08 / A | 1.49 / C | 1.49 / C | 1.67 / C | 1.64 / C | 2.05 / C | 2.29 / C | 2.41 / C | 2.55 / C |
| | Nourybond 276 | 0.57 / A | 1.35 / C | 1.43 / C | 1.41 / A | 1.91 / C | 1.92 / C | 2.34 / C | 2.32 / C | 2.34 / C |
| | Nourybond 301 | 1.46 / C | 1.45 / C | 1.47 / C | 1.77 / C | 1.92 / C | 2.09 / C | 2.37 / C | 2.61 / C | 2.82 / C |
| | Nourybond 308 | 1.48 / C | 1.54 / C | 1.74 / C | 1.73 / C | 2.03 / C | 2.20 / C | 2.44 / C | 2.55 / C | 2.70 / C |
| | Nourybond 312 | 1.73 / C | 1.75 / C | 1.75 / C | 1.88 / C | 2.33 / C | 2.39 / C | 2.56 / C | 2.71 / C | 2.92 / C |
| | Nourybond 316 | 1.59 / C | 1.80 / C | 1.58 / C | 1.77 / C | 1.92 / C | 2.15 / C | 2.33 / C | 2.63 / C | 2.63 / C |
| | Nourybond 346 | 1.27 / C | 1.41 / C | 1.54 / C | 1.41 / C | 1.77 / C | 1.72 / C | 2.39 / C | 2.21 / C | 2.44 / C |
| | Nourybond 356 | 1.38 / C | 1.53 / C | 1.68 / C | 1.62 / C | 2.00 / C | 2.19 / C | 2.39 / C | 2.39 / C | 2.67 / C |
| | Nourybond 368 | 1.56 / C | 1.59 / C | 1.66 / C | 1.64 / C | 1.81 / C | 2.23 / C | 2.08 / C | 2.45 / C | 2.50 / C |
| PPG 6060 Primed Substrate | Nourybond 272 | 0.78 / A | 1.41 / C | 1.48 / C | 1.59 / A | 1.90 / C | 1.90 / C | 2.30 / C | 2.56 / C | 2.50 / C |
| | Nourybond 276 | 0.61 / A | 1.32 / A | 1.52 / C | 1.48 / A | 1.81 / C | 1.78 / C | 2.52 / C | 2.46 / C | 2.28 / C |
| | Nourybond 301 | 1.43 / C | 1.50 / C | 1.43 / C | 1.64 / C | 2.07 / C | 1.90 / C | 2.43 / C | 2.80 / C | 2.71 / C |
| | Nourybond 308 | 1.45 / A | 1.39 / C | 1.79 / C | 1.63 / C | 2.23 / C | 2.22 / C | 2.28 / C | 2.80 / C | 2.63 / C |
| | Nourybond 312 | 1.83 / C | 1.65 / C | 1.77 / C | 1.78 / C | 2.42 / C | 2.37 / C | 2.63 / C | 2.86 / C | 2.86 / C |
| | Nourybond 316 | 1.52 / C | 1.52 / C | 1.63 / C | 1.73 / C | 2.03 / C | 2.19 / C | 2.41 / C | 2.84 / C | 2.55 / C |
| | Nourybond 346 | 1.38 / C | 1.43 / C | 1.51 / C | 1.54 / C | 1.79 / C | 1.83 / C | 2.23 / C | 2.52 / C | 2.59 / C |
| | Nourybond 356 | 1.24 / A | 1.41 / C | 1.66 / C | 1.53 / A | 2.05 / C | 2.12 / C | 2.50 / C | 2.72 / C | 2.54 / C |
| | Nourybond 368 | 1.39 / C | 1.50 / C | 1.70 / C | 1.63 / C | 1.82 / C | 2.36 / C | 2.22 / C | 2.58 / C | 2.59 / C |
| DuPont EC-3000AM Primed Substrate | Nourybond 272 | 0.70 / A | 1.27 / A | 1.55 / C | 0.91 / A | 1.25 / A | 1.88 / C | 1.77 / C | 2.57 / C | 2.16 / C |
| | Nourybond 276 | 0.95 / A | 1.32 / C | 1.57 / C | 1.19 / A | 1.87 / C | 1.43 / C | 1.98 / C | 2.58 / C | 2.13 / C |
| | Nourybond 301 | 1.63 / A | 1.57 / C | 1.61 / C | 1.61 / C | 1.74 / C | 1.74 / C | 2.32 / C | 2.85 / C | 2.08 / C |
| | Nourybond 308 | 0.97 / A | 1.54 / C | 1.77 / C | 1.56 / A | 2.00 / C | 1.97 / C | 2.31 / C | 2.78 / C | 2.58 / C |
| | Nourybond 312 | 1.57 / C | 1.68 / C | 2.23 / C | 1.90 / C | 2.25 / C | 2.24 / C | 2.72 / C | 2.92 / C | 3.06 / C |
| | Nourybond 316 | 1.07 / A | 1.45 / C | 1.57 / C | 1.88 / A | 2.12 / C | 2.14 / C | 2.31 / C | 2.63 / C | 2.50 / C |
| | Nourybond 346 | 1.29 / A | 1.28 / C | 1.37 / C | 1.65 / A | 1.92 / C | 1.55 / C | 2.12 / C | 2.72 / C | 2.46 / C |
| | Nourybond 356 | 0.83 / A | 1.36 / C | 2.13 / C | 1.11 / A | 2.06 / C | 1.97 / C | 2.41 / C | 2.71 / C | 2.48 / C |
| | Nourybond 368 | 1.11 / A | 1.61 / C | 1.45 / C | 1.60 / A | 1.93 / C | 1.99 / C | 2.08 / C | 2.29 / C | 2.36 / C |
| DuPont CorMax VI Primed Substrate | Nourybond 272 | 0.86 / A | 1.34 / C | 1.63 / C | 1.31 / A | 1.61 / C | 2.01 / C | 2.26 / C | 2.28 / C | 2.48 / C |
| | Nourybond 276 | 0.61 / A | 0.54 / A | 1.59 / C | 1.08 / A | 1.77 / A | 1.92 / C | 2.20 / C | 2.47 / C | 2.27 / C |
| | Nourybond 301 | 1.52 / C | 1.53 / C | 1.55 / C | 1.86 / C | 2.00 / C | 2.13 / C | 2.33 / C | 2.80 / C | 2.81 / C |
| | Nourybond 308 | 1.31 / A | 1.76 / C | 1.68 / C | 1.67 / C | 2.25 / C | 2.23 / C | 2.32 / C | 2.62 / C | 2.74 / C |
| | Nourybond 312 | 2.01 / C | 1.87 / C | 1.77 / C | 1.99 / C | 2.43 / C | 2.32 / C | 2.29 / C | 2.91 / C | 2.95 / C |
| | Nourybond 316 | 1.38 / A | 1.52 / C | 1.58 / C | 1.58 / C | 1.97 / C | 2.16 / C | 2.57 / C | 2.57 / C | 2.88 / C |
| | Nourybond 346 | 1.19 / C | 1.21 / C | 1.45 / C | 1.65 / C | 1.79 / C | 1.88 / C | 2.37 / C | 2.39 / C | 2.48 / C |
| | Nourybond 356 | 0.94 / A | 1.54 / C | 1.61 / C | 1.54 / A | 2.05 / C | 2.11 / C | 2.35 / C | 2.54 / C | 2.70 / C |
| | Nourybond 368 | 1.28 / C | 1.50 / C | 1.52 / C | 1.61 / C | 1.84 / C | 2.24 / C | 2.22 / C | 2.52 / C | 2.76 / C |

*Mode of Failure: C = cohesive failure, A = adhesive failure

# 2. Rheology

During application, a PVC plastisol goes through varying degrees of shear, making rheology a plastisol's second-most important characteristic after adhesion. The rheological behavior of each model plastisol was measured as a function of adhesion promoter loading level and storage time.

## Test Method:

Rheology was evaluated at 25 °C by exposing plastisol samples to an increasing and then decreasing shear rate on a coaxial cylindrical viscometer (Anton Paar: Physica MCR 101 with Z4 spindle). Testing was performed after 24 hours, one week, two weeks and four weeks of storage at 23 °C. During testing, shear rate was steadily increased from 0 to 400 sec-1 in 120 seconds. After reaching 400 sec-1, shear rate was held constant for 180 seconds and then steadily decreased to zero in 120 seconds.

Shear stress was plotted as a function of shear rate for both the upward stroke (increasing shear rate) and the downward stroke (decreasing shear rate). From these plots, the rheological behaviors of the model plastisols can be observed, including differences in yield point, viscosity and hysteresis area.

**Figure 2** illustrates a typical rheological profile of a plastisol formulation.

Thixotropy is reflected in the hysteresis area between the upward and downward strokes—in general, the greater the area between the strokes, the more thixotropic the formulation. The desirability of low or high thixotropy is a function of the application and therefore a distinguishing feature of plastisols and adhesion promoters. Seam sealers that are highly sag-resistant demonstrate very little thixotropy, while sprayable applications require greater thixotropy to aid flow and leveling once the plastisol is on the substrate surface.

The theoretical yield point is calculated as the y-intercept of a linear regression, fit to a Bingham model, performed on the data from the downward stroke. It is an indicator of the force required to induce flow in a plastisol. A relatively high yield point will offer improved sag resistance.

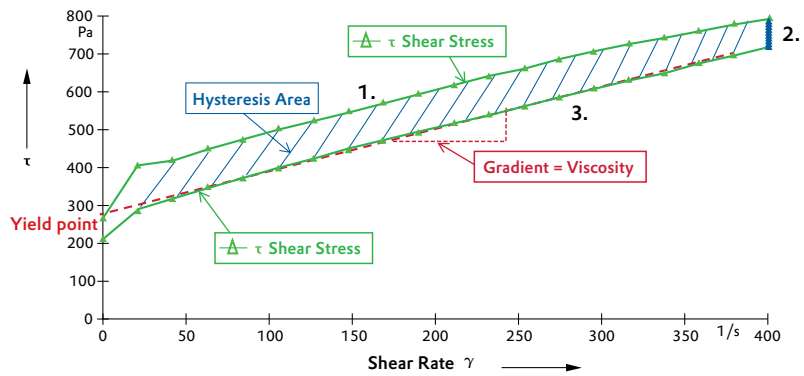
## Results:

**Table 7** presents the yield point, viscosity and hysteresis area for model plastisols formulated with polyamide-based Nourybond adhesion promoters.

## Conclusions:

- Adhesion promoter and loading level impact the rheology of a PVC plastisol formulation.
- In general, formulations with lower loading levels of Nourybond adhesion promoters (0.5 parts) show better rheology.
- Increasing the loading level of Nourybond adhesion promoter decreases a formulation's yield point and increases its viscosity.
- Across all loading levels, yield values greater than 200 Pa produce sufficient sag resistance for sprayable applications.
- Nourybond® 346 and 356 adhesion promoters demonstrate good rheology, with relatively high yield points and low viscosities across all loading levels.
- Overall, Nourybond 276 adhesion promoter demonstrates the best rheological profile across all loading levels.

**FIGURE 2** Typical Rheological Profile




1. Profile during increasing shear rate.
2. Profile during steady shear rate.
3. Profile during decreasing shear rate.

**Table 7** Rheology Data

| Adhesion Promoter | 0.5 PARTS | | | 1.0 PARTS | | | 1.5 PARTS | | | After |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yield Value [Pa] | Viscosity [Pa·s] | Hysteresis Area [Pa/s] | Yield Value [Pa] | Viscosity [Pa·s] | Hysteresis Area [Pa/s] | Yield Value [Pa] | Viscosity [Pa·s] | Hysteresis Area [Pa/s] | |
| **Nourybond 272** | 607 | 1.94 | 153,340 | 332 | 1.22 | 57,550 | 201 | 1.38 | 60,840 | 24h |
| | 631 | 1.86 | 121,640 | 278 | 1.47 | 63,330 | 197 | 1.59 | 82,140 | 1 week |
| | 581 | 1.91 | 129,910 | 265 | 1.57 | 75,250 | 187 | 1.56 | 84,340 | 2 weeks |
| | 477 | 1.68 | 159,140 | 246 | 1.56 | 77,400 | 198 | 1.73 | 113,740 | 4 weeks |
| **Nourybond 276** | 747 | 1.43 | 116,70 | 472 | 1.66 | 107,330 | 277 | 1.32 | 61,350 | 24h |
| | 608 | 1.66 | 159,370 | 405 | 1.59 | 169,350 | 261 | 1.46 | 113,390 | 1 week |
| | 605 | 1.65 | 197,170 | 423 | 1.70 | 199,500 | 262 | 1.48 | 112,640 | 2 weeks |
| | 562 | 1.56 | 183,580 | 405 | 1.71 | 218,120 | 246 | 1.55 | 141,300 | 4 weeks |
| **Nourybond 301** | 238 | 1.21 | 42.200 | 243 | 1.78 | 90,390 | 253 | 2.02 | 90,800 | 24h |
| | 213 | 1.39 | 59.470 | 263 | 1.84 | 126,020 | 281 | 2.29 | 109,300 | 1 week |
| | 217 | 1.45 | 66,390 | 278 | 2.11 | 123,730 | 299 | 2.25 | 124,410 | 2 weeks |
| | 218 | 1.45 | 68,480 | 276 | 2.07 | 154,440 | 280 | 2.26 | 145,200 | 4 weeks |
| **Nourybond 308** | 337 | 1.33 | 79,930 | 236 | 1.42 | 84,460 | 194 | 1.57 | 87,340 | 24h |
| | 288 | 1.56 | 81,100 | 223 | 1.70 | 108,050 | 210 | 1.85 | 135,820 | 1 week |
| | 288 | 1.60 | 78,790 | 251 | 1.85 | 140,360 | 214 | 1.94 | 159,700 | 2 weeks |
| | 287 | 1.63 | 84,480 | 241 | 1.96 | 155,190 | 207 | 1.90 | 202,680 | 4 weeks |
| **Nourybond 312** | 240 | 1.22 | 45,920 | 232 | 1.74 | 92,080 | 211 | 1.99 | 99,080 | 24h |
| | 244 | 1.45 | 60,740 | 247 | 1.85 | 125,350 | 238 | 2.17 | 121,470 | 1 week |
| | 247 | 1.51 | 63,120 | 276 | 1.60 | 115,279 | 262 | 2.08 | 136,50 | 2 weeks |
| | 239 | 1.50 | 63,720 | 245 | 1.94 | 142,570 | 261 | 2.40 | 151,920 | 4 weeks |
| **Nourybond 316** | 433 | 1.49 | 98,250 | 245 | 1.30 | 56,340 | 228 | 1.62 | 90,410 | 24h |
| | 380 | 1.71 | 92,610 | 213 | 1.48 | 87,460 | 269 | 1.86 | 113,330 | 1 week |
| | 391 | 1.79 | 87,170 | 234 | 1.56 | 83,280 | 282 | 1.96 | 119,210 | 2 weeks |
| | 387 | 1.85 | 96,520 | 213 | 1.59 | 97,510 | 281 | 2.03 | 136,260 | 4 weeks |
| **Nourybond 346** | 380 | 1.19 | 55,060 | 245 | 1.35 | 60,890 | 212 | 1.44 | 52,410 | 24h |
| | 274 | 1.47 | 63,030 | 222 | 1.53 | 88,690 | 199 | 1.64 | 83,710 | 1 week |
| | 266 | 1.51 | 63,920 | 240 | 1.58 | 94,590 | 215 | 1.62 | 91,080 | 2 weeks |
| | 261 | 1.57 | 74,250 | 229 | 1.66 | 108,130 | 206 | 1.79 | 99,060 | 4 weeks |
| **Nourybond 356** | 509 | 1.49 | 106,540 | 220 | 1.21 | 56,540 | 216 | 1.41 | 79,480 | 24h |
| | 391 | 1.79 | 110,470 | 253 | 1.43 | 86,410 | 239 | 1.51 | 115,820 | 1 week |
| | 382 | 1.80 | 104,340 | 258 | 1.55 | 102,850 | 255 | 1.65 | 126,630 | 2 weeks |
| | 370 | 1.81 | 100,310 | 283 | 1.48 | 121,830 | 243 | 1.68 | 145,060 | 4 weeks |
| **Nourybond 368** | 386 | 1.26 | 62,910 | 246 | 1.43 | 72,400 | 221 | 1.60 | 87,670 | 24h |
| | 298 | 1.55 | 74,530 | 289 | 1.67 | 106,340 | 235 | 1.72 | 109,560 | 1 week |
| | 293 | 1.52 | 68,980 | 295 | 1.70 | 121,190 | 251 | 1.87 | 136,560 | 2 weeks |
| | 282 | 1.56 | 71,070 | 318 | 1.74 | 111,600 | 255 | 2.01 | 163,970 | 4 weeks |

# 3. Tensile properties

Tensile properties such as tensile strength and tensile elongation at break are important parameters that contribute to plastisol performance. The following information highlights the tensile properties and performance of the model plastisols formulated with polyamide-based Nourybond adhesion promoters.

## Test Method:

Samples were prepared from model plastisol formulations in accordance with the methodology prescribed in DIN 53-504. Sample type "S2" (75 mm in length) was selected for this experiment. The samples were pulled at a crosshead speed of 200 mm/min until failure (break). Tensile strength and percent elongation at break were recorded for each formulation as a function of adhesion promoter loading level and bake temperature.

## Results:

**Tables 8 and 9** present results for tensile strength and tensile elongation at break.

## Conclusions:

- Tensile strength and tensile elongation at break increase significantly with higher bake temperatures.
- Nourybond 276, 308, 312, 316 and 368 adhesion promoters produce the greatest balance of tensile strength and tensile elongation across the entire range of bake temperatures.
- For formulations with a loading level of 0.5 parts and a bake temperature of 130 °C, Nourybond 276 adhesion promoter offers the best balance of tensile strength and elongation.
- For formulations with a bake temperature of 160 °C, Nourybond 316 adhesion promoter offers the best performance.

**Table 8** Tensile Strength at Break ($N/mm^2$)

| | BAKE TEMPERATURE AND LOADING LEVEL | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 MINUTES AT 130 °C | | | 30 MINUTES AT 140 °C | | | 30 MINUTES AT 160 °C | | |
| **Adhesion Promoter** | **0.5** | **1.0** | **1.5** | **0.5** | **1.0** | **1.5** | **0.5** | **1.0** | **1.5** |
| **Nourybond 272** | 1.56 | 1.82 | 1.65 | 1.90 | 2.24 | 2.14 | 2.45 | 2.30 | 2.65 |
| **Nourybond 276** | 1.62 | 1.85 | 1.75 | 2.07 | 2.43 | 2.12 | 2.40 | 2.76 | 2.63 |
| **Nourybond 301** | 1.41 | 1.77 | 1.66 | 1.94 | 2.03 | 2.09 | 2.64 | 2.75 | 3.00 |
| **Nourybond 308** | 1.41 | 1.95 | 2.03 | 1.94 | 2.08 | 2.01 | 2.52 | 2.65 | 2.83 |
| **Nourybond 312** | 1.40 | 2.16 | 2.01 | 2.10 | 2.19 | 2.13 | 2.44 | 3.17 | 3.07 |
| **Nourybond 316** | 1.43 | 1.65 | 1.38 | 1.57 | 1.65 | 1.75 | 2.26 | 2.52 | 2.26 |
| **Nourybond 346** | 1.35 | 1.79 | 1.51 | 1.76 | 1.86 | 2.10 | 2.50 | 2.90 | 2.63 |
| **Nourybond 356** | 1.11 | 1.93 | 1.74 | 2.10 | 1.98 | 1.94 | 2.38 | 2.87 | 2.94 |
| **Nourybond 368** | 1.40 | 1.88 | 1.97 | 1.75 | 2.10 | 1.92 | 2.56 | 2.64 | 3.12 |

# 4. Viscosity stability

Viscosity stability is an important parameter for defining a plastisol's workability and shelf stability. Typically, a plastisol's viscosity increases over time. The more stable a plastisol's viscosity remains over time, the better its workability in terms of pumpability and overall performance.

## Test Method:

Model PVC plastisol formulations were mixed at 25 °C. After 24 hours, the initial viscosity (time zero) of the plastisols was measured. The plastisols were then stored for 90 days at 25 °C. During this period, plastisol viscosities were measured at 30, 60 and 90 days. In a separate test, the viscosities of model plastisols were measured after three days of storage at 38 °C. Viscosity was tested using a rotational viscometer (Anton Paar: Physica MCR 101 and Z4 spindle). Measurements were taken after 4 minutes of shearing at a shear rate of 700 sec-1 and a temperature of 25 °C.

## Conclusions:

The following conclusions were made based on the observed results:

- Storage temperature has a significant impact on viscosity stability.
- Increased loading levels of Nourybond adhesion promoters do not appear to negatively impact viscosity stability.
- Three days of storage at 38 °C and 90 days of storage at 25 °C result in similar increases in viscosity.
- For formulations with loading levels of 0.5 parts, Nourybond 301, 312 and 346 adhesion promoters offer low plastisol viscosity and excellent viscosity stability.
- For formulations with loading levels of 1.0 and 1.5 parts, Nourybond 346 and 356 adhesion promoters offer low plastisol viscosity over 90 days of storage at 25 °C.
- All formulations demonstrate an approximate 15 to 20 percent increase in viscosity over 90 days of storage at 25 °C.
- Overall, Nourybond 346 adhesion promoter shows the best viscosity and viscosity stability.

**Table 9** Tensile Elongation at Break (percent)

| | BAKE TEMPERATURE AND LOADING LEVEL | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 MINUTES AT 130 °C | | | 30 MINUTES AT 140 °C | | | 30 MINUTES AT 160 °C | | |
| **Adhesion Promoter** | **0.5** | **1.0** | **1.5** | **0.5** | **1.0** | **1.5** | **0.5** | **1.0** | **1.5** |
| **Nourybond 272** | 37 | 56 | 59 | 57 | 80 | 84 | 101 | 108 | 115 |
| **Nourybond 276** | 47 | 56 | 58 | 66 | 65 | 77 | 90 | 103 | 103 |
| **Nourybond 301** | 40 | 53 | 61 | 82 | 81 | 92 | 129 | 122 | 94 |
| **Nourybond 308** | 43 | 55 | 61 | 68 | 64 | 79 | 123 | 114 | 68 |
| **Nourybond 312** | 41 | 59 | 75 | 70 | 84 | 105 | 97 | 125 | 104 |
| **Nourybond 316** | 46 | 67 | 62 | 55 | 76 | 75 | 132 | 120 | 122 |
| **Nourybond 346** | 37 | 58 | 63 | 63 | 83 | 77 | 110 | 133 | 125 |
| **Nourybond 356** | 30 | 64 | 66 | 70 | 78 | 95 | 101 | 131 | 122 |
| **Nourybond 368** | 35 | 56 | 63 | 51 | 86 | 89 | 119 | 105 | 107 |

# 5. Color stability

Color and color stability are important parameters that contribute to plastisol performance. Visible applications like seam sealers in hem flange areas require both very low initial color and long-term resistance to yellowing. This test provides a comparative evaluation of the color stability of plastisols containing Nourybond adhesion promoters.

## Test Method:

Plastisol formulations with various adhesion promoter loadings were applied to an E-coat primed metal substrate and baked for 30 minutes at 160 °C. After baking, the discoloration grade was subjectively recorded on a scale of 1 to 5, where grade 1 describes no discoloration (high color stability) and grade 5 describes the most visible discoloration (low color stability).

## Results:

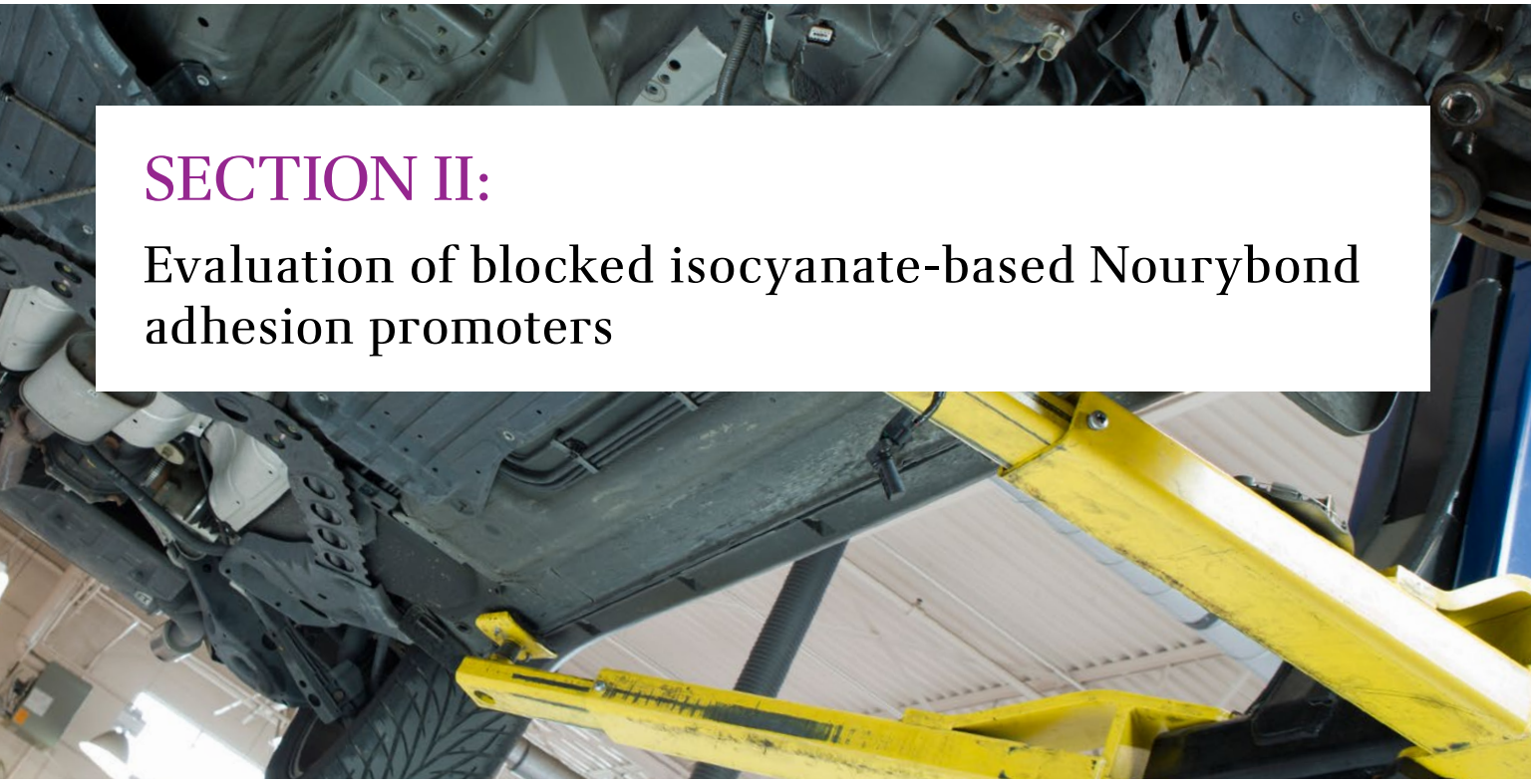
**Table 10** presents the discoloration ratings of various plastisol formulations.

## Conclusions:

- In general, increasing the loading level of a Nourybond adhesion promoter reduces a formulation's color stability, except when using Nourybond 272 and 308 adhesion promoters.
- Nourybond 276 adhesion promoter demonstrates the best color stability at all loading levels, followed by Nourybond 301

**Table 10** Discoloration Rating

| Adhesion Promoter | PARTS | | |
|---|---|---|---|
| | 0.5 | 1.0 | 1.5 |
| **Nourybond 272** | 4 | 4 | 4 |
| **Nourybond 276** | 1 | 1 | 1 |
| **Nourybond 301** | 2 | 3 | 4-5 |
| **Nourybond 308** | 4 | 4 | 4 |
| **Nourybond 312** | 3 | 5 | >5 |
| **Nourybond 316** | 4 | 4-5 | 5 |
| **Nourybond 346** | 3 | 3 | 4 |
| **Nourybond 356** | 4 | 3 | 4-5 |
| **Nourybond 368** | 4 | 3-4 | 5 |



# SECTION II:

## Evaluation of blocked isocyanate-based Nourybond adhesion promoters

The following comparative evaluations of blocked isocyanate-based Nourybond adhesion promoters use a model PVC plastisol formulation. While we recognize this formulation cannot approximate every type of application or performance requirement in the marketplace, it is useful and necessary in order to demonstrate the general capabilities of our products for automotive applications.

**Table 11** describes the components and composition of the model formulation. It is neither our intention nor recommendation that this formulation be used in actual commercial applications.

Sample preparation was carried out as follows. A carefully measured amount of a polyamide-based adhesion promoter was added to a plasticizer and then mixed. Next, three types of PVC resins, two grades of $CaCO_3$, fumed silica, CaO and ZnO were introduced, followed by the addition of solvent *and a blocked isocyanate-based adhesion promoter*. Once the solid materials were sufficiently wet, the plastisol was mixed under medium shear at room temperature until completely homogeneous. Additional dispersion followed using a three-roll mill. Finally, the plastisol was degassed under vacuum to remove any entrapped air.

In this evaluation, blocked isocyanate-based adhesion promoters (described in **Table 2** except Nourybond 291) were tested in combination with a polyamide-based co-adhesion promoter. Model formulations were prepared with the following loading levels: 5.0 parts blocked isocyanate-based adhesion promoter combined with 0.5 parts polyamide-based Nourybond 316 adhesion promoter; and 2.0 parts blocked isocyanate-based adhesion promoter combined with 1.0 parts Nourybond 316 adhesion promoter. Nourybond 289 adhesion promoter was evaluated without a polyamide-based co-adhesion promoter.

Model PVC plastisols were evaluated for the following key properties.

- Adhesion
- Rheology
- Tensile properties
- Color stability

**Table 11** Model PVC Plastisol Formulation

| Component | Function | Parts by weight | Supplier |
|---|---|---|---|
| **Diisononylphthalate** | Plasticizer | 30 | BASF |
| **PVC - VESTOLIT® 1353 K** | PVC-homopolymer | 7.5 | Vestolit GmbH & Co. KG |
| **PVC - Lacovyl® PA 1384** | PVC - copolymer | 5 | ARKEMA |
| **PVC - Vinnolit® SA 1062/7** | PVC - copolymer | 17.5 | Vinnolit GmbH & Co. KG |
| **Socal® 312** | Coated chalk | 16 | Solvay Chemicals |
| **Ulmer Weiss XM** | Natural chalk | 16 | Eduard Merkle GmbH |
| **AEROSIL® 200** | **Thixotropic agent** | **0.5** | **Evonik Corporation** |
| **CaO Precal® 30S** | Drying agent | 2 | Schaefer Kalk |
| **Zinc Oxide** | Stabilizer | 0.2 | AppliChem GmbH |
| **ExxsolTM D 80** | Solvent | 4.3 | Exxon Mobil Chemical |
| **Nourybond** | **Adhesion Promoter** | **Varies*** | **Evonik Corporation** |

* Two different combinations of blocked isocyanate-based adhesion promoters and a polyamide-based adhesion promoter were used, as explained at right.

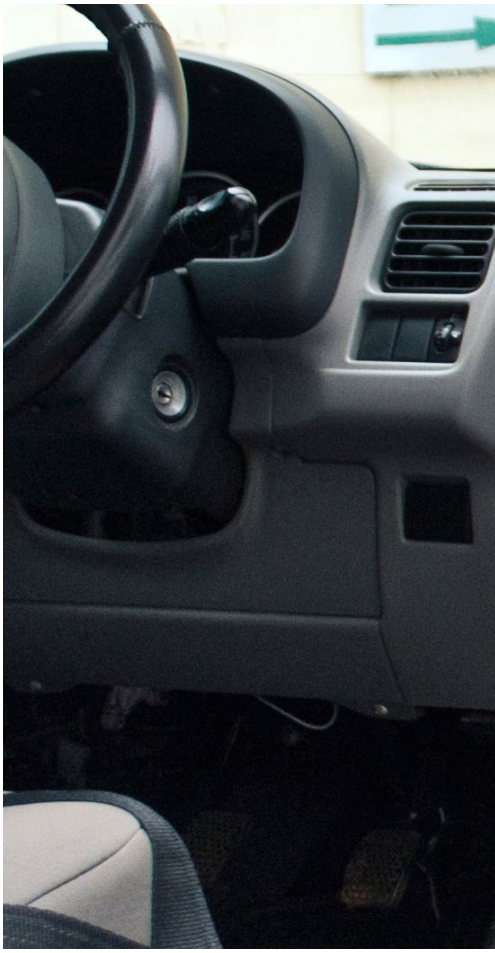
# 1. Adhesion

Plastisol adhesion to E-coat primed metals was evaluated by a manual adhesion test and a single lap shear test.

Both tests used the following five E-coat primed metals and three bake cycles.

E-coat primers used on steel substrates:
BASF CathoGuard 520, BASF U32 AD350 V, PPG-6060, DuPont EC-3000AM and DuPont CorMax VI

Bake time in oven and temperature:
30 minutes at 130 °C, 140 °C or 160 °C



**MANUAL ADHESION:**

The manual adhesion test examines the adhesion of model plastisols to E-coat primed substrates. This test provides a preliminary evaluation of the efficiency and effectiveness of Nourybond adhesion promoters. Adhesion was evaluated as a function of adhesion promoter loading level, bake temperature and substrate.

## Test Method:

Adhesion was evaluated using the method described in Section I.

## Results:

**Table 12** presents the results of the manual adhesion test.

## Conclusions:

- Adhesion is impacted by baking conditions, E-coat primer and the loading level of an adhesion promoter.
- Adhesion is significantly improved by increasing the loading level of Nourybond 316 adhesion promoter in combination with a blocked isocyanate-based adhesion promoter (except Nourybond 289 adhesion promoter).
- A combination of 1.0 parts Nourybond 316 adhesion promoter and 2.0 parts of a blocked isocyanate-based adhesion promoter (except Nourybond 289 adhesion promoter) appears to be a good system for adhesion.
- At a loading level of 5.0 parts, Nourybond 289 adhesion promoter demonstrates excellent adhesion for all substrates and bake conditions tested.
- At all loading levels, Nourybond 292 adhesion promoter demonstrates very good adhesion for all substrates and bake conditions tested.
- Overall, Nourybond 289, 292 and 293 adhesion promoters provide excellent adhesion.

**Table 12** Manual Adhesion Results

| Bake Cycle | Adhesion Promoter | BASF CATHOGUARD 520 | | BASF U32 AD350 V | | PPG 6060 | | DUPONT EC-3000AM | | DUPONT CORMAX VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5.0 parts 0.5 parts NB 316 | 2.0 parts 0.0 parts NB 316 | 5.0 parts 0.5 parts NB 316 | 2.0 parts 1.0 parts NB 316 | 5.0 parts 0.5 parts NB 316 | 2.0 parts 1.0 parts NB 316 | 5.0 parts 0.5 parts NB 316 | 2.0 parts 1.0 parts NB 316 | 5.0 parts 0.5 parts NB 316 | 2.0 parts 1.0 parts NB 316 |
| 30 minutes at 130 °C | Nourybond 289* | +++ | | +++ | | +++ | | +++ | | +++ | |
| | Nourybond 290 | +++ | + | ++ | + | ++ | + | ++ | + | ++ | + |
| | Nourybond 292 | +++ | +++ | +++ | + | +++ | +++ | +++ | +++ | +++ | +++ |
| | Nourybond 293 | +++ | +++ | + | +++ | ++ | +++ | ++ | +++ | ++ | +++ |
| 30 minutes at 140 °C | Nourybond 289* | +++ | | +++ | | +++ | | +++ | | +++ | |
| | Nourybond 290 | +++ | + | + | + | ++ | ++ | ++ | ++ | ++ | + |
| | Nourybond 292 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | + | +++ | +++ |
| | Nourybond 293 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | + | +++ |
| 30 minutes at 160 °C | Nourybond 289* | +++ | | +++ | | +++ | | +++ | | +++ | |
| | Nourybond 290 | +++ | + | + | ++ | +++ | ++ | ++ | + | +++ | ++ |
| | Nourybond 292 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | + | +++ | +++ |
| | Nourybond 293 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ |

+++ Excellent adhesion ++ Acceptable adhesion + Unacceptable adhesion
*Nourybond 289 adhesion promoter was tested without a polyamide-based adhesion promoter.

## LAP SHEAR ADHESION:

The most important parameters controlled by adhesion promoters are plastisol adhesion to primed metals and mode of failure. The following information presents the shear adhesion properties of formulations containing blocked isocyanate-based Nourybond adhesion promoters.

## Test Method:

Lap shear adhesion was evaluated using the method described in Section I.

## Results:

**Table 13** presents lap shear strengths in N/mm$^2$ and mode of failure.

## Conclusions:

- In general, a higher loading level of Nourybond 316 adhesion promoter results in greater shear strength.
- For formulations with 5.0 parts of blocked isocyanate-based adhesion promoter, a higher bake temperature results in greater shear strength.
- For formulations with 2.0 parts of blocked isocyanate-based adhesion promoter, bake temperature does not appear to affect shear strength.
- Nourybond 289 and 292 adhesion promoters demonstrate the best shear adhesion across all substrates, bake temperatures and loading levels.

**Table 13** Lap Shear Strength in N/mm$^2$ and Mode of Failure[(1)]

| | | BAKE TEMPERATURE AND LOADING LEVEL | | | | | |
|---|---|---|---|---|---|---|---|
| | | 30 MINUTES AT 130 °C STRENGTH / MODE OF FAILURE | | 30 MINUTES AT 140 °C STRENGTH / MODE OF FAILURE | | 30 MINUTES AT 160 °C STRENGTH / MODE OF FAILURE | |
| | Adhesion Promoter | 5.0 parts 0.5 parts NB 316 | 2.0 parts 1.0 parts NB 316 | 5.0 parts 0.5 parts NB 316 | 2.0 parts 1.0 parts NB 316 | 5.0 parts 0.5 parts NB 316 | 2.0 parts 1.0 parts NB 316 |
| BASF U32 AD350 V Primed Substrate | **Nourybond 289*** | 1.30* / C | Not tested | 1.51*/ C | Not tested | 2.15*/ C | Not tested |
| | **Nourybond 290** | 1.31 / C | 1.97 / C | 1.84 / C | 2.18 / C | 2.05 / C | 2.57 / C |
| | **Nourybond 292** | 1.69 / C | 2.30 / C | 1.91 / C | 2.38 / C | 2.40 / C | 2.47 / C |
| | **Nourybond 293** | 1.68 / C | 2.26 / C | 1.95 / C | 2.04 / C | 2.10 / C | 2.52 / C |
| PPG 6060 Primed Substrate | **Nourybond 289*** | 1.31* / C | Not tested | 1.56*/ C | Not tested | 1.93*/ C | Not tested |
| | **Nourybond 290** | 0.75 / A | 1.89 / C | 1.84 / C | 2.23 / C | 2.15 / C | 2.41 / C |
| | **Nourybond 292** | 1.56 / C | 1.68 / C | 2.02 / C | 2.41 / C | 2.21 / C | 1.49 / C |
| | **Nourybond 293** | 1.64 / C | 1.82 / C | 1.99 / C | 2.35 / C | 2.29 / C | 2.35 / C |
| DuPont CorMax VI Primed Substrate | **Nourybond 289*** | 0.83*/ A | Not tested | 1.58*/ C | Not tested | 1.99*/ C | Not tested |
| | **Nourybond 290** | 0.26 / A | 1.92 / C | 0.61 / A | 2.34 / C | 1.90 / A | 2.38 / C |
| | **Nourybond 292** | 1.49 / C | 2.05 / C | 2.00 / C | 2.22 / C | 2.30 / C | 2.46 / C |
| | **Nourybond 293** | 0.53 / C | 1.90 / C | 1.79 / A | 2.09 / C | 2.14 / C | 2.25 / C |
| DuPont EC-3000AM Primed Substrate | **Nourybond 289*** | 1.16*/ C | Not tested | 1.29*/ A | Not tested | 1.92*/ C | Not tested |
| | **Nourybond 290** | - | 1.97 / C | 0.58 / A | 2.13 / C | 2.04 / A | 2.35 / C |
| | **Nourybond 292** | 1.59 / C | 0.46 / C | 1.98 / C | 2.06 / C | 2.01 / C | 2.33 / C |
| | **Nourybond 293** | 0.47 / C | 2.00 / C | 1.51 / A | 2.11 / C | 2.09 / C | 2.54 / C |

*Nourybond 289 adhesion promoter was tested without a polyamide-based adhesion promoter.
[(1)]Mode of failure: C = cohesive failure, A= adhesive failure

# 2. Rheology

During application a PVC plastisol goes through varying degrees of shear, making rheology a plastisol's second-most important characteristic after adhesion. The rheological behavior of each model plastisol was measured as a function of adhesion promoter loading level and storage time.

## Test Method:

Rheology was evaluated using the method described in Section I.

## Results:

**Table 14** presents the yield point, viscosity and hysteresis area for model plastisol formulations.

## Conclusions:

- Nourybond 289 adhesion promoter offers the best overall rheology.
- Nourybond 290 adhesion promoter offers good rheology, especially at a loading level of 2.0 parts.
- Overall, formulations with 2.0 parts of a blocked isocyanate-based adhesion promoter offer better rheology than formulations with 5.0 parts.

**Table 14** Rheology Data

| Adhesion Promoter | 5.0 PARTS WITH 0.5 PARTS NOURYBOND 316 | | | 2.0 PARTS WITH 1.0 PARTS NOURYBOND 316 | | | After |
|---|---|---|---|---|---|---|---|
| | Yield Value [Pa] | Viscosity [Pa·s] | Hysteresis Area [Pa/s] | Yield Value [Pa] | Viscosity [Pa·s] | Hysteresis Area [Pa/s] | |
| **Nourybond 289*** | 347.0 | 1.04 | 65,110 | NOT TESTED | | | 24h |
| | 289.6 | 1.16 | 80,890 | | | | 1 week |
| | 281.2 | 1.25 | 83,980 | | | | 2 weeks |
| | 234.7 | 1.29 | 97,670 | | | | 4 weeks |
| **Nourybond 290** | 218.7 | 1.07 | 47,630 | 219.4 | 1.09 | 61,600 | 24h |
| | 171.6 | 1.26 | 63,720 | 228.4 | 1.23 | 83,710 | 1 week |
| | 164.8 | 1.31 | 75,240 | 229.9 | 1.29 | 92,810 | 2 weeks |
| | 158.6 | 1.43 | 95,100 | 263.8 | 1.33 | 104,110 | 4 weeks |
| **Nourybond 292** | 263.3 | 1.11 | 45,010 | 193.3 | 1.34 | 78,180 | 24h |
| | 169.2 | 1.58 | 93,740 | 216.0 | 1.70 | 119,990 | 1 week |
| | 159.7 | 1.84 | 109,090 | 220.2 | 1.91 | 140,030 | 2 weeks |
| | 155.7 | 2.01 | 154,610 | 237.3 | 2.04 | 165,610 | 4 weeks |
| **Nourybond 293** | 335.9 | 1.20 | 57,080 | 198.4 | 1.32 | 83,180 | 24h |
| | 232.2 | 1.52 | 85,620 | 205.7 | 1.56 | 117,880 | 1 week |
| | 223.6 | 1.65 | 99,610 | 195.8 | 1.57 | 113,770 | 2 weeks |
| | 190.3 | 1.83 | 120,930 | 198.7 | 1.79 | 154,610 | 4 weeks |

*Nourybond 289 adhesion promoter was tested without a polyamide-based adhesion promoter.

# 3. Tensile properties

Tensile properties such as tensile strength and tensile elongation at break are important parameters that contribute to plastisol performance. The following information highlights the tensile properties of formulations containing blocked isocyanate-based Nourybond adhesion promoters.

## Test Method:

The tensile properties of the model plastisols were measured using the method described in Section I.

## Results:

**Tables 15 and 16** present results for tensile strength and tensile elongation at break.

## Conclusions:

- Tensile strength and tensile elongation at break increase significantly with bake temperature.
- In general, increasing the loading level of a polyamide-based adhesion promoter in combination with a blocked isocyanate-based adhesion promoter produces a slight improvement in tensile strength but no gain in tensile elongation.
- At a loading level of 5.0 parts, Nourybond 290, 292 and 293 adhesion promoters provide the best balance of tensile strength and tensile elongation across all bake temperatures.
- Of the five formulations tested, Nourybond 290 adhesion promoter offers the best balance of tensile strength and tensile elongation at a loading level of 5.0 parts and a bake temperature of 130 °C or 140 °C.

**Table 15** Tensile Strength at Break ($N/mm^2$)

| | BAKE TEMPERATURE AND LOADING LEVEL | | | | | |
|---|---|---|---|---|---|---|
| | 30 MINUTES AT 130 °C | | 30 MINUTES AT 140 °C | | 30 MINUTES AT 160 °C | |
| **Adhesion Promoter** | **5.0 parts with 0.5 parts NB 316** | **2.0 parts with 1.0 parts NB 316** | **5.0 parts with 0.5 parts NB 316** | **2.0 parts with 1.0 parts NB 316** | **5.0 parts with 0.5 parts NB 316** | **2.0 parts with 1.0 parts NB 316** |
| **Nourybond 289*** | 1.32 | - | 1.61 | - | 2.09 | - |
| **Nourybond 290** | 1.28 | 1.51 | 1.61 | 2.10 | 2.50 | 2.57 |
| **Nourybond 292** | 1.52 | 1.67 | 2.00 | 2.21 | 2.39 | 2.44 |
| **Nourybond 293** | 1.42 | 1.74 | 2.08 | 2.44 | 2.41 | 2.65 |

**Table 16** Tensile Elongation at Break (percent)

| | BAKE TEMPERATURE AND LOADING LEVEL | | | | | |
|---|---|---|---|---|---|---|
| | 30 MINUTES AT 130 °C | | 30 MINUTES AT 140 °C | | 30 MINUTES AT 160 °C | |
| **Adhesion Promoter** | **5.0 parts with 0.5 parts NB 316** | **2.0 parts with 1.0 parts NB 316** | **5.0 parts with 0.5 parts NB 316** | **2.0 parts with 1.0 parts NB 316** | **5.0 parts with 0.5 parts NB 316** | **2.0 parts with 1.0 parts NB 316** |
| **Nourybond 289*** | 32 | - | 59 | - | 88 | - |
| **Nourybond 290** | 51 | 58 | 64 | 71 | 119 | 96 |
| **Nourybond 292** | 63 | 64 | 76 | 69 | 100 | 109 |
| **Nourybond 293** | 62 | 59 | 85 | 73 | 97 | 94 |

*Nourybond 289 adhesion promoter was tested without a polyamide-based adhesion promoter.

# 4. Color stability

Color and color stability are important parameters that contribute to plastisol performance. Visible applications like seam sealers in hem flange areas require very low initial color and longterm resistance to yellowing. The following information highlights the color stability of plastisols containing blocked isocyanate-based Nourybond adhesion promoters.

## Test Method:

Formulations containing blocked isocyanate-based adhesion promoters were evaluated for discoloration following the method described in Section I.

## Results:

**Table 17** presents the discoloration ratings of various plastisol formulations.

## Conclusions:

- Increasing the loading level of a polyamide-based adhesion promoter (in this test, Nourybond 316 adhesion promoter) reduces the color stability of a plastisol formulation.
- Model plastisols formulated with Nourybond 289 adhesion promoter (without the addition of Nourybond 316 adhesion promoter) demonstrate the best color stability.

**Table 17** Discoloration Rating

| Blocked Isocyanate-Based Adhesion Promoter | LOADING LEVEL | | |
|---|---|---|---|
| | 5.0% with 0% Nourybond 316 | 5.0% with 0.5% Nourybond 316 | 2.0% with 1.0% Nourybond 316 |
| **Nourybond 289** | 1 | – | – |
| **Nourybond 290** | – | 3 | 5 |
| **Nourybond 291** | – | 1 | 2 |
| **Nourybond 292** | – | 2 | 4 |
| **Nourybond 293** | – | 2 | 4 |

# ABOUT US

Evonik is the world's only global gas and chemicals company. Founded in 1940, the business has annual revenues of more than $10 billion and operations in over 40 countries. The company is recognized for its innovative culture, operational excellence, and commitment to safety and the environment. Our aim at Evonik is to develop lasting relationships with our customers and communities based on human qualities: an understanding of their needs, integrity and honesty in the way we do business, and a passion for exceeding expectations.

Evonik offers unique insight into helping formulators create products that are better than the competition— and better for the environment. We combine our technology and market leadership strengths in specialty surfactants, specialty amines, polyurethane additives, epoxy curatives and resins. These specialty chemicals are providing performance, environmental and cost benefits to customers in coatings, inks, adhesives, civil engineering, personal care, institutional and industrial cleaning, mining, oil field, polyurethane and other industries.

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