Bio-hybrid Epoxy Diluent - Alternative to Nonylphenol

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Coatings Trends & Technologies SUMMIT

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02 Nonylphenol Functionality in Epoxy Coating

03 • Nonylphenol Environmental Effects

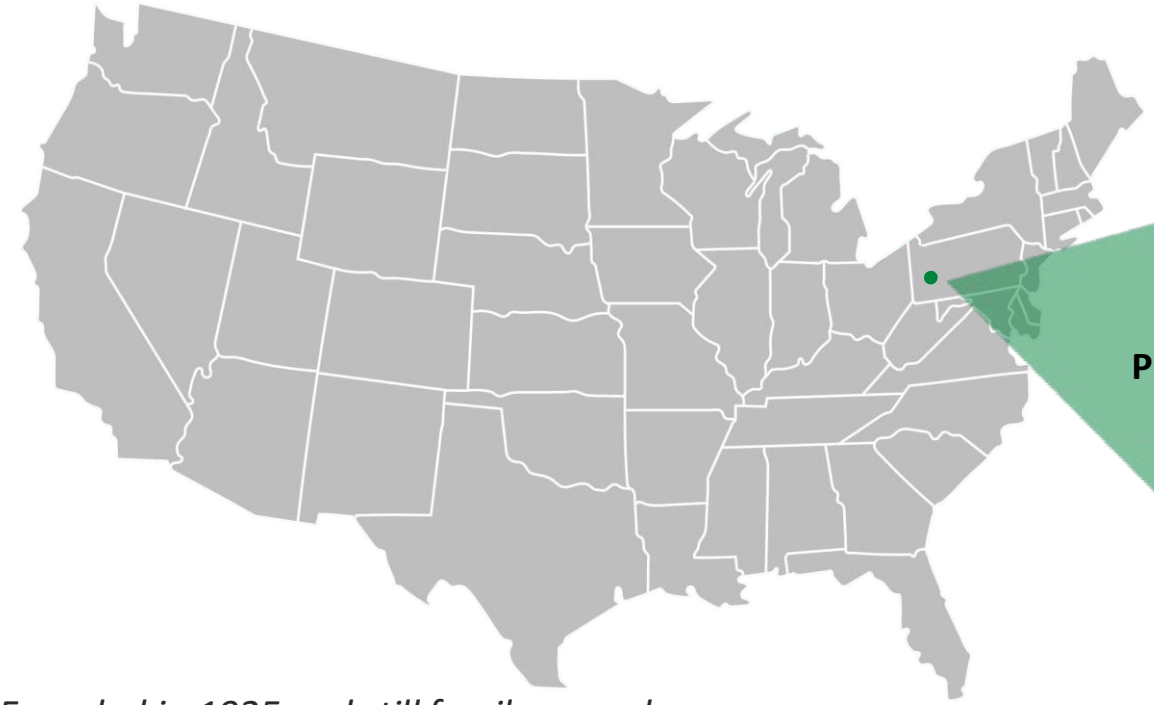
04 • Novel Biohybrid Resin Properties

05 • Key Performance: Accelerator & Viscosity Stability

06 • Epoxy Film Performance: Nonylphenol vs Novel Resin

07 • Novel Resin Capabilities Conclusion

Neville Chemical Company Introduction



Pittsburgh, PA

- *Founded in 1925 and still family owned*
- *Global Manufacturing Footprint*
- *The only C9 Resin producer in North America*
- *Major producer of Thermal Polymerized Resins*
- *Major producer of substituted phenol resins*
- *Strategically positioned to ship FTL, TW, Rail & Barge*

Neville Chemical Company Introduction- Coatings and More

Coatings

- Marine coatings
- Industrial and maintenance
- Wood care and stains

Adhesives

- Packaging
- Tapes and labels
- Woodworking and joinery

Construction

- Construction Adhesives
- Asphalt modification
- Concrete Cure & Sealants

Rubber

- Natural and synthetic rubber
- Belts and hoses
- Industrial products
- Rubber compounding

Ink

- Coldset inks
- Dispersion vehicles
- Flushing vehicles
- Metallic inks

Custom Solutions

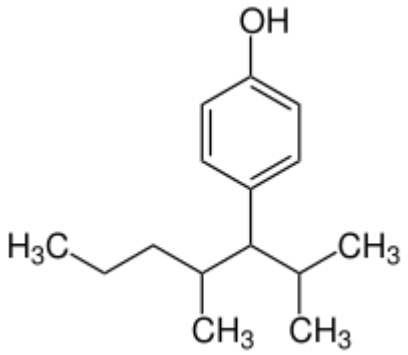
- R&D Support
- Lab > Pilot > Production

Resin Family to Promote Sustainability in the Coatings Industry

Properties	Novel Resin	Neville Biohybrid Resin for Coatings #2	Neville Biohybrid Resin for Coatings #3
Purpose	**Replacement to Nonylphenol**	Epoxy film performance enhancement	Plasticizer and pot life extender
Gardner Color (Straight)	**3**	3	1
Appearance			
Brookfield Viscosity@ 25°C (cps)	**500**	100	50
Hydroxyl Number	**190**	104	34
Non-Volatile, Wt.%	**85%**	90%	75%

Significance of Nonylphenol in Epoxy Coatings

- Accelerator
  - Reduces cure time
- Plasticizer
  - Improves mechanical properties:
    - Flexibility
    - Adhesive strength
    - Elongation
    - Film appearance
- Light Color
- Workable Viscosity



Para-Nonylphenol

Nonylphenol Environmental Effects

Regulatory Constraints

- European Union banned use and production of nonylphenol
- Nonylphenol is strictly monitored in Canada and Japan for harmful effects
- Increased attention in the U.S.
  - EPA proposed a Significant New Use Rule (SNUR) under the Toxic Substances Control Act
    - Applies to 15 nonylphenols and nonylphenol ethoxylates

Environmental Impact of Nonylphenol

- Persistent in aquatic environment
  - Highly toxic to aquatic organisms
- Bioaccumulative
  - Weeks/months for nonylphenol to breakdown in the environment
- Endocrine Disruptor and Xenoestrogen
  - Interferes with hormonal system of numerous organisms
  - Reproductive toxin

Novel Resin Replacement Capabilities

- Accelerator
  - Reduces cure time by 25%
- Film Properties
  - Adhesion
  - Flexibility
  - Chemical resistance
  - Hardness
- Light Color
- Workable Viscosity
- Lowers VOCs of formulation

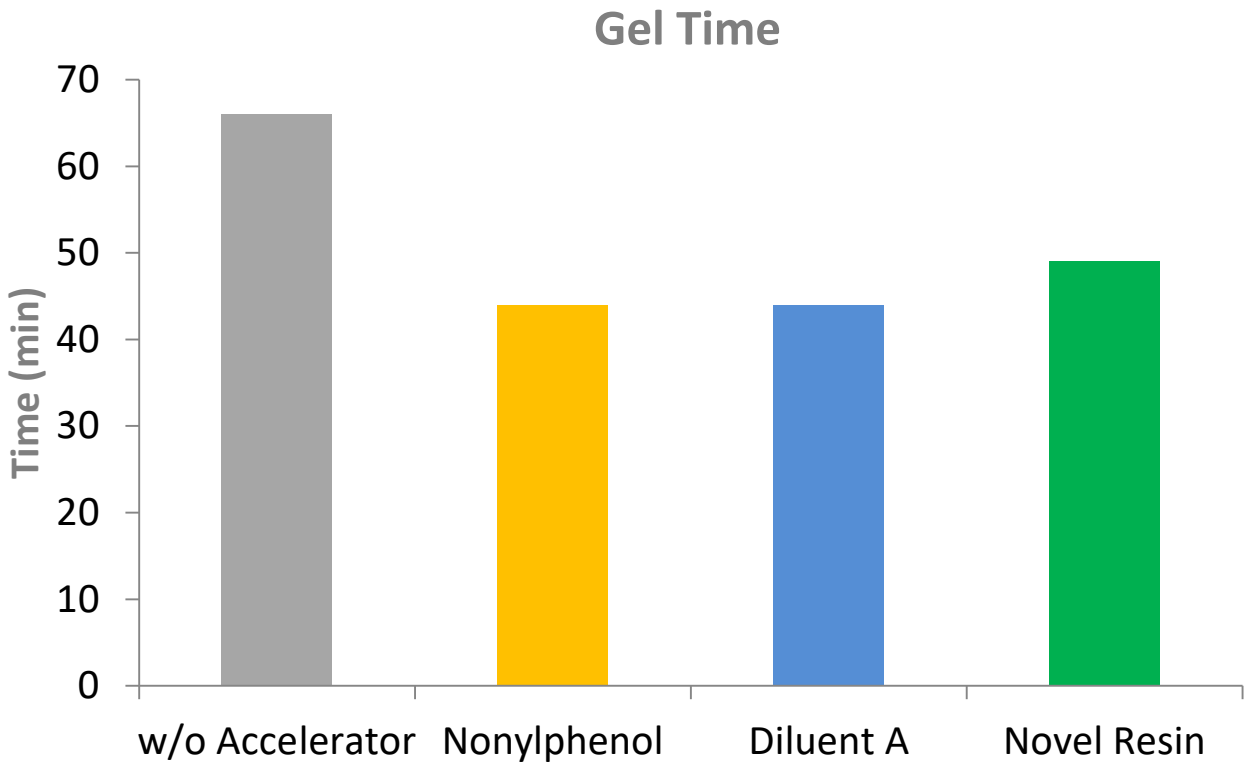
Resins of Interest- Experimental Study

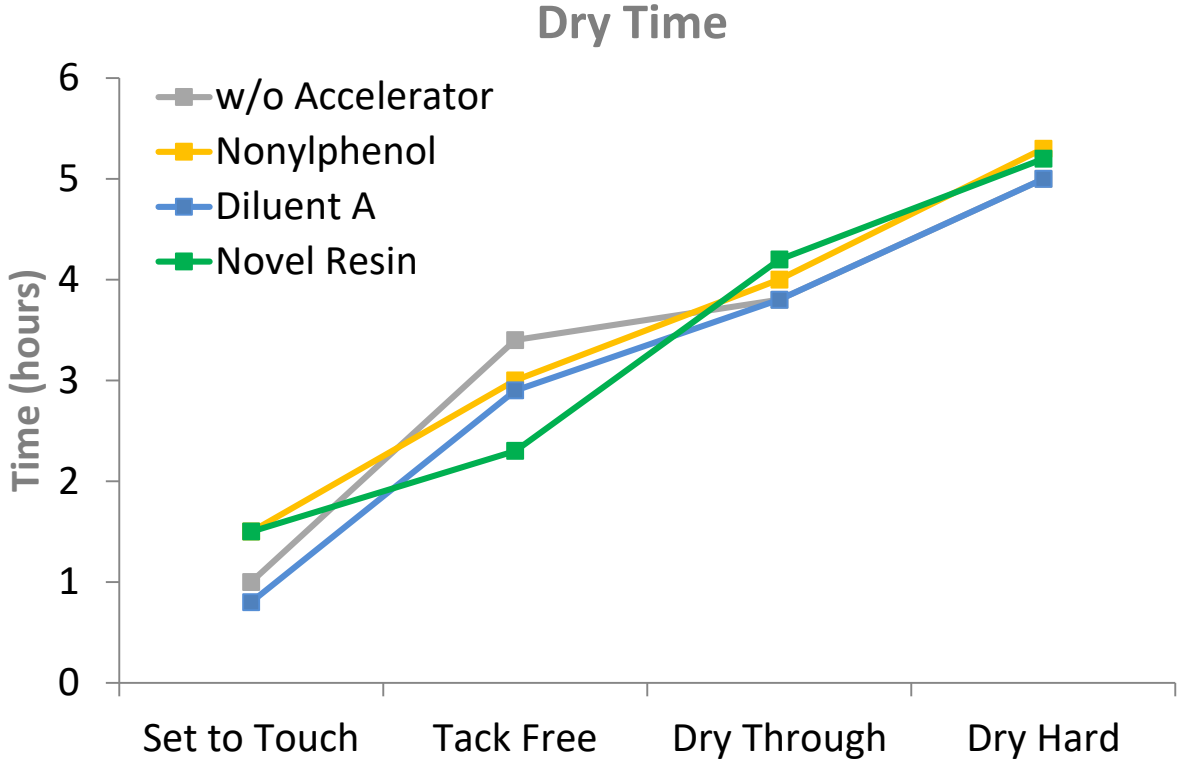
Properties	Test Method	Nonylphenol	Diluent A (market alternative)	Novel Resin
Gardner Color (Straight)	ASTM D1544	1	3	**3**
Appearance	Visual	Clear liquid	Pale yellow liquid	Pale yellow liquid
Brookfield Viscosity@ 25°C (cps)	ASTM 2196	1200	800	**500**
Hydroxyl Number	ASTM D1957	225	230	**190**
Non-Volatile, Wt.%	ASTM D2369	46%	75%	**85%**

Experimental Study

- 2k Epoxy Resin
  - BPA/epichlorohydrin based epoxy (Epon 828 & Epon 1001-X-75) with polyamide hardener (Epicure 3125)
- 2K Epoxy Control (with 0% resin) compared to 2K Epoxy with 5% Nonylphenol, 5% Diluent A, and 5% Novel Resin
  - Gel time, dry time, and 6 film performance tests.
- Resins also evaluated by their viscosity stability with three different amines

Key Performance Metric #1- Accelerator



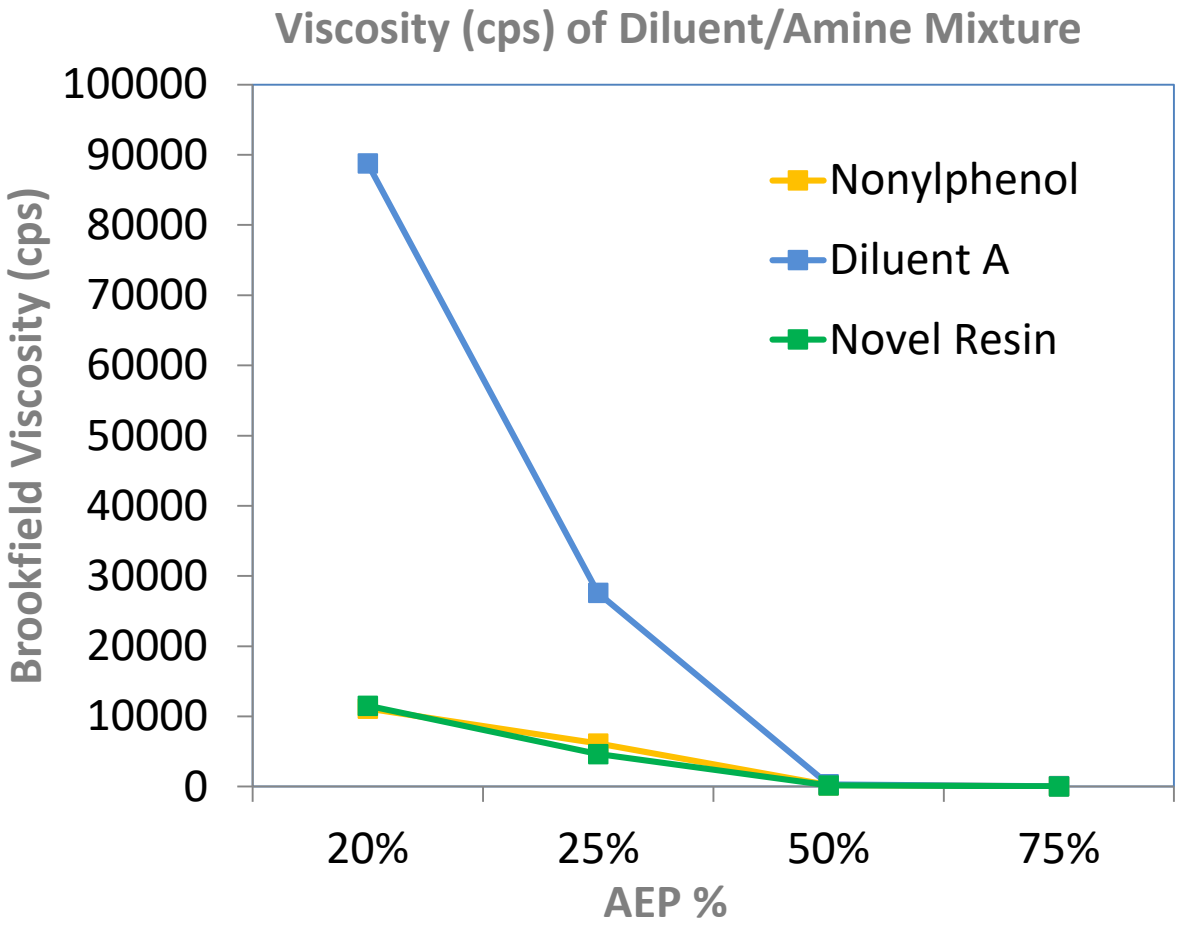


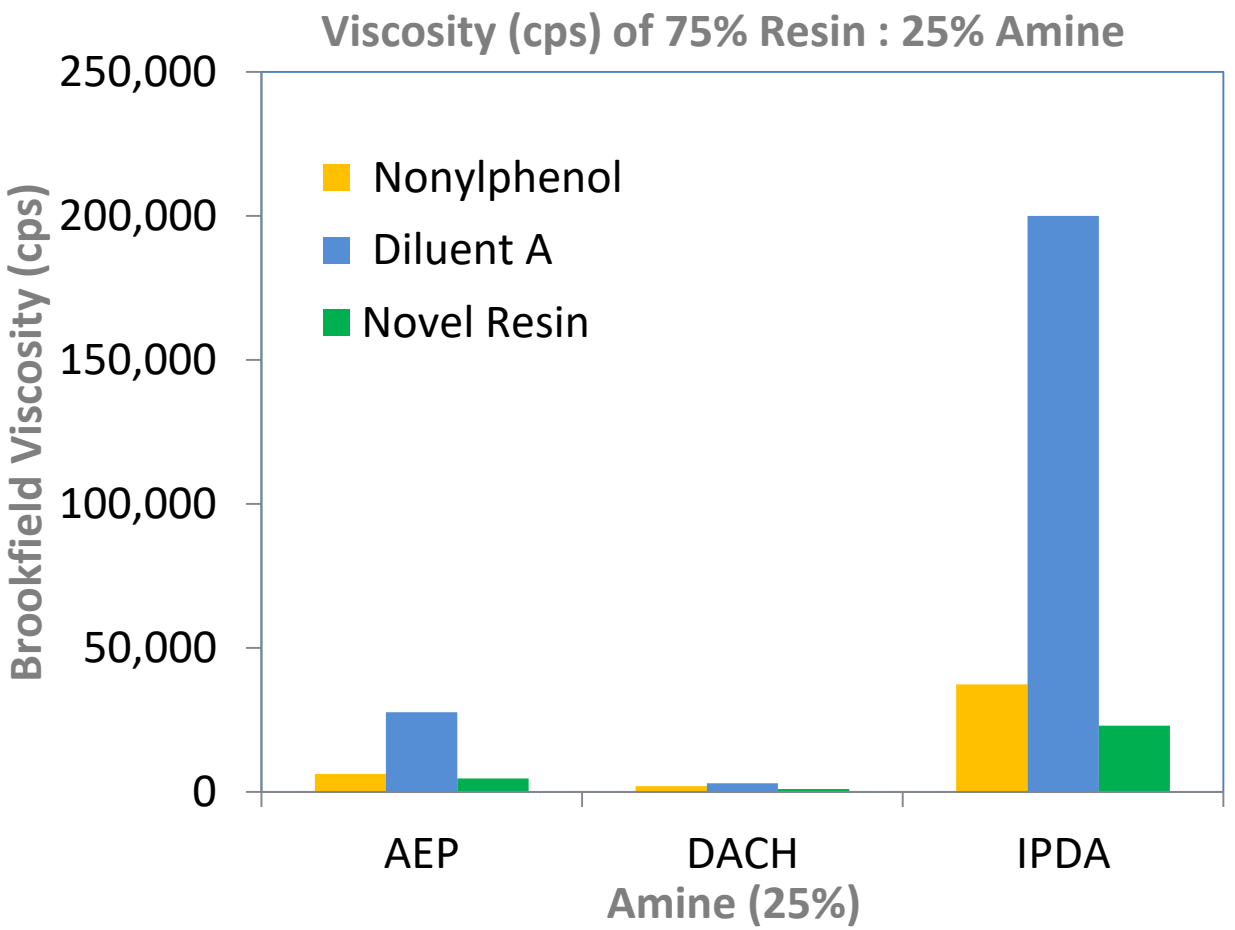
- Novel resin accelerates the cure time of the epoxy resin by 25%
  - This is incredibly close to nonylphenol's acceleration capabilities
- Tested via Shyodu Standard Gel Timer
- 2k Epoxy Resin (with 0% or 5% Resin)
  - BPA/epichlorohydrin based epoxy with polyamide hardener

- Novel resins maintains a dry time very similar to that of nonylphenol
- Tested via BYK Drying Time Recorder, ASTM D5895
  - 5% Resin in 2K Epoxy System

Key Performance Metric #2- Viscosity Stability

- AEP (Aminoethylpiperazine)
- DACH (1,2-Diaminocyclohexane)
- IPDA (Isophorone diamine)





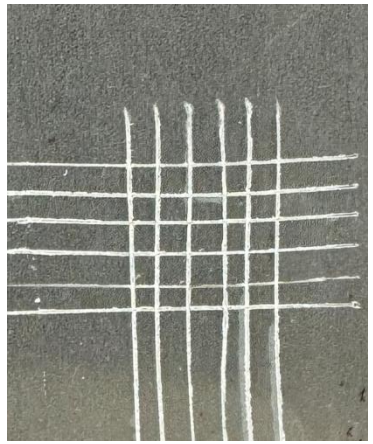
- The Novel Resin showed incredible viscosity stability with varying concentrations of AEP
- The Novel Resin showed persistent viscosity stability with three different amines tested (AEP, DACH, and IPDA)

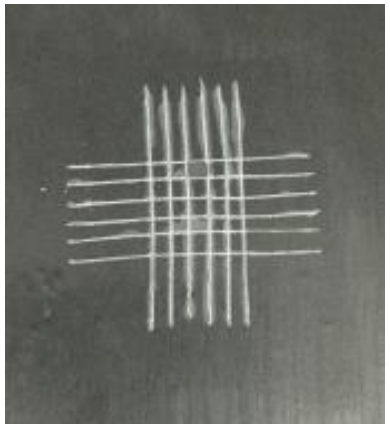
Epoxy Film Performance- Adhesion

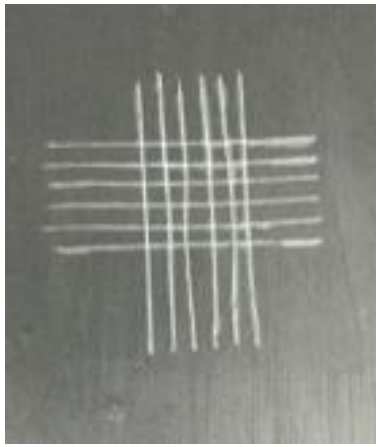
Test Result	Control	Nonylphenol	Diluent A	Novel Resin
Percent Area Removed	2%	48%	16%	4%
Adhesion Rating	4B	1B	2B	4B

<u>Test Conditions</u>

- Epoxy film cured for 7 days
  - 2K Epoxy Resin (5% Resin except Control)
  - BPA/epichlorohydrin based epoxy with polyamide hardener
  - 3mil film on cold rolled steel
- Crosshatch Adhesion Test
  - ASTM D3359
  - 5B is the highest rating, 0B is the lowest (>65% film loss)







<u>Conclusion</u>

Novel Resin promotes improved adhesion to steel substrate

Epoxy Film Performance- Flexibility

Test Conditions

- Mandrel Bend Test
  - ASTM D522
  - To measure elongation, the bend time is 15s. To determine crack resistance, the bend time is 1s.
- Epoxy film cured for 7 days
  - 3mil film thickness
- Resin dosage is 5%
- Substrate is cold rolled steel

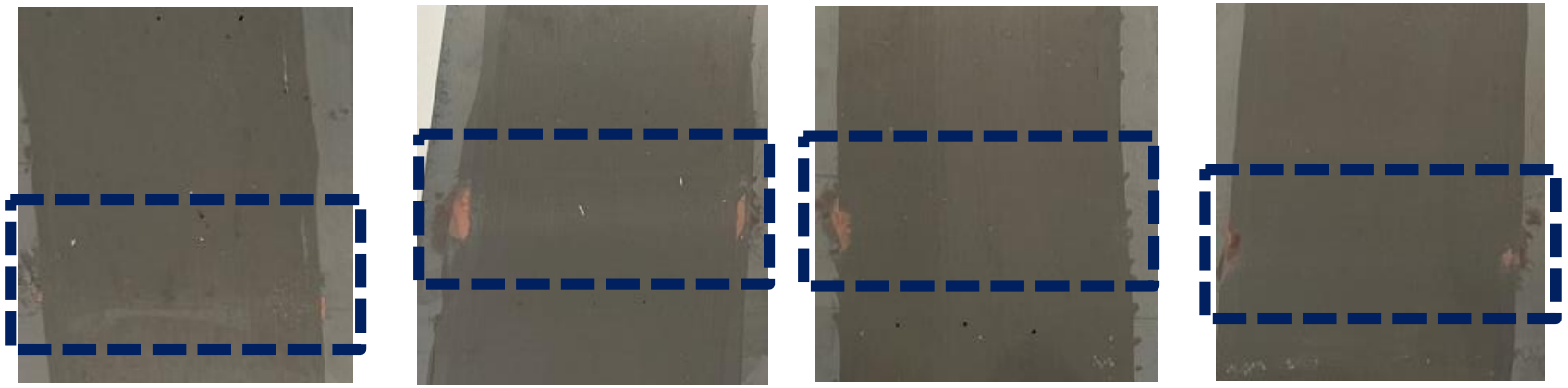
Conclusion

- **Novel Resin** has equal elongation effects, but superior crack resistance to nonylphenol in the cured epoxy film

Test Result	Control	Nonylphenol	Diluent A	Novel Resin
Elongation (slow bend)	Pass 	Pass 	Pass 	Pass 
Crack Resistance (fast bend)	Pass 	Fail: 5” delamination & film fracture 	Fail: 3.5”delamination & film fracture 	Pass 

Epoxy Film Performance- Chemical Resistance (MEK)

Test Results	Control	Nonylphenol	Diluent A	Novel Resin
Rating after 100 MEK double rubs	Pass	Pass	Pass	Pass



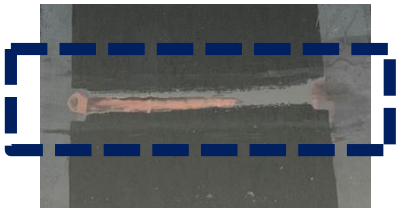
Test Conditions

- MEK Chemical Resistance
  - ASTM D5402
  - Pass: no film penetration after 100 double rubs
  - Copper sulfate is used to determine penetration
  - Edge breakthrough is due to edge thinner film
- Epoxy film cured for 7 days
  - 3mil film thickness
- Resin dosage is 5%
- Substrate is cold rolled steel

Conclusion

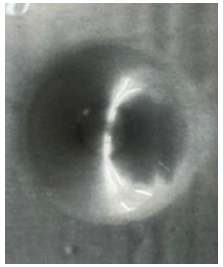
Novel Resin has equal MEK chemical resistance capabilities to nonylphenol and control

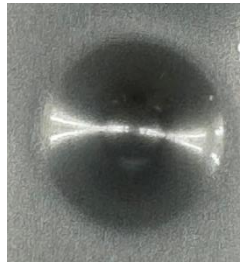
Example of Failure (film penetration)

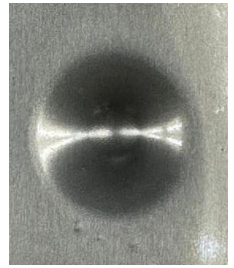


Epoxy Film Performance- Impact Resistance and Hardness

Test Results	Control	Nonylphenol	Diluent A	Novel Resin
Impact Resistance	>96 in-lbs	>96 in-lbs	>96 in-lbs	>96 in-lbs
Pencil Hardness	H	H	H	H







Test Conditions

- Gardner Impact Resistance
  - ASTM D2794
  - >96 in-lbs is the highest rating with equipment used
- Pencil Hardness
  - ASTM D3663
  - Rating from 6B (softest) to 6H (hardest)
- Epoxy film cured for 7 days
  - 3mil film thickness
- Resin dosage is 5%
- Substrate is cold rolled steel

Conclusion

Novel Resin elicited equal impact resistance and film hardness in epoxy compared to nonylphenol and control

Conclusion: Resin Performance Evaluation

Film Performance Metric	Control	Nonylphenol	Diluent A	Novel Resin
Gel Time	66 min	↑	↑	↑
Dry Through Time	4 hours	✓	✓	✓
Viscosity Stability	N/A	✓	↓	✓
Adhesion to substrate	4B	↓	↓	✓
Elongation	Pass	✓	✓	✓
Crack Resistance	Pass	↓	↓	✓
MEK Chemical Resistance	100+	✓	✓	✓
Impact Resistance	>96 in-lbs	✓	✓	✓
Pencil Hardness	H	✓	✓	✓

↑ Improved Performance ✓ Equivalent Performance ↓ Decreased Performance

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Thank you!

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