



WATER-BORNE URETHANE BASED ON RENEWABLE RESOURCES FOR WOOD COATINGS

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Piedmont Section: SSCT
University of North Carolina at Greensboro
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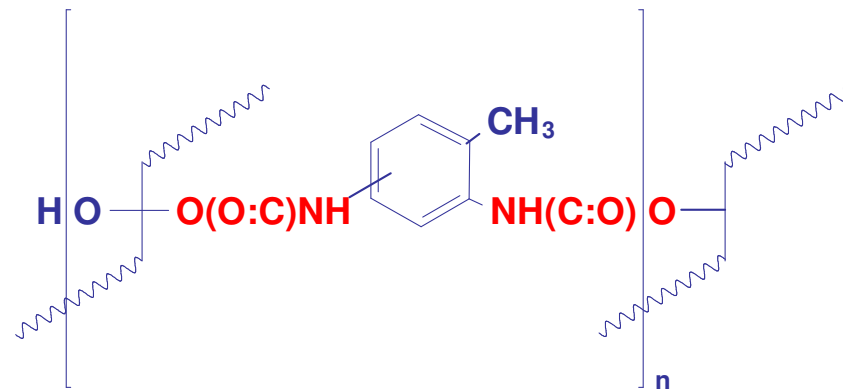
Urethane Coatings

□ ASTM D16 Classification

- **Type I: One-package pre-reacted urethane**
 - **Fatty acid modified urethanes, oxidative cure**
- Type II: One-package moisture cured
 - Moisture curable, cured by NCO Rx with atmospheric moisture
- Type III: One-package heat cured
 - Blocked urethane, cured by NCO / compound containing active H groups
- Type IV: Two-package catalyst
 - Prepolymer crosslinking with monomeric polyol or polyamine
- Type V: Two-package polyol
 - Prepolymer or other polyisocyanate crosslinking with polyols
- Type VI: One-package non-reactive lacquer
 - Solution urethane coatings, lacquer dried

Oil Modified Urethanes

□ Polymer Structure

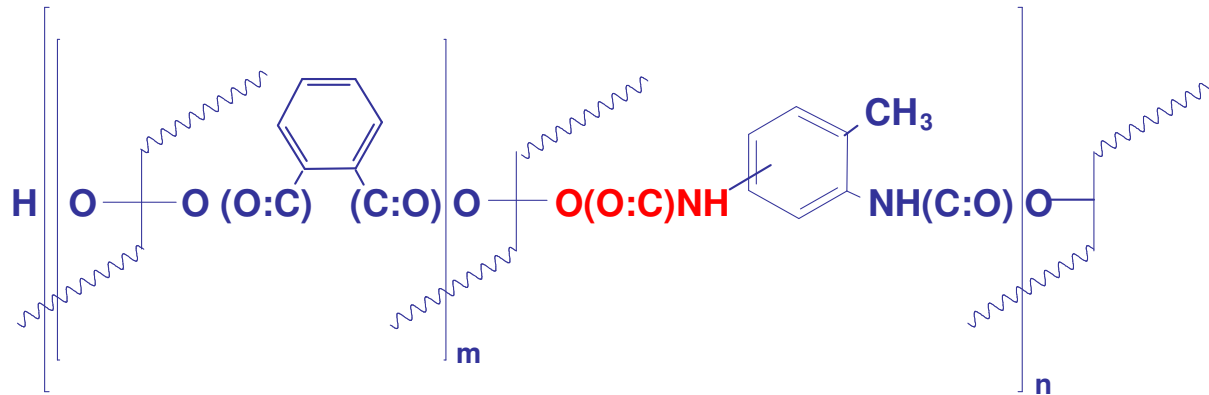


Oil Modified Urethane

~~~~~ = fatty acid residue

# Oil Modified Urethanes

## □ Polymer Structure

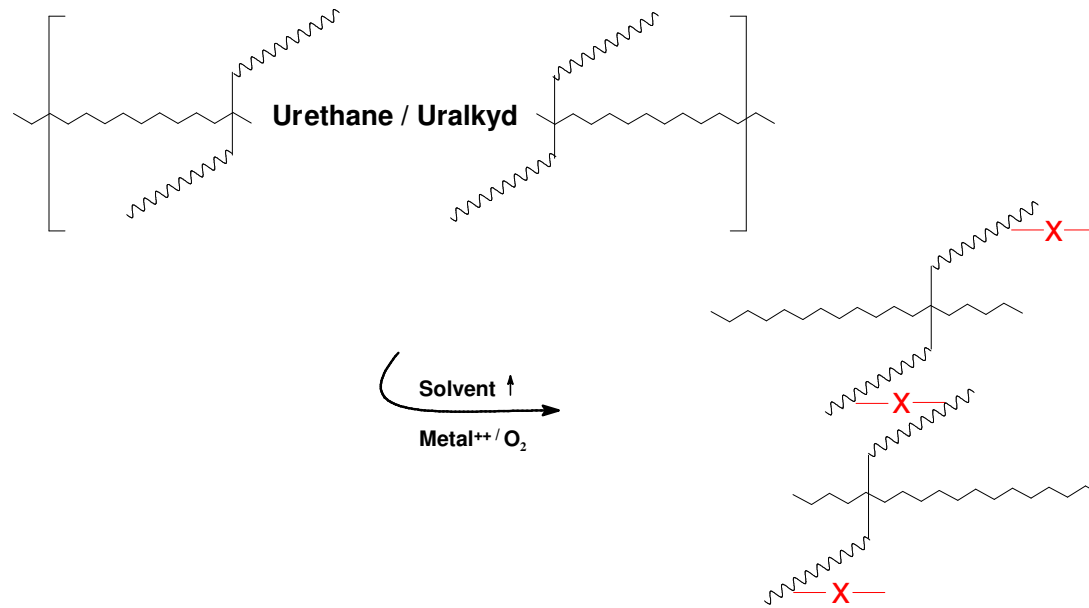


Uralkyd

~~~~~ = fatty acid residue

Oil Modified Urethanes

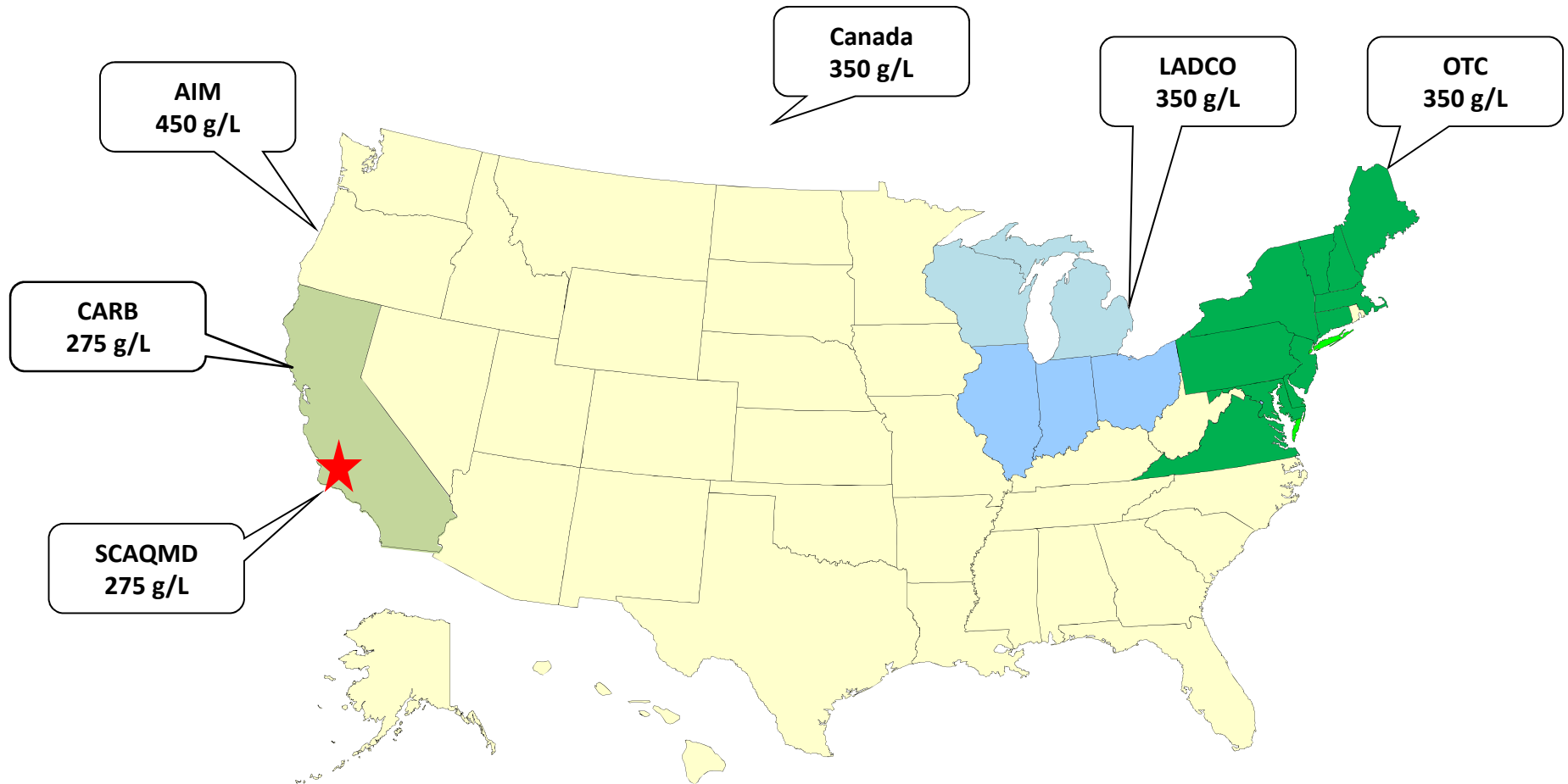
□ Crosslinking



Oil Modified Urethanes

- ❑ Oil Modified Urethane Characteristics
 - Single stable package
 - No NCO groups
 - Low odor
 - Good abrasion resistance
 - Non-toxic air oxidative crosslinking
 - Easy to use
 - Mar resistance
 - Good chemical resistance
 - Warm color
 - Renewable resource
 - High VOC
 - Conventional VOC ≥ 450 g/L; low VOC ≥ 275 g/L
 - Film deficiency in low VOC varnish
 - Slow dry, soft film
 - 60+ MM lbs. consumed in 2017

Clear Varnish VOC Limits



Oil Modified Urethanes

- ☐ Solvent-borne Oil Modified Urethane
 - Low VOC Option – High Solids

| | Designed VOC | | |
|-----------------------------|---------------------|---------------------|---------------------|
| | 550 g/L | 450 g/L | 350 g/L |
| Solvent | LAMS ⁽¹⁾ | LAMS ⁽¹⁾ | LAMS ⁽¹⁾ |
| Solids, % Weight | 40 | 49 | 62 |
| Viscosity, cps | 79 | 108 | 111 |
| Molecular Weight, Mn | 7000 | 6000 | 3500 |
| VOC, g/L | 523 | 445 | 348 |

(1) Low Aromatic Mineral Spirits
 (2) All contain 200 ppm Cobalt on resin solids

Oil Modified Urethanes

- ☐ Solvent-borne Oil Modified Urethane
 - Low VOC Option – High Solids

| | Designed VOC | | |
|---|--------------|---------|---------|
| | 550 g/L | 450 g/L | 350 g/L |
| Gardner Dry Hard, hr:min | 1:30 | 2:45 | 6:00 |
| Sward Hardness | 48 | 36 | 14 |
| Mar Resistance | Good | Good | Good |
| Taber Abrasion Resistance ⁽¹⁾ | 98 | 86 | 104 |
| Stain Resistance, Average ⁽²⁾ | 3.6 | 3.2 | 2.8 |

(1) Taber, CS-17 wheels, 1 kg load, 1000 cycles, mg loss

(2) ASTM D1308 spot test, 23 chemicals, 4 hr exposure, covered, rating 0-5 no effect

Oil Modified Urethanes

- Solvent-borne Oil Modified Urethane
 - Low VOC Option – Exempt Solvents

| | Conventional | High Solids | Exempt Solvent (Experimental) |
|-----------------------------|---------------------|---------------------|-------------------------------|
| Solvent | LAMS ⁽¹⁾ | LAMS ⁽¹⁾ | LAMS / PCBTF ⁽¹⁾ |
| Solids, % Weight | 49 | 62 | 46 |
| Viscosity, cps | 108 | 111 | 109 |
| Molecular Weight, Mn | 6000 | 3500 | 6000 |
| VOC, g/L | 445 | 348 | 358 |

(1) Low Aromatic Mineral Spirits

(2) P-Chloro benzo trifluoride

(3) All contain 200 ppm Cobalt on resin solids

Oil Modified Urethanes

- Solvent-borne Oil Modified Urethane
 - Low VOC Option – Exempt Solvents

| | Conventional | High Solids | Exempt Solvent (Experimental) |
|---|--------------|-------------|-------------------------------|
| Gardner Dry Hard, hr:min | 2:45 | 6:00 | 4:30 |
| Sward Hardness | 36 | 14 | 38 |
| Mar Resistance | Good | Good | Good |
| Taber Abrasion Resistance ⁽¹⁾ | 88 | 104 | 87 |
| Stain Resistance, Average ⁽²⁾ | 3.2 | 2.8 | 3.7 |

(1) Taber, CS-17 wheels, 1 kg load, 1000 cycles, mg loss

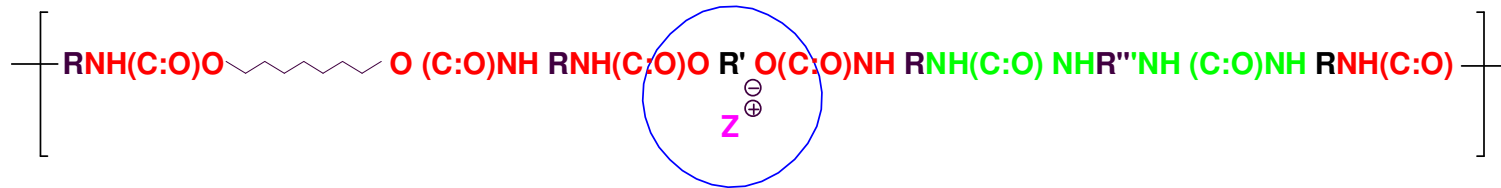
(2) ASTM D1308 spot test, 23 chemicals, 4 hr exposure, covered, rating 0-5 no effect

Oil Modified Urethanes

- Solvent-borne Oil Modified Urethane Summary
 - Low VOC Options
 - High solids OMU
 - Low molecular weight
 - 350 g/L VOC
 - Softer
 - Less durable
 - Exempt solvent OMU
 - High molecular weight
 - VOC \geq 275 g/L
 - Better performance vs. high solids

Water-borne Urethanes

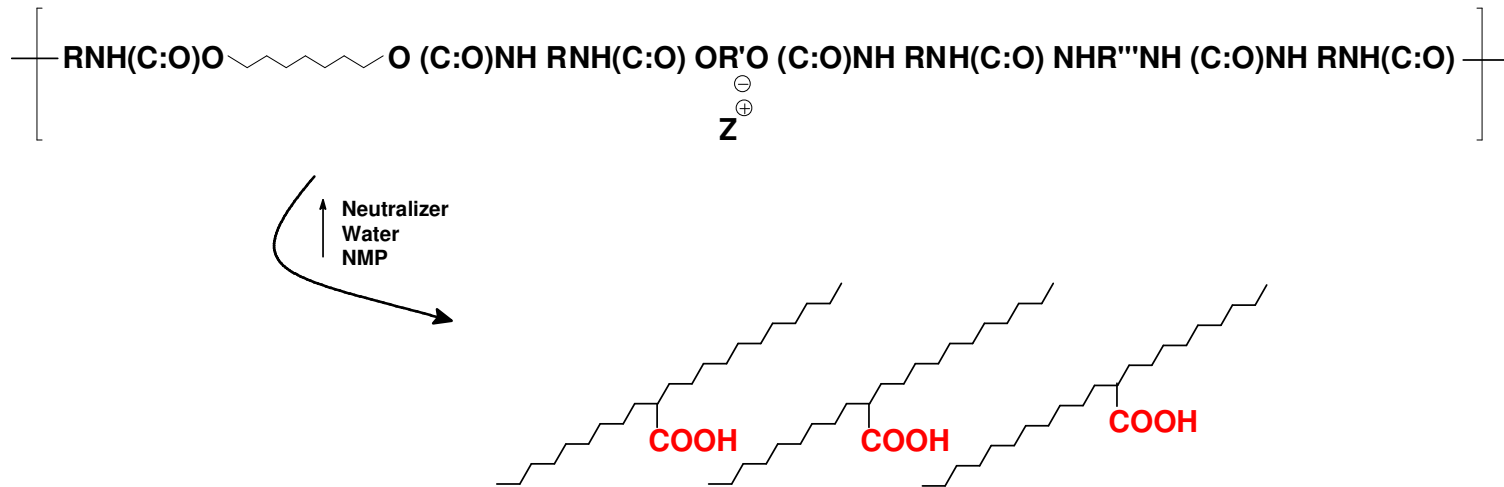
□ Polymer Structure



Anionic Polyurethane

Water-borne Urethanes

□ Film Formation



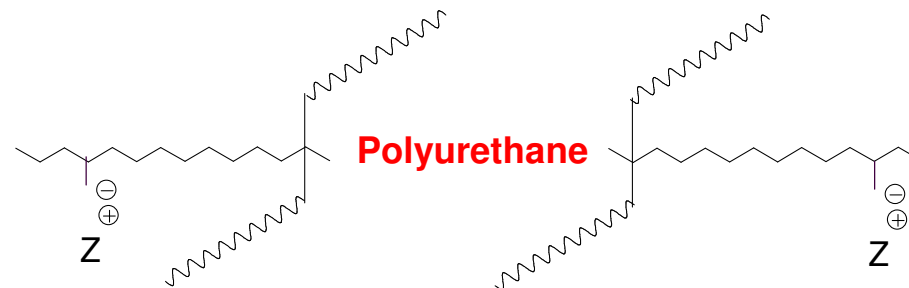
Most PUDs in the market are thermoplastic

Water-borne Urethanes

- Water-borne Polyurethane Dispersion
 - Typical PUD Characteristics
 - High molecular weight
 - Thermoplastic
 - Low VOC
 - Non-flammable
 - Fast drying
 - Abrasion resistance
 - Poor mar resistance
 - Compatible with acrylic emulsions
 - Crosslinkable

Self Crosslinkable Water-borne Oil Modified Urethanes

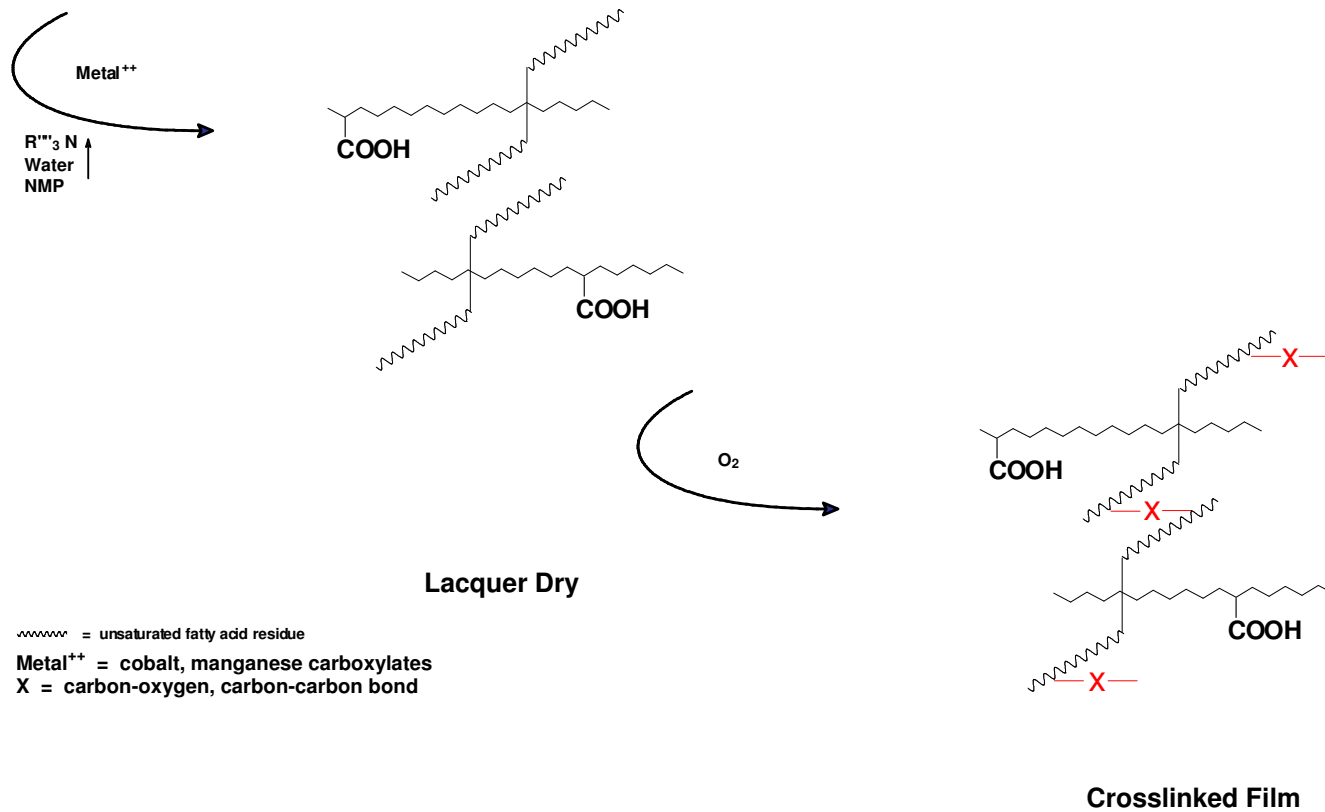
□ Polymer Structure



 = unsaturated fatty acid residue

Water-borne Oil Modified Urethanes

☐ Oxidative Crosslinking



Water-borne Oil Modified Urethanes



☐ Water-borne vs. Solvent-borne Oil Modified Urethane

| | NMP Containing Conventional Solids Water-borne OMU | Conventional Solids Solvent-borne OMU |
|-------------------------------------|--|---------------------------------------|
| VOC, g/L | 185 | 450 |
| Gardner Dry Hard, hr:min | 0:45 | 2:00 |
| Sward Hardness | 32 | 40 |
| Pencil Hardness | H | H |
| Impact Resistance, Direct / Reverse | 160 / 160 | 160 / 160 |

Water-borne Oil Modified Urethanes



□ Water-borne vs. Solvent-borne Oil Modified Urethane

| | NMP Containing Conventional Solids Water-borne OMU | Conventional Solids Solvent-borne OMU |
|---|--|---------------------------------------|
| Mar Resistance | Good | Good |
| Taber Abrasion Resistance ⁽¹⁾ | 44 | 100 |
| Scuff Resistance ⁽²⁾ | 4 | 5 |
| Stain Resistance, Average ⁽³⁾ | 4.5 | 4.1 |
| Solvent Resistance, 200 Double Rubs | | |
| Xylene | > 200 | > 200 |
| Ethanol | > 200 | > 200 |
| Methyl Ethyl Ketone | > 200 | > 200 |

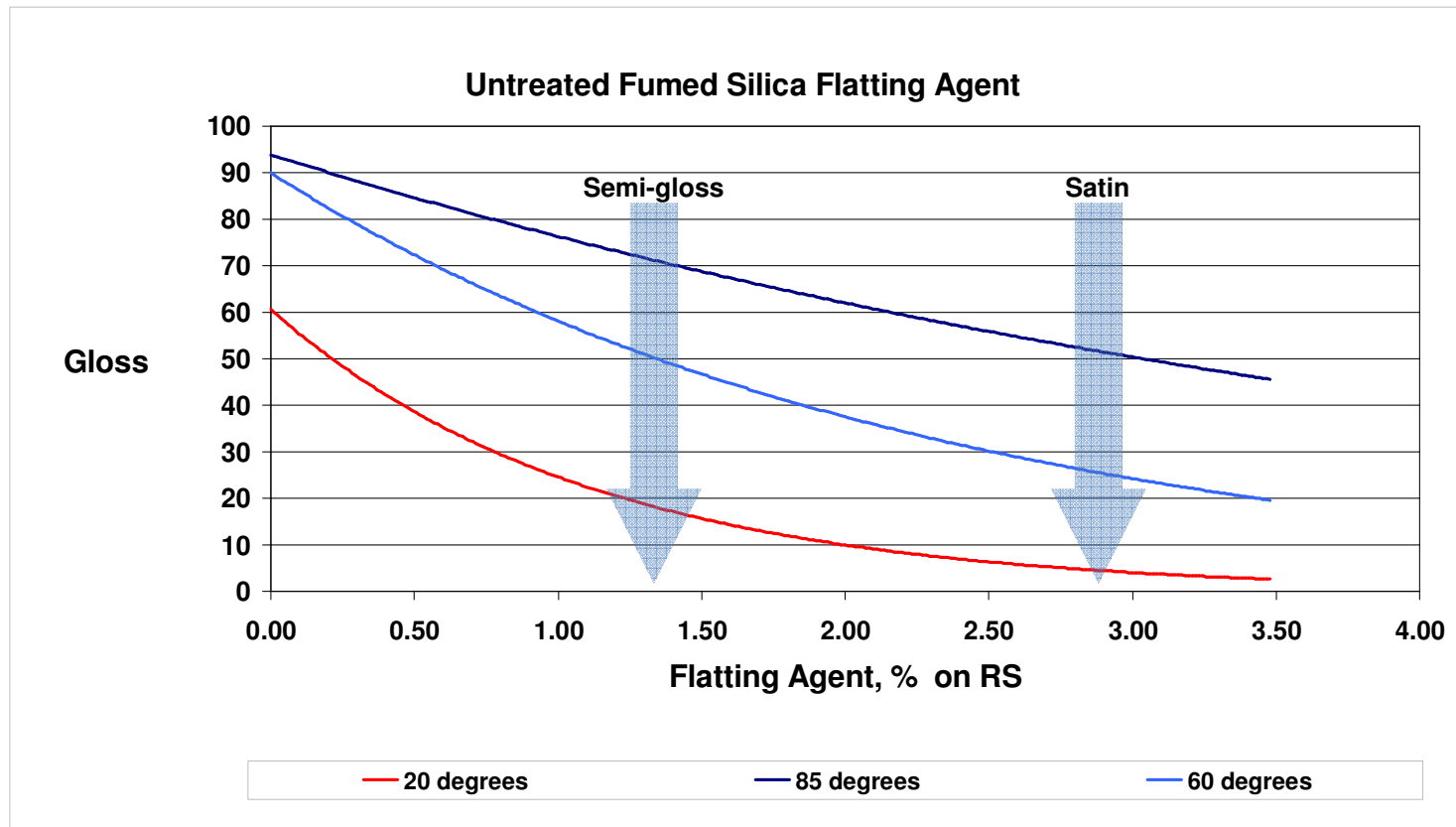
(1) Taber, CS-17 wheels, 1 kg load, 1000 cycles, mg loss

(2) Rating 0-5 no effect

(3) ASTM D1308 spot test, 23 chemicals, 4 hr exposure, covered, rating 0-5 no effect

Water-borne Oil Modified Urethanes

- Water-borne Oil Modified Urethane
 - Flattening ability



Water-borne Oil Modified Urethanes



□ Water-borne Oil Modified Urethane vs. Conventional Thermoplastic Polyurethane Dispersion

| | Conventional Solids PUD | Conventional Solids PUD + Crosslinker | NMP Free Conventional Solids Water-borne OMU |
|---|-------------------------|---------------------------------------|--|
| VOC, g/L | 275 | 275 | 180 |
| Taber Abrasion Resistance ⁽¹⁾ | 17 | 16 | 34 |
| Co-solvent | Ethyl Carbitol | Ethyl Carbitol | DPM ⁽²⁾ |
| Crosslinker | None | Polyaziridine | Oxidative |
| Gardner Dry Hard, hr:min | 1:05 | 0:45 | 0:35 |
| Sward Hardness | 46 | 46 | 34 |
| Konig Hardness | 136 | 132 | 98 |
| Pencil Hardness | HB | F | F |
| Impact Resistance, Direct / Reverse | 160 / 160 | 160 / 160 | 160 / 160 |

(1) Taber, CS-17 wheels, 1 kg load, 1000 cycles, mg loss

(2) Dipropylene Glycol Monomethyl Ether

Water-borne Oil Modified Urethanes



□ Water-borne Oil Modified Urethane vs. Conventional Thermoplastic Polyurethane Dispersion

| | Conventional Solids PUD | Conventional Solids PUD + Crosslinker | NMP Free Conventional Solids Water-borne OMU |
|---|-------------------------|---------------------------------------|--|
| Mar Resistance | Fair | Good | Good |
| Mar Resistance, Grams ⁽¹⁾ | 50 | 150 | 200 |
| Coefficient of Friction ⁽²⁾ | 0.46 | 0.47 | 0.69 |
| Stain Resistance, Average ⁽³⁾ | 3.52 | 3.85 | 3.93 |
| Solvent Resistance, 200 Double Rubs | | | |
| Methyl Ethyl Ketone | > 200 | > 200 | > 200 |
| Xylene | > 200 | > 200 | > 200 |
| Isopropanol | > 200 | > 200 | > 200 |
| Film Color | Clear | Clear | Amber |

- (1) Hoffman Tester, loop stylus, weight needed to mar film
- (2) ASTM D2047, James machine
- (3) ASTM D1308 spot test, 23 chemicals, 4 hr exposure, covered, rating 0-5 no effect

Water-borne Oil Modified Urethanes



- Water-borne Oil Modified Urethane vs. Conventional Thermoplastic Polyurethane Dispersion
 - Water-borne OMU advantages
 - Lower VOC
 - Inherent black heel mark (mar) resistance
 - Single stable package
 - Oxidative crosslinking (self-crosslinking)
 - Fast dry and amber film
 - Renewable resource
 - Conventional PUD advantages
 - Better abrasion resistance
 - Clear non-yellow film
 - Crosslinkable with external crosslinkers

Water-borne Oil Modified Urethanes



Water-borne Oil Modified Urethane

| | NMP Containing
Conventional Solids
Water-borne OMU | NMP Free
Conventional Solids
Water-borne OMU | NMP Containing
High Solids
Water-borne OMU |
|------------------------------------|--|--|--|
| Resin Cosolvent as Supplied | NMP | None | NMP |
| Additional Cosolvent | None | DPM | None |
| Varnish VOC, g/L | 187 | 175 | 142 |
| Solids, % Weight | 32 – 34 | 35 – 37 | 44 – 46 |

Novel Water-borne Oil Modified Urethane



□ Typical Resin Properties

| | Novel Water-borne Oil Modified Urethane |
|--------------------------|---|
| Appearance | Hazy |
| Cosolvent ⁽¹⁾ | TPM* |
| Solids, % Weight | 45.0 |
| Solids, % Volume | 42.2 |
| pH | 8.2 |
| Viscosity, Stokes | 10 |
| Viscosity, G-H Letter | V+2/3 |
| Density, #/gal | 8.60 |
| VOC, #/gal | 0.79 |
| VOC, g/L | 95 |

(1) Tripropylene Glycol Mono Methyl Ether

Novel Water-borne Oil Modified Urethane



☐ Varnish Formula & Analysis

| Varnish Formula & Analysis | Novel Water-borne Oil Modified Urethane |
|---|---|
| Varnish Formula, Grams | |
| Novel Water-borne Oil Modified Urethane | 200.00 |
| 1% Iron Drier Supplied in Water | <u>0.84</u> |
| Total | 200.84 |
| Varnish Analysis | |
| Non-volatile, % Weight | 45.8 |
| pH | 8.05 |
| Viscosity, Stokes | 5.94 |
| Viscosity, G-H Letter | T+1/2 |
| Density, #/Gallon | 8.619 |
| VOC, #/gal | 0.79 |
| VOC, g/L | 95 |

☐ Formulating Notes

- Add drier to the dispersion gradually under moderate agitation and allow it to sweat in for seven days prior to use to ensure optimum film performance.
- Adjust solids as needed with water, filter (50μ) and package with minimum head space.
- Add defoamer, surfactant or flattening agent as needed.

Novel Water-borne Oil Modified Urethane



□ Typical Varnish Properties: Dry Time & Gloss

| Film Performance ⁽¹⁾ | Novel Water-borne OMU | NMP Containing Conventional Solids Water-borne OMU | NMP Free Conventional Solids Water-borne OMU | NMP Containing High Solids Water-borne OMU |
|--|-----------------------|--|--|--|
| Resin Cosolvent as Supplied | TPM | NMP | None | NMP |
| Additional Cosolvent | None | None | DPM | None |
| Varnish VOC, g/L | 95 | 187 | 175 | 142 |
| Gardner Dry Time, hr:min ⁽²⁾ | | | | |
| Set | 0:05 | 0:15 | 0:10 | 0:10 |
| Hard | 0:18 | 0:35 | 0:35 | 0:30 |
| Through | 0:20 | 1:00 | 0:55 | 1:05 |
| Zapon Tack Free Time, hr:min ⁽²⁾ | | | | |
| 200g | 0:15 | 1:00 | 0:55 | 1:00 |
| 500g | 0:16 | 1:10 | 1:00 | 1:05 |
| Gloss 60° / 20° ⁽³⁾ | 93 / 85 | 91 / 74 | 93 / 83 | 92 / 84 |

(1) Except where noted, film applied with #60 WWR to B1000 panel, air dried 7 days

(2) Film applied by 3 mil Bird bar to glass plate

(3) Film applied by 3 mil Bird bar to Leneta chart

Novel Water-borne Oil Modified Urethane



□ Typical Varnish Properties: Film Performance

| Film Performance ⁽¹⁾ | Novel Water-borne OMU | NMP Containing Conventional Solids Water-borne OMU | NMP Free Conventional Solids Water-borne OMU | NMP Containing High Solids Water-borne OMU |
|--|-----------------------|--|--|--|
| Sward Hardness, 7 Day ⁽²⁾ | 32 | 38 | 38 | 34 |
| Konig Hardness, 7 Day | 75 | 96 | 98 | 77 |
| Pencil Hardness, 7 Day | HB | HB | HB | HB |
| Impact Resistance, Direct / Reverse | 160 / 160 | 160 / 160 | 160 / 160 | 160 / 160 |
| Mandrel Bend, 1/8" | Pass | Pass | Pass | Pass |
| Taber Abrasion, mg loss ⁽³⁾ | 66 | 46 | 41 | 62 |
| Mar Resistance, Grams ⁽⁴⁾ | 700 | 700 | 200 | 200 |
| Mar Resistance, Days ⁽⁵⁾ | < 2 | < 1 | < 1 | < 2 |
| Stain Resistance, Average ⁽⁶⁾ | 3.88 | 4.15 | 4.08 | 4.04 |
| Solvent Resistance, 200 Double Rubs | | | | |
| Ethanol | > 200 | > 200 | > 200 | > 200 |
| Isopropanol | > 200 | > 200 | > 200 | > 200 |
| Methyl Ethyl Ketone | > 200 | > 200 | > 200 | > 200 |

(1) Except where noted, film applied with #60 WWR to B1000 panel, air dried 7 days

(2) Film applied by 3 mil Bird bar to glass plate

(3) Taber, CS-17 wheels, 1 kg load, 1000 cycles, mg loss

(4) Hoffman Tester, loop stylus, weight needed to mar film

(5) Time to achieve, finger nail scratch

(6) ASTM D1308, 4 hr exposure, covered, rating 0-5 no effect

Novel Water-borne Oil Modified Urethane



□ Features:

- High solids
- Low VOC for varnishes <100 g/L
- NMP free
- High percent biobased content
- Anionic stabilized
- Fast drying
- Good leveling
- Mar and wear resistance
- Stable single self-crosslinkable package
- High gloss capability and easily flattened



□ Primary Applications:

- Clear gloss and satin architectural coatings for wood
 - Floor finishes
 - Furniture
 - Trim

Thank You!

Obrigado!

Danke! Merci!

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Gracias!

धन्यवाद !

Takk!

谢谢!

Grazie!

Děkujeme!

Dank!