FRP Construction with DERAKANE* Epoxy Vinylester Resins ; Codes and Standards

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Outline

• Short Introduction to Ashland
• Brief History DERAKANE resins
• DERAKANE resins technology
• Corrosion Resistant Composite Applications Codes and Standards
• Case History
Ashland Overview

Ashland Hercules Water Technologies

Revenue: $1.8B
The #1 global producer of specialty papermaking chemicals

Ashland Performance Materials

Revenue: $1.4B
The #1 global leader in unsaturated polyester resins and vinyl ester resins

Ashland Aqualon Functional Ingredients

Revenue: $1.0B
The #1 global producer of cellulose ethers

Ashland Consumer Markets

Revenue: $1.9B
The #3 passenger car motor oil and #2 franchised quick-lube chain in the United States
Environmental Stewardship

Ashland is committed to the continuous evolution of technology and service solutions that promote health, safety and environmental protection around the world.

*Responsible Care and RC14001 are registered service marks of the American Chemistry Council in the United States and other entities in various countries.
Composites

Business Overview

- Largest global producer of unsaturated polyester resin and vinyl ester resin for composite products
- Second largest global producer of gelcoats for composite products
- Enabling innovations around the world:
  - R&D facilities in North America, Europe and Asia
  - Developing products to meet changing demands in regional markets
- Markets
  - Transportation: Automotive and truck body panels
  - Building and construction: tub, shower, solid surface countertops, structural, corrosion / fire retardant materials
  - Recreational marine
Corrosion-Resistant Applications

• Our main brand is DERAKANE Epoxy Vinyl Ester Resins
History of DERAKANE Epoxy Vinyl Ester Resins (EVER)

- 1960 Dow and Shell develop and tests the first EVER
- 1962 First patent granted
- 1966 Market introduction of DERAKANE* 411-45 resin
- 1967 Dow develops Novolac Epoxy based Vinyl Ester Resins
- 1972 Dow starts the production of EVER in Germany
- 1982 Ashland acquires the EVER from Shell
- 2000 Commercialisation of DERAKANE MOMENTUM resins
- 2004 Ashland acquires the DERAKANE from Dow
- 2006 Ashland creates a new plant for DERAKANE production in Spain
- 2011 50 years of field experience with EVER in corrosion resistant applications and developing new applications
Properties of DERAKANE Epoxy Vinyl Ester Resins

- Steric Shielding
- Hydroxyl Group
- Epoxy Backbone: Toughness
- Good Corrosion Resistance
- Good Wetting and Bonding to Glass
- Terminal Unsaturation

Polymerisation Site
Properties of DERAKANE Epoxy Vinyl Ester Resins

- Mechanical Resistance
  - And
  - Thermal Resistance
- Viscosity
- Handling
- Cure
- Chemical Resistance

- Similar to Epoxy Resins
- Similar to unsaturated polyester resins (UP)
- Better than Epoxy - or UP resins
DERAKANE Resins - Main Product Families

- Bisphenol-A Epoxy Resin
- Novolac Epoxy Resin
- Brominated Epoxy Resin
- Bisphenol-A Epoxy Resin + Flexibiliser

Reaction with Methacrylic Acid
Dissolution in Styrene

- DERAKANE 411 / 441 / 602 Series Chemical Resistance
- DERAKANE 455/470/HTSeries Heat + Chemical Resistance
- DERAKANE 510A/510C Series Flame + Chemical Resistance
- DERAKANE 8084 / 8090 Toughness + Adhesion
Corrosion Resistant Composite Applications
Based on DERAKANE Resins

Codes and Standards
Design and Construction

- FRP is anisotropic material
- Its characteristic are not normalized every fabricator qualifies its own material (laminate)
- Material performance is dependent on the process and quality of fabrication
- The FRP will be designed to achieve a certain degree of performance to meet required needs in terms of corrosion resistance (design of the chemical resistant liner) and mechanical strength (design of the structural part of the laminate) in order to hold the static load, pressure or depressurize load it will be submitted to.
- Hence the choice of the different layers (Tissue, Roving, CSM) as well as the process (Hand-Lay Up, Filament Winding) are crucial towards the end-results
Example Brine Tank

- FRP Based on DERAKANE 411
- Operation Conditions
  - Brine d=1,2 with 1% salt crystals
  - Volume 12 m3
  - Max 18 tonnes dont 8 tonnes de sel
  - Lighter equipment as previous one
  - Equipment on 3rd Floor

Salt and Brine Inlet
Example Tank fall down after 10 hours of service
Root Cause of the Failure
Wrong support design
Root Cause of the Failure
Wrong support design

• After analysis and calculation it was found that the support was not designed appropriately
  - Weak resistance of the support to the tank
  - Too weak support

• The code used does not take supporting into account

• The manufacturer had freedom of design

• The new European Standard corrects this point
  - supports for equipments with diameter > 1.5m et de height > 2m are forbidden, ring support is recommended
Construction codes

- EN 13121-2: 2003, GRP tanks and vessels for use above ground - Part 2: Composite materials - Chemical resistance, European Committee for Standardization
- NFT 57 900: 1987, Réservoirs et appareils en matières plastiques renforcées, Association Française de Normalisation
- BS 4994: 1973, Specification for Vessels and Tanks in Reinforced Plastics, British Standards Institution
Construction codes

- DIN 18820: 1991, Part 3, Glass Fibre Reinforced Unsaturated Polyester (GF-UP) and Phenacrylic (GF-PHA) Resin Structural Composites; Protection of Structural Layer, Deutsches Institut für Normung e.V.
- DIN 16965-4, Rohre aus Glasfaserverstärkten Polyesterharzen (UP-GF), gewickelt, Rohrtyp D; Masse, DIN Deutsches Institut für Normung e.V.
- DIN 16965-5, Rohre aus Glasfaserverstärkten Polyesterharzen (UP-GF), gewickelt, Rohrtyp E; Masse, DIN Deutsches Institut für Normung e.V.
- AS 2634-1983, Chemical Plant Equipment made from Glass-Fibre Reinforced Plastics (GRP) based on Thermosetting Resins, Standards Association of Australia
Construction codes

- Companies develop also their own design code and specifications

- New European Standard EN 13121 for tanks above ground

- EN 13121 – GRP tanks and vessels for use above ground, this Standard is divided in four parts, namely:
  
  - Part 1 – Raw Materials – Specification conditions and acceptance conditions
  
  - Part 2 – Composite materials – Chemical resistance
  
  - Part 3 – Design and workmanship
  
  - Part 4 – Delivery, Installation and maintenance
# EN 13121- Part 1 Raw Material

## Table 2: Classification scheme for UP- and VE-resins

<table>
<thead>
<tr>
<th>Group</th>
<th>Resin type</th>
<th>Type of glycols</th>
<th>Type of acids</th>
<th>content of styrene mass-%</th>
<th>T\textsubscript{s} (°C)</th>
<th>HDT (°C)</th>
<th>σ\textsubscript{t} (MPa)</th>
<th>ε\textsubscript{t} (%)</th>
<th>σ\textsubscript{f} (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>UP</td>
<td>Standard glycols\textsuperscript{1)} \textsuperscript{2)}</td>
<td>Orthophthalic acid Ethylenedicarboxylic acids</td>
<td>45 85 60 60 2.0 90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>UP</td>
<td>Standard glycols\textsuperscript{1)} \textsuperscript{2)}</td>
<td>Orthophthalic acid Ethylenedicarboxylic acids</td>
<td>45 120 90 50 1.5 75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>UP</td>
<td>Standard glycols\textsuperscript{1)} \textsuperscript{2)}</td>
<td>Isophthalic acid, HET acid Ethylenedicarboxylic acids</td>
<td>50 85 60 60 2.0 90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>UP</td>
<td>Standard glycols\textsuperscript{1)} \textsuperscript{2)}</td>
<td>Isophthalic acid, HET acid Ethylenedicarboxylic acids</td>
<td>50 120 90 50 1.5 75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>UP</td>
<td>Standard glycols\textsuperscript{1)}</td>
<td>Terephthalic acid Ethylenedicarboxylic acids</td>
<td>50 140 110 75 3.0 120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>UP</td>
<td>Neopentyl and halogenated neopentyl glycol (min. 80 mol-%)\textsuperscript{3)} and a diol with at least one secondary OH-group (max. 20 mol-%)\textsuperscript{3)}</td>
<td>Isophthalic acid Orthophthalic acid Ethylenedicarboxylic acids</td>
<td>55 120 90 65 3.0 110</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>UP</td>
<td>Bis (hydroxymethyl)-tricyclodecane</td>
<td>Orthophthalic acid Ethylenedicarboxylic acids</td>
<td>45 120 90 50 1.5 100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>UP</td>
<td>Dipropoxy-Bisphenol A and halogenated Bisphenol A (min. 80 mol-%)</td>
<td>Ethylenedicarboxylic acids</td>
<td>55 130 110 60 2.0 110</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7A</td>
<td>VE</td>
<td>Epoxidised Bisphenol A and halogenated Bisphenol A</td>
<td>Methacrylic-Acryl acid</td>
<td>55 110 90 75 4.0 130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7B</td>
<td>VEU</td>
<td>Dialkox (halogenated) Bisphenol A (min 90 mol-%) Alkox (meth)acrylate</td>
<td>Ethylenedicarboxylic acids</td>
<td>50 120 105 75 3.5 130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>VE</td>
<td>Epoxidised-Novolak</td>
<td>Methacrylic-Acryl acid</td>
<td>50 150 120 75 2.5 130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{1)} Ethylen-, 1,2-propylene-, diethylene-, dipropylene-, neopentylglycol, 1,3-butandiol 1,4-butandiol and corresponding halogenated glycols

\textsuperscript{2)} May also contain cyclic unsaturated hydrocarbons.

\textsuperscript{3)} Related to the sum of the diol components.
## Table 4: Test methods for determination of cured resin properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barcol hardness</td>
<td>EN 59</td>
</tr>
<tr>
<td>Density</td>
<td>ISO 1183</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>EN ISO 527</td>
</tr>
<tr>
<td>Tensile strain at break</td>
<td>EN ISO 527</td>
</tr>
<tr>
<td>Modulus of elasticity in tension</td>
<td>EN ISO 527</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>EN ISO 178</td>
</tr>
<tr>
<td>Modulus of elasticity in flexure</td>
<td>EN ISO 178</td>
</tr>
<tr>
<td>Heat deflection temperature</td>
<td>EN ISO 75-2 Method A</td>
</tr>
<tr>
<td>Glass transition temperature&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>ISO 6721-2</td>
</tr>
</tbody>
</table>

<sup>1</sup) Optional property
5 Curing agents for unsaturated polyester and vinyl ester resins

5.1 General

Both unsaturated polyester and vinyl ester resins cure by a free radical polymerisation mechanism. To start the process radicals are generated by the addition of an initiator (e.g. organic peroxide) and an accelerator or promoter to liberate, at a sufficient rate, a supply of free radicals to allow the polymerisation to initiate.

The resin and/or cure system manufacturer shall state the compatibility of the curing system with the resins, shall give recommendations on the quantities and conditions of use and shall state any limitations on use in service.
### Table 5: Textile glass types

<table>
<thead>
<tr>
<th>Glass type</th>
<th>Chemical characterisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Alumina-borosilicate glass, ( \leq 1 % ) alkali content</td>
</tr>
<tr>
<td>E-CR</td>
<td>Alumina-limesilicate glass, ( \leq 1 % ) alkali content</td>
</tr>
<tr>
<td>AR</td>
<td>Zirconium-lime glass, ( \approx 15 % ) ( \text{ZrO}_2 )</td>
</tr>
<tr>
<td>A</td>
<td>Alkali-lime glass, little or no Boron content, ( \approx 15 % ) Alkali content</td>
</tr>
<tr>
<td>C</td>
<td>Alkali-lime glass, ( \approx 8 % ) Alkali content</td>
</tr>
</tbody>
</table>
En 13121 Part 2 – Composite materials – Chemical resistance

<table>
<thead>
<tr>
<th>Protective layer</th>
<th>Required thickness mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPL</td>
<td>0.4 to 0.6</td>
</tr>
<tr>
<td>CRL</td>
<td>2.5 to 4.0</td>
</tr>
<tr>
<td>PVC-U</td>
<td>3.0 to 4.5</td>
</tr>
<tr>
<td>PP-H, -B, -R</td>
<td>3.0 to 6.0</td>
</tr>
<tr>
<td>PVDF</td>
<td>2.4 to 4.0</td>
</tr>
<tr>
<td>E-CTFE, FEP, PFA</td>
<td>1.7 to 4.0</td>
</tr>
</tbody>
</table>

- a chemical resistant layer (CRL) of a single or double veil layer (VL), followed by a layer of either chopped strand mat or sprayed fibres with a total mass per unit area greater than or equal to 900g/m²;

- the fibre content shall be between 25 % and 35 % by mass;

- following the veil layer (VL), the subsequent chopped strand mats or sprayed fibre layers shall be applied before cure.
En 13121 Part 2 – Composite materials – Chemical resistance

Figure 1 — Determination of partial design factor $\lambda_1$
**En 13121 Part 2 – Composite materials – Chemical resistance**

### Table A.3 — Maximum design temperature $T_D$ for category 2 media

<table>
<thead>
<tr>
<th>Medium</th>
<th>CRL $T_D$ °C</th>
<th>PVC-U $T_D$ °C</th>
<th>PP-H, PP-B, PP-R $T_D$ °C</th>
<th>PVDF, E-CTFE $T_D$ °C</th>
<th>FEP, PFA $T_D$ °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adipic Acid, aq</td>
<td>80</td>
<td>45</td>
<td>80</td>
<td>25</td>
<td>80</td>
</tr>
<tr>
<td>Alcohols (2 to 10 C-atoms), ≤ 20 % aq a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. Ethanol</td>
<td>60</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Isobutanol</td>
<td>40</td>
<td></td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Isodecanol</td>
<td>60</td>
<td></td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>50</td>
<td>25</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Propanol</td>
<td>60</td>
<td>25</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Benzoic Acid, aq</td>
<td>80</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Boric Acid, aq</td>
<td>80</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Citric Acid, aq (≤ 50 %)</td>
<td>80</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Glycols</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. Butanediol 1,2</td>
<td>80</td>
<td>25</td>
<td>25</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Butanediol 1,3</td>
<td>80</td>
<td></td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Butanediol 1,4</td>
<td>80</td>
<td>25</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Diethylene Glycol</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Dipropylene Glycol</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>80</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Glycerin</td>
<td>80</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Neopentyl Glycol</td>
<td>65</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>1,2-Propylene Glycol</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Triethylene Glycol</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Tripropylene Glycol</td>
<td>65</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Hydrocarbons (5 to 10 C-atoms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. Pentanes/Pentenes (≤ 50 °C)</td>
<td>70</td>
<td>25</td>
<td>25</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Hexanes/Hexenes (≤ 50 °C)</td>
<td>70</td>
<td>25</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Heptanes/Heptenes</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Octanes/Octenes</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Nonanes/Nonenes</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Decanes/Decenes</td>
<td>80</td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>
En 13121 Part 2 – Composite materials – Chemical resistance

<table>
<thead>
<tr>
<th></th>
<th>SPL</th>
<th>CRL</th>
<th>Structural Laminate</th>
<th>$A_2$</th>
<th>$A_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_0 \leq 30 ^\circ C$</td>
<td>1B,2-8</td>
<td>1B,2-8</td>
<td>1-8</td>
<td>1,2</td>
<td>1,3</td>
</tr>
<tr>
<td>$30 ^\circ C &lt; T_0 \leq 40 ^\circ C$</td>
<td>2-8</td>
<td>2-8</td>
<td>1-8</td>
<td>1,3</td>
<td>1,4</td>
</tr>
<tr>
<td>$40 ^\circ C &lt; T_0 \leq 60 ^\circ C$</td>
<td>use other methods</td>
<td>3-8</td>
<td>3-8</td>
<td>1,4</td>
<td>use other methods</td>
</tr>
<tr>
<td>$60 ^\circ C &lt; T_0 \leq 80 ^\circ C$</td>
<td>use other methods</td>
<td>6-8</td>
<td>6-8</td>
<td>1,4</td>
<td>use other methods</td>
</tr>
</tbody>
</table>

NOTE: Numbers 1A-8 see table 2 of prEN 13121-1.
En 13121 Part 3 – Design and workmanship

a) Conical section with knuckle
EN 13121

- Status of a norm
- It starts to be used
- Resin Supplier provide data to answer part 1 and to help with A2 partial factor determination as well as for the resin choice and corrosion resistant liner design
Chemical & Physical Degradation Mechanisms of FRP

- Degradation of physical nature due to absorption, permeation, solvent action etc.
- Oxidation, where chemical bonds are attacked
- Hydrolysis, where ester linkages are attacked
- Thermal degradation, involving de-polymerization
- Combinations of these mechanisms and others
Example Hot Caustic Pipe

Laminate section from pipe after 10 years of hot caustic service:

The Chemical Resistance (CR) Barrier is whitened 1.6mm deep only, out of 3mm total (411-45)
Example Hot Caustic Pipe
Wrong Chemical Barrier Design

Laminate section from pipe after 5-10 years of hot caustic service:

DERAKANE 411 Resin is the resin of choice for hot alkalis,

DERAKANE 470 Resin is more suitable for hot gases, oxidisers, strong acids, and solvents.
Example Pipe Connection
Wrong Chemical Barrier Design

FRP Pipe Connection
Corrosion of EVER Resin by an aromatic solvant:
Swelling and color change
Evaluation Of Corrosion Resistance

• ASTM C 581 Standard

• Corrosion Barrier is Tested
  12 months with evaluation at 1, 3, 6 & 12 months

• Evaluation of Test Coupons
  Barcol Hardness & Appearance
  Flexural Strength & Modulus
  Weight & Thickness

• Concentration and Temperature Limits are derived from the Results
ASTM C-581 Standard Construction

1 or 2 Ply Veil

2 or 3 Ply 450g/ m²
Chopped Glass Mat
ASTM C-581 Test Set-Up
DERAKANE Chemical Resistance Guide

Over 1000 Chemicals across the entire DERAKANE resin family
## DERAKANE Chemical Resistance Guide

<table>
<thead>
<tr>
<th>Chemical Environment</th>
<th>Concentration</th>
<th>DERAKANE 411°C/°F</th>
<th>DERAKANE 441°C/°F</th>
<th>DERAKANE 470°C/°F</th>
<th>510A/C °C/°F</th>
<th>510N °C/°F</th>
<th>8084 °C/°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Fat</td>
<td>100</td>
<td>80/180</td>
<td>100/210</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anionic Surfactant</td>
<td>All</td>
<td>40/100</td>
<td>50/120</td>
<td>50/120</td>
<td>40/100</td>
<td>50/120</td>
<td></td>
</tr>
<tr>
<td>Anionic/Cationic Polymer Emulsions in Kerosene or Petroleum Distillates/Water</td>
<td>0 - 50</td>
<td>40/100</td>
<td>50/120</td>
<td>50/120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anodize (15% Sulfuric acid)</td>
<td>0 - 50</td>
<td>100/210</td>
<td>100/210</td>
<td>100/210</td>
<td>100/210</td>
<td>100/210</td>
<td></td>
</tr>
<tr>
<td>Antimony Pentachloride, for aqueous solutions</td>
<td>&gt; 99</td>
<td>40/100</td>
<td>40/100</td>
<td>40/100</td>
<td>40/100</td>
<td>40/100</td>
<td>40/100</td>
</tr>
<tr>
<td>Hydrochloric Acid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aqua Regia*</td>
<td>100</td>
<td>40/100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Armeen* H.T. Amines (C8-C18)</td>
<td>100</td>
<td>40/100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Naphtha/ Naphthalene/isopropanol</td>
<td>60/5/10</td>
<td>50/120</td>
<td>50/120</td>
<td>50/120</td>
<td>50/120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arseric Acid</td>
<td>&gt; 0.5</td>
<td>80/180</td>
<td>80/180</td>
<td>80/180</td>
<td>80/180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arseric Acid/Copper Sulfate/ Sodium Dichromate</td>
<td>17/37/20</td>
<td>80/180</td>
<td>80/180</td>
<td>80/180</td>
<td>80/180</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*ASHLAND*
DERAKANE Resin Selection

- Chemicals
- Concentrations (Max./Min.)
- Temperatures (Operating/Max./Min.)
- Upsets
- Flame Resistance
- Abrasion
- Insulation
- Manufacturing Process
Typical Laminate Sequence For Corrosion Service – Filament Wound

- CSM two or more ply of ~350-450 g/M² Total Thickness of Corrosion Barrier (2.5 – 6.3 mm or more) or sprayed roving
- Resin rich surface
- Corrosion Veil – 0.5 mm thickness (C or ECR Glass, Synthetic, Carbon)
- Exterior Top Coat – May Contain Pigment, U.V. Inhibitor, or Veil
- One Mat Ply Over Cured Liner
- Filament Wound with Continuous Roving
- Process Side
- Corrosion Barrier Portion
- Structural Portion
Corrosion Resistant Barrier Design

• The corrosion barrier is a critical component of fiberglass-reinforced plastic (FRP) designed for service in chemical environments. It is a sacrificial layer.

• So its thickness can often be directly related to the service life of the FRP part.

• A number of standards have been written to specify the minimum requirements for the thickness and composition of a corrosion barrier for service in liquid chemical environments.

• We present an overview of existing standards and how they impact the number of layers of chopped strand mat that are required to meet these standards.
# Corrosion Resistant Barrier Design

<table>
<thead>
<tr>
<th>Standard</th>
<th>Minimum Thickness</th>
<th>Minimum Layers</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASME RTP-1-2005</td>
<td>100 mils (2.5 mm)</td>
<td>Veil between 10 and 20 mils (0.25 and 0.5 mm), 2 layers of total 3 oz/ft² (900 g/m²), CSM or chopped/sprayed</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. This has priority over the number of layers to reach the required thickness. This standard specifies the veil layer.</td>
</tr>
<tr>
<td>EN 13121-2 2003</td>
<td>2.5 mm (100 mils)</td>
<td>1 or 2 Veils, 1 or 2 layer(s) of total 900 g/m² (3 oz/ft²) CSM, 25 % to 35 % glass content, by weight</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. This has priority over the number of layers to reach the required thickness. This standard specifies the veil layers and the glass content.</td>
</tr>
<tr>
<td>NF T 57900 1987</td>
<td>2.5 mm (100 mils)</td>
<td>Veil of minimum 0.25 mm, 2 layers of 300 g/m² (1.0 oz/ft²) CSM</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. This has priority over the number of layers to reach the required thickness. This standard severely overestimates the thickness obtained with 2 CSM of 300 g/m².</td>
</tr>
<tr>
<td>BS 4994 1973</td>
<td>Not specified</td>
<td>Veil between 0.25 and 0.5 mm, 1200 g/m² (4.5 oz/ft²) CSM, 25 % to 33 % glass content, by weight</td>
<td>Minimum thickness is not specified. The total weight of the CSM layers is considered sufficient to reach the required thickness of 2.5 mm / 100 mils. This standard specifies the veil layers and the glass content.</td>
</tr>
<tr>
<td>BS 6464 1984</td>
<td>Not specified</td>
<td>Veil between 0.25 and 1.0 mm, 900 g/m² (3 oz/ft²) CSM, 25 % to 33 % glass content, by weight</td>
<td>Minimum thickness is not specified. The total weight of the CSM layers is not considered sufficient to reach the required thickness of 2.5 mm / 100 mils. This standard specifies the veil layers and the glass content.</td>
</tr>
</tbody>
</table>
## Corrosion Resistant Barrier Design

<table>
<thead>
<tr>
<th>Standard</th>
<th>Minimum Thickness</th>
<th>Minimum Layers</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN 18820-3 : 1991</td>
<td>2.5 mm (100 mils)</td>
<td>V/CSM, max. 30 % glass content, by weight</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. The number of CSM layers is not specified. This standard specifies the veil layers and the glass content.</td>
</tr>
<tr>
<td>DIN 16965-4, Pipe Type D</td>
<td>2.5 mm (100 mils)</td>
<td>V/CSM, 25 - 30 % glass content, by weight</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. The number of CSM layers is not specified. This standard specifies the veil layers and the glass content.</td>
</tr>
<tr>
<td>DIN 16965-5, Pipe Type E</td>
<td>2.5 mm (100 mils)</td>
<td>V/CSM, 25 - 35 % glass content, by weight</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. The number of CSM layers is not specified. This standard specifies the veil layers and the glass content.</td>
</tr>
<tr>
<td>AS 2634 1983</td>
<td>2.5 mm (100 mils)</td>
<td>V/CSM, 20 - 30 % glass content, by weight</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. The number of CSM layers is not specified (E-Glass is specified, 6-900 g/m2 considered sufficient). This standard specifies the veil layers and the glass content.</td>
</tr>
<tr>
<td>NBS PS15-69</td>
<td>2.5 mm (100 mils)</td>
<td>V/CSM, 20 - 30 % glass content, by weight</td>
<td>Minimum thickness of 2.5 mm / 100 mils is specified. The number of CSM layers is not specified. This standard specifies the veil layers and the glass content.</td>
</tr>
</tbody>
</table>
Corrosion Resistant Barrier Design

- As can be seen in the table above, all the standards except for two require a minimum corrosion barrier thickness of at least 2.5mm (100 mils).

- If the veil layer is 0.25 mm (10 mils) thick, the chopped glass fiber stand layer must be at least 2.25 mm (90 mils) thick. If chopped strand mat is being used, the total thickness of the mats must be at least 2.25 mm (90 mils) thick.
Corrosion Resistant Barrier Design

• When using chopped strand mat, the thickness can vary depending on the supplier. Therefore, it is important to measure the actual thickness of the corrosion barrier after the resin has cured.

• This can be done by measuring cutouts of the finished product using a micrometer or similar device. The surface of the cutout needs to be sanded until smooth and polished so that accurate measurements can be taken.

• The above recommendation also applies to corrosion barriers made with chopped roving. To make sure that the minimum thickness has been applied, it is recommended that the corrosion barrier thickness is measured as described above.
Corrosion Resistant Barrier Design

• Current standards require corrosion barriers with a minimum thickness of 2.5 mm (100 mils). Prior to 1999, two layers of 450 g/m² (1.5 oz/ft²) CSM was usually sufficient to meet the requirement.

• This is not necessarily the case today. The only way to insure that these standards are being met is to measure the corrosion barrier thickness on a finished part.
CONCLUSION

• In Order to Develop The FRP Corrosion Resistant Industry Standards and Design Codes are very important to design and manufacture the correct equipment
• The correct use of Industry Standards and Design Codes will also build trust and confidence amongst the buyer and users of FRP Corrosion Resistant Equipment
Corrosion Resistant Composite Applications based on DERAKANE* Epoxy Vinyl Ester Resins

- Mining & Metal – M&M
- Flue Gas Cleaning - FGD
- Special Cases
M&M - Tower Washer In Copper Mining Industry

- Two (2) towers installed in Poland
- Operating conditions 60°C and 80°C
- Environment 50-60% sulfuric acid
- DERAKANE® 411 resin for 60°C tower
- DERAKANE® 470 resin for 80°C tower
- Replaced lead lined steel
M&M - Mixer Settler Tanks
Uranium (SX) Plant

- Tanks hold sulfuric acid leach liquor
- Uranium is selectively extracted using amine/kerosene solvent in mixer tanks
- DERAKANE® 411 resin
- Tanks hold up to 150 cubic meters
- Installed in Australia
M&M – Goro Nickel New-Caledonia

Nickel Extraction, Wet process based on solvents and acids DERAKANE resins selected for the plant
FGD – Chlorine Gas Handling

DOW Stade, D

Equipment:
Chlorine Cooling Tower

Cl₂-gas; 95 vol.%; NaCl 300 g/l; traces of hypochlorite; 40 °C

Dimension: 13 m high

DERAKANE* 470

In service 1971-1995 and replaced with same design and resin type.
FGD – Flue Gas Cleaning

The World largest Scrubbers at PCK refinery in Schwedt, D
300 tons weight
49 m high, 9 m diameter
DERAKANE* 411 / 470
In service since 1997.
FGD – Hot Gases Quench
DERAKANE 470HT-400

Quench for Flue Gas / Municipal Waste Incinerator, Alkmaar (NL)

Environment:
Flue Gas (including HCl, HF, SO₂, SO₃, NOₓ, Dust etc.)

T = 210–230 º C

Fabricator: ACS
Year: 1995
Flue Gas Stack Liner at Simmering / Vienna (A)

Environment: Flue Gas after Desulfurisation
Size: 4.8 m x 164 m, electrical pre-heating

\[ T_{\text{Operating}} = 90^\circ\text{C} \]
\[ T_{\text{Bypass}} = \text{ca.} 180^\circ\text{C} \]
\[ T_{\text{Upset}} = 3 \text{ h at} 200^\circ\text{C} \]

Fabricator: Fiberdur-Vanck
Year: 2000

ASHLAND
FGD – Hot Gases Chimney
DERAKANE 470HT-400

Flue Gas Stack Liner at Simmering / Vienna (A) – Electrical Heating
Special Cases – Gas Cylinders

Full FRP Gas Bottle for natural gas, lightweight & translucent

DERAKANE 8090

In service since 1997
Special Cases – Gas Cylinders with New Design

*Composite Scandinavia Leaflet
Special Cases – Polymer Concrete

Polymer concrete electrolytic cell for copper refining; empty weight 11,000 kg; Medium 20 % sulphuric acid at 65 °C; DERAKANE* MOMENTUM* 411-350. In service since 1998.
Special Cases - Infrastructure
Special Cases – Windmill Blades

Rotor blades for wind turbines DERAKANE 411-45 resin, and now new DERAKANE 603

In service since 1996.

Blades at test rig
Thank You For Your Attention

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