KING INDUSTRIES
SPECIALTY CHEMICALS

# K-FLEX®

## Polyester Diol Selection Guide

### For High Performance VOC Compliant Coatings

***K-FLEX®*** polyester diols are used primarily as modifiers for acrylic, alkyd, epoxy and polyester formulations with isocyanate or melamine crosslinkers. The low molecular weight and narrow molecular weight distribution (NMWD) of the K-FLEX polyesters allows the formulation of VOC compliant systems without exempt solvents, while also providing improved performance. Primary hydroxyl groups provide high reactivity for lower temperature cure. Typical modification levels are 5% to 15% on total resin solids.

**Formulate lower VOC coatings**

**Lower cure temperature**

**Increase flexibility & maintain hardness**

**Maintain higher crosslink density**

**Improve adhesion**

**Excellent resistance properties**

**Excellent compatibility**

## *Table of Contents*

***K-FLEX®*** polyester diols are presented in two different charts below. The top chart includes K-FLEX polyester diols with hydroxyl numbers between 220 to 265. These diols display a positive correlation between Tg, viscosity, film hardness, moisture resistance and exterior durability. These values tend to increase with increasing Tg.

The bottom chart includes K-FLEX polyester diols with lower hydroxyl numbers, ranging from 122 to 140. Due to the lower hydroxyl numbers, there is a lower crosslinker demand (isocyanate or melamine) compared to the resins in the above table. Both K-FLEX A307 and K-FLEX 171-90 typically provide good flexibility.

### *High Crosslinker Demand*

| | System | % Active | Hydroxyl # as Supplied | Viscosity 25°C (cP) | Tg | Attributes / Uses |
|---|---|---|---|---|---|---|
| HARDER | ***XM-337*** | SB, WB | 100% | 220 | 55,000 | -20 | Provides increased toughness and chemical resistance for solvent based and high solids systems. Highest Tg and modulus. |
| | ***188*** | SB, WB | 100% | 230 | 10,000 | -32 | Improves flexibility while maintaining hardness. Also improves salt spray, humidity resistance and exterior durability. Most versatile. |
| | ***148*** | SB | 100% | 235 | 3,750 | -42 | Improves flexibility and gloss. Increases solids at lower viscosity. Good flow and leveling. Recommended for primers. |
| | ***A308*** | SB | 100% | 260 | 1,500 | -59 | Medium hardness with great flexibility. Best for mar and scratch resistance. |
| SOFTER | ***XM-332*** | SB | 100% | 265 | 400 | -68 | Lowest viscosity for lowest VOC. Softer films. Low temperature impact resistance. |

*K-FLEX Viscosity / Tg & Film Hardness*

*Lowest* ← ***XM-332*** — ***A308*** — ***188*** — ***XM-337*** → *Highest*

### *Low Crosslinker Demand*

| | | | | | | |
|---|---|---|---|---|---|---|
| ***A307*** | SB | 100% | 140 | 5,400 | -50 | Flexibility modifier with lower crosslinker demand. |
| ***171-90**** | SB | 90% | 122 | 3,700 | -30 | Offering longer pot life, improved adhesion and flexibility. Lower crosslinker demand. |

*Supplied 90% solids in xylene / n-butyl acetate

***K-FLEX®*** polyester diols can be used in solvent based (SB), waterborne (WB) or 100% non-volatile coatings, inks, adhesives, sealants and elastomer thermoset systems. This brochure will focus on the SB coatings market. Some of the top applications for K-FLEX polyester diols include:

**Aerospace** | **Agricultural & Construction Equipment** | **Marine** | **Anti-ballistics**

**Can & Coil** | **Automotive OEM & Refinish** | **Flooring** | **Metro/Rail**

## Resin Compatibility and Solubility

***K-FLEX®*** polyester diols are soluble at 10-50% by weight in most organic solvents including exempt and non-exempt solvents. Other polyester polyol resins and caprolactone diols have poor solubility in difficult to use, weak solvents like Oxsol[1] 100 and t-butyl acetate. K-FLEX polyester diols demonstrate nearly universal solubility in comparison.

Due to their NMWD, the K-FLEX polyester diols are very effective at compatibilizing other resins that are not otherwise compatible. Increasing K-FLEX 188 level, increases the compatibility of Sovermol[2] 750 with Basonat[3] HI-100 (HDI Trimer), seen on the right.

### Resin Compatibilization

*Polyol/HDI Trimer (NCO:OH = 1.04:1.00)*

Solvermol 750 | Solvermol 750 / ***K-FLEX 188***

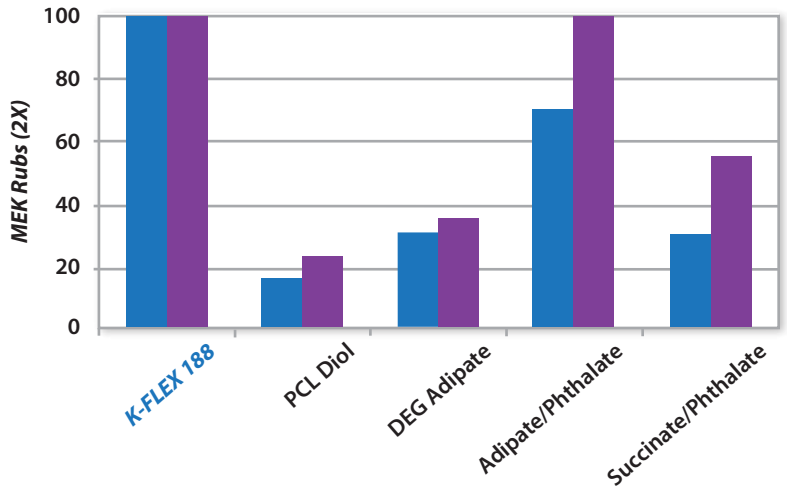
100% | 90/10 | 85/15 | 80/20

## Low Temperature Cure

Due to the primary hydroxyl groups of the K-FLEX polyester diols, it is possible to achieve a reaction at lower temperatures than other resins. To the right is a comparison of the low temperature cure of K-FLEX 188 compared to other competitive polyol technologies.

Polyester/HMMM: 60/40
10 Minute Bake
Solids %: 90
***NACURE® 155*** % on TRS: 1.8
200°F
225°F

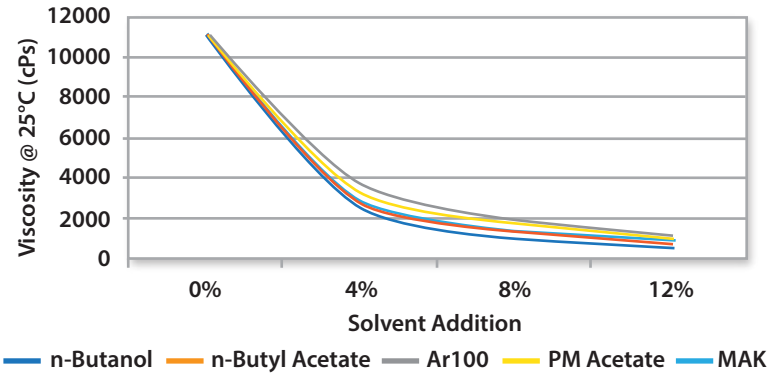
### Cure Evaluation - K-FLEX 188 vs. Competitive Technology




## Solvent Viscosity Reduction

***K-FLEX®*** polyester diols provide efficient viscosity reduction with low levels of solvent due to their NMWD and hydrogen bonding of a low MW diol with ester groups and primary hydroxyl groups. A spray viscosity is possible with K-FLEX 188 at around 80-90% solids. Efficient viscosity reduction of K-FLEX 188 with typical solvents is demonstrated in the graph below.

### K-FLEX 188 Solvent Viscosity Reduction

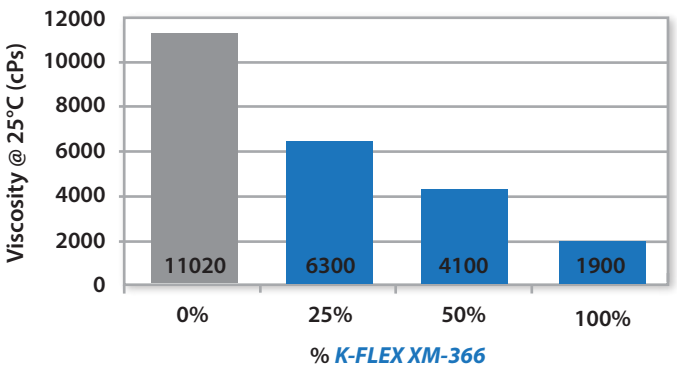



## K-FLEX Blends and Viscosity Reduction

***K-FLEX® 188*** has a high viscosity (10,000 cPs) at 100% active without solvent. The high viscosity of K-FLEX 188 can be reduced by blending it with other K-FLEX polyester diols. Shown below is the effect of blending 25% of a lower viscosity K-FLEX polyester diol with K-FLEX 188. Blends provide some synergy to these diols.

### K-FLEX Blends

*K-FLEX 188 blended with K-FLEX XM-366*



## Flexibility and Hardness - Melamine

In the King formulation below (HS-19), ***K-FLEX® 188*** polyol is used as a modifier to provide improved flexibility, hardness and chemical resistance to a high solids polyester/melamine coating. Additionally, the K-FLEX modified systems resulted in better water resistance and a major viscosity reduction.

### *Film Performance - Benefits*

- Improved impact resistance
- Reduced viscosity
- Maintained hardness
- Improved MEK resistance
- Better blushing resistance

| CHARACTERISTICS | Control | K-FLEX 188 18% on TRS | K-FLEX 188 23% on TRS | K-FLEX 188 34% on TRS |
|---|---|---|---|---|
| HS 57-5776[4]/K-188/Cymel[5] 325 | 75/-/25 | 54/18/28 | 46/23/31 | 33/34/33 |
| Total resin solids, weight % | 75 | ***75*** | ***75*** | ***75*** |
| Brookfield viscosity (cPs), 25°C | 1000 | ***440*** | ***340*** | ***220*** |
| ***FILM PROPERTIES*** | | | | |
| Pencil hardness | H-2H | H-2H | H-2H | H-2H |
| MEK Resistance (2X Rubs) | 90 | ***120*** | ***130*** | ***150*** |
| Crosshatch adhesion | 100 | 100 | 100 | 100 |
| Direct impact (in-lbs) | 50-60 | ***100-110*** | ***160+*** | ***160+*** |
| Reverse impact (in-lbs) | 5 | ***30-40*** | ***140-150*** | ***150-160*** |
| Water soak, 360 hr @ 50°C | MD/9 Blushed | MD/9 | MD/9 | MD/9 |

## Flexibility and Hardness - 2K PU

King Industries formulation API-20 is summarized below. Various K-FLEX products are compared as modifiers of a pigmented (0.65:1.0 P:B ratio) high solids aliphatic acrylic 2K PU formulation. When typical low MW polyols are used to lower VOC, it usually comes at a cost of some performance criteria, such as hardness, flexibility, water resistance, UV resistance, or exterior durability. With K-FLEX polyester diols, VOC compliance is achieved while providing improved film properties and resistance properties. Please note in the table below, the reduction in VOC at equal viscosity with K-FLEX modification. VOC is reduced by as much as 18%.

Control
FAIL: 160 in-lbs

Control (Magnified)
FAIL: 160 in-lbs

***K-FLEX 188***
***PASS: 160 in-lbs***

Dry Film Thickness: 25µ (1 mil)
Substrate: Iron Phosphated cold rolled steel
Cure Schedule: 2 weeks ambient cure

| CHARACTERISTICS | Acrylic Control | K-FLEX XM-337 14% on TRS | K-FLEX 188 13.9% on TRS | K-FLEX XM-366 13.7% on TRS | K-FLEX A308 13.7% on TRS | K-FLEX XM-332 13.6% on TRS |
|---|---|---|---|---|---|---|
| Total resin solids, weight % | 67 | 73 | 73.3 | 73.5 | 73.4 | 73.5 |
| VOC, g/l (calc) | 407 | ***343*** | ***339*** | ***336*** | ***337*** | ***334*** |
| Viscosity (cPs), 25°C | 600 | 600 | 600 | 600 | 600 | 600 |
| ***FILM PROPERTIES*** | | | | | | |
| Pendulum hardness, cycles | 121 | ***118*** | ***116*** | ***106*** | ***110*** | ***77*** |
| Pencil hardness | 2H-3H | 3H-4H | 2H-3H | H-2H | 2H-3H | H-2H |
| Reverse impact (in-lbs) | 20-30 | ***120-130*** | ***160+*** | ***160+*** | ***160+*** | ***160+*** |
| Direct impact (in-lbs) | 90-100 | 160+ | 160+ | 160+ | 160+ | 160+ |

## Chemical Resistance

Modification of this filled **100% non-volatile 2K polyurethane** floor coating formulation (PI-13) demonstrates higher hardness, tensile strength, elongation, elastic modulus, tear strength and improved gasoline and transmission fluid stain resistance. The control system was modified with 10% ***K-FLEX®***. It partially replaced the branched polyether-polyester triol and the linear polyether diol. Mechanical properties can be found in the table below and chemical resistance advantages are demonstrated in the lower images.

| FILM PROPERTIES | Control | *XM-337* | *188* |
|---|---|---|---|
| Shore D hardness | 53 | 65 | 60 |
| Tensile strength, psi | 1,022 | 1,440 | 1,041 |
| Elongation, % | 40 | 63 | 50 |
| Elastic modulus, psi | 5,951 | 10,067 | 5,013 |
| Break/load - Die C, pli | 43 | 86 | 76 |
| Tear strength - Die C, psi | 176 | 305 | 272 |
| Taber abrasion, wear index | 56 | 54 | 39 |
| Crockmeter, rating | 6 | 1 | 3 |

*Taber Abrasion and Crockmeter: Lower number = Better performance*

### *Cure & Application Conditions*

**Cure Schedule:** 2 weeks ambient

**Dry Film Thickness:** 3 mm

**Substrate:** 2K PU castings

# *K-FLEX*

## *Gasoline Soak, 30 Hours*

***Control*** ***K-FLEX XM-337***
*10% on TRS*

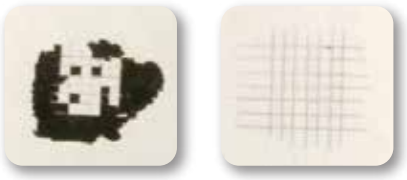
## *Transmission Fluid, 3 Day Spot Test*

1 2 3
**Exposure days**
***Control***

1 2 3
**Exposure days**
***K-FLEX XM-337***

## Plastics Adhesion

### Polyester 2K PU - Adhesion to Plastics



Control *13% K-FLEX 188*

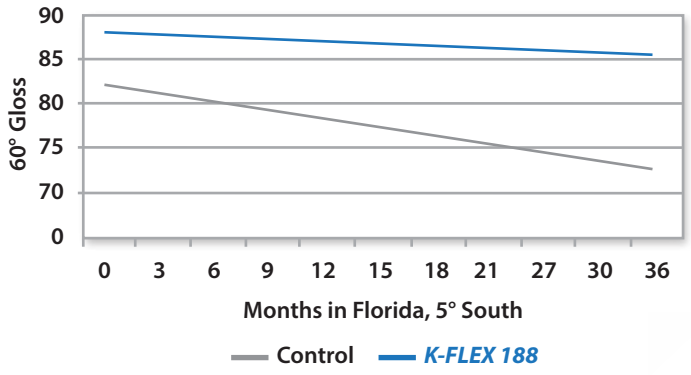
K-FLEX polyester diols provide excellent adhesion to most substrates including plastics. K-FLEX 188 crosslinked with Desmodur[6] N-75 *(formulation PM-6)* or with Resimene[7] 747 *(Formulation PI-5)* provides 100% crosshatch adhesion to ABS, RIM, RRIM, Polycarbonate, PVC, SMC and Xenoy. Improved adhesion is also possible over TPO with a CPO adhesion promoter. To the left is an example of K-FLEX 188 improving the adhesion of a polyester/NCO 2K PU system.

## Exterior Durability

K-FLEX polyester diols do not have any ether functionality nor an acid number. Absence of an acid number helps to minimize water and salt spray sensitivity. The K-FLEX polyester diols are completely aliphatic and saturated. As a result, we could expect excellent performance in QUV testing and exterior durability, which has been demonstrated below for two different systems:

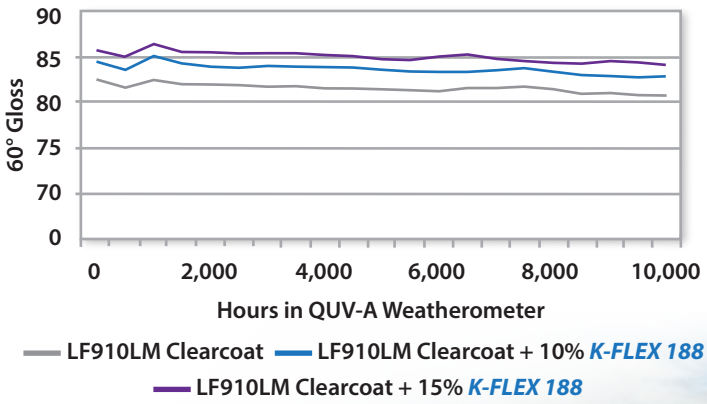
### 60° Gloss - Desmophen[8] 651A-65/Tolonate[9] HDB-75X

*36 Months Florida Exposure*




### 60° Gloss - Lumiflon[10] LF910LM Clearcoat Formulation*

*10,000 hours QUV-A*




*Study courtesy of AGC, Ltd.

## Mar & Scratch Resistance

K-FLEX polyester diols when crosslinked with melamine or isocyanate will usually improve the mar and scratch resistance of coatings. The example below illustrates the improved mar and scratch resistance found with K-FLEX A308 compared to competitive polyol technologies in a melamine baking system, baked 30 minutes at 80°C and catalyzed with K-CURE 129B.

### Mar & Scratch Resistance - K-FLEX A308 vs. Competitive Technology

Competitor A | Competitor B | *K-FLEX A308*

## K-FLEX® Polyester Diol Selection Guide

### Solvent Based High Solids 2K PU (K-FLEX Polyester Diol Modified)

| | |
|---|---|
| PI-5 | ***Polyester:*** adhesion to xenoy, flexibility with K-FLEX 188 |
| API-4 | ***Pigmented acrylic:*** improved adhesion to bare steel, flexibility, gasoline resistance with K-FLEX 188 |
| API-5 | ***Pigmented acrylic:*** abrasion resistance, flexibility, elongation, adhesion metals/plastics with K-FLEX 188 |
| API-11 | ***Pigmented acrylic:*** flexibility and salt spray resistance with K-FLEX A307 |
| API-12 | ***Clearcoat acrylic:*** elongation, abrasion resistance, flexibility with K-FLEX A307 |
| API-18 | ***Pigmented acrylic modified with exempt solvents:*** improved flexibility (Zero VOC) |
| API-20 | ***Pigmented acrylic modified with conventional solvents:*** improved flexibility (Low VOC) |

### 100% Non-Volatile 2K PU (K-FLEX Polyester Diol modified)

| | |
|---|---|
| PI-13 | ***Highly filled polyether-polyester triol modified floor coating:*** hardness, elongation, tensile strength, tear strength, gasoline resistance, transmission fluid resistance (Zero VOC) |

### Solvent Based High Solids Melamine baking System (K-FLEX Polyester Diol modified)

| | |
|---|---|
| APM-9 | ***Pigmented acrylic:*** improved flexibility with hardness, QUV resistance, humidity and salt spray resistance |
| APM-10 | ***Pigmented acrylic:*** higher gloss, flexibility, humidity resistance and improved FL exposure with K-FLEX 188 |
| HS-19 | ***Clearcoat polyester:*** lower temperature cure, hardness, MEK resistance, flexibility, water soak resistance (50°C) with K-FLEX 188 |
| PM-3 | ***Clearcoat polyester:*** low temp. cure, improved adhesion to polycarbonate, inter-coat adhesion, with K-FLEX 188 |
| PM-6 | ***Clearcoat polyester:*** plastic adhesion to different plastics compared to other low MW polyester diols, low temperature cure, hardness, MEK resistance with K-FLEX 188 |
| PM-7 | ***Clearcoat polyester:*** low temperature cure compared to other low molecular weight diols, hardness and MEK resistance with K-FLEX 188 |

### *Trademark References*

| | |
|---|---|
| 1. OXSOL | Makhteshim Agan |
| 2. SOVERMOL | BASF |
| 3. BASONAT | BASF |
| 4. POLYMAC | Polynt |
| 5. CYMEL | Allnex |
| 6. DESMODUR | Covestro |
| 7. RESIMENE | INEOS |
| 8. DESMOPHEN | COVESTRO |
| 9. TOLONATE | VENCOREX |
| 10. LUMIFLON | AGC |

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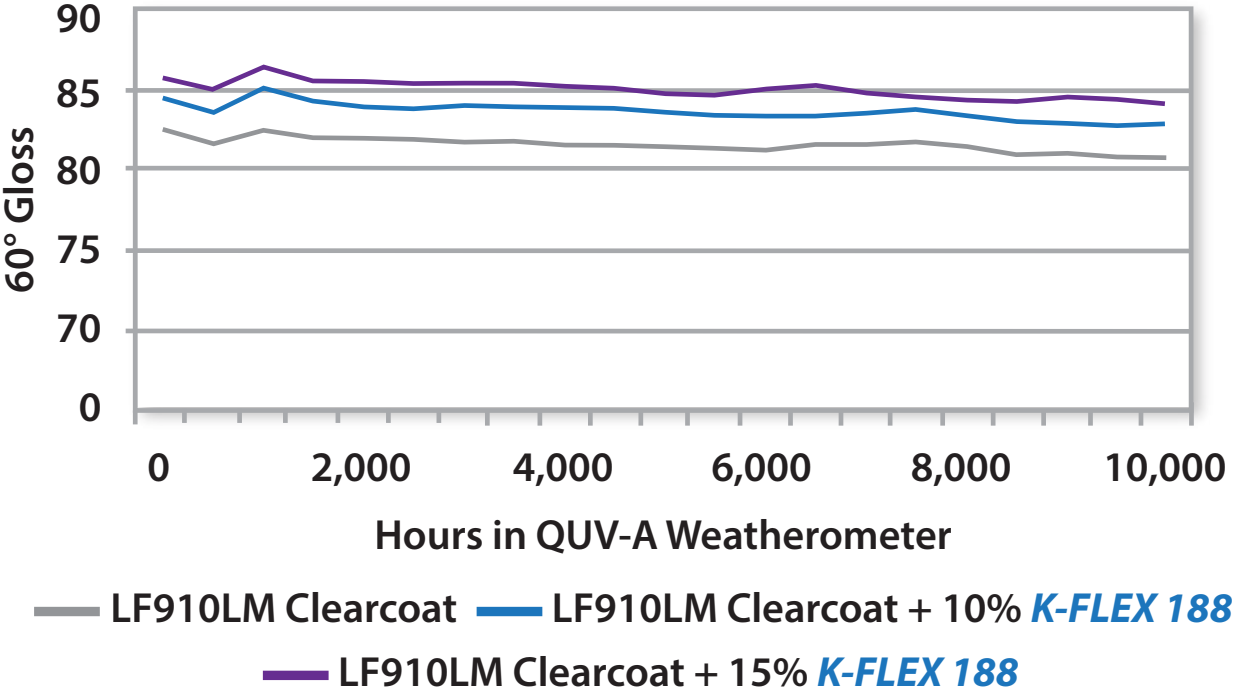
KING INDUSTRIES® SPECIALTY CHEMICALS

| | System | % Active | Hydroxyl # as Supplied | Viscosity 25°C (cP) | Tg | Attributes / Uses |
|---|---|---|---|---|---|---|
| HARDER | **XM-337** | SB, WB | 100% | 220 | 55,000 | -20 | Provides increased toughness and chemical resistance for solvent based and high solids systems. Highest Tg and modulus. |
| | **188** | SB, WB | 100% | 230 | 10,000 | -32 | Improves flexibility while maintaining hardness. Also improves salt spray, humidity resistance and exterior durability. Most versatile. |
| | **148** | SB | 100% | 235 | 3,750 | -42 | Improves flexibility and gloss. Increases solids at lower viscosity. Good flow and leveling. Recommended for primers. |
| | **XM-366** | SB, WB | 100% | 265 | 2,000 | -45 | Newest polyester with medium hardness. Great flexibility and gloss. |
| SOFTER | **XM-332** | SB | 100% | 265 | 400 | -68 | Lowest viscosity for lowest VOC. Softer films. Low temperature impact resistance. |

K-FLEX Viscosity / Tg & Film Hardness
Lowest
Highest
XM-332
XM-366
148
188
XM-337

# 60° Gloss - Lumiflon LF910LM Clearcoat Formulation

## *10,000 hours QUV-A*



| | System | % Active | Hydroxyl # as Supplied | Viscosity 25°C (cP) | Tg | Attributes / Uses |
|---|---|---|---|---|---|---|
| HARDER | ***XM-337*** | SB | 100% | 220 | 55,000 | -20 | • Highest Tg and modulus<br>• Improves hardness |
| | ***188*** | SB, WB | 100% | 230 | 10,000 | -32 | • Improves flexibility while maintaining hardness<br>• Most versatile |
| | ***148*** | SB | 100% | 235 | 3,750 | -42 | • Improves flexibility and gloss<br>• Good flow and leveling |
| | ***XM-366*** | SB, WB | 100% | 265 | 2,000 | -45 | • Great flexibility with medium hardness and gloss |
| SOFTER | ***XM-332*** | SB | 100% | 265 | 400 | -68 | • Softest films<br>• Lowest Tg and lowest VOC |

| | System | Hydroxyl # as Supplied | Viscosity 25°C (cP) | Applications |
|---|---|---|---|---|
| HARDER | **XM-337** | SB | 220 | 55,000 • Highest Tg and modulus<br>• Improves hardness |
| | **188** | SB, WB | 230 | 10,000 • Improves flexibility while maintaining hardness<br>• Most versatile |
| | **148** | SB | 235 | 3,750 • Improves flexibility and gloss<br>• Good flow and leveling |
| | **XM-366** | SB, WB | 265 | 2,000 • Great flexibility with medium hardness and gloss |
| SOFTER | **XM-332** | SB | 265 | 400 • Softest films<br>• Lowest Tg and lowest VOC |

| | System | Hydroxyl # as Supplied | Viscosity 25°C (cP) | Applications |
|---|---|---|---|---|
| HARDER | | | | |
| ***XM-337*** | SB | 220 | 55,000 | • Transparencies<br>• Aerospace<br>• Protective Armor |
| ***188*** | SB, WB | 230 | 10,000 | • Aerospace<br>• Automotive OEM<br>• Protective and Marine Coatings |
| ***148*** | SB | 235 | 3,750 | • Automotive Refinish<br>• Appliances |
| ***XM-366*** | SB, WB | 265 | 2,000 | • Transportation<br>• General Industrial<br>• Maintenance |
| ***XM-332*** | SB | 265 | 400 | • Reactive Diluent<br>• Transparencies<br>• Prepolymer Synthesis<br>• Automotive Refinish |
| SOFTER | | | | |