Resins for Improved Coatings for LVT

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allnex
The Coating Resins Company

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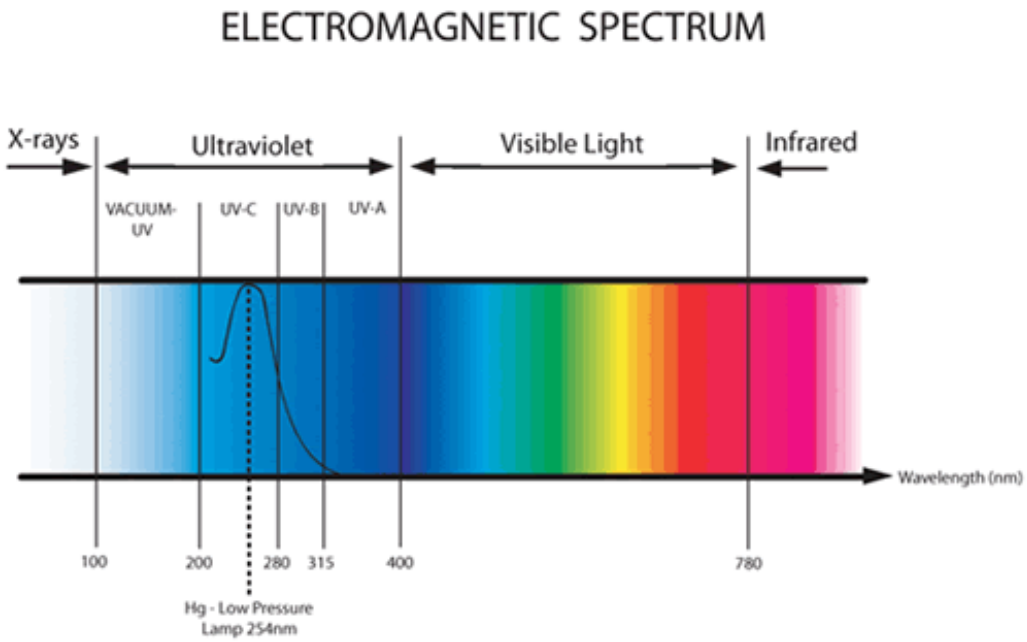
Background

What is Ultra-Violet (UV) curing?

- Using UV energy or visible light, as opposed to heat, solvent evaporation, or oxidation (air-drying), to convert a liquid formulation into a solid material
- Types of energy used:
  - Ultra Violet (UV): 200 – 400 nm
  - Visible light: typically 380 - 450 nm



Advantages of 100% Solids UV Curable Systems

- Productivity, Productivity, Productivity
  - Seconds to cure vs. minutes or hours
- Lower Overall Cost (per cured part)
  - 100% solids, cure speed, recycling of coating, etc.
- Single component formulas
  - Eliminates mixing errors found in 2 component systems
- Regulatory Concerns (VOC emission)
  - Avoid solvent use in most cases
- Smaller equipment footprint
  - Less floor space needed
- Energy costs

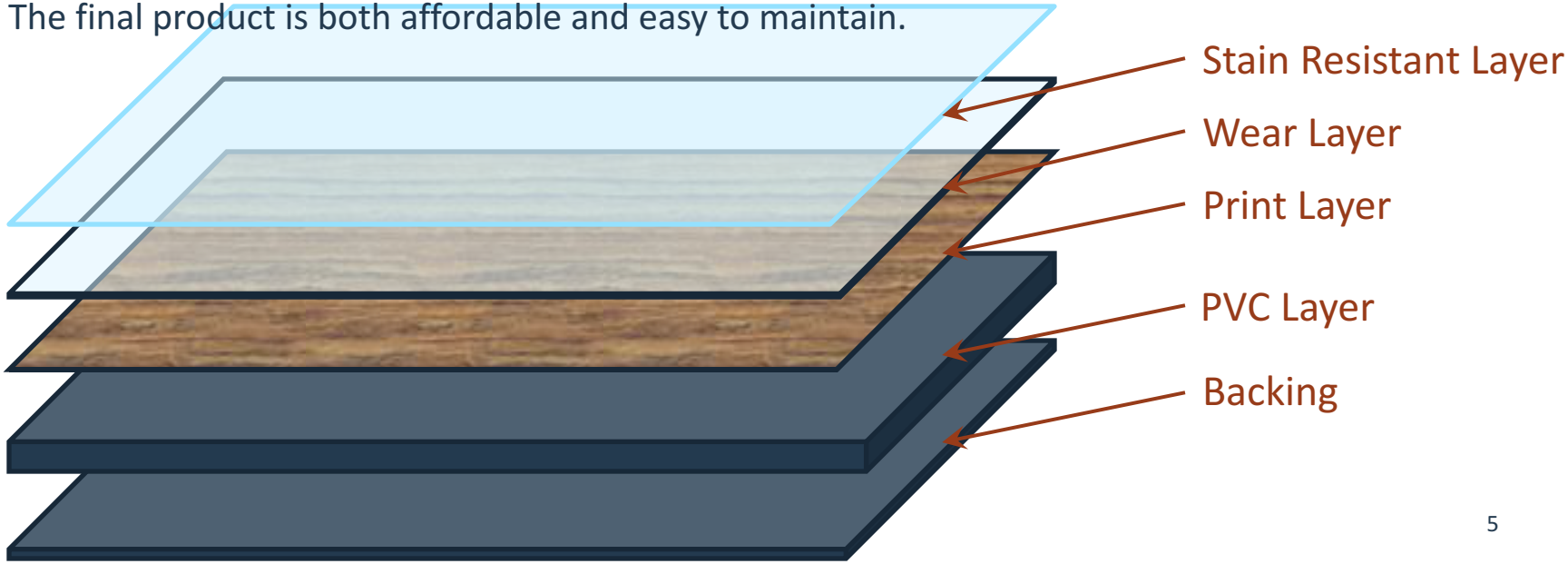
Challenges in 100% Solids UV Curable Systems

- Line of sight curing
  - All areas of the part must be exposed to UV energy
  - Lamp placement critical, but not difficult
  - Absorbance of system: components that absorb/block UV may interfere with cure
    - > Select components that don't absorb UV or select PI that absorbs in another region of the UV spectrum

- Shrinkage
  - All reactions generate shrinkage, which may lead to poorer adhesion
    - > Mitigate with selection of diluents, oligomers
    - > Use of WB systems can reduce shrinkage (no monomers needed to reduce viscosity)

Luxury Vinyl Tile – What is it?

- Luxury vinyl tile (LVT) is one of many types of resilient flooring, characterized by its successful combination of aesthetics and performance.
- LVT uses the latest 3D imaging technologies and embossing to replicate real hardwoods and stones to the point where it is often difficult to distinguish between real wood or stone and LVT.
- LVT is comprised of multiple layers of material, and usually includes one or two layers of PVC as the foundation, a photographic image layer, a wear layer and a scratch and stain resistant topcoat.
- This construction makes LVT a very durable flooring material.
- LVT is typically thinner than most hardwood planks, stone, or ceramic tiles and can be glued down or floated – a relatively easy process, particularly for do-it-yourselfers.
- The final product is both affordable and easy to maintain.



Luxury Vinyl Tile – Why is it attractive?

Successful combination of aesthetics and performance:

- Amazing Realism: latest 3D imaging technologies & embossing. The ability to replicate real hardwoods and stones using advanced photographic technologies is the foundation of luxury vinyl flooring systems and allows for limitless design options
- Enhanced Durability: urethane top layer for increased protection
- More Installation Options: LVT is typically thinner than most hardwood planks, stone, or ceramic tiles. Floors can be glued down or floated – a relatively easy process, particularly for do-it-yourselfers.
- Easy to maintain and affordable.

“Double-digit growth” numbers reported (WFCA)

Residential market is embracing the authentic good looks and proven durability.

Luxury Vinyl Tile – Market Needs

- End users a very satisfied with the performance of LVT.
- LVT manufacturers are trying to determine ways to differentiate themselves from competition
  - Consumers research on-line before buying
  - Small differences in performance can result in sale
- Focus on improvement in stain resistance

Resin screening of existing products:
List of Stains

Stain	Description	Severe Stain
Lugol's Iodine Solution	Iodine / KI / water	X
Wright's Stain	Methylene blue / Eosin Y / ethanol / water	X
Betadine	pNVP / Iodine / water	X
Black RIT Dye		X
Ketchup		
Mustard		X
Antiseptic Solution	pNVP / Iodine / water	X
Blue Food Coloring (blue, red)		
Coffee		
50% Ethanol Solution		
Bleach		
Sharpie Markers (red, blue, green, black)		X
Kiwi Brown Shoe Polish		X
Coal Tar		X
Vinegar		
Water		

Resin screening of existing products:
List of Resins

Oligomer	Functionality	Viscosity (25°C)
ALUA 1	2	132,500
ALUA 2	2	23,000
ALUA 3	2	7,000
ALUA 4	3	7,000
ALUA 5	3	25,000
ALUA 6	3	2,300
ALUA 7	4	85,000
ALUA 8	6	15,780
ALUA 9	6	24,600
ALUA 10	9	86,000
ALUA 11	10	75,500
ARUA 1	2	7,000
ARUA 2	3	17,000
ARUA 3	3	3,200
ARUA 4	6	28,500
ARUA 5	6	6,000
Mod EA	2	190,000
PEA 1	2	5,000
PEA 2	3	40,000
PEA 3	3	36,000
PEA 4	3.5	580
PEA 5	4	14,000
PEA 6	4	450

ALUA = **AL**iphatic **U**rethane **A**crylate
ARUA = **AR**omatic **U**rethane **A**crylate
Mod EA = **MOD**ified **E**poxy **A**crylate
PEA = **P**olyEster **A**crylate

Resin screening of existing products:
Initial Screen for Stain Resistance

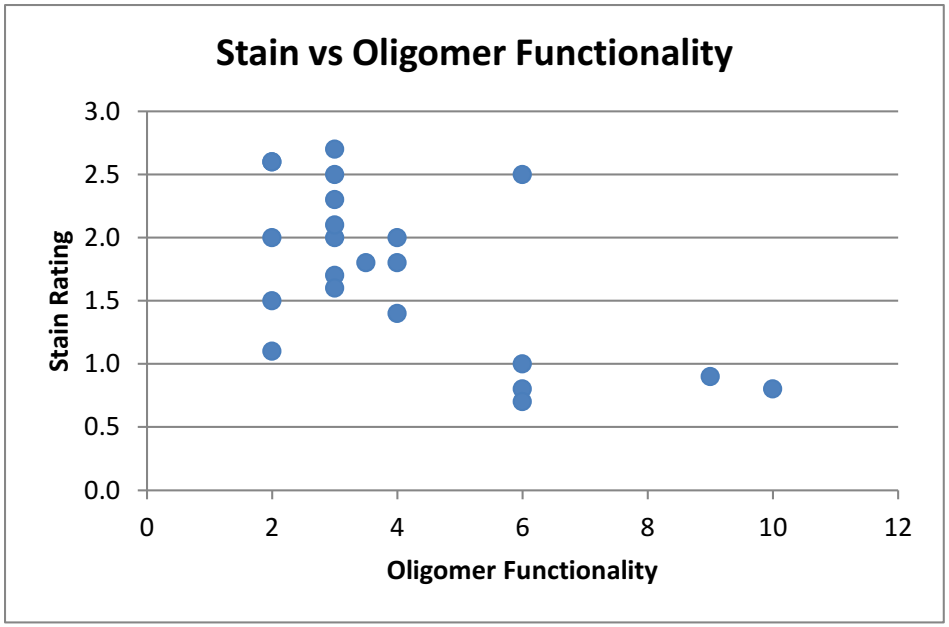
Formulation:

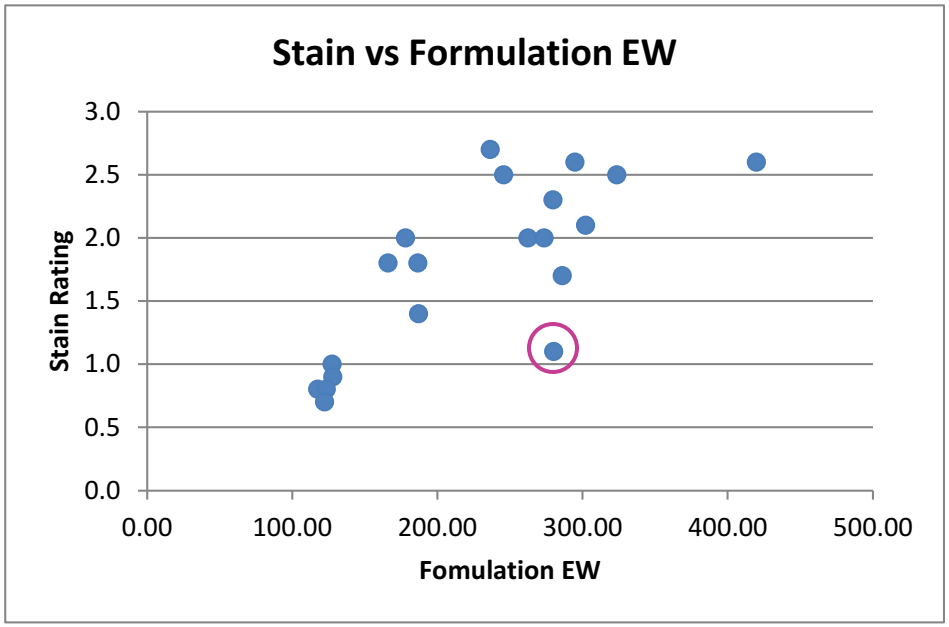
Raw Material	Parts
Oligomer	40
Monofunctional monomer	20
Trifunctional monomer	5
Difunctional monomer	as needed to hit 750 cps +/- 50
Silica	6 (for Matte formulation only)
Amine synergist	3
Photoinitiator	3

Coating Preparation:

Parameter:	Value:
Substrate:	“Chalk” colored VCT substrate
Dry Film Thickness:	1 Mil
Energy Density:	700 ± 40 mJ/cm2
Sample Viscosity:	750 ± 90 cps
Draw Down Tool:	1 Mil Bird Bar, 6" Length

Resin screening of existing products:
Initial Screen for Stain Resistance





Higher functionality generally equates to lower stain rating but there is a wide range even within a given functionality

Slightly better correlation when plotting stain vs. equivalent weight (EW) with lower EW resulting in lower stain rating but variation still exists

Resin screening of existing products:
Full Formulation Evaluation for Stain Resistance

Comments on initial resin screening

- Screening work done on gloss formulations – LVT generally has matte finish
- High functionality leads to high shrinkage (internal stress) and curl
- Target viscosity lower than necessary – influence of oligomer “diluted”

Resin screening of existing products – SPF for Testing

Raw Material	Function	Wt. %
Oligomer	Bulk Film Properties	30.5
HDDA	Viscosity control, film properties	34.0
TMPTA	Viscosity control, film properties	3.0
Photoinitiator 1	Cure	3.0
Photoinitiator 2	Cure	3.5
Silica 1	Gloss control	11.3
Silica 2	Gloss control	3.8
Wax 1	Gloss control	4.5
Wax 2	Gloss control	3.0
Additive 1	Dispersant	3.4
Additive 2	Flow and leveling	0.1

- Viscosity ~ 1000, 60° gloss ~10
- Dispersant is essential in viscosity control for high silica formulation
- Combination of silicas gives much lower gloss than using just one
- Ratio of the two silicas also has significant impact on gloss and viscosity

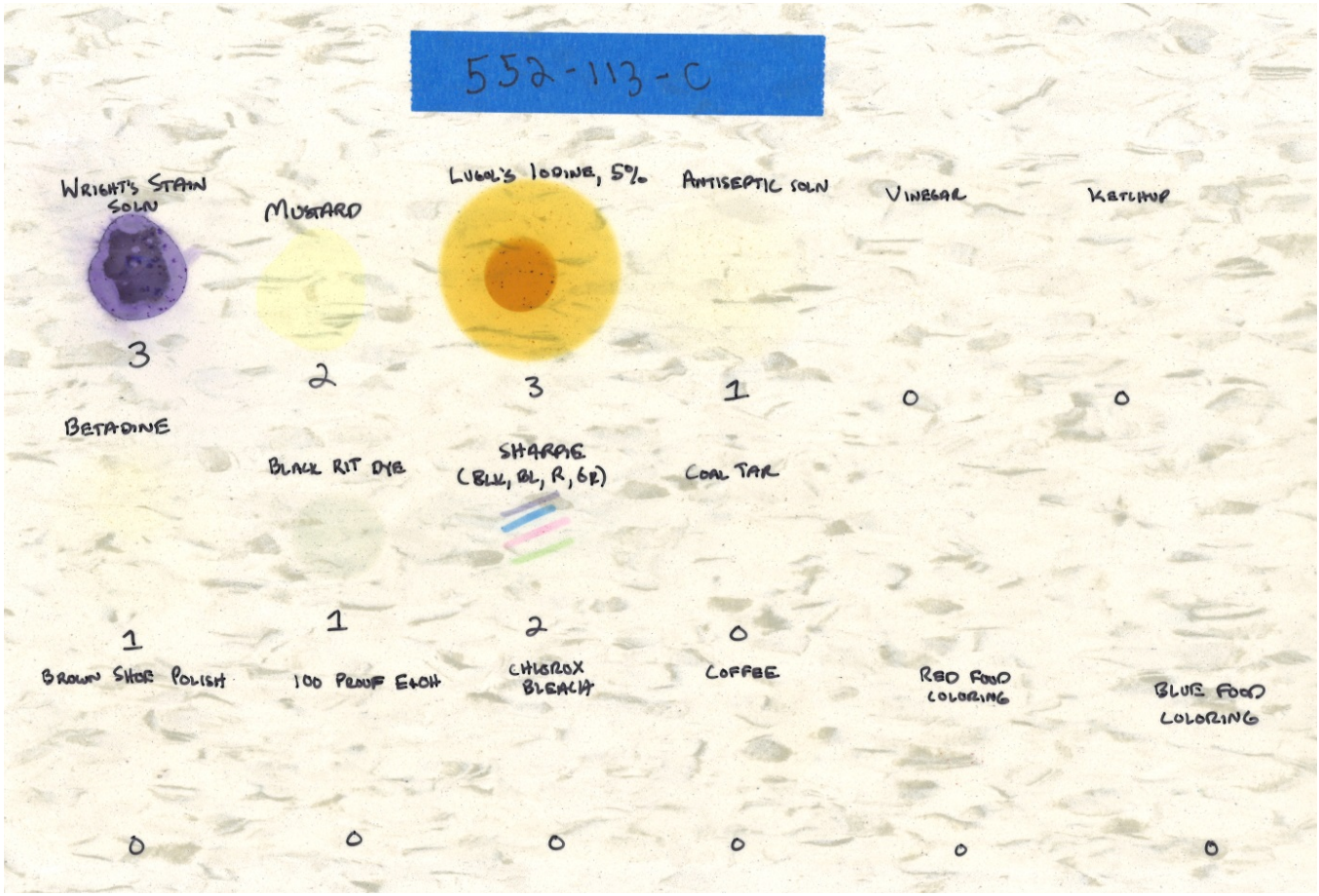
Resin screening of existing products – SPF for Testing

		522-72-C	552-82-A
EB 206 (soft)		14.0%	
EB 5129 (hard)		16.5%	30.5
Viscosity at shear rate of 9.3/sec (25°C)		**1385**	**2520**
Gloss (60°) on White VCT		**26**	**34**
Gloss (60°) on Brown uncoated Mannington LVT		**21**	**24**
Stain Test	Wright's Stain Solution	3	3
Duration = 2 hours	Mustard	2	1
(0= no stain, 3 = severe stain)	Lugol's iodine solution	3	3
	Antiseptic Solution	1	0
	Betadine Solution	1	1
	Black RIT dye	1	1
	Sharpie Markers (R,B,G,Bk)	2	2
	Coal Tar	0	0
	Average Stain	**1.6**	**1.4**
Flexibility (1” mandrel test)	1 mil coating on LVT	pass	pass
Adhesion (1" mandrel test)	1 mil coating on LVT	pass	pass

Resin screening of existing products – SPF for Testing

Base Stains
- Wright's stain
- Lugol's stain
- Mustard
- Antiseptic soln.
- Betadine
- Black RIT Dye
- Sharpie (4 colors)
- Coal Tar

Extra Stains
- Vinegar
- Ketchup
- Brown Shoe Polish
- 50% EtOH
- Chlorox
- Coffee
- Red Food Coloring
- Blue Food Coloring

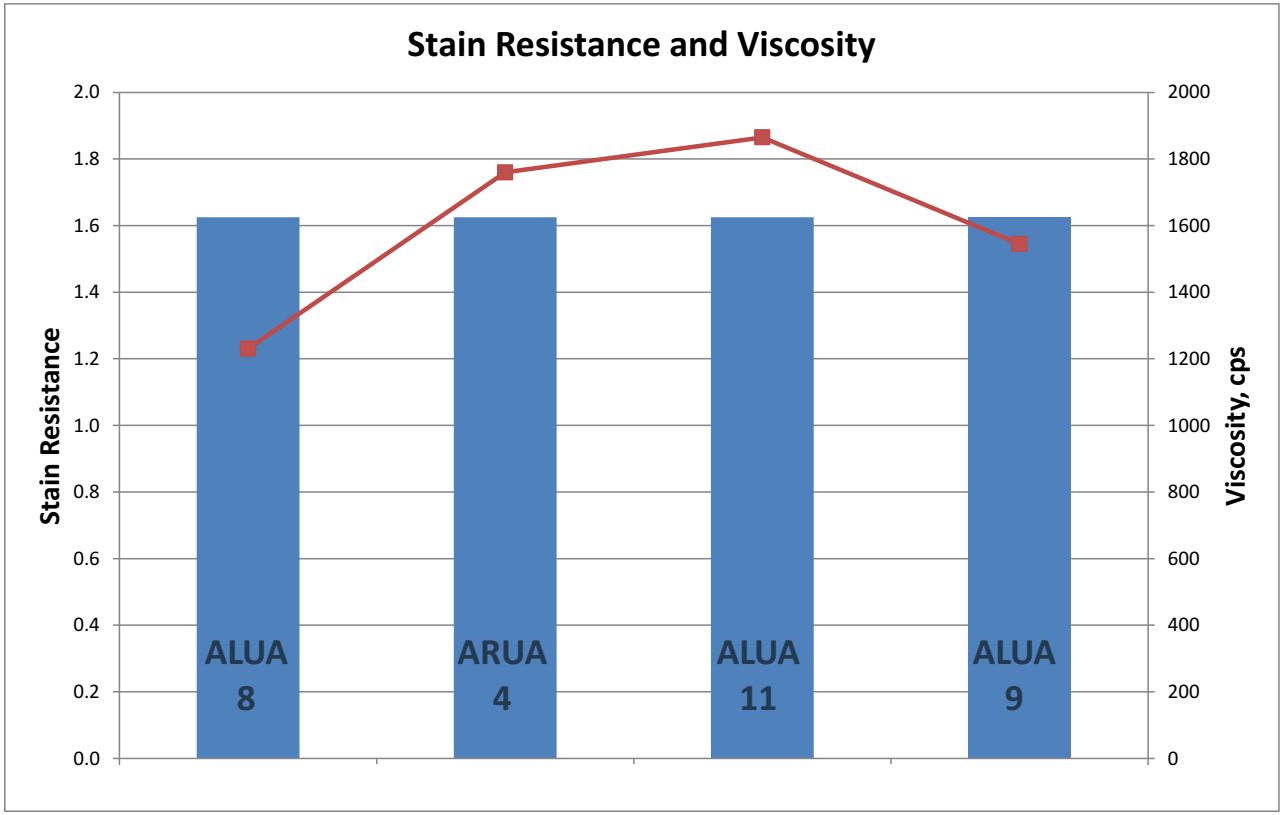


Resin screening of existing products – Test Protocol

- Coating /Curing: 1 H-bulb, 720 mJ/cm^2,
- Rheology: Viscosity at various shear rates (targeted < 1,500 cps at 25 C)
- Gloss: 20, 60, and 85 degree gloss
- Stain Test: see prior slide
- Flexibility: 1" and ¼" mandrel bend (2" wide coated LVT)
- Adhesion (cross-hatch): Scotch 898 tape, rank 0-5 (0: no adhesion, 5: perfect adhesion)
- Scratch:
  - Steel wool (0, and 0000), 15 DR
  - Sclerometer, N to first gouge
  - Scotch Brite pad (various colors)
  - Company specific proprietary scratch tests
- Curl: 80C for 6 hours, 23 C for 8 hours and measure height of edge

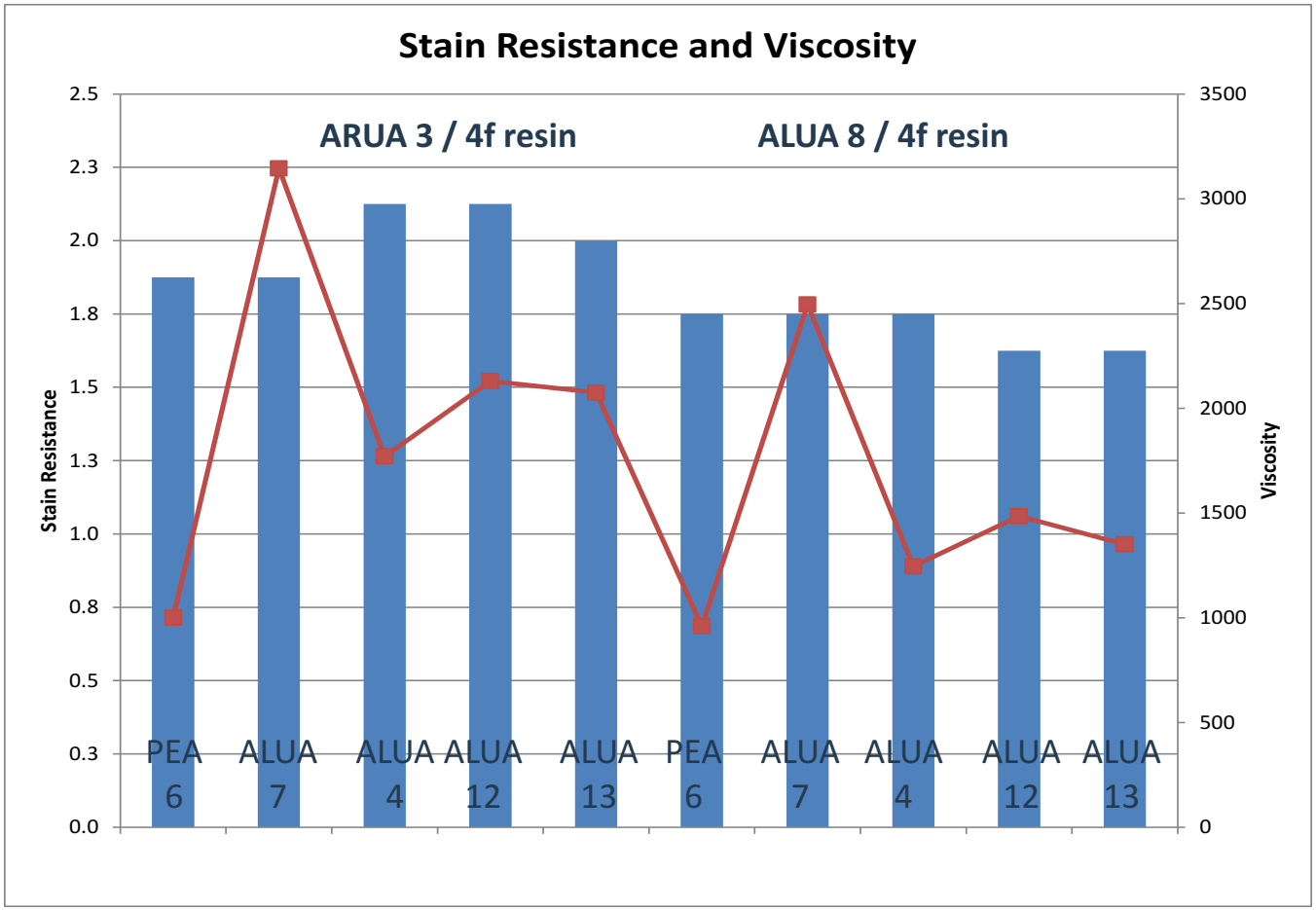
Resin screening of existing products – High functionality resins

- Evaluate alternate high functionality resins in blend with ARUA 3 (tough, 3f)
  - ARUA 4 (6f)
  - ALUA 11(10f)
  - ALUA 9 (6f)
  - ALUA 8 (6f)
- Same stain resistance, ALUA 8 best for viscosity
- All passed adhesion, scratch (steel wool), mandrel bend



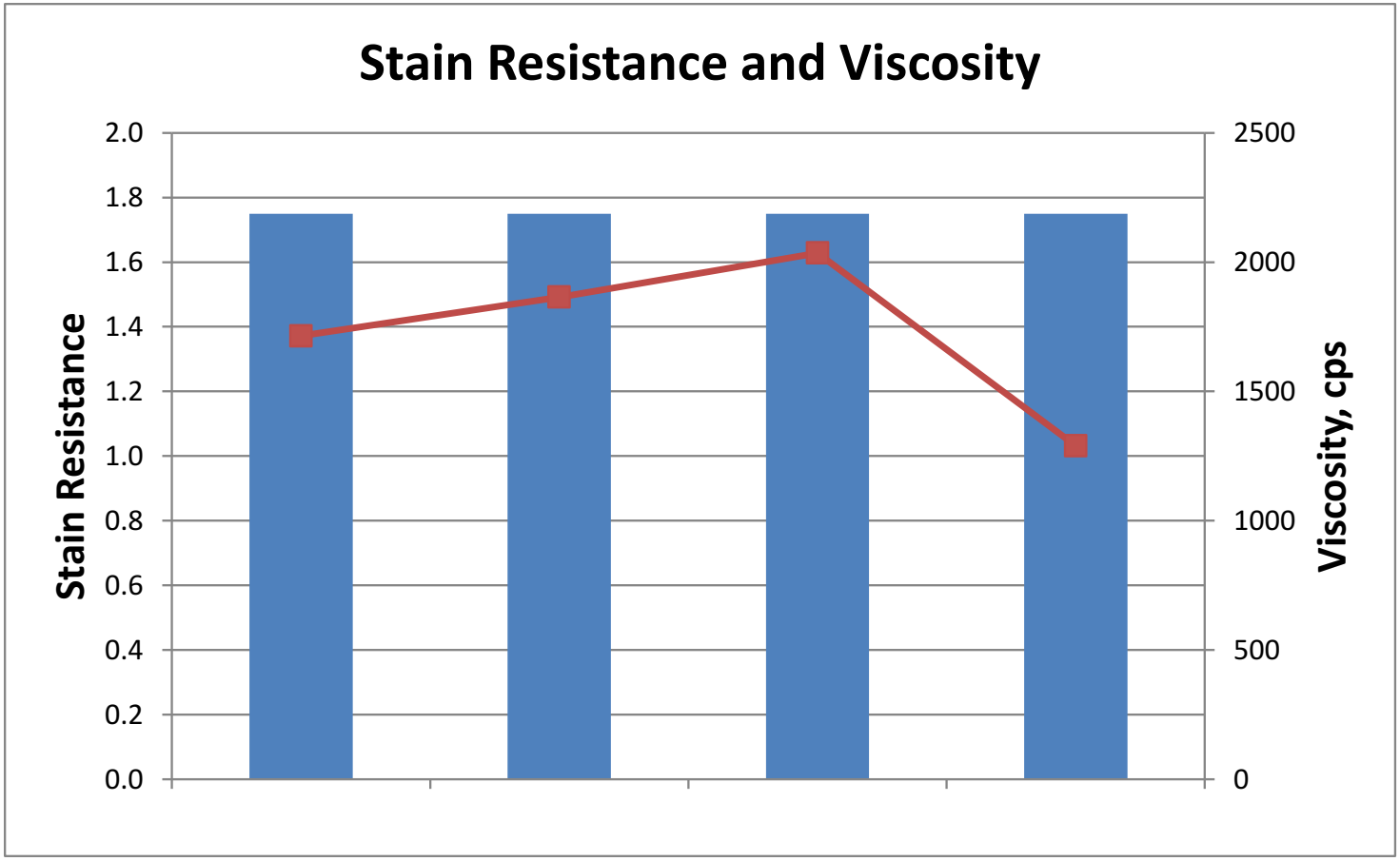
Resin screening of existing products – 4 functional resins

- Evaluate 4f resins (PEA 6, ALUA 7, 4, 12, & 13) with either ARUA 3 or ALUA 8
- ALUA 8 based formulations outperform ARUA 3 based formulas
- All coatings pass 15 DR using 0000 steel wool and have excellent adhesion
- All coatings pass ¼” mandrel bend



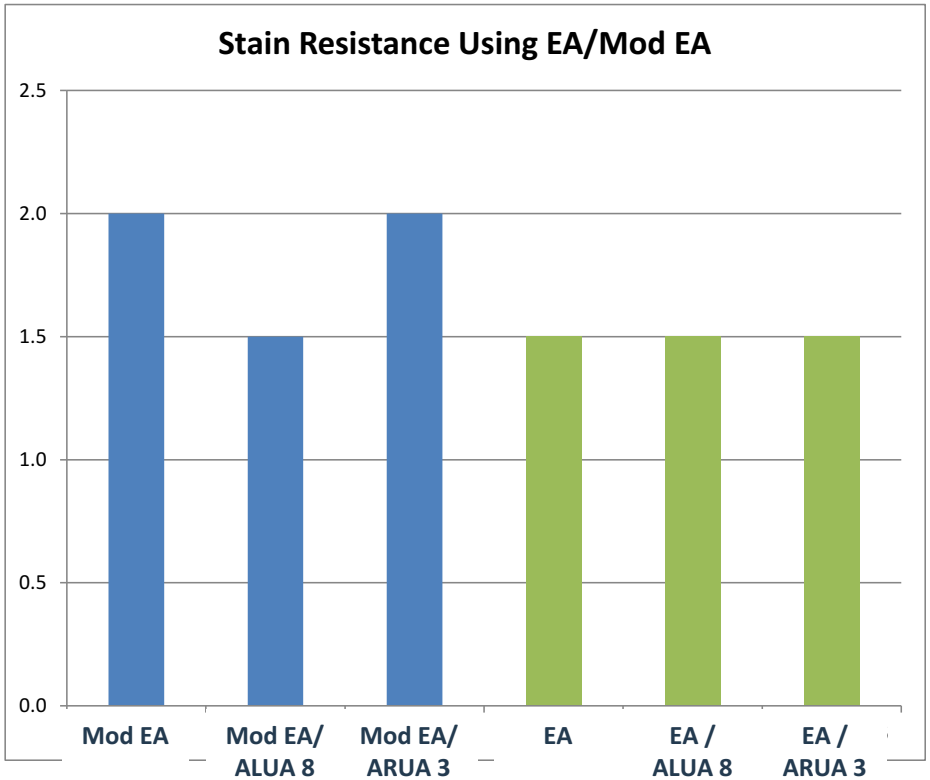
Resin screening of existing products – 4 functional PEA resins

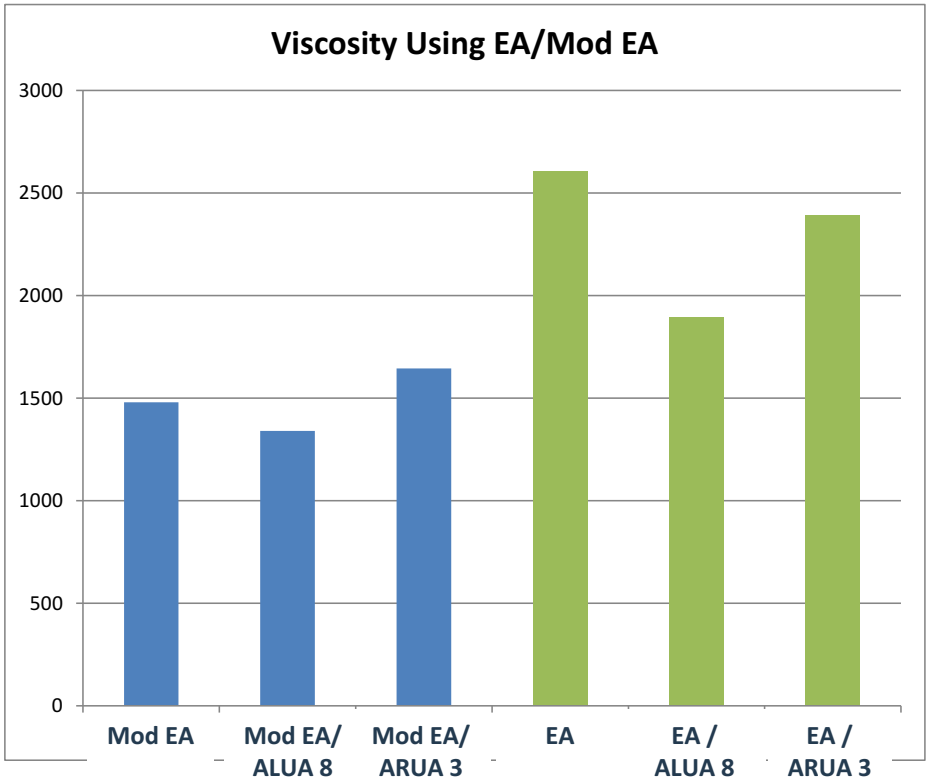
- Evaluate PEAs (PEA 5 (4f), PEA 2 (3f), PEA 3 (3f), PEA 4 (4f) with ARUA 3
- Similar stain resistance (not quite as good as ALUA 8/ ARUA 3)
- PEA 4 best for viscosity
- All coatings pass 15 DR using 0000 steel wool and have excellent adhesion



Resin screening of existing products – Epoxy Acrylates

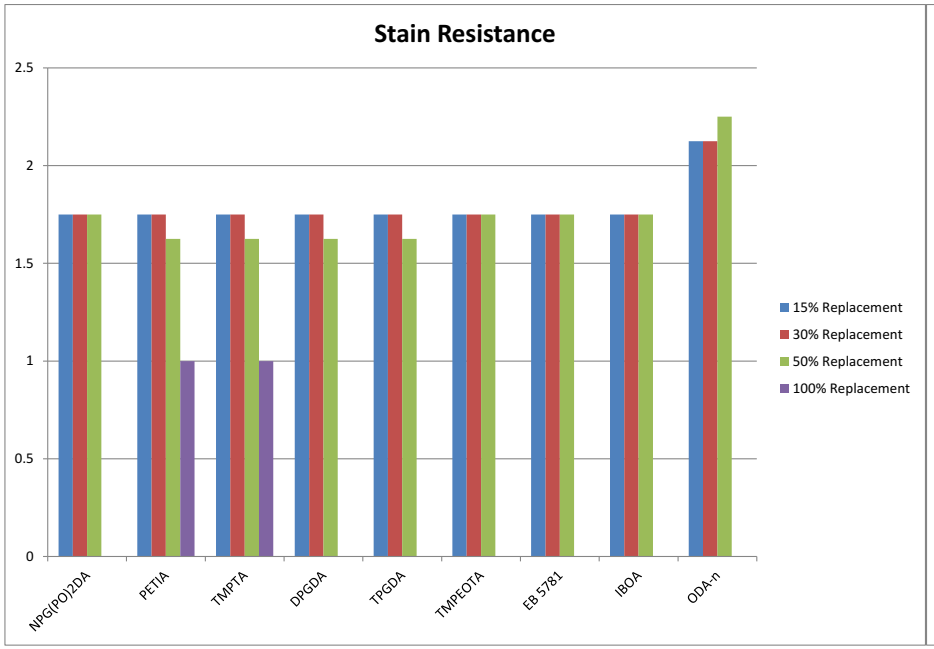
- Evaluate either an EA or modified EA with either ALUA 8 or ARUA 3
- Use of EA gives reasonable stain resistance but higher viscosity
- Use of modified EA give good stain resistance and viscosity only with ALUA 8
- All coatings pass 15 DR using 0000 steel wool

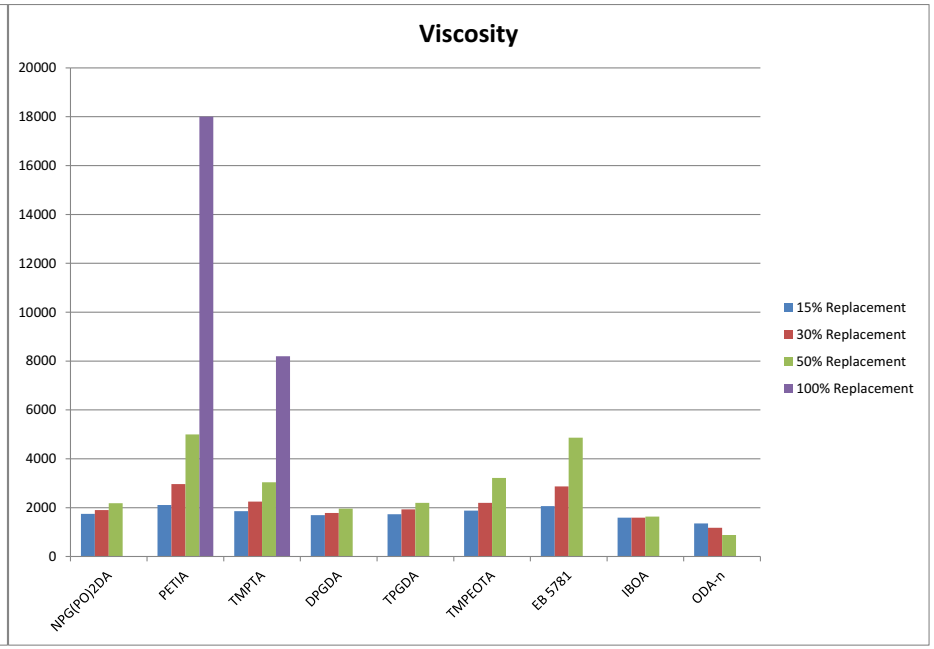




Resin screening of existing products – Effect of Diluent

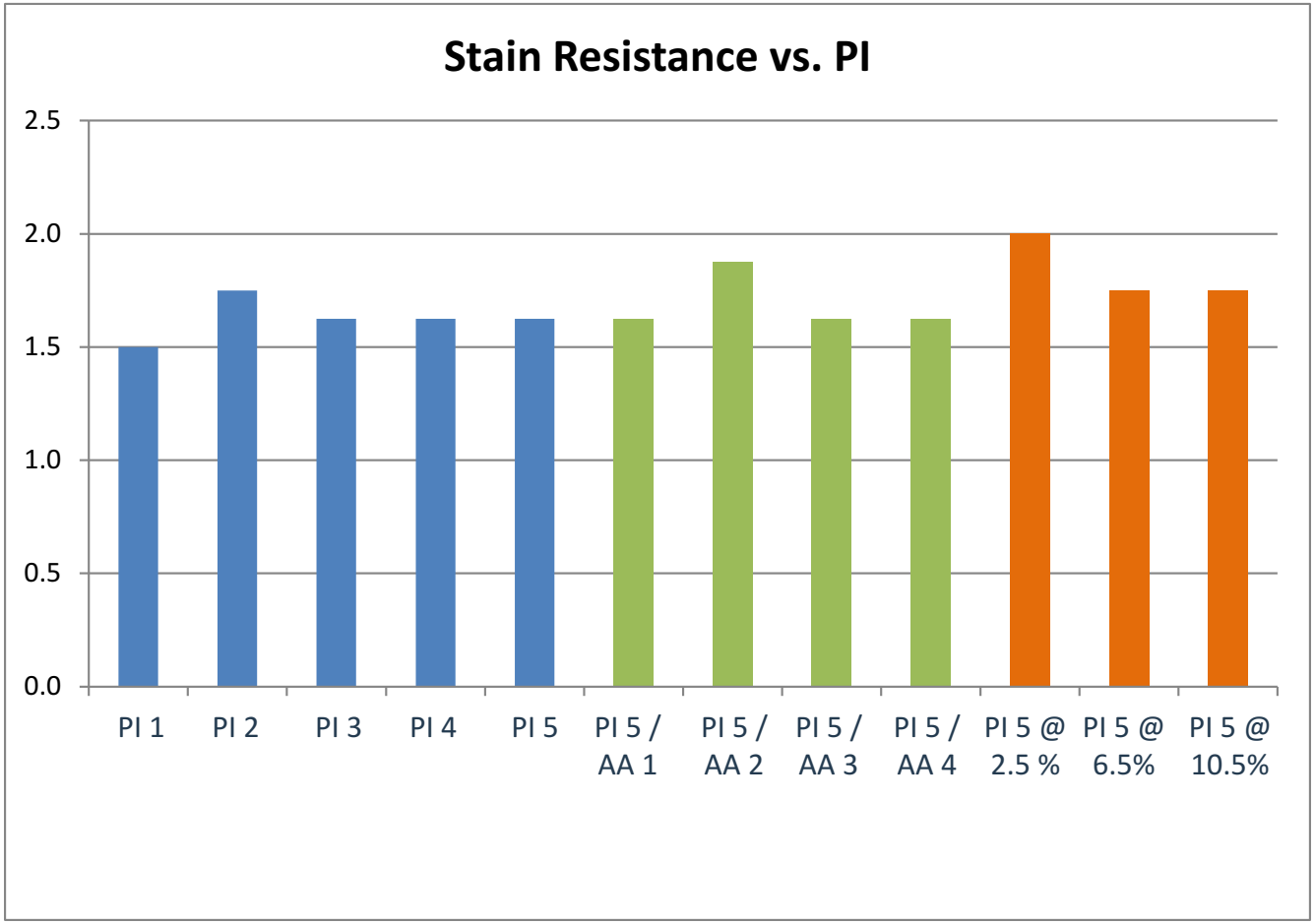
- Replace HDDA with alternate diluent @ 15%, 30%, 50 %, 100%
- Little to no difference stain resistance, except with high levels of TMPTA, DPHA
- Viscosity increases as HDDA decreases
- Little to no difference in flexibility, adhesion, steel wool scratch





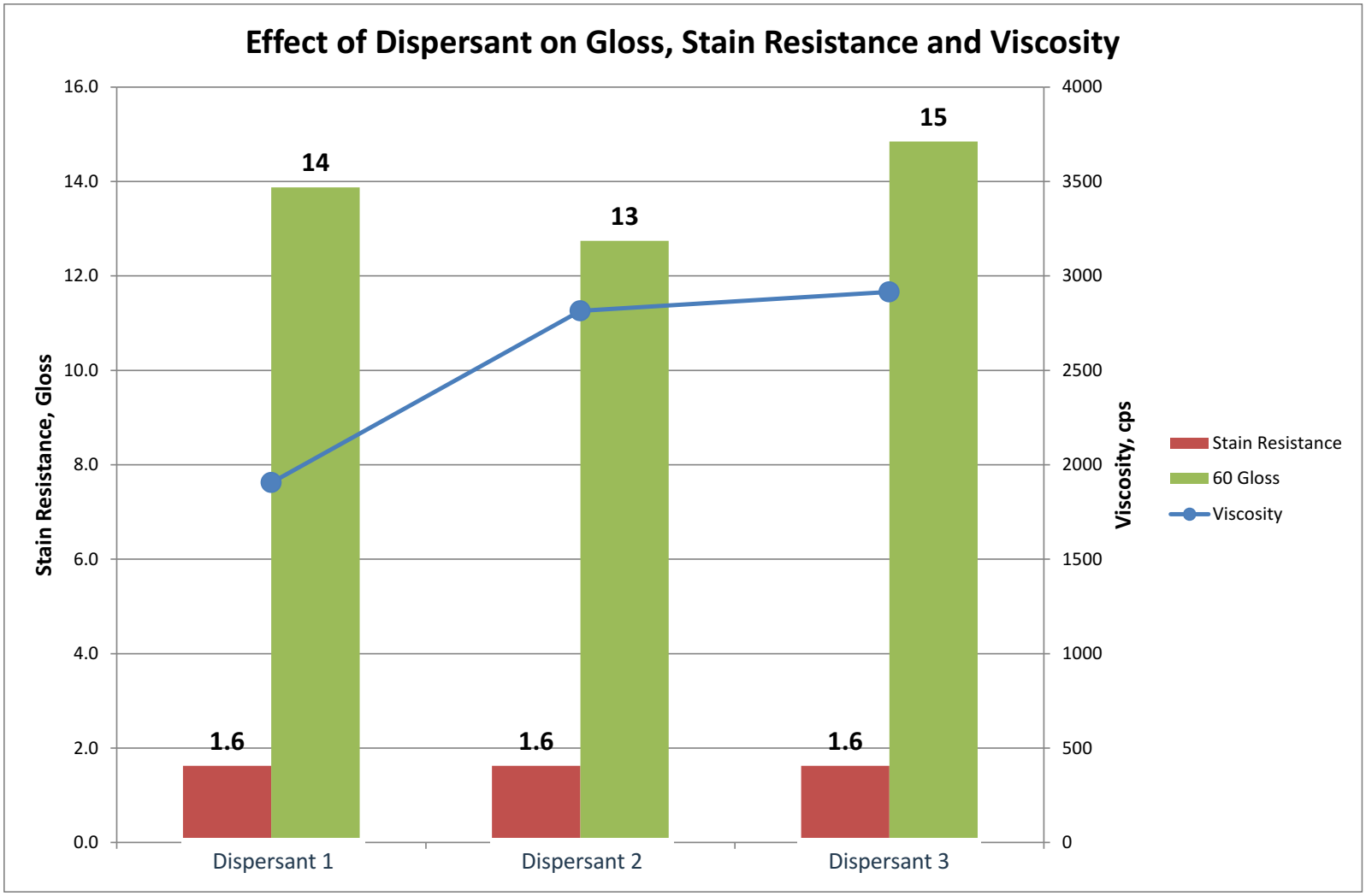
Resin screening of existing products – Effect of PI

- Evaluate 4 different PI @ 6.5%
- Evaluate blends of PI 5 plus aminoacrylates (AA)
- Evaluate total PI concentration at 2.5, 6.5 and 10.5%
- PI 1 best by itself, little difference by addition of amines



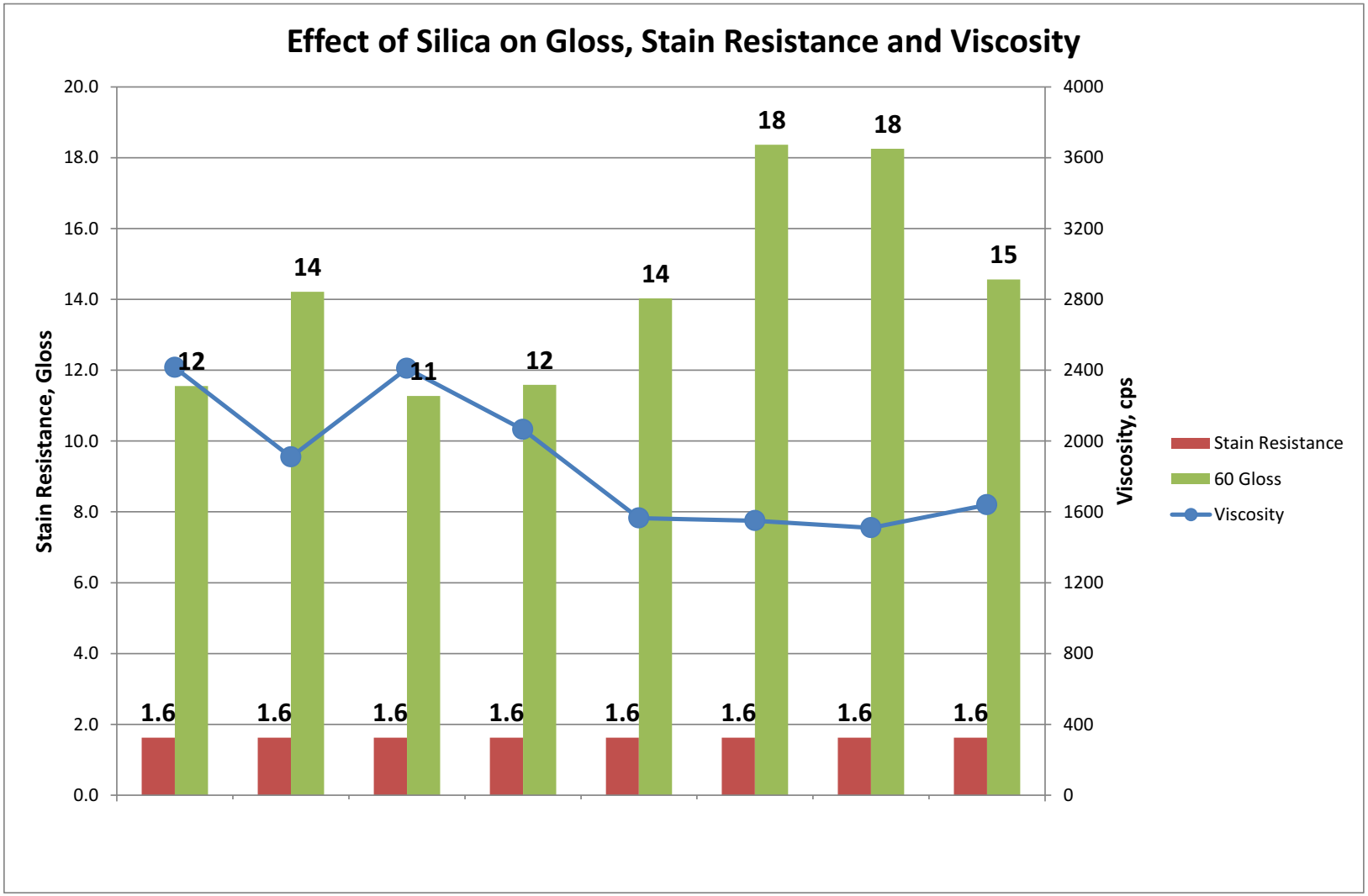
Resin screening of existing products – Effect of Dispersant

- Evaluate 3 different dispersants (offset viscosity rise generated by silica addition)
- Gloss and stain resistance similar for all 3 dispersants, large difference in viscosity



Resin screening of existing products – Effect of silica

- Evaluate 8 different silica blends
- Stain resistance remains constant, some variation in gloss, viscosity



Conclusions

- A wide variety of UV curable resins were evaluated as candidates for coatings on LVT.
- In general, high functionality Urethane Acrylates work best, but need to be combined with a lower functionality tough resin.
- Polyester acrylate resins work well, but do not have quite the performance of UA resins.
- Epoxy acrylate resins have either good stain resistance and high viscosity or reasonable viscosity and poorer stain resistance
- Stain resistance was not improved by using increased PI or an aminoacrylate to reduce O_2 inhibition

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