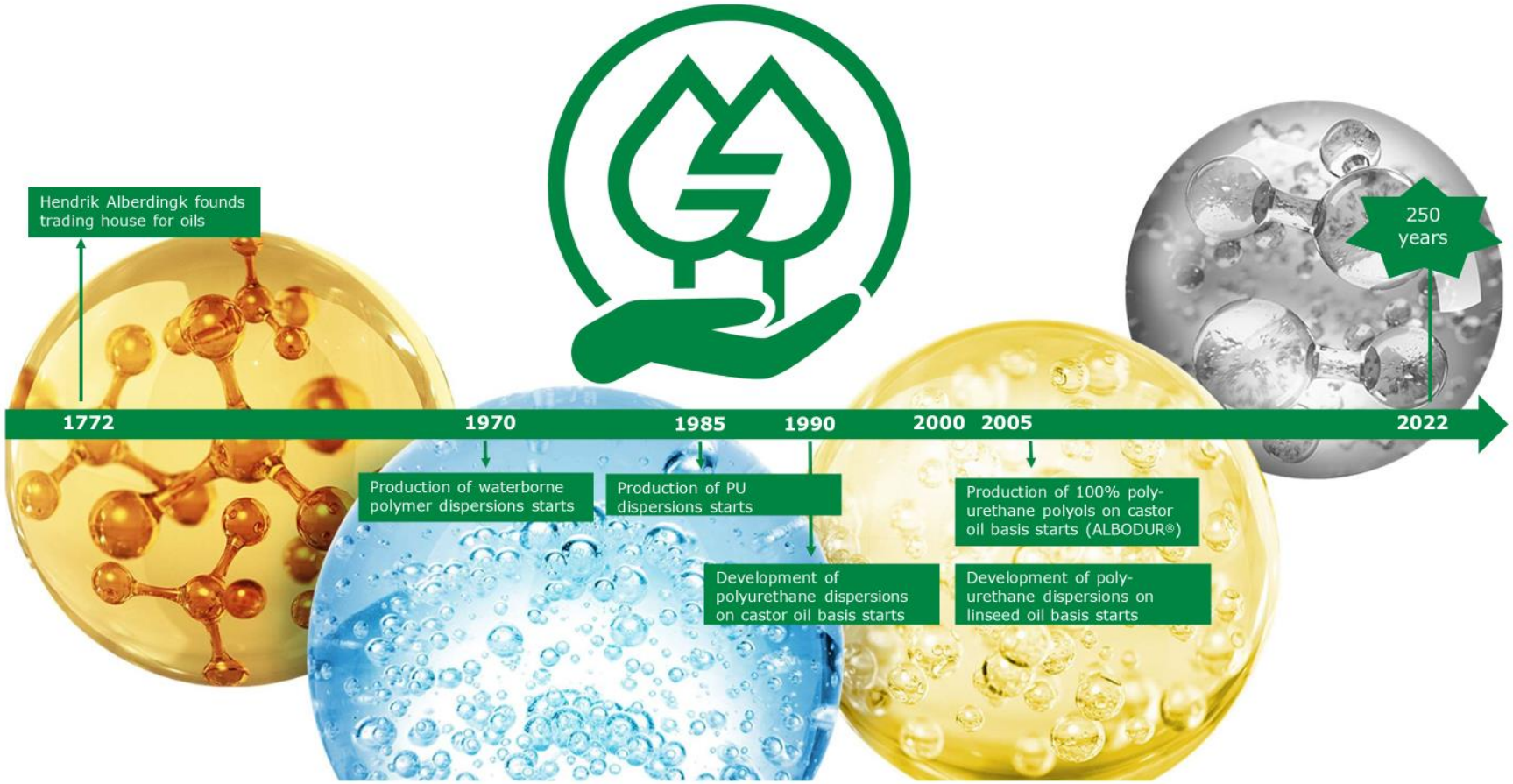
Renewable Multipurpose Polyurethane Coatings

Alberdingk Boley Inc.

David Folkman and Dr Terri Carson

ALBERDINGK BOLEY - Green for 250 years



Where you can find us

All over the world: production sites and application development in Germany, the US and China, R & D centre in Krefeld (D) and multiple representatives on all continents

Agenda

- Market perspective
- Introduction to oil based PUD development
- Application of renewable PUDs
- Summary and Outlook

Why the trend towards Renewable PUDs?

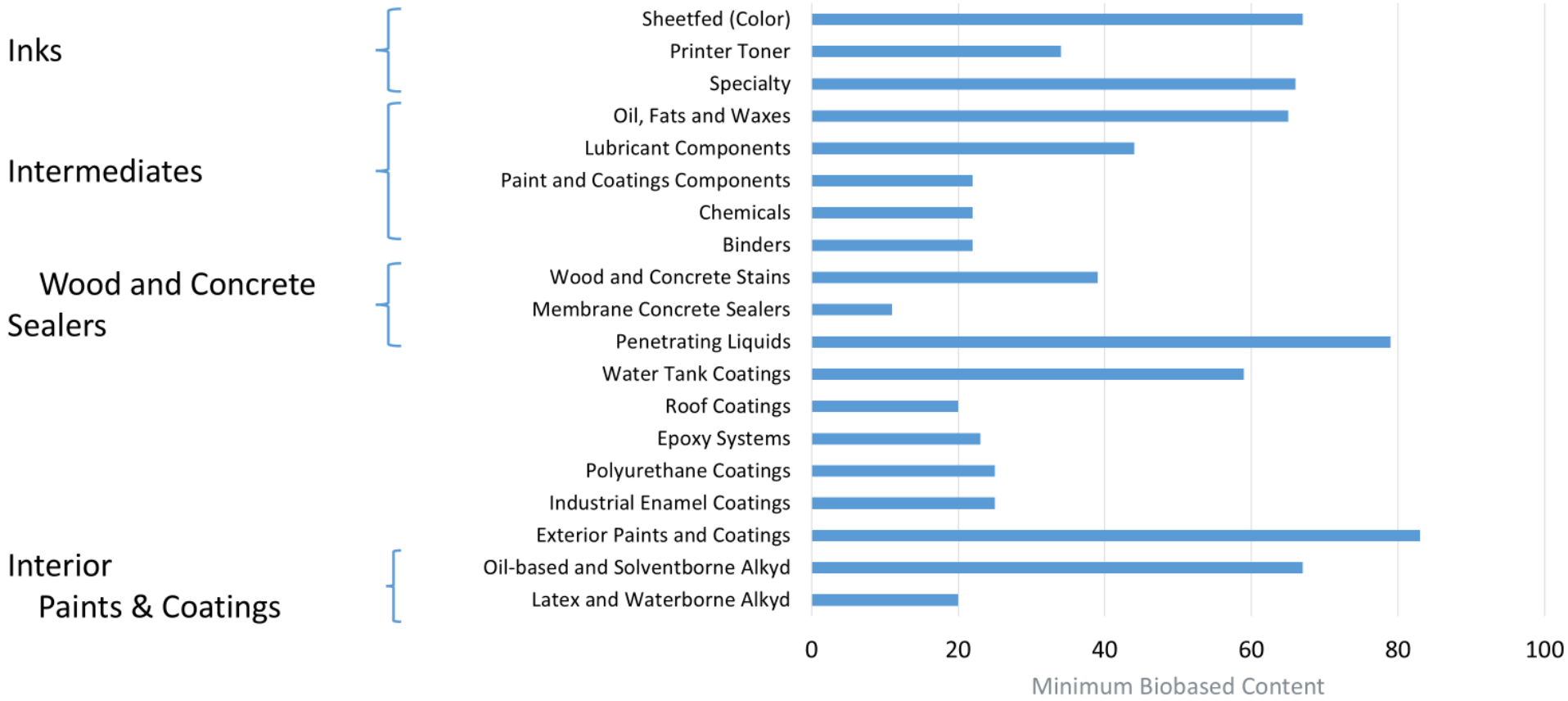
- Global sustainability
- Increasing regulations and specifications worldwide
  - Volatile Organic Compounds (VOCs)
    - EPA, SCAQMD (California), OTC etc.
  - Hazardous Air Pollutants (HAPs)
  - Interior air quality
    - LEED, Greenguard etc.
- Less dependence on petroleum based raw materials
- Green initiative programs

USDA BioPreferred Program

- "Managed by the U.S. Department of Agriculture (USDA), the goal of the BioPreferred Program is to increase the purchase and use of biobased products. The BioPreferred Program was created by the 2002 Farm Bill and reauthorized and expanded as part of the Agriculture Improvement Act of 2018 (2018 Farm Bill).
- The Program's purpose is to spur economic development, create new jobs and provide new markets for farm commodities. The increased development, purchase, and use of biobased products reduces our nation's reliance on petroleum, increases the use of renewable agricultural resources, and contributes to reducing adverse environmental and health impacts."

www.biopreferred.gov

BioPreferred Categories for the Coatings Industry



Major components of PUDs

Isocyanates

- Aromatic Isocyanates MDI & TDI
- Aliphatic Isocyanates HDI, H_{12}MDI, IPDI
- Ar-aliphatic Isocyanates TMXDI, XDI

Polyols

- Polyether Polyols
- Polyester Polyols
- Polyacrylate Polyols
- Polycarbonate Polyols

Solvents Amines

- NMP
- MEK
- Acetone
- TEA
- DMEA

Polyurethane

Appearance
- High Gloss
- Wet look

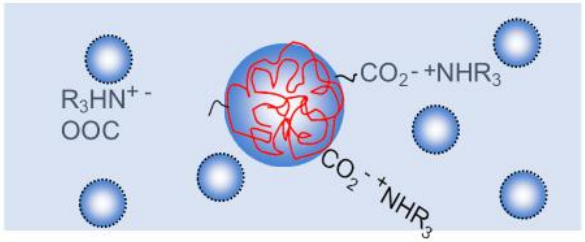
Weatherability
- Environmental etch
- Hydrolytic stability

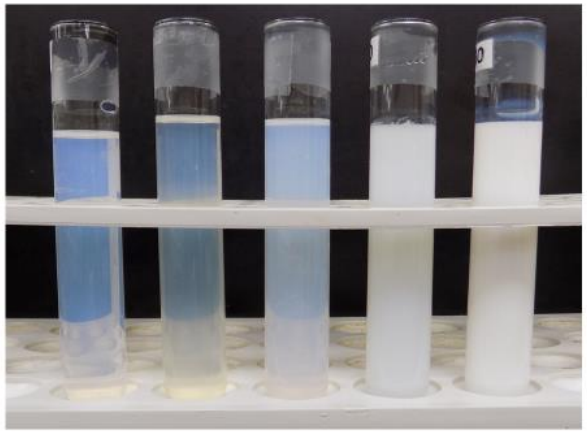
Resistance
- Abrasion
- Chemical
- Solvent

Mechanical
- Toughness
- Flexibility

Temperature
- Low and High Tg

Crosslinkable





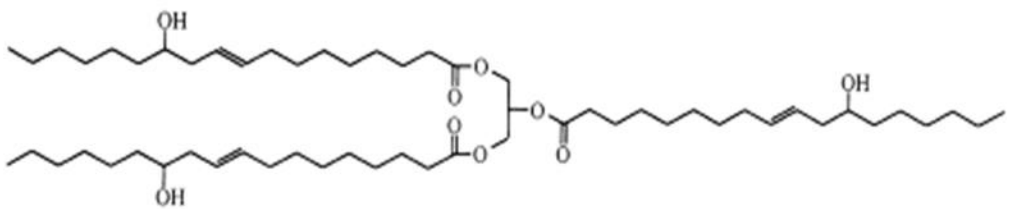
Research on Renewable PUDs

- Vegetable oils
  - Soybean
  - castor
  - linseed
- Biosuccinic acid
- Isosorbide
- Chitosan
- Lignin

(Remya, V.R. et al., "Biobased Materials for Polyurethane Dispersions", Chemistry) International 2(3), 2016

Castor oil based PUDs

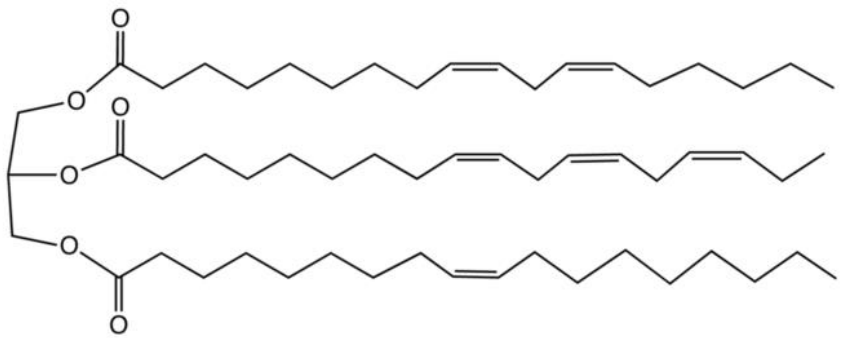
- Extracted from seeds of *Castor plant*
- Excellent gloss
- Outstanding wood warming properties
- Hydrophobic
- Non-drying oil



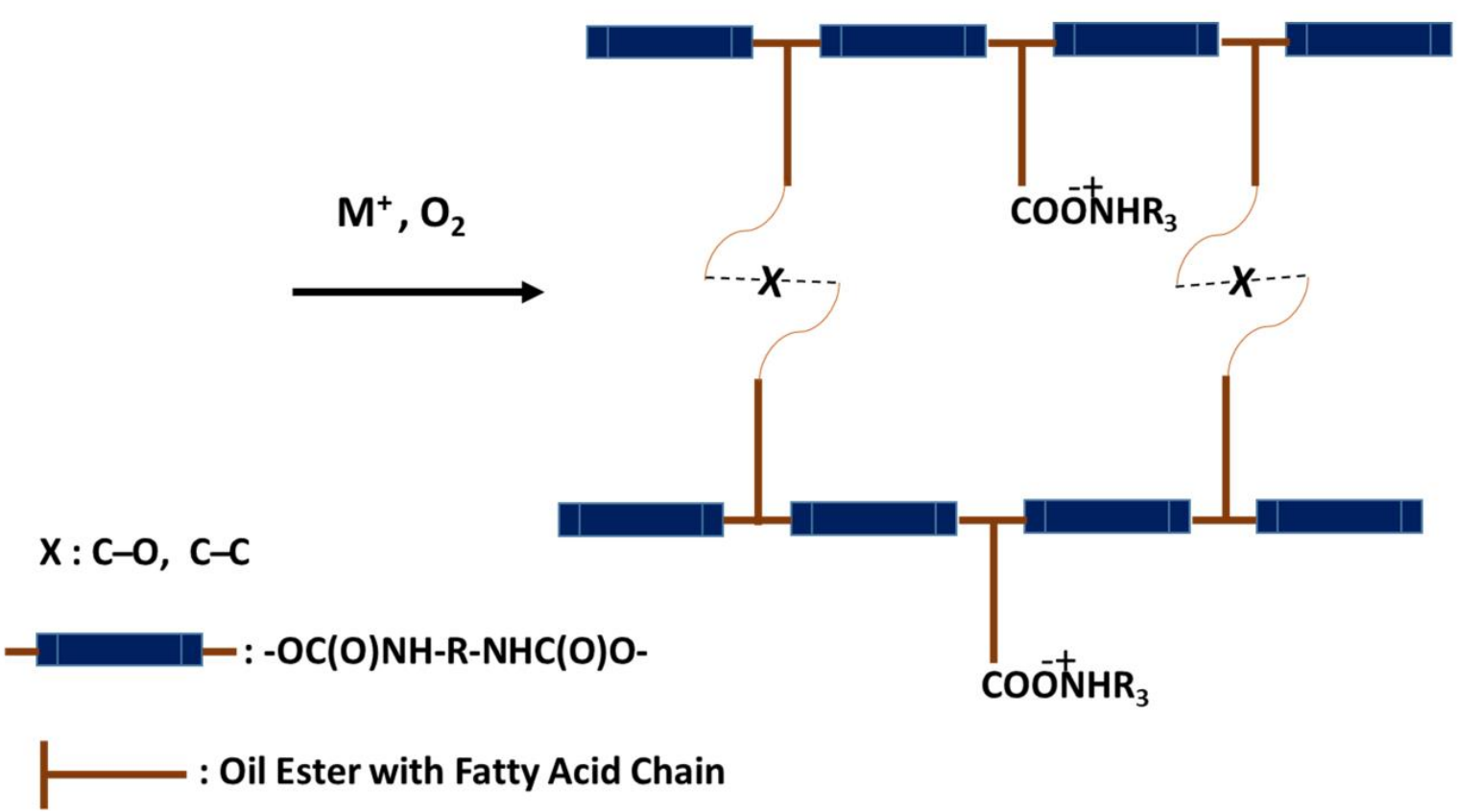
Ricinoleic acid triglyceride

Linseed oil based PUDs

- Derived from seeds of the flax plant
- Drying oil with good hardness
- Outstanding wood warming properties
- Alkyd-like flow



Oxidative cure of Linseed oil based PUDs



Renewable PUDs

	Solids [%]	Viscosity [mPas]	MFFT [°C]	Renewable content [% on solids]
LO - 1	100	500-1500	n/a	approx. 88
LO – 2	34-36	20-200	approx. 21	approx. 32
U - 1	34-36	20 – 200	approx. 0	approx. 21
AC - 1	42 - 46	500-4000	approx. 4	approx. 44

Woodcare Applications

Linseed oil based PUDs

- Non-PU containing finishes like Danish oil have long been used in the DIY market to enhance the wood appearance.
- These type of finishes bring out the natural beauty of wood but do not offer much surface protection.
- A 100% solids PU has been developed and formulated to offer an upgrade to traditional oil products.
- An evaluation has been conducted benchmarking product against competitor commercial products.

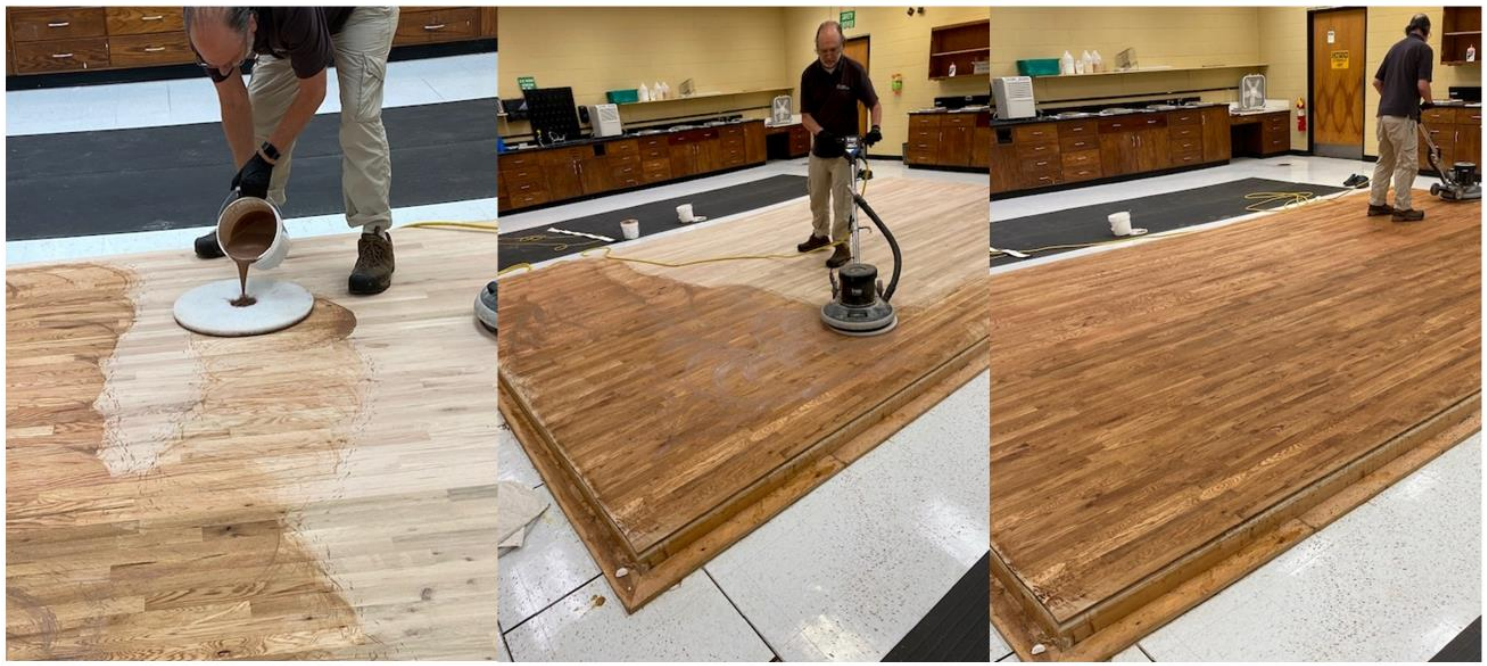
Starting Point Formula

Pos.	Raw Material	weight
1	LO-3	74.4
2	Refined linseed oil	18.6
3	Wax	5.0
4	Metal Drier	2.0
	Total	**100.0**

- Crosslinked with 100% solids, low VOC isocyanate
- Total VOC is 13 g/L

Color Development

Emulsion Application



- LO-1 can be emulsified for easier application
- The emulsion can be crosslinked with Isocyanate
- Easier cleanup with soap and water

Wood Flooring using Renewable PUDs

- Polyurethanes are the dominant choice for wood floors due to their flexibility, toughness and chemical resistance.
- Solvent (1K oil modified) and water-based (1 & 2K) materials are available in the market.
- Developmental PUDs have been evaluated according to the testing protocol of the Maple Flooring Manufactures Association (MFMA). Competitor commercial controls were benchmarked for comparison.

  Performance Criteria:
  - Black Heel Mark Resistance
  - Chemical Resistance
  - Taber Abrasion
  - Coefficient of Friction (CoF)

M F M A
Maple Flooring Manufacturers Association, Inc.
The Sports Flooring Authority

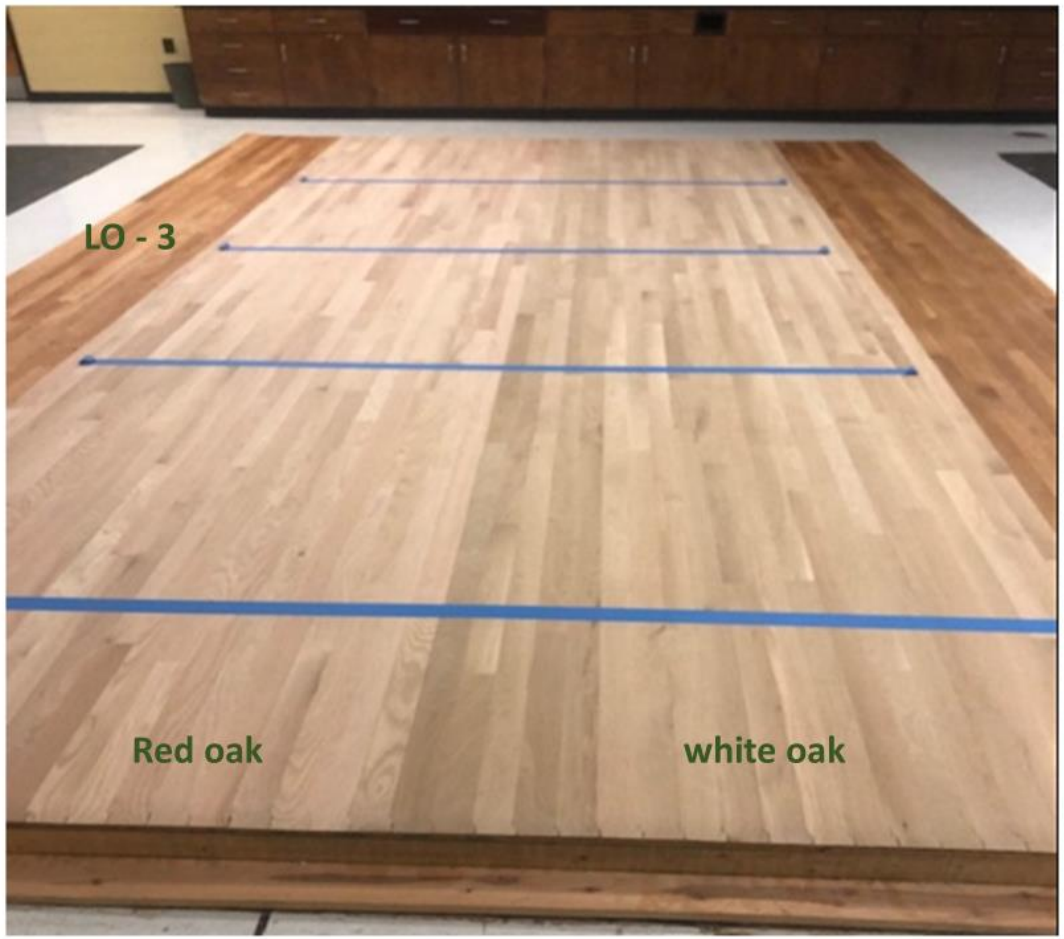
Appearance

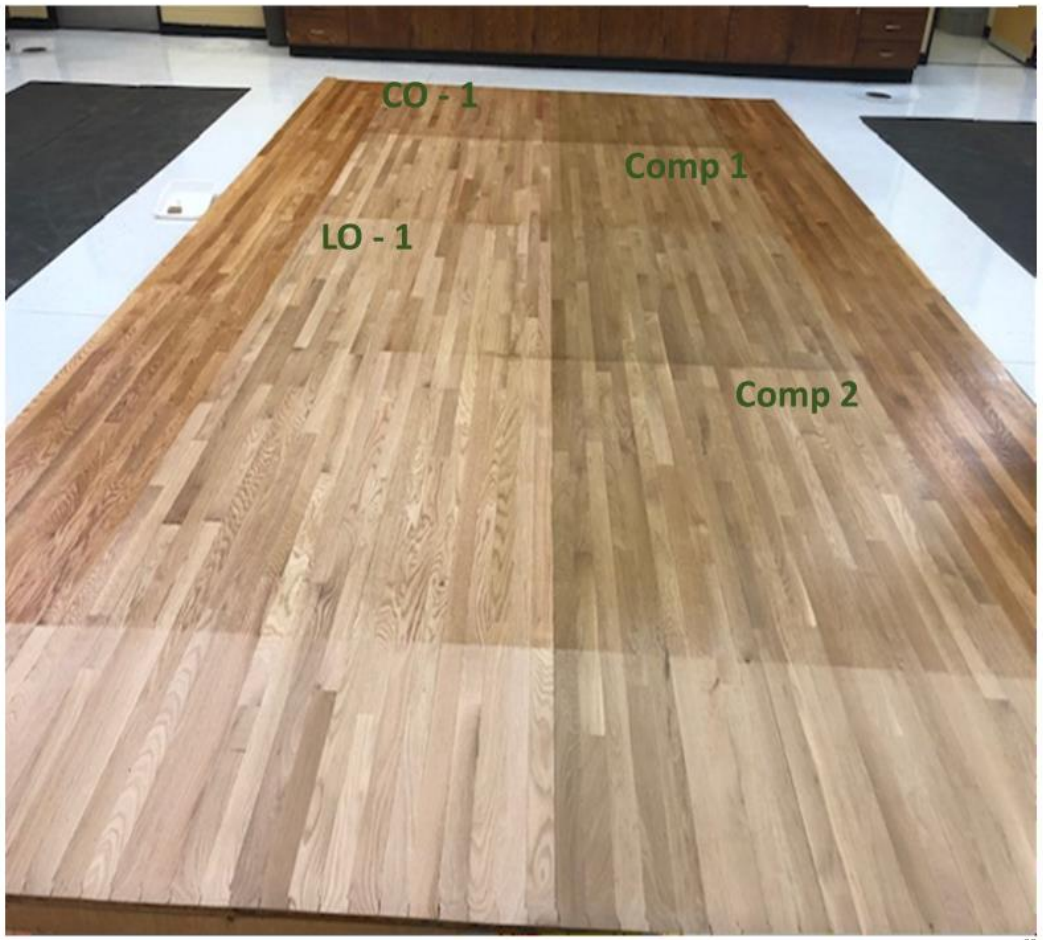
Starting Point Formula

Pos.	Raw Material	weight
1	**PUD**	**80.08**
2	Defoamer	0.10
3	Water	9.32
4	Solvent	5.00
5	Substrate Wetting Additive	0.50
6	Wax Dispersion	5.00
	Total	**100.00**

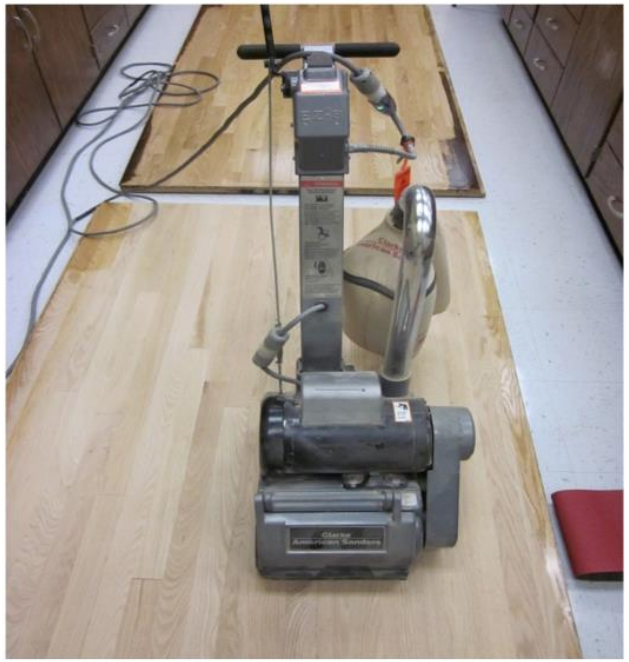
Wt/Gal (lb/gal):	8.64
VOC (lb/gal):	1.38
VOC (g/l):	165.00
% solids by weight:	30.00
% solids by volume:	27.00

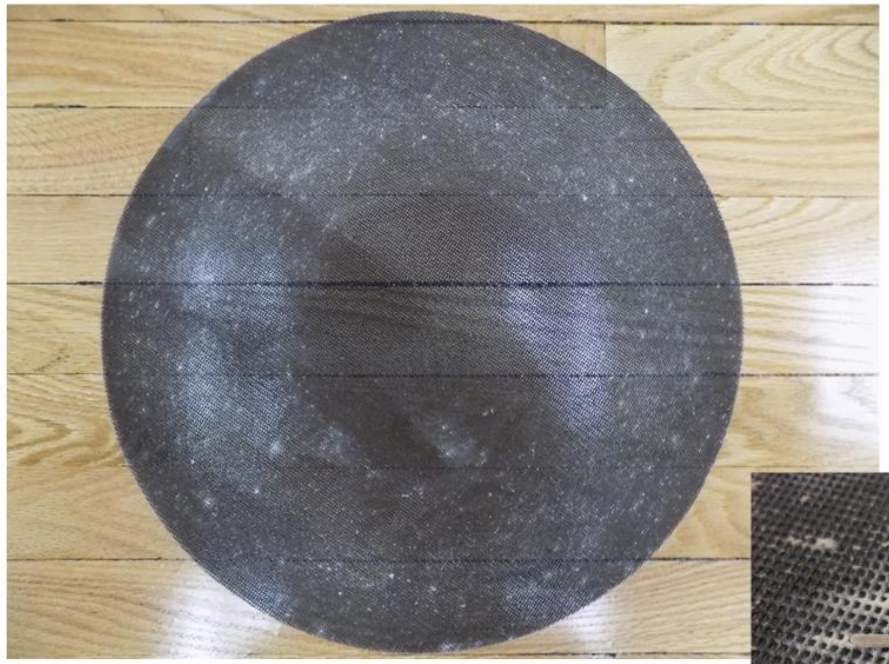
Renewable PUD application

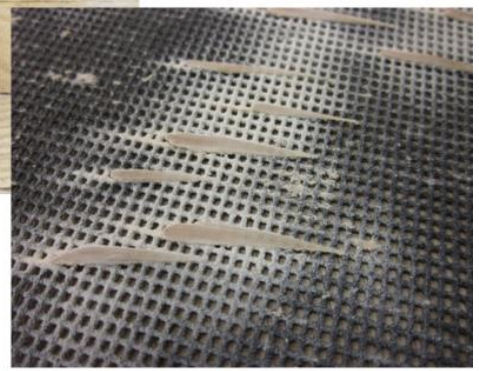




Sanding Performance

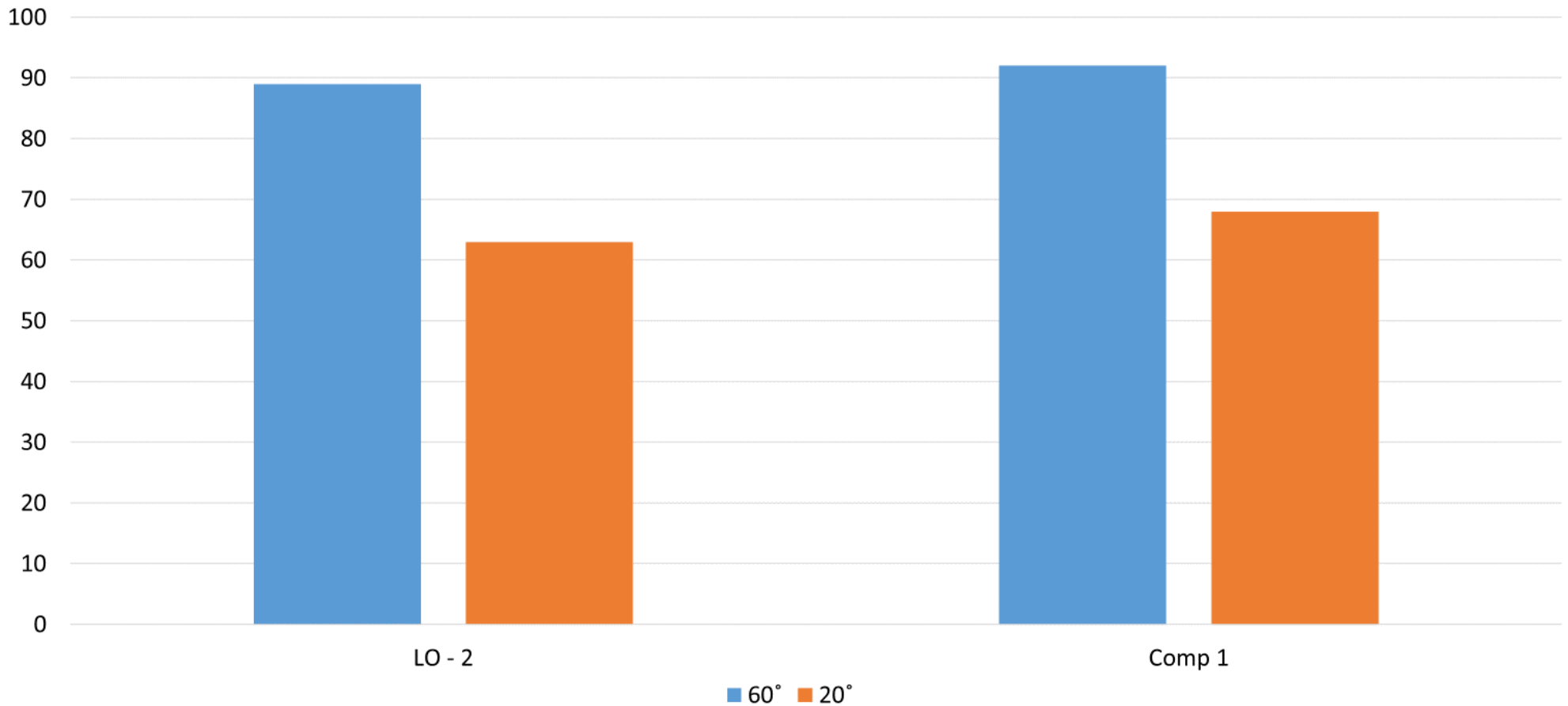




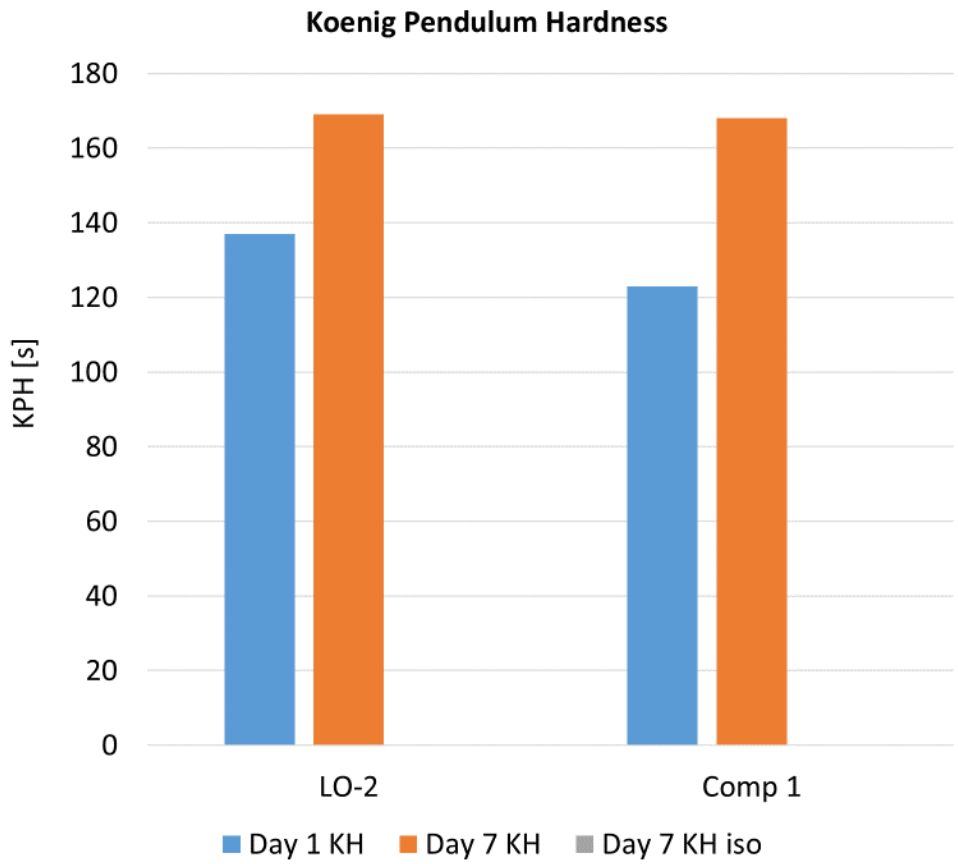


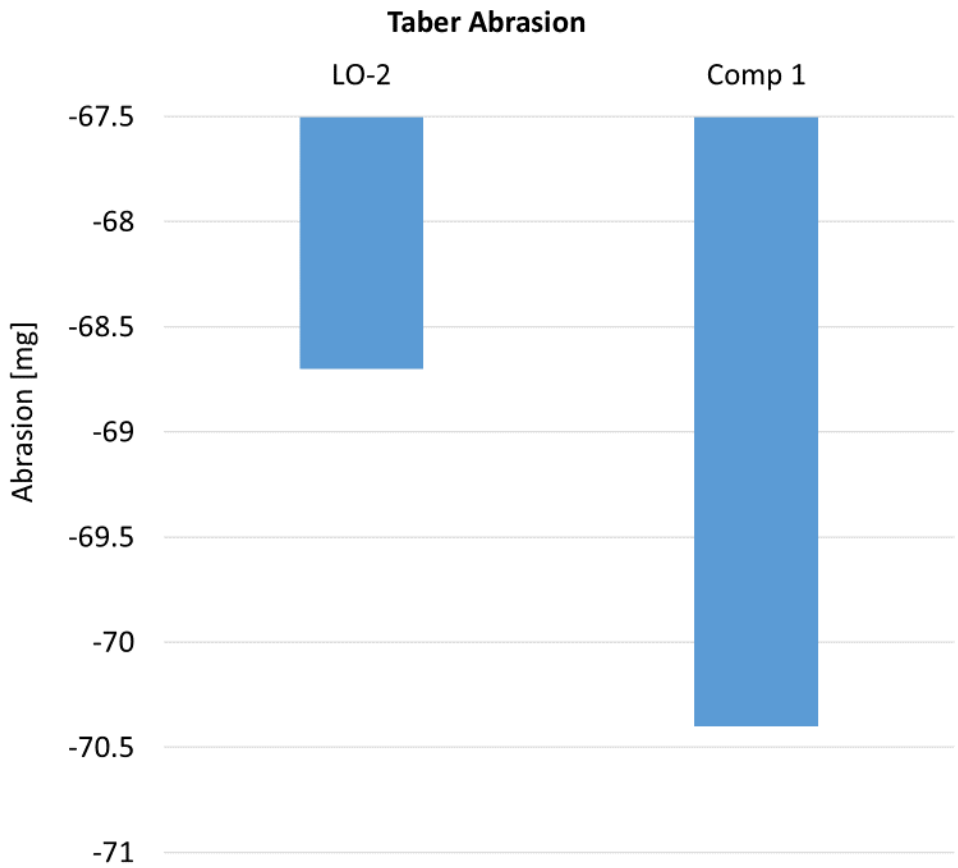
LO - 2 has very good sanding performance.

Gloss comparison



König hardness and Taber abrasion





Additional testing

Test Procedures	LO-2	Commercial Control 1
Coefficient of Friction	0.54	0.51
Stain Resistance	Pass	Pass
Scrape Adhesion (5kg)	Pass	Pass
Scratch Resistance (% Gloss loss)	29.8	22.1

Summary

- Unique linseed/castor oil PUDs have been developed and offer excellent performance on wood substrates, including flooring and decorative applications.
- These products are easy to formulate and perform similarly to competitor materials in the market.
- Linseed oil PUDs are more environmentally friendly compared to traditional solvent based OMUs, have less reliance on petroleum feedstocks and offer versatile performance for a broad range of markets.
- Further development continues expanding application to other substrates(masonry) using exterior grade linseed oil PUDs.

Features of U - 1

- Solvent Free
- Very easy mixing with crosslinkers
- Very good chemical and stain resistance
- High gloss
- Biobased content approx. 14% (on solids)

Technical Data – U - 1

Solids content [%]	34 – 36
Viscosity [mPas]	20 – 200
pH-value	7.5 – 8.5
MFFT [°C]	approx. 0
Koenig Hardness (s)	125
Polymer type	Polyester
VOC capability	< 50 g/L

Competitor
2K Waterborne Finish

PHYSICAL CHARACTERISTICS:

Ingredients - Water, polymeric resins, and amorphous silica.

Color – Milky white (wet)

pH – 7.9

Solids – 32% (with hardener)

Density – 8.70 lbs./gallon (1.04 S.G.)

US Regulatory VOC Compliant – 150 g/L (with hardener), 155 g/L Gloss (with hardener)

Coefficient of Friction - ≥ 0.5

Gloss Level – (60°): 7-10 for Commercial Extra Matte, 15-20 for Commercial Satin,
40-45 for Commercial Semi-Gloss, 65-70 for Commercial Gloss

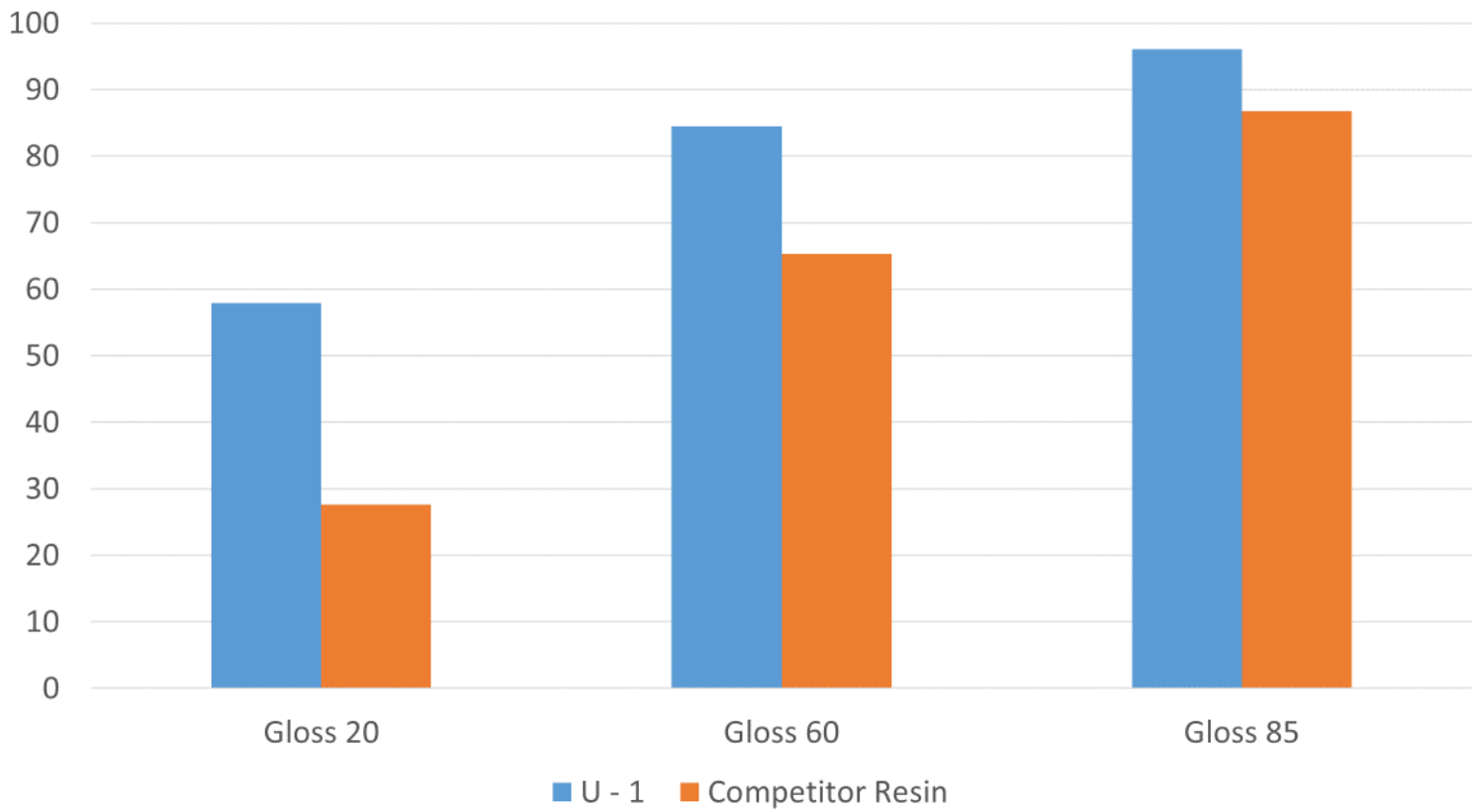
Odor – Very slight non-offensive odor

Formulas

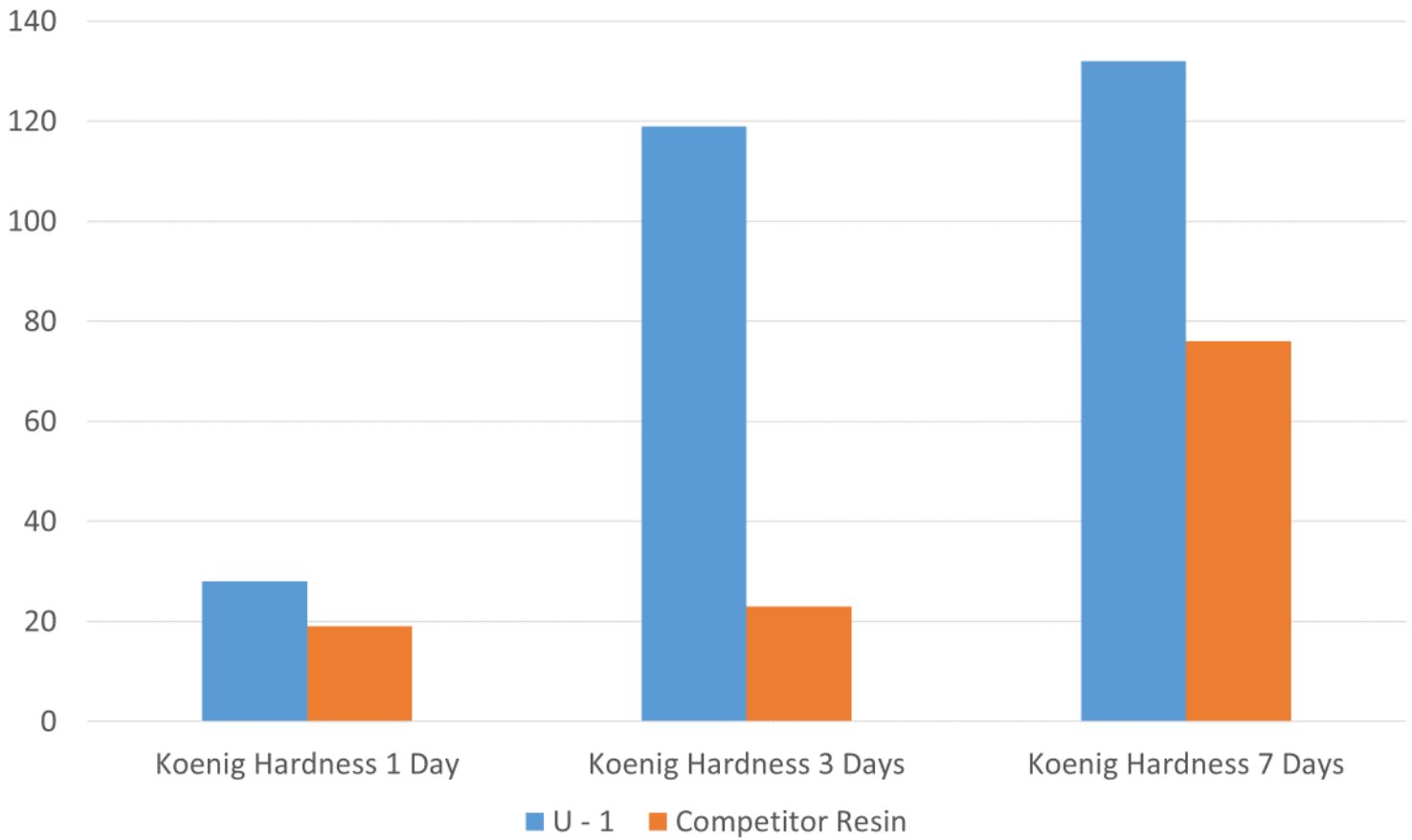
Ingredients	Competitor Resin	U 8500
U -1		**78.80**
Defoamer		1.20
Flow Additive		0.80
Water		18.90
Rheology Modifier		0.30
Water Dispersible NCO		10.00
Competitor Resin	100	
Competitor crosslinker	10	
Total	**110**	**110**

	% solids (mixed)	VOC (g/L)
U - 1	34.87	37.3
Competitor resin	32	155

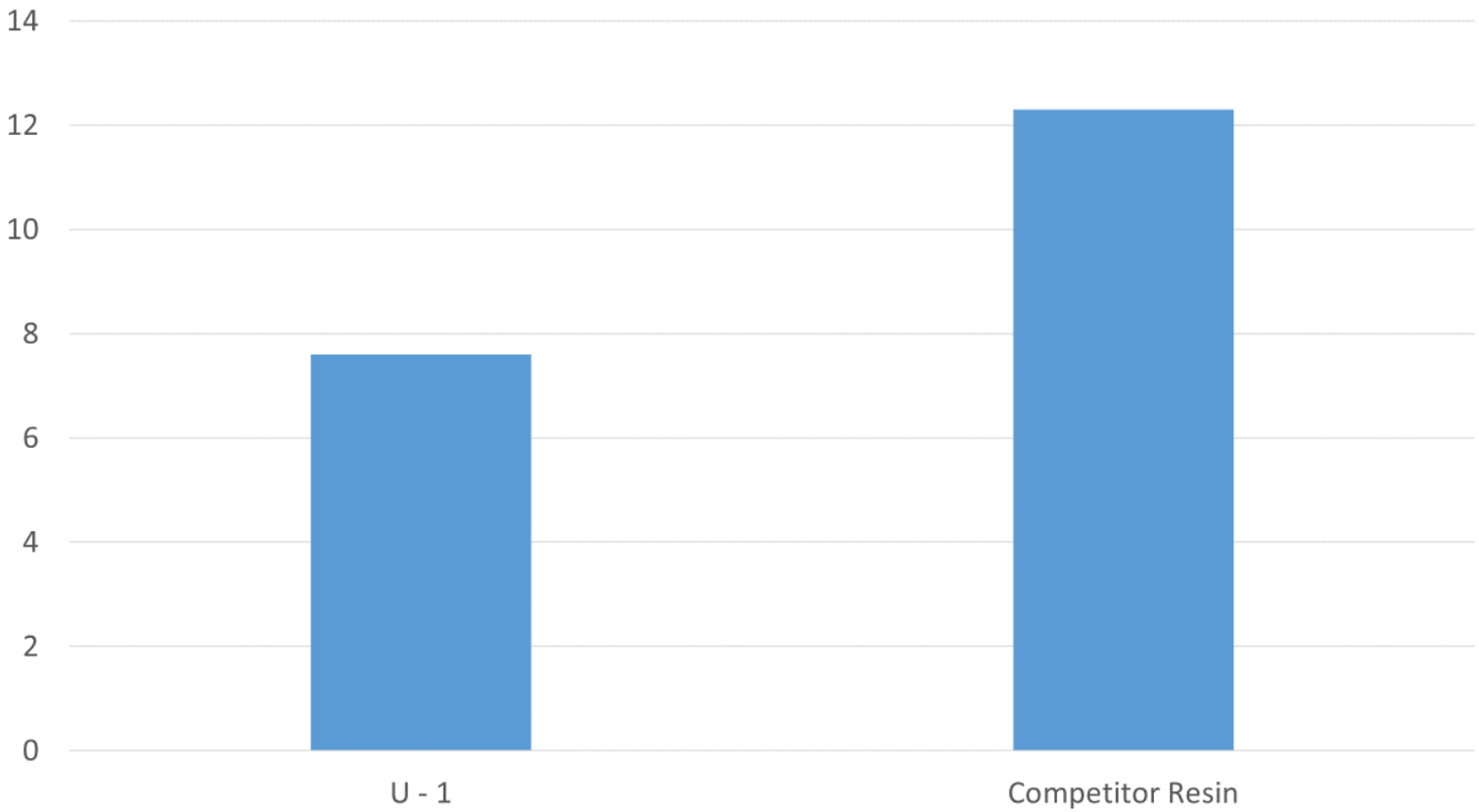
Gloss


100
90
80
70
60
50
40
30
20
10
0
Gloss 20
Gloss 60
Gloss 85
U - 1
Competitor Resin

Koenig Hardness (s) @ 1/3/7 Days



Taber Loss mg



Other Physical Properties

- Black Heel Mark Resistance – Both Excellent
- Fingernail Mar Resistance – Both Excellent
- Coefficient of Friction – U - 1 0.50
  Comp Resin 0.42

Chemical Resistance

	U - 1	Competitor Resin
DI Water	Pass	Pass
100 Proof Ethanol	Pass	Pass
Cleaning Solution	Pass	Pass
Olive Oil	Pass	Pass
VM&P Naphtha	Pass	Pass
Beer Cola	Pass	Pass

U - 1 combined with an inherently dull PUD offers an unseeable finish with:

- Ultra low gloss (20°/60°/85°): 0.3/3.5/18.0
- Can be used with any sealer or self-sealing
- Suitable for residential and high traffic

Conclusion

U - 1 offers a “Best” 2K wood floor finish

- Higher gloss
- Higher hardness
- Improved Taber wear resistance
- Excellent chemical resistance

Project Scope:

U-1 was evaluated against hydroxy functional acrylics, also competitive / commercial products for use on concrete floors.

Properties Evaluated

Gloss

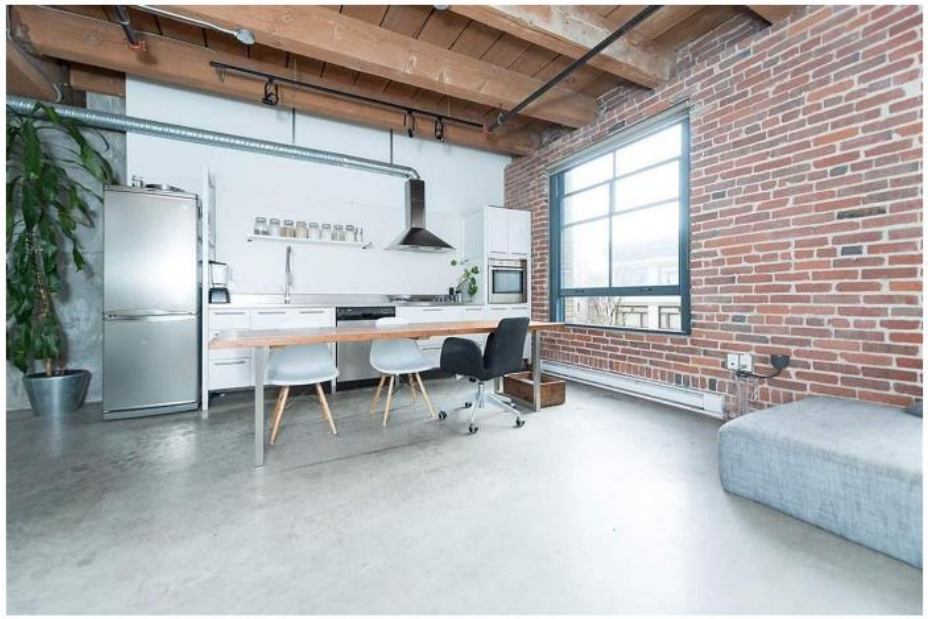
Surface Hardness

Chemical Resistance

Hot Tire Pickup Resistance

Wear Resistance

Thermal Shock



Features of AC - 1

- For wood floor lacquers and DIY furniture coatings
- Very good chemical resistance
- Low MFFT
- Easily sandable
- Biobased content approx. 42% (on solids)

Technical Data – AC - 1

Solids content [%]	42 - 44
Viscosity [mPas]	500 - 4000
pH-value	7.0 – 8.0
MFFT [°C]	approx. 4

Technical Data – AC - 2

Solids content [%]	37 - 39
Viscosity [mPas]	10 - 2000
pH-value	7.5 – 8.5
Hydroxy Eq. Wt.	944

	U - 1	U – 1 + AC - 1	AC - 2	Competitor Resin
U - 1	78.8	55.16		
AC - 1		23.64		
AC – 2			70.01	
Defoamer	1.2	0.84	0.5	
Flow Additive	0.8	0.42	0.3	
Water	18.9	16.9	28.89	
Rheology Modifier	0.3	0.26	0.3	
Water Dispersable NCO	10	10	25.5	
Competitive Resin				100
Competitive NCO				10
Total	110	111.38	125.5	110
% Solids	34.87	34.87	41.82	32
VOC g/l	37.3	37.3	5.25	155

	U – 1	U-1 + AC – 1	AC - 2	Competitor Resin
VOC g/l	37.3	37.3	5.25	155
Percent Bio in Resin	14.1	28.9	n/a	n/a
Gloss 20/60/85	57.9/84.5/96.1	69.5/86.3/98.4	64.3/83.5/96.2	27.6/65.3/86.8
Gloss Loss %	30.4	27.7	18.9	20.4
Hardness Koenig 1/3/7 Days	28/119/132	60/82/82	20/48/176	19/23/76
Taber Loss mg	7.6	74.6	24.1	12.3
CoF	0.5	0.5	0.48	0.42
MEK 2X Rubs	200	175	200	50
Fingernail Mar	5	5	5	5
BHMR	5	5	5	5
Early Water Resistance	5	5	5	5

	U - 1	U -1 + AC - 1	AC - 2	Competitor Resin
10% Acidic Acid	5	5	5	5
50% NaOH	5	5	5	5
Betadine	2	3	2	2
Brake Fluid	5	5	5	5
ECO-Lab Wash N Walk	5	4	5	5
Stainless Steel Cleaner	5	5	5	5
15% Paracetic Acid	5	5	4	5
95% Ethanol	5	5	0	5
10% Glycolic Acid	5	5	5	5
20% HCL	5	4	5	5
35% H2O2	4	5	5	4
IPA	5	5	5	5
10% Lactic Acid	5	5	5	5
Red Wine	5	4	5	5
Skydrol	3	4	5	4
Spor Klenz RTU	5	5	5	5
DI Water	5	5	5	5
Mustard	3	3	3	3
Olive Oil	5	5	5	5
Pickle Juice	5	5	5	5
Ketchup	5	5	5	5
Hand Fat	5	3	5	5
Chlorox Pro	5	5	5	5
Total	112	103	104	113

Conclusion

U - 1 offers:

- Lower NCO demand compared to the OH functional acrylics (perhaps offering lower total formula cost to you or your).
- Very good physical properties including incredibly low taber wear resistance (7.6 mg).
- Can be blended with renewable acrylics for higher renewable content.
- Best overall chemical resistance.

Thank You

Questions?