The Evolution of WB Epoxy Technology- "We've Come A Long Way"

April 10, 2017

Outline

- Introduction
  - Epoxy Coatings
    - Solvent-borne Epoxy Coating Systems
    - Current VOC trend
  - Waterborne Epoxy Systems
    - Benchmark System
    - Next Generation Epoxy System
      - Epoxy Resin Dispersion with Improved Value
      - Value Engineered Waterborne Curing Agent
- Conclusions

Conventional solvent-borne epoxy coatings

HEXION

Solid Epoxy
Supplied in solution

Solvent-borne System
Solid Epoxy Resin (type-1) + Polyamide
e.g. EPON™ Resin 1001-X-75 + EPIKURE™ Curing Agent 3115-X-70

Highly viscous polyamide
Supplied in solution

-450 g/L VOC
-Induction time required

+

-High VOC
-Induction time
-Compatibility
-Cure speed, recoat time

Sustainability – Product Innovation

At Hexion, we take an integrated business approach to sustainability with ultimate goal of creating long-term stakeholder value through environmental and product stewardship, risk management, safety and compliance. Our sustainability initiative can be grouped into three broad categories

- Operational excellence
- **Product innovation**
- Good corporate citizenship

High Solids

Waterborne

Hexion believes and pursues the technology platforms for coating systems such as waterborne and high solids technologies that will continue to contribute environment, health and safety

VOC Regulation Trends

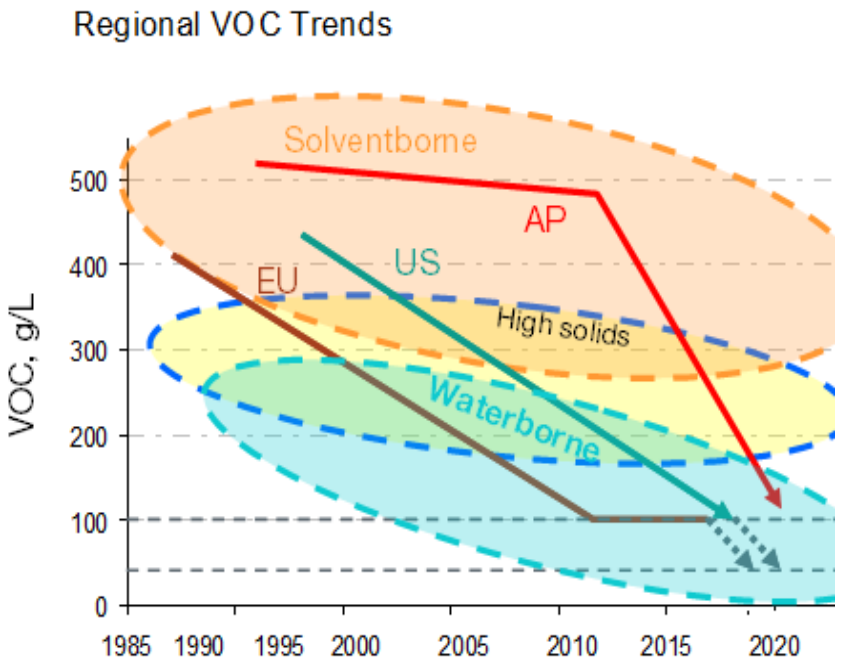
- USA (South Coast Air Quality Management District):
  - California (as low as <50 g/L on concrete).
  - Nov 2015 new lower ozone limits
- Europe (at forefront of VOC reductions):
  - VOC Solvents directive 1999/13/EG (regulates the emissions from factories)
  - The VOC (Decorative) Paints Directive 2004/42/EC (lower VOC limits from 2010 onwards)
  - Local legislations or application related requirements (e.g. max 3% solvents, etc.)
- China: Initiatives to reduce solvent emissions.

Ministry of Environmental Protection

- Technical requirement for environmental labeling products (TRELP) – Water Based Coatings (HJ2537-2014) - Effective July 2014

- 5% tax proposal for solvent-based coatings in 2 ~ 3 years

- 2017 VOC reductions: Beijing / Tianjin / Hebei (-25-30%), Shanghai (-20%), Guangzhou (-15%), etc



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Waterborne Epoxy Systems

Historical Development

Flooring
Masonry coatings

Liquid epoxy Emulsion	Water soluble amine


1st Gen.

LER technology

<200 g/L VOC

Too hydrophilic for anti-corrosion

Metal primers
Flooring
Masonry coatings

Solid epoxy Dispersion	Water soluble amine


2nd Gen.

"Universal" WB epoxy system

Solid epoxy resin dispersion

Better corrosion resistance

~150 g/L VOC

Metal primers
Chemical resistance

Multi functional Solid epoxy Dispersion	Amine solution


3rd Gen.

Multifunctional approach

~150 g/L VOC

Improved performance

Metal primers & topcoat

Solid epoxy Dispersion	Amine dispersion


4th Gen. (NewGen™ WB Epoxy)

Improved Compatibility, better corrosion and chemical resistance.

1970-1980 → 1980s → 1990s → 2000s

Lower VOC (~50-100 g/L

Waterborne Epoxy Systems

Historical Development

HEXION

VOC

Performance

Liquid epoxy Emulsion

soluble amine

1st Gen.

VOC

hydrophilic for anti-corrosion

Metal primers

Flooring

coatings

Solid ep… ter Dispersion

Cur…

2nd Gen.

"Universal" WB epoxy system

Solid epoxy resin dispersion

Better corrosion resistance

~150 g/L VOC

Metal primers

Chemical re…

…poxy …ion

…mine solution

EPIKURE Curing Agent

3rd Gen.

Multifunctional approach

~150 g/L VOC

Improved performance

M… …rimers & topcoat

Solid … Dis…

EPI…

Resi…

Amine dispersion

EPIKURE Curing Agent

4th Gen. (NewGen™ WB Epoxy)

Improved Compatibility, better corrosion and chemical resistance.

1970-1980 1980s 1990s 2000s

Lower VOC (~50-100 g/L

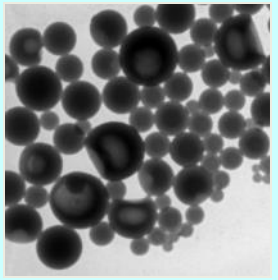
High Performance WB Epoxy System:
NewGen™ Waterborne Systems

HEXION™

- No induction time
- Better film formation
- Lower VOC
- Performance benchmark for current study

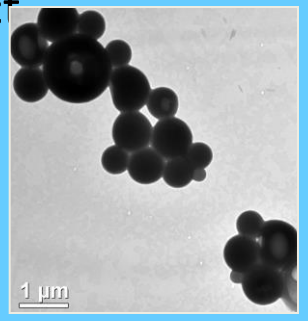
EPI-REZ™ Resin 6520-WH-53 (SER dispersion)

Description	Modified 1001-type
EEW, g/eq, solids	550
Viscosity, cP †	< 3,000
Solids, % weight	53
VOC Solvent	(5%)



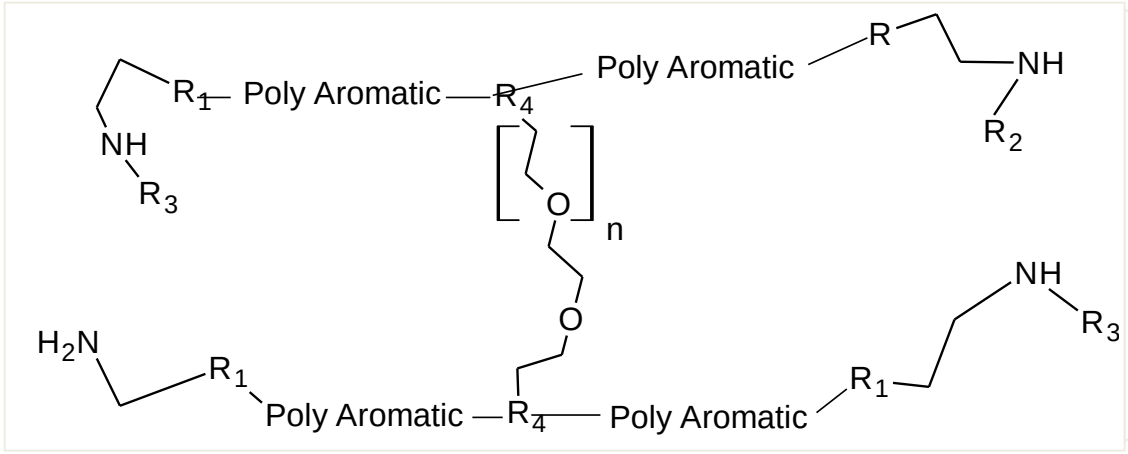
EPIKURE™ Curing Agent 6870-W-53 (amine curing agent dispersion)

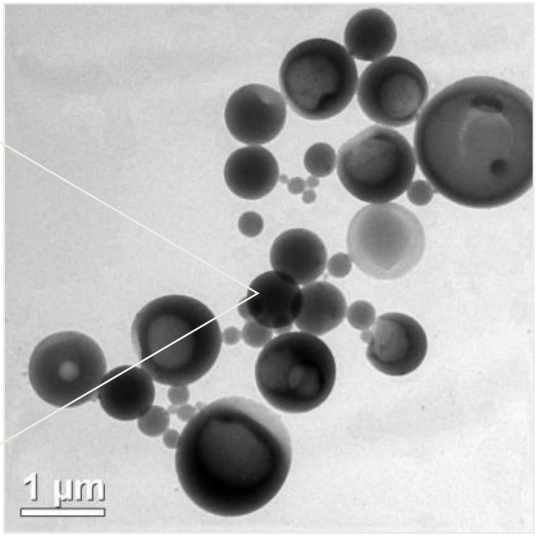
Description	Modified polyamine adduct
AHEW, g/eq, solids	225
Viscosity, cP †	<8,000
Solids, % weight	53
VOC Solvent	None



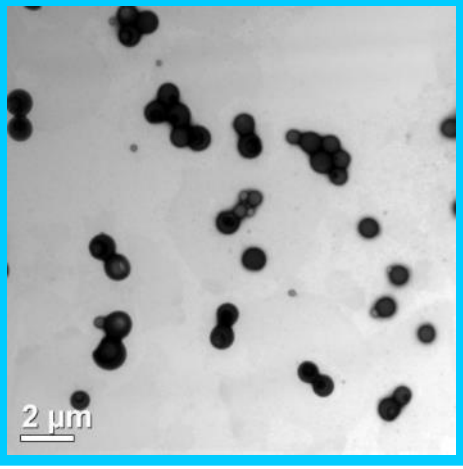
NewGen™ 2K Epoxy/Amine System

NewGen™ Curing Agent (EPIKURE™ Curing Agent 6870)





EPIKURE Curing Agent 6870-W-53



Epoxy resin curing agent

- Better compatibility
- Good shelf life
- Easy to apply
- Performance
- Patented technology

Waterborne Amine Dispersion

High Performance WB Epoxy System:

NewGen™ Waterborne System vs Solventborne

Three Coat System on Grit blasted steel SA2.5

1. NewGen Anticorrosion primer (SPF 1700) — 100 microns DFT
2. NewGen Mid coat (SPF 1728) — 125 microns DFT
3. WB Acid functional acrylic / Epoxy topcoat — 75 microns DFT

Hot Water (60°C) | Standard Salt Fog | Continuous Condensation | Prohesion Testing

5000 Hour Results

	NEWGEN™ Waterborne	E1001 / EK3115 Solventborne
VOC, g /L	100	445
Dry Time, hrs., Cotton-Free	4	8.5
24 Hr. Pencil Hardness	2B	4B
14 Day Pencil Hardness	H	F
Impact (Dir/Rev)	140 / 140	160 / 160
1000 Hr. Salt Spray	8F - 6F	6F
25 °C Water Resistance, days	>250	>250
MEK Double Rubs	308	337

*Film performance in clear enamels

2000 Hour Salt Spray Cold Rolled Steel

(3-4 mil DFT)

SB epoxy / polyamideNEWGEN™ WB system

- Better corrosion
- Better chemical resistance
- Faster dry
- No induction time

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Objective

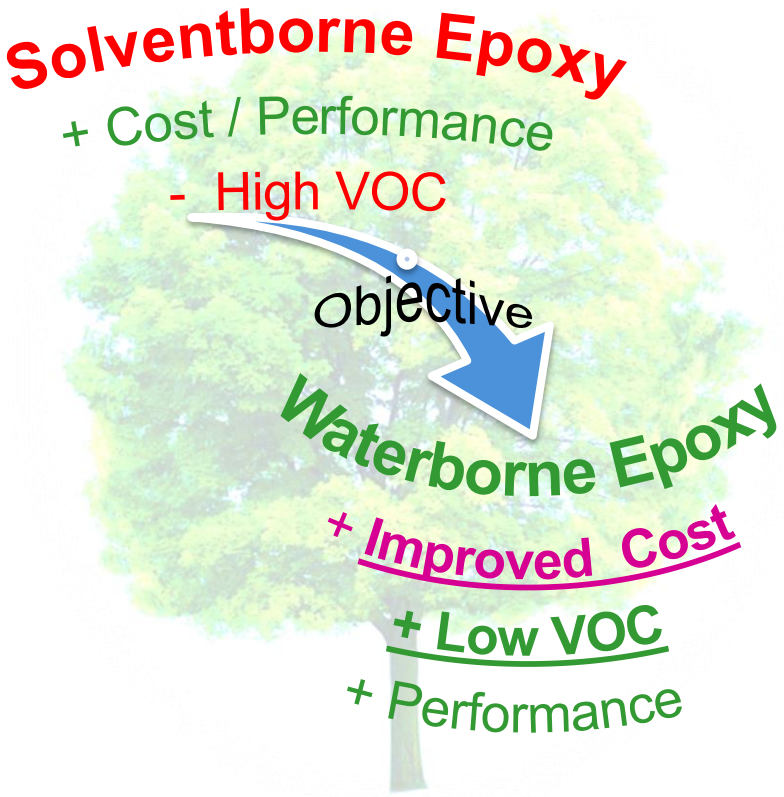
HEXION

- Develop a low-VOC waterborne epoxy resin and curing agent system with a balance of cost and performance to replace solventborne epoxy coatings
  - –NewGen™ Epoxy Waterborne System performs as well or better than solventborne at very low VOC levels
    - <100 g/L for metal (ACE, railway, transportation) and for concrete.

Need to reduce applied cost gap

Waterborne SER Epoxy Dispersion EPI-REZ Resin 7520-WD-52

HEXION



A cost effective, low-VOC, HAPS-free and high performance SER Dispersion performing similar to SB epoxy coating system

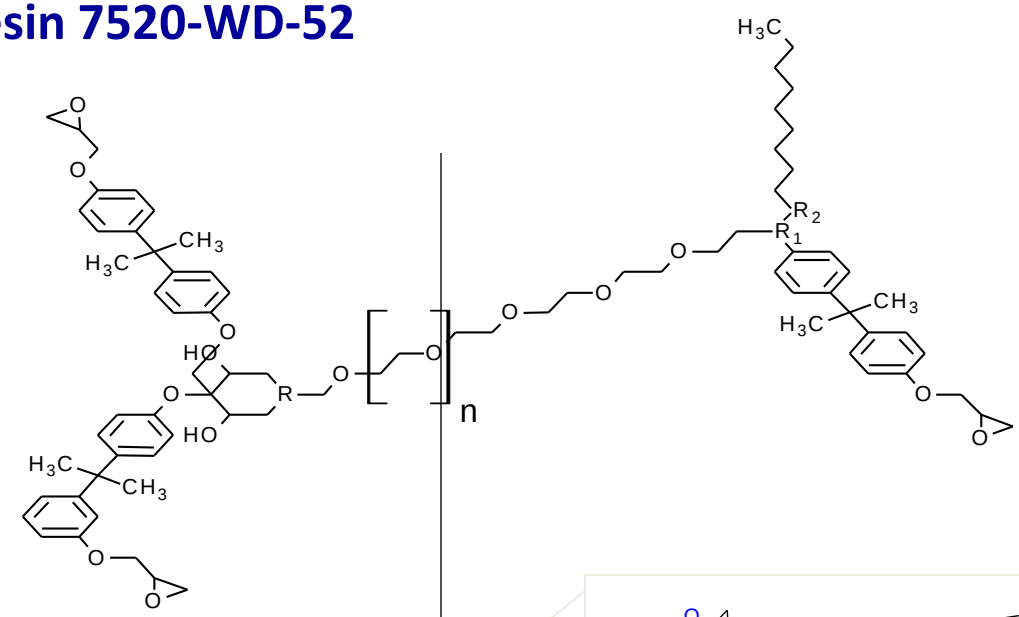
Property	ER7520-WD-52
Solids (wt.%)	51.0-54.0
Viscosity (cP)	1000-6000
EEW	475-575
Solvent (%)	5%

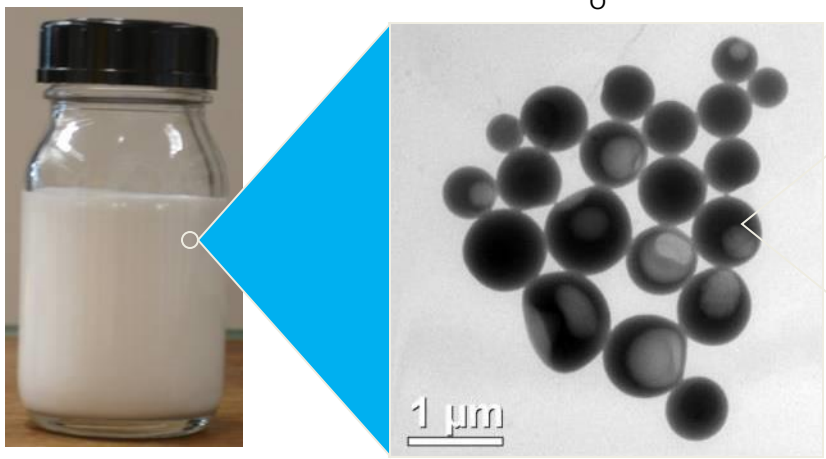
NextGen Epoxy™ Resin Dispersion

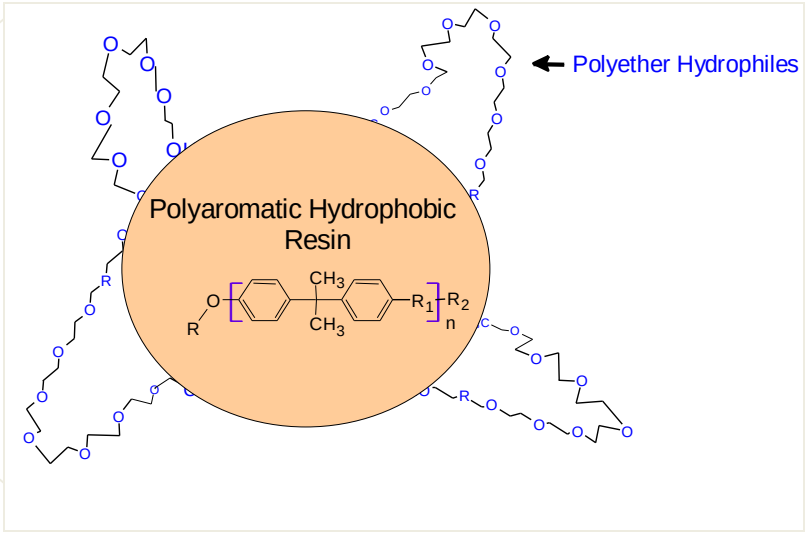
EPI-REZ™ Resin 7520-WD-52

HEXION™

- Shear stable
- Freeze-thaw stability
- Paint stability
- Improved applied cost
- High performance
- Zero induction time







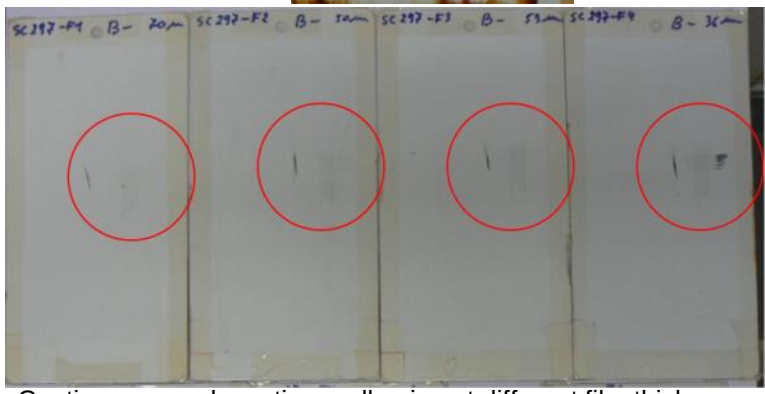
EPI-REZ Resin 7520-WH-53
(Waterborne SER Epoxy Dispersion)

Patented Technology

ER7520-WD-52 SER Dispersion Performance Properties*

	EPI-REZ 6520-WH-53	EPI-REZ 7520-WD-52
Dry film thickness (mil)	3-4	3-4
Dry times (hr)		
• Set to Touch, Stage II	--	1.5
• Cotton Free, Stage III	1.0	2.5
• Through, Stage IV	9.5	6.5
Pencil hardness, 7 days	H	F
Salt spray resistance (hr)	1000	1000
• Adhesion, in field	4A	5A
• Blister rating, field	10	10
• Scribe creep (mm)	3	2

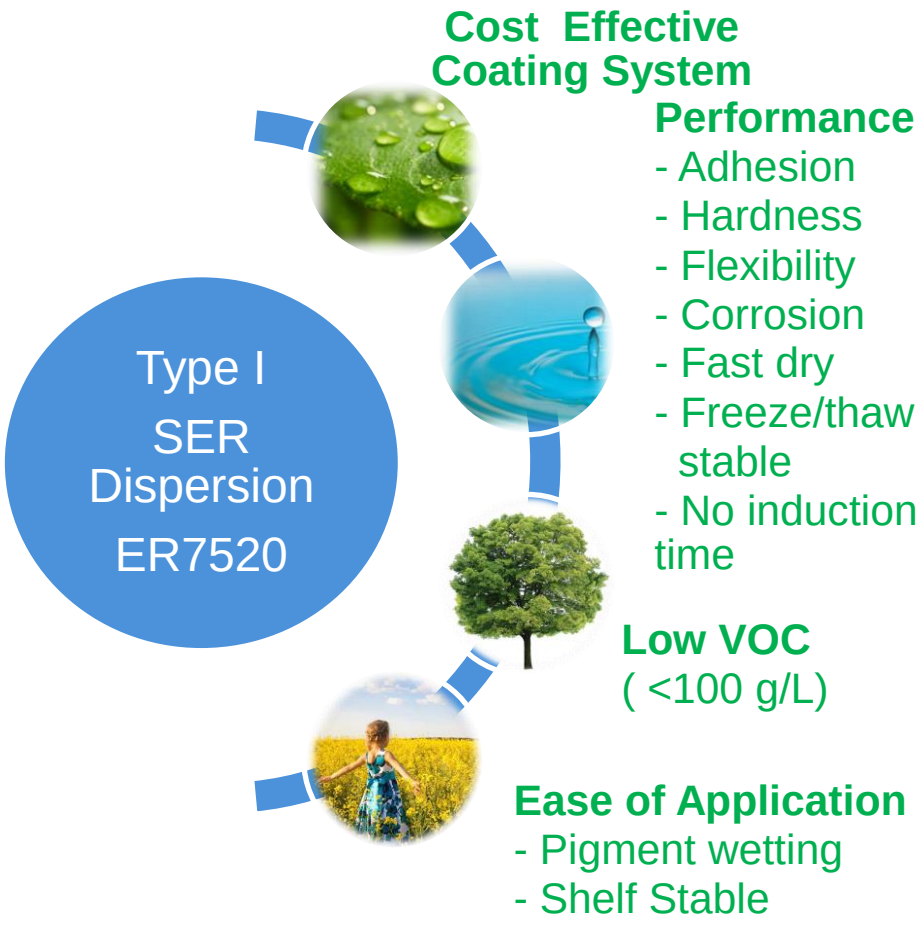
*QD-46 CRS panels, 7-day cure at 77F and 50% humidity; cured with EK6870-W-53



Continuous condensation: adhesion at different film thickness

ER7520-WD-52
Similar Performance to Benchmark WB ER 6520-WH-53
But more Cost Effective (applied cost)

ER7520-WD-52 Summary



- Viscosity and gloss pot life are 5-6 hours on concrete, 3-4 hours on metal
- Long shelf life reduces waste-related costs
- Low cost achieved by product design and manufacturing improvements
- Additional cost benefits from low VOC (solvent capture, safety, possible tax benefits)

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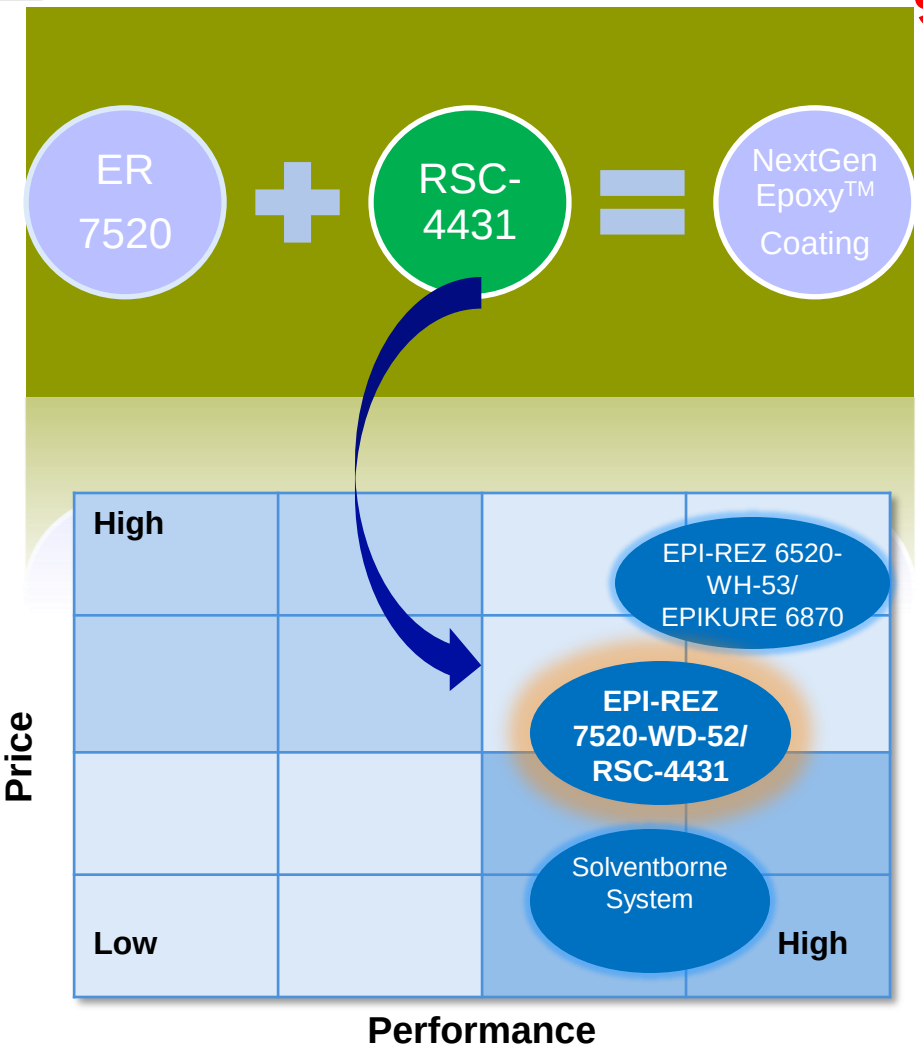
Research Curing Agent RSC-4431
Cost Effective & High Performance

HEXION



Solventborne Epoxy

+ Cost / Performance

- High VOC

objective

Waterborne Epoxy

+ Improved Cost

+ Lower VOC

+ Performance

Solution (Non-dispersion)
WB Curing Agent
Curing agent for development
of ultra-low VOC metal and concrete coating

Critical to Quality (CTQ's for RSC-4431 development)

HEXION

WB Curing Agent CTQ's

Solution Based
- Freeze/thaw stability
- Shelf stability
- Water reducible
- Shear/grind stable

Cost
- Low AHEW
- Manufacturability
- No organic solvents
- High solids/low viscosity

Performance
- Corrosion resistance
- Adhesion
- Flexibility
- Pot life
- Low viscosity

EHS
- Long shelf life
- No organic solvents

Research Curing Agent RSC-4431
Cost Effective & High Performance

HEXION

Properties	RSC-4431	Competitive	Epikure 6870-W-53
Solids	75	70	51-54
AHEW	120	200	420
Color	2-3	11-12	Milky white
Viscosity	10,700	30,000	

Economical
- Low Amine demand (Low AHEW)
- Product design

Low VOC
- Environmental Benefits
- Compliance with changing global regulations

Low Gardner Color
- Can be used as primer and topcoat (concrete)

Low Viscosity Solution
- Easy to formulate and application
- Great grind vehicle and stable
- Low VOC coatings

RSC-4431 – Metal Primer* with ER7520-WD-52

	ASTM Method	RSC-4431/ ER7520-WD-52
VOC, g/L	Calculated	**<100**
Dry film thickness, mil	D-1186	**3-4**
Dry times (hr)	D-5895B	
• Set to Touch, Stage II		**1.5**
• Cotton Free, Stage III		**2.5**
• Through, Stage IV		**7.5**
Pencil hardness, 7 days	D-3363	**H**
Adhesion	D-3359	**5A**
Salt spray resistance (hr)	B-117	**1000**
• Adhesion,in field, after 1h	D-3359	**5A**
• Blister rating, field	D-714	**10-9F**
• Scribe creep, mm	D-1654	**0-3**

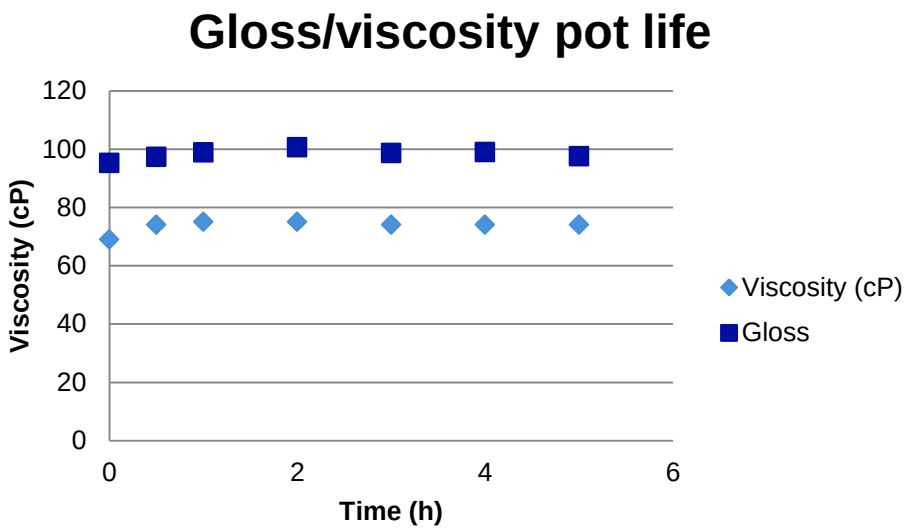
*Hexion formulation available

RSC-4431/ER7520
1000 hours saltspray
3-4 mil film thickness
75F, 50% humidity cure

Research Curing Agent RSC-4431 – with ER7520-WD-52 - Concrete *

	Units	Value
VOC	g/L	100
Dry film thickness	mils	3-4
Dry times		
• Set to Touch, Stage II	Hr	1
• Cotton Free, Stage III	Hr	9
• Through, Stage IV	Hr	18
Pencil hardness, 7 days		F
Adhesion		5A/5B
Flexibility	% elongation	32
Dollies pull-off	psi	>300
MEK resistance	Double rubs	>200
Gloss & viscosity pot-life**	# hours with no change in gloss or viscosity (KU)	>5

*Dollies pull-off and MEK resistance done on concrete
**24-hour gloss was >95 at 60° for more than 5 hours



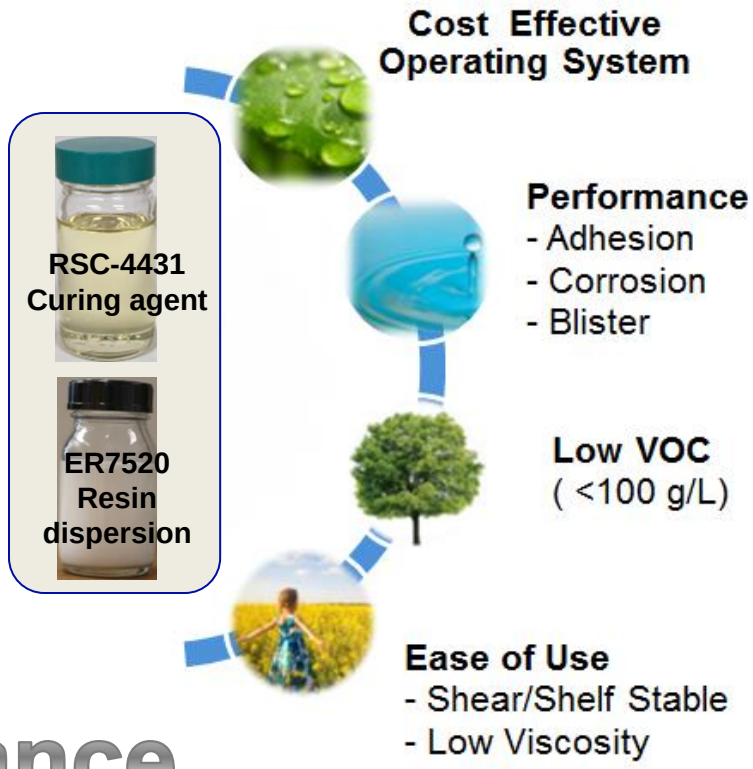
Were CTQ's met?

HEXION

Product properties CTQ

Properties	CTQ	RSC-4431
Solids (Wt. %)	**>50**	**75**
Viscosity at 25 °C (cP)	**~10000**	**~10000**
AHEW as supplied (g/eq)	**<430**	**120**
Appearance	**White dispersion**	**Clear Liquid**
Gardner color (max)	**Opaque**	**<6**

Performance CTQ



Cost/performance balance

No organic solvents

RSC-4431 Summary

- Curing agents typically the most expensive component of WB formulation
  - RSC-4431 value engineered
  - Formulation cost reduced further by low amine demand level
- Long shelf life reduces waste-related costs, relative to curing agent dispersions
- Viscosity and gloss pot life are 5 hours in concrete formulation
  - Further reduces waste-related cost
- Low VOC formulations for environmental benefits and potential savings

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ZVOC SER Dispersion (Research Resin RSW-4426)

HEXION

ZVOC Solid Epoxy Resin Dispersion for Ultra Low VOC 2K Epoxy Coating system (< 50 g/L)

APPLICATION

- **Protective Coating (Metal) :**
  - **Primer & DTM High Gloss**
- **High performance Architectural**
  - Schools
  - Sports Gyms/Halls
  - Hospitals
  - Stadiums
  - Public buildings
    - High Traffic Area
    - Repeated Cleaning
      - Solvent/Chemical Resistance
    - Environmentally Friendly
      - **<50 g/L VOC formulation**

Property	**ZVOC SER Dispersion** RSW-4426
Solids (wt.%)	52
Viscosity (cP)	<4000
EEW	495
Particle Size (Dv)	< 0.8 um
Solvent (%)	0%

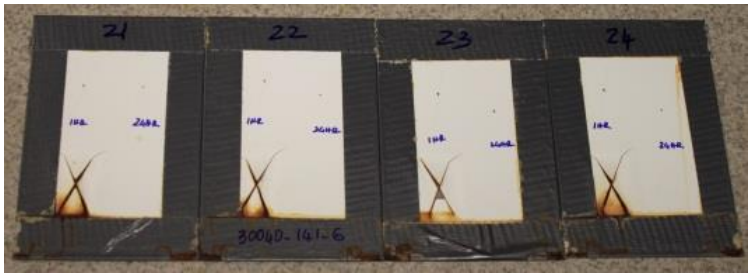
ZVOC SER Dispersion – 2K Metal Primer

	VOC	PVC	CORROSION BENCHMARKING
30040-141-1 **Competitor C**	17.2	33.3	
30040-141-2 **Competitor C2**	N/A	N/A	
30040-141-3 **Competitor D**	36	27.1	
30040-141-4 **Competitor A**	62	37.40	
30040-414-5 **Competitor A2**	0.8	35.65	

- All competitive samples had adhesion failures 1000 h
  - Using competitor formulation
  - Poorer performance compared to Hexion's WB NewGen™

Ultra low VOC formulation (~38 g/L) based on ZVOC RSW-4426 performs similar to high performance / high VOC SER Dispersion (100g/L)

RSW-4426 Performance (SF 1741)



Ultra low VOC Metal Primer!

Outperforms Existing Competitor Technologies

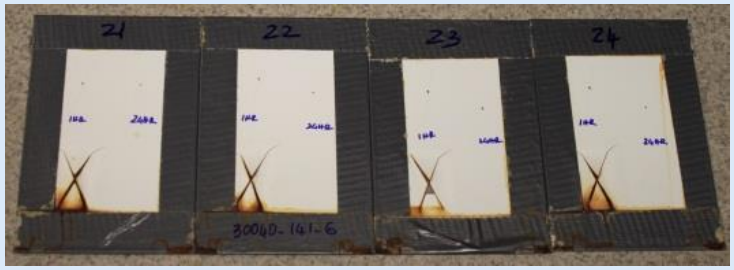
ZVOC SER Dispersion (RSW-4426 / EK6870-W-53)

HEXION

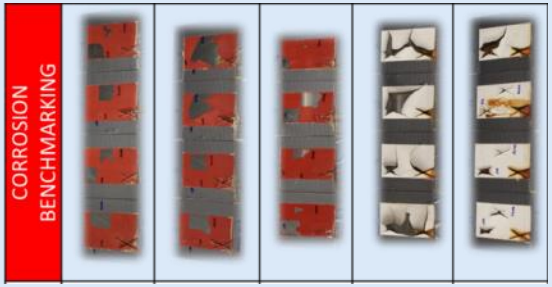
METAL

Ultra low VOC Metal Primer

VOC :~37 g/L



Equivalent to SB Epoxy

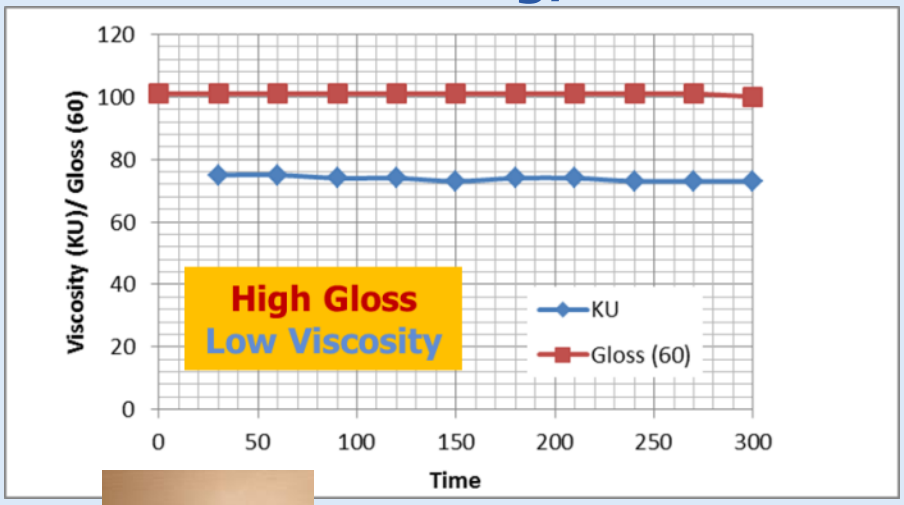


Outperforms existing competitive WB technologies using external surfactant technologies

INSTITUTIONAL COATING

Long Potlife & High Gloss

VOC :~48 g/L

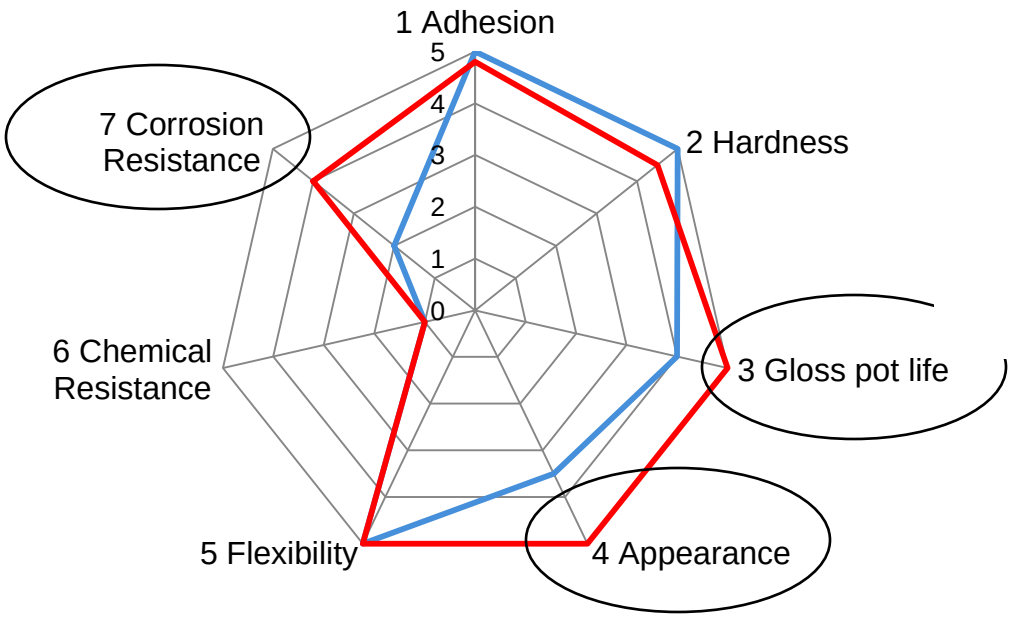


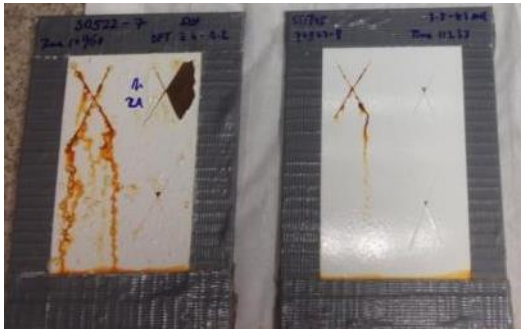
	Units	Value
Part A : Part B	Vol	4:1
VOC	g/L	44.0
Dry time	h	5.0
Induction time	min	0
Viscosity @ 25°C	KU	~75
Gloss (90 60°)	hours	5

Outperforms Existing High Gloss Epoxy Coating Technologies

RSW-4426 Coatings Performance

Commercial Low VOC WB Epoxy Coating vs Hexion RSW-4426





	Commercial Product	Hexion RSW-4426
Salt Spray	-	+
Prohesion	-	+
Humidity	=	=
Flexibility	=	=
Taber	-	+

Hexion- Institutional Coating System RSW-4426 & EK 6870

- Low VOC (< 50 g/L)
- High Gloss (90< @ 60 degree)
- Long Pot life (5-6 h)
- Very Low Viscosity Formulation
- Shelf Stable Formulation
- Much better Corrosion resistance
- Much better Gloss retention
- Good Flexibility
- Good scrub & chemical resistance

Epoxy Resin A and Curing Agent Resin B

- Commercially available products.
- Technical Data Sheets
- Application Guides
- Recommended Starting Formulations
- Lab Test Results
- Samples available

- For additional information, contact your Hexion Sales Representative or Distributor. In the alternative, contact:

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