Corrosion Resistant FRP Industrial Equipment

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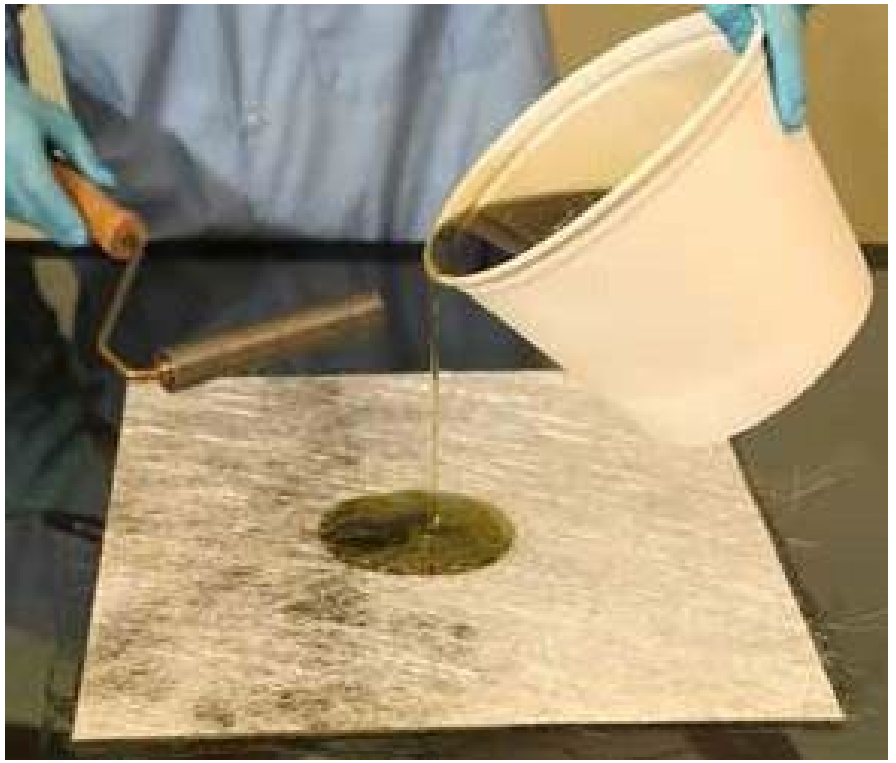
INEOS Composites

Composites
AN INFINITE WORLD OF POSSIBILITIES

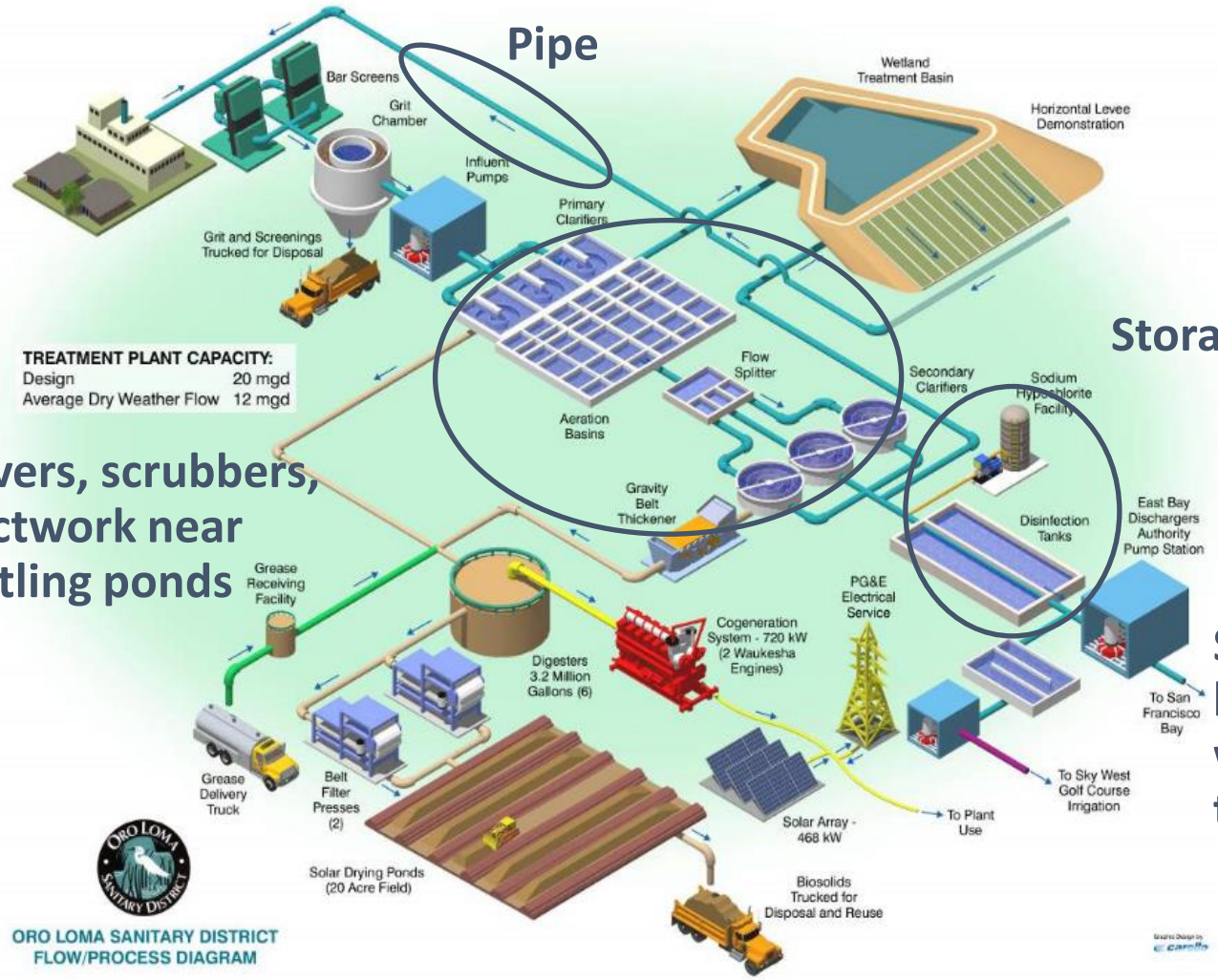
Outline

- Wastewater Treatment Process
- Typical environments in wastewater treatment facilities
- Recommended resins and fabrication practices for fiber-reinforced polymer (FRP) in wastewater treatment
- Case Histories
- Summary



FRP – Fiber Reinforced Polymer
Industrial fiberglass based on thermoset resin chemistry

FRP in the Wastewater Treatment Process



Storage Tanks – NaOCl, HCl NaOH

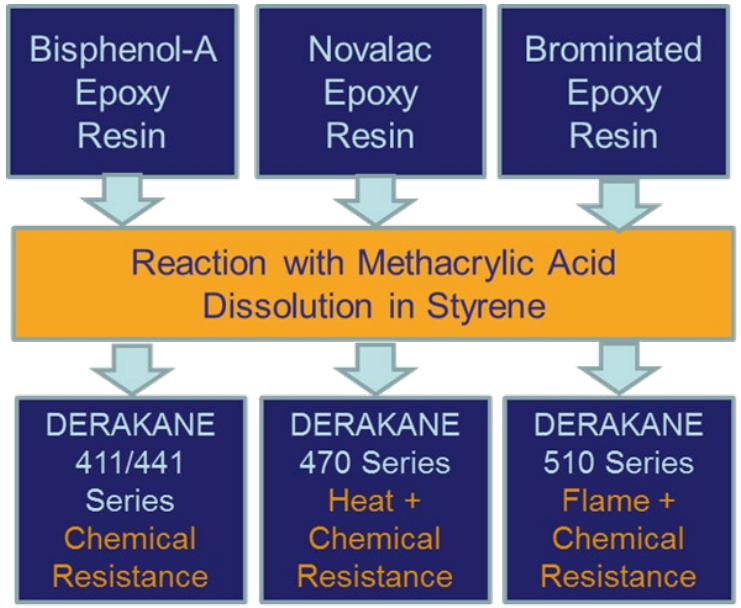
Covers, scrubbers, ductwork near settling ponds

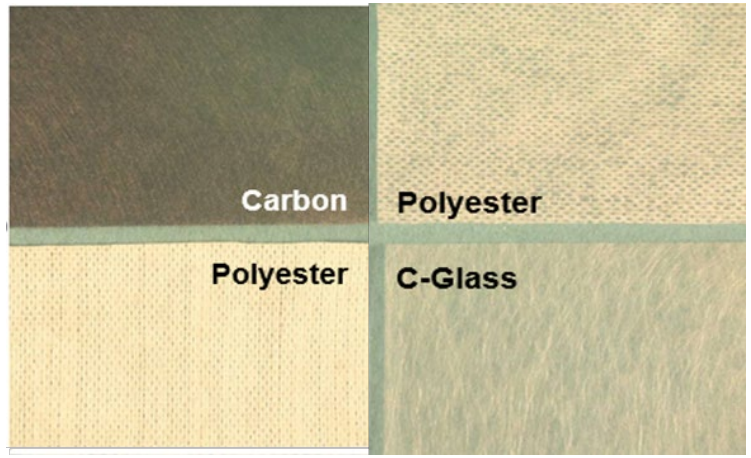
Stairways, grating, handrails, elevated walkways throughout the facility

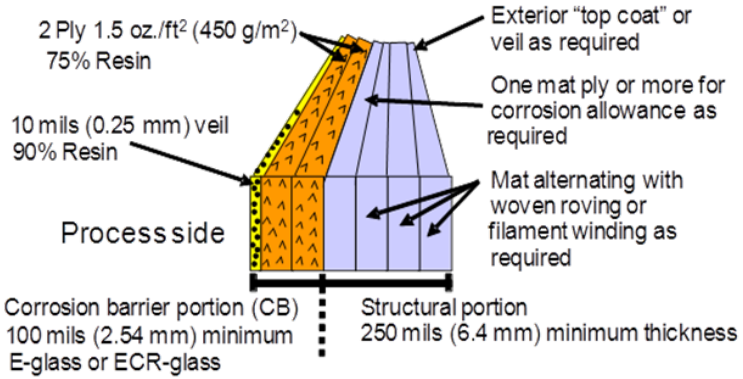
Typical Environments in Wastewater Treatment

- Chemical Storage and Transport
  - Sodium Hypochlorite
  - Sodium Hydroxide
  - Hydrochloric Acid
  - Fluorosilicic Acid
  - Brine
  - Ferric Chloride / Aluminum Sulfate
- Odor Abatement
  - Hydrogen Sulfide
  - Various Organics
- Corrosive Air Exposure

Importance of Material Selection & Construction







Resin

Corrosion resistance
Flame resistance
Heat Resistance
Toughness

Glass & Veil

Glass – Strength & Modulus
Veil – Resin Richness for Corrosion Resistance

Laminate / CR Barrier

CR Barrier – Protective resin-rich layer
Structural layer – To meet Design

Proper material selection & laminate design greatly influences the performance and longevity of process equipment

Typical Environments – Chemical Storage and Treatment

Chemical Storage and Treatment – Tanks

- Sodium Hypochlorite (NaOCl)
- Sodium Hydroxide (NaOH)
- Hydrochloric Acid (HCl)
- Brine
- Ferric Chloride, Aluminum Sulfate
- Fluorosilicic Acid

Sodium Hypochlorite (NaOCl)

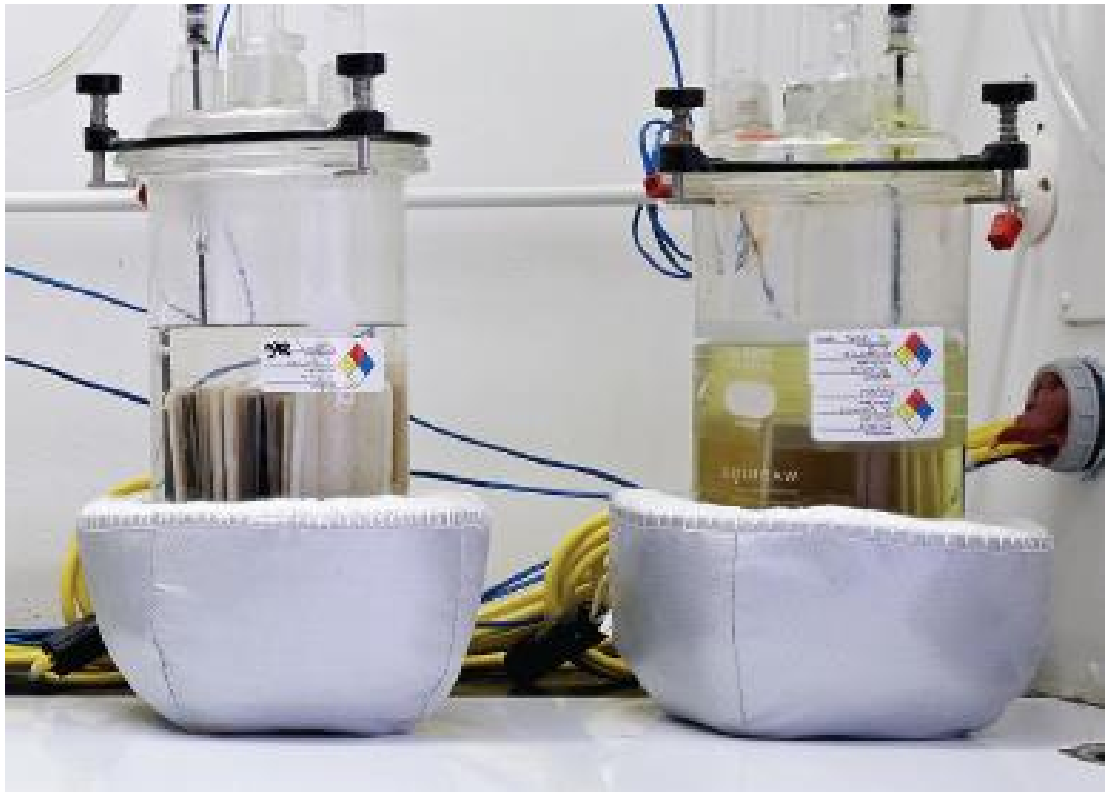
- NaOCl (bleach) commonly used to treat effluent
- Storage concentrations
  - 9-18% at ambient temperatures (100°F, 40°C)
- Some facilities generate low concentrations (<1%) of NaOCl on site

- Sodium hypochlorite is very aggressive
- Suitability of FRP depends on
  - NaOCl concentration
  - Stabilization / pH > 11
  - Temperature
  - Metal impurities
    - Hard water
    - Metal promoters
  - Light
- Bleach solutions becoming more aggressive
  - Use of very hard water to make bleach
  - Destabilized bleach more effective in purifying water

Sodium Hypochlorite Corrosion Study

- ASTM C-581 Corrosion testing

- Laboratory testing - coupons exposed to stabilized NaOCl
  - Concentration: 9 – 15%
  - Temperature: 120 - 150°F (50 - 60°C)
  - Visual and physical property evaluation: 1, 3, 6, 12 months



Sodium Hypochlorite Corrosion Study

- Evaluated three types of resin
  - Bis-A EVER (Derakane™ 411 epoxy vinyl ester resin)
  - Novolac EVER (Derakane™ 470 novolac epoxy vinyl ester resin)
  - Brominated EVER (Derakane™ 510A and 510B brominated epoxy vinyl ester resin)

- Veil types
  - C-glass
  - Polyester
  - Carbon

- Cure systems (polymerize thermoset resin matrix)
  - Cobalt / DMA / MEKP (Promotor/Accelerator/Initiator)
  - DMA / BPO

Resin Comparison

- 12% NaOCl at 120°F (50°C) for 12 months

Resin	Bis-A EVER	Novolac EVER	Brominated EVER
Veil	C-glass	C-glass	C-glass
Cure System	BPO/DMA	BPO/DMA	BPO/DMA
Surface Appearance	Slightly flat	No gloss	Glossy
Resin Attack	Slight	Moderate	None

- Brominated Epoxy Vinyl Ester (Brominated EVER) resins performed best
- Bromine appears to protect sites commonly attacked
- Bisphenol-A Epoxy Vinyl Ester (Bis-A EVER) suitable for lower concentrations and temperatures

Veil Comparison

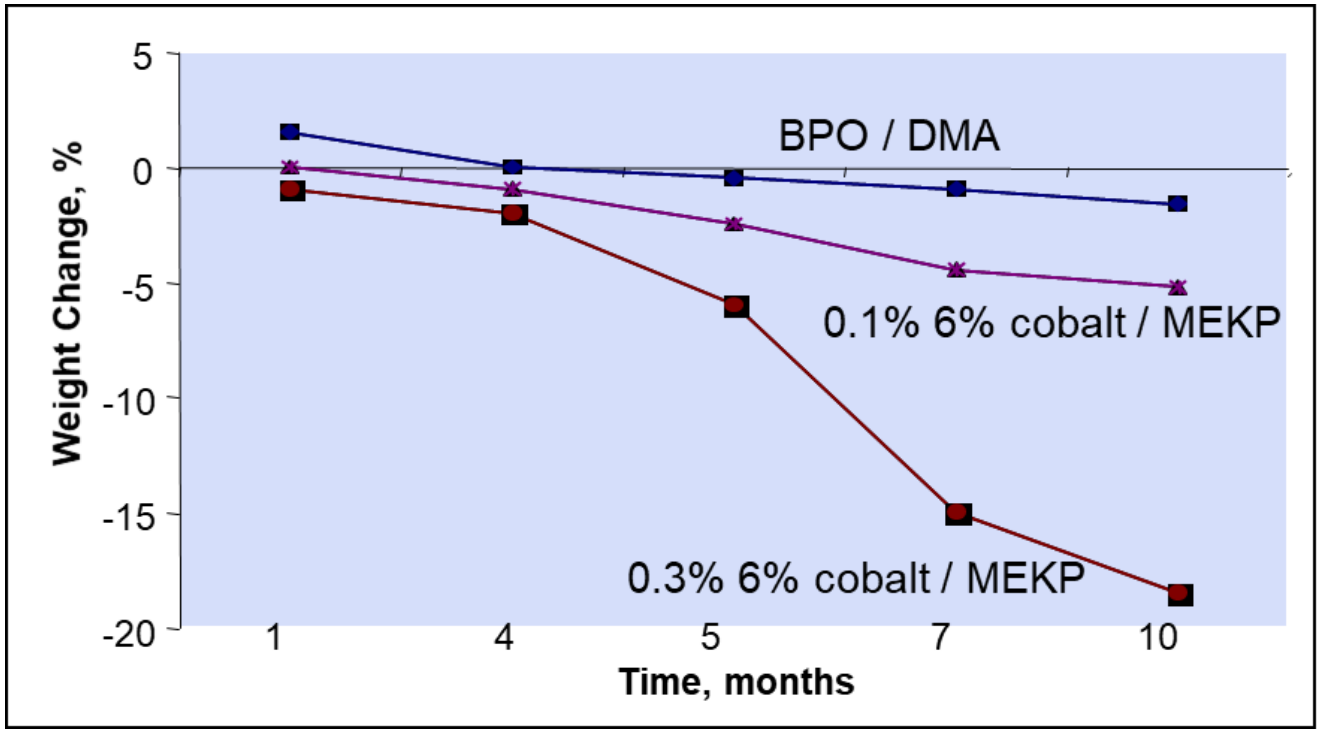
- 10% NaOCl at 150°F (65°C) for 12 months

Resin	Brominated EVER	Brominated EVER	Brominated EVER
Veil	polyester	C-glass	carbon
Cure System	BPO/DMA	BPO/DMA	BPO/DMA
Flex Strength, % retention	29	71	-
Flex Modulus, % retention	26	65	-
Surface Hardness, % retention	0	47	-
Resin Attack	moderate	slight	no veil left after 1 month

- C-veil performs best at elevated temperatures

Cure System Comparison

- Bis-A EVER resin in 5.25% NaOCl at 150°F (65°C)



- DMA/BPO cure system performed best
- Presence of cobalt reduces chemical resistance

Cure System and Veil Comparison

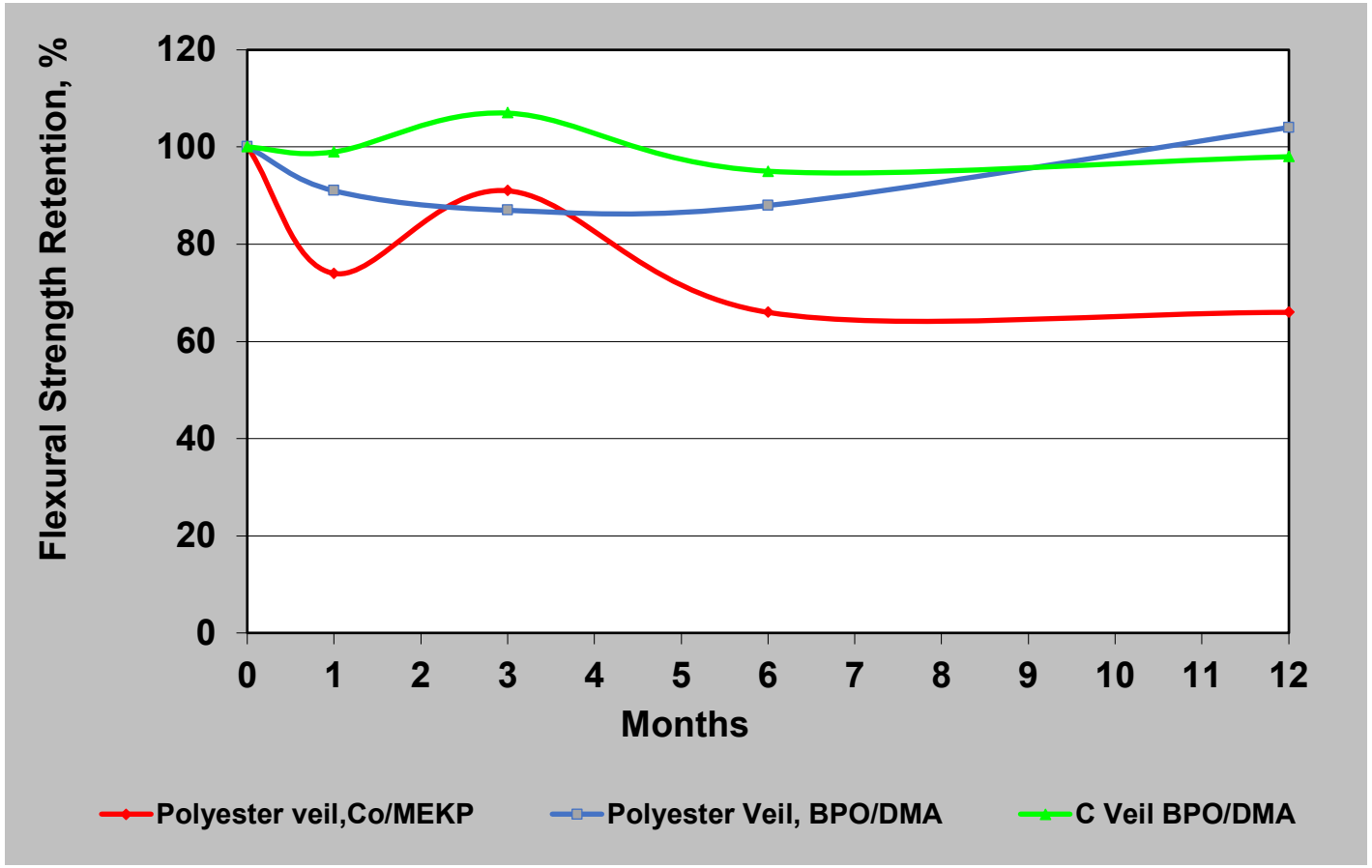
- 12% NaOCl at 120°F (50°C) for 12 months

Resin	Brominated EVER	Brominated EVER	Brominated EVER
Veil	Polyester	Polyester	C-glass
Cure System	Cobalt/MEKP	BPO/DMA	BPO/DMA
Flex Strength, % retention	66	104	93
Flex Modulus, % retention	79	101	93
Surface Hardness, % retention	73	100	98
Surface Appearance	flat	flat	semi-gloss
Resin Attack	moderate	slight	none

- Cobalt in resin increases resin attack
- C-glass veil slightly better than polyester veil (if excess NaOH then polyester veil)

Cure System and Veil Comparison

- Brominated EVER
- 12% NaOCl at 120°F (50°C) for 12 months
- C-glass veil with BPO/DMA performs best



Sodium Hydroxide

- Strong base used for
  - pH Adjustment
  - Metal precipitant
  - Alkaline cleaner
- 10 - 30% concentrations most aggressive
- Preferred resin
  - Derakane™ 411 series resins
- Corrosion barrier
  - Two layers of synthetic veil or carbon veil
  - 100 mils (2.5 mm) thick

Hydrochloric Acid

- Strong acid used for
  - pH adjustment
- Preferred resins
  - Derakane™ 411 and 470 vinyl ester resins
- Corrosion barrier
  - Two layers of C-glass veil
  - 200 mils (5.0 mm) thick
  - Boron-free chopped strand ECR glass

Ferric Chloride, Aluminum Sulfate

- Highly effective coagulants for clarification
- Used for industrial and sanitary wastewater treatment
- FRP is material of choice
- Bis-A epoxy vinyl ester resin can be used up to 212°F (100°C)
- Corrosion barrier
  - One layer of C-glass veil
  - 100 mil (2.5 mm) thick

Brine

- Water with high salt concentration
- On-site production of sodium hypochlorite
- Waste streams
- FRP is material of choice
- Bis-A epoxy vinyl ester resin can be used up to 212°F (100°C)
- Corrosion barrier
  - One layer of C-glass veil
  - 100 mil (2.5 mm) thick

Fluorosilicic Acid

- Additive for water fluoridation
- FRP is material of choice
- Bis-A epoxy vinyl ester resin can be used up to 180°F (80°C), slightly lower temperature with higher concentrations
- Corrosion barrier
  - 2 layers polyester veil
  - 100 mil (2.5 mm) thick

ANSI / NSF 61 Potable Water Equipment Certification

- American National Standards Institute (ANSI) maintains and updates the ANSI / NSF 61 certification
- Many available testing labs and certification bodies, not just the National Sanitation Foundation (NSF)
- Facilities beginning to require ANSI/NSF 61 approval
  - Being required when treating or storing chemicals used for drinking water
  - Resin coupons submitted to NSF
  - Coupons undergo extraction testing
- Bis-A EVER coating systems have ANSI/NSF 61 approval and are commonly used in potable water applications

Case Histories – Chemical Storage

Case History – Sodium Hypochlorite and Sodium Hydroxide Storage Tanks

- Epoxy vinyl ester resin
- Brominated epoxy vinyl ester resin at higher concentration and temperature
- Note building structure provides tanks shade (hypo stability)

Case History - 50% Sodium Hydroxide Storage Tank

- Bis-A epoxy vinyl ester resin
- 8500 gallons at ambient temperature
- Corrosion liner
  - One layer C-glass veil, two layers synthetic veil
  - 116 mils (3 mm) thick
- Installed in 2010
- Fields Point Wastewater Treatment Facility, Providence, RI

Case History – Piping and Header System

- NSF/ANSI 61 certified Bis-A epoxy vinyl ester resin
- Installed at a California desalination plant

Case Histories – Odor Abatement

Odor Abatement – Hydrogen Sulfide

- Settling Tank Covers
- Ductwork
- Scrubbers, Carbon Absorbers
- Commonly used resins
  - Bis-A epoxy vinyl ester resin can be used up to 210°F (80°C)
  - Brominated epoxy vinyl ester resin when flame retardance required
- Corrosion barrier
  - 1 layer C-glass veil
  - 100 mil (2.5 mm) thick

Case History – Odor Control System

- Brominated epoxy vinyl ester resin
- Biological odor control filtering system
- Installed in 2010 at the Orange County Sanitation District, Plant 2 in Huntington Beach, CA
- Treats hydrogen sulfide and other organic compounds released during wastewater treatment process
- 10 ft. diameter x 42 ft. tall (3 m x 13 m)
- Ambient temperature
- 100 mil corrosion liner

Case Histories – Corrosive Air

Case Histories – Corrosive Air Exposure

- Grating, Stairs, Handrails
- FRP is material of choice
- Bis-A epoxy vinyl ester resin can be used up to 210°F (100°C)
- Pultrusion used for many applications

Summary and Conclusions

Summary – WWTP Resin Selection

Sodium Hypochlorite

- Bis-A EVER lower % and temp
- Brominated EVER at higher % and temp
- 100 mil (2.5 mm) corrosion liner
- 2 layers C-glass veil
- BPO/DMA cure system in corrosion liner
- Post cure

Hydrochloric Acid

- Bis-A EVER , Novolac EVER
- 200 mil (5.0 mm) corrosion liner
- 2 layers C-glass veil
- Post cure

Sodium Hydroxide, Fluorosilicic Acid

- Bis-A EVER
- 100 mil (2.5 mm) corrosion liner
- 2 layers synthetic veil or carbon veil
- Post cure

Brine, Ferric Chloride, Aluminum Sulfate, Hydrogen Sulfide

- Bis-A EVER
- 100 mil (2.5 mm) corrosion liner
- C-glass veil
- Brominated EVER if fire retardance is needed

Conclusions

- Vinyl ester based FRP is material of choice for many wastewater treatment applications
- Resin selection, design, and fabrication of FRP equipment are all key to a long service life
- INEOS technical support allows you to proceed with confidence
  - Resin recommendations based on corrosion testing, years of experience and multiple case histories
  - INEOS Corrosion Science Center – **derakane@ineos.com**

INEOS Composites

Thank You!

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- Feel free to contact me for
  - Lunch and Learn with your team (qualifies for PDH credit)
  - Specification guidance
  - Resin and corrosion barrier recommendations
  - Resin Selection Guide – corrosion data for 1000's of applications
  - FRP Fabrication Tips Guide
  - Technical papers and reference materials

Supplemental Information – Case Histories, Chemical Storage

Case History - Sodium Hypochlorite Tank Farm

- Bis-A Epoxy vinyl ester resin
- Ambient temperature

Case History – Sodium Hypochlorite Storage Tank

- Brominated epoxy vinyl ester resin
- Ambient temperature
- Municipal wastewater treatment facility

Case History – 15% Sodium Hypochlorite Storage Tank

- Brominated epoxy vinyl ester resin
- 5000 gallon tank at ambient temperature
- Installed in 2008 at Buffalo Sewer Authority Bird Island wastewater treatment plant
- Corrosion liner
  - One layer each C-glass veil and Nexus veil
  - 120 mil (3.0 mm) thick
  - BPO/DMA cure system
  - MEKP/cobalt cure system for structural layers
  - Post cure

Plas-Tanks Industries

Case History - 0.8% Sodium Hypochlorite Storage Tank

- On-site NaOCl generation Smyrna, TN
- pH = 9.5, ambient temperature
- Brominated EVER, BPO/DMA cure system
- Excellent condition after 5 years service

Case History – 50% Sodium Hydroxide Storage Tank

Justin Tanks

- Bis-A epoxy vinyl ester resin
- Ambient temperature
- Corrosion liner
  - Two layers synthetic veil
  - 120 mils (3.0 mm) thick
- Installed 1993 at a SOLENIS facility in Houston, TX
- Still in service after 25 years with no maintenance required

Case History – Piping System

- NSF/ANSI 61 certified Bis-A epoxy vinyl ester resin
- Installed at a California desalination plant

Case History – Brine Piping

- Bis-A epoxy vinyl ester resin
- 22” diameter x 6 miles
- Service temp. = 140 -160°F (60 - 70°C)

Case History – 25% Ferric Chloride Storage Tank

- Bis-A epoxy vinyl ester resin
- Ambient temperature
- Installed in 1967
- Tank in good condition in 1996 when removed due to process change

Case History – Ferric Chloride Storage Tank

- Bis-A poxy vinyl ester resin
- Ambient temperature
- 100 mil corrosion liner

Supplemental Information – Case Histories, Odor Abatement

Case History – Scrubber System

- Brominated epoxy vinyl ester resin
- Scrubber system installed at the Allegheny County Sanitary Authority in PA

Belco Manufacturing

Case History – Odor Control System

- Brominated epoxy vinyl ester resin
- Installed at the North Central Outfall Sewer Air Treatment Facility in Los Angeles, CA

Daniel Company

Case History – Odor Control System

- Brominated epoxy vinyl ester resin
- Biological odor control filtering system
- Installed in 2016 at a water reclamation plant in Lubbock, TX
- Treats hydrogen sulfide and other organic compounds released during wastewater treatment process
- Ambient temperature
- 100 mil corrosion liner

Case History – Odor Control Duct

- Bis-A epoxy vinyl ester resin
- Ambient temperature
- 100 mil corrosion liner