FABRICATION GUIDELINES

Slide 1 Fabrication Guidelines AOC VIPEL Corrosion Resistant Resins

Slide 2 Terminology – FRP FIBERGLASS REINFORCED PLASTIC; RTP REINFORCED THERMOSET PLASTIC; GRP GLASS REINFORCED PLASTIC

Slide 3 Composites – RESIN CONTROLS CORROSION AND FIRE RETARDANCY; REINFORCEMENT CONTROL STRENGTH (GLASS FIBERS); CATALYST CONTROLS CURE

Slide 4 Picture of resin being poured onto glass mat.

Slide 5 Catalyst

Catalyst is mixed into promoted resins immediately prior to use by hand lay-up or in the wet out bath when filament winding. Catalyst is injected into the promoted resin stream in spray-up equipment systems.

Catalyst is NEVER mixed with promoters or accelerators. Direct contact of a catalyst with a promoter or accelerator can create an explosive condition or cause a fire. Consult the MSDS for each of these materials for safe handling and storage.

MEKP (methyl ethyl ketone peroxide) is the most commonly used organic peroxide. MEKP provides 9% active oxygen. MEKP is used with CoNAP promoter and DMA/DEA accelerators for room temperature curing of most polyester and vinyl ester resins. Concentration of isomers/active oxygen variations of MEKP can provide additional cure flexibility with some resin and promoter systems.

CHP (cumene hydroperoxide) is principally used with high reactivity vinyl ester resins such as Vipel F085 to provide lower exotherm temperatures and reduced shrinkage. CHP performs well with CoNAP/DMA formulations. CHP is also suitable for some other resins where slower cures are required or thicker laminates are made in a single pass without intermediate cure and exotherm stopping points.

BPO (benzoyl peroxide) is available in powder form, as a paste or in a liquid emulsion. Powders and pastes are difficult to use and control. When BPO is required, emulsions with 40% active BPO content are to be used with caution when used with Vipel® vinyl ester resins. Failures in the field were contributed to the water vehicle in the 40% BPO. BPO (paste) catalyst with DMA accelerator is preferred for laminates in sodium hypochlorite service in place of conventional MEKP/CoNAP/DMA cure systems. The ratio of BPO to DMA is critical to avoid gel and cure inconsistencies. Post curing with dry heat is recommended to achieve complete cure with BPO/DMA. TBPB at 0.1 to 0.2% helps maximize cure during post cure.

Blended catalysts.

Proprietary blends of catalyst that reduce foaming in some vinyl ester resins are available. Trigonox® 239A (Akio Chemicals, Inc.) and CHP-5 (Crompton formerly Witco Chemical Company) are proprietary blends of CHP that reduce foaming in some vinyl ester resins.

Slide 6 Promoters and Accelerators

CoNAP (cobalt naphthenate) promoter is available with 6% cobalt in an organic solvent solution. The 6% solution is the most commonly used. The formulations provided on slides 11 & 12

DMA (N.N di-methylaniline) is used as an accelerator in conjunction with Co Nap promoter when using MEKP or CHP catalysts or by itself with BPO. DMA is normally provided as a 100% active solution.

DEA (N,N di-ethylaniline) can be substituted for DMA in some systems to extend gel times and reduce exotherm temperatures in highly reactive systems. With respect to health safety, DEA is marginally safer than DMA. Consult the MSDS for current status.

Slide 7 Inhibitors and Gel Time Extenders

TBC (tertiary butyl catechol) is an inhibitor frequently added to styrene monomer to provide longer shelf life when the monomer is purchased in drum quantities. When any styrene containing TBC is added to promoted resin mixes, the resin gel time and cure characteristics may be altered. TBC as purchased is usually 85% active inhibitor and should be used very carefully. A very small amount of TBC can have a significant and inconsistent impact on gel and cure. Addition of small quantities is best controlled using a 5 or 10% solution in styrene and adjusting formulations accordingly. Care must be taken to prevent TBC solutions from contacting the skin. Refer to the MSDS.

2,4 P (2,4-pentanedione or acetylacetone) is a gel time extender or retarder for vinyl ester resins; however, it is also a promoter for polyester resins. 2,4P is recommended for long gel times because it has minimal effect on the ultimate cure. It is effective for MEKP and CHP catalyst systems but is not effective with BPO catalyst systems. Caution is needed using 2.4P. Refer to the MSDS for handling instructions. One of the tables in the Appendix of this publication demonstrates a formulation based on Viper' F010 where gel time has been adjusted through the use of 2,4P.

The addition of HQ (hydroquinone) and THQ (toluhydroquinone) inhibitor are acceptable in most AOC resins.

Calculating 100ppmTHQ inhibitor for a 450lb. drum = 100x10-6 x 10(10% solution) x 454 x 450 = 204.3 grams will extend gel time 3-5 minutes. (454grams = 1 lb.)

Copper Naphthenate 8% is an exotherm suppressant.

Slide 8 Other Resin Additives

Other chemicals and materials may be added to the resin formulation to achieve specific end-use requirements. Fabricators should review the appropriate literature and check with an AOC technical representative and the additive supplier to see how a particular additive may affect resin processing or performance. Fillers can accelerate or inhibit resin cure.

Ultraviolet absorbers are often added for applications that must resist the degrading effects of long-term exposure to sunlight. UV absorbers are used on the exterior portion of the laminate and where specified by the buyer. Most specifications define the amount and type of UV absorber. Consult AOC Technical Service for a recommendation of UV absorbers. UV absorbers are most commonly added to the top coal but may be added at a lower loading to the reinforcement layer.

Flame retardants are often used to meet specifications calling for Underwriters Laboratory ASTM E-84, Factory Mutual, or similar code recognition. The most common class of fire retardant fillers that are used are antimony oxides. These products are normally used with halogenated resins to enhance the flame retardant properties. Addition of these products to non halogenated resins does not improve the flame resistance significantly.

Antimony (Fire Retardant Synergist with halogenated resins)

Antimony trioxide has been the most common product and it should be incorporated with a high shear mixer in order to ensure that the particles are suitably dispersed into the resin.

For fabricators who do not have high shear equipment available, liquid dispersions of antimony pentoxide can be used. Since the liquid dispersions such as Nyacol 3040 are only 40% active, this dilution factor must be taken into account. The Nyacol is dispersed in a non corrosion resistant resin and this should be taken into consideration for some severe corrosion applications. Generally antimony oxides are not incorporated into the corrosion barrier so this is not normally a concern. Some grades of antimony trioxide have been known to cause gel drift. Thus any antimony oxide product should be added to the resin just prior to fabrication

One significant advantage of using a liquid dispersion such as Nyacol® 3040 is that the laminate is not as opaque. Thus the removal of air bubbles from a resin containing Nyacol® 3040 is much easier than removing air bubbles from an antimony trioxide filled resin.

Laminate samples:

1. Vipel K022-CCC-00 control with no FR additive

2. Vipel K022-CCC-00 with 1.5% antimony trioxide

3. Viplel K022-CCC•00 with 1.5% Nyacol 3040

4. Vipel K022-CCC-00 with 3.75% Nyacol 3040 in a dispersion of 40% antimony fillers

(Note: Sample 2 and Sample 4 have the same concentration of antimony products) Alumina Trihydrate

Alumina trihydrate is used to improve flame retardancy and reduce smoke emissions of specific resin systems.

Alumina trihydrate is a fine, white powdered filler which, when added in the proper amount, can improve flame retardancy of both halogenated and non-halogenated resin systems. When a properly filled laminate is exposed to fire,the alumina trihydrate decomposes into water vapor and anhydrous alumina. The water vapor cools the laminate thus slowing the rate of decomposition or burning.

Alumina trihydrate differs from antimony trioxide in several ways. As mentioned earlier, antimony trioxide is effective only with halogenated resin systems and is used in small percentages. Alumina trihydrate can be effective with both halogenated and non-halogenated resin systems but much higher filler loadings are required to achieve the desired flame retardance. Consequently, alumina trihydrate can not be used directly in place of antimony trioxide. The addition of high levels of alumina trihydrate can produce a higher viscosity system and reduce the physical properties of the laminate. It can also reduce smoke emissions, especially in non-halogenated systems.

The addition of alumina trihydrate to the corrosion barrier can result in a significant reduction in corrosion resistance. Before using alumina trihydrate in corrosion applications, contact AOC Technical Service for specific recommendations.

Graphite

We recommend 25% loading of Dixon Ticonderoga #635 graphite in conjunction with two plies of 5mil carbon veil to render conductivity in a composite.

Pigments

Pigments add inherent color to the finished part. Pigments are not widely used in the fabrication of corrosion resistant equipment but may be incorporated to meet specific safety or marketing requirements. AOC's Chroma-Tek® pigment dispersions are recommended if color is desired. The Chroma-Tek® product line includes colorants that meet FDA requirements. No pigments or fillers should be used in the corrosion liner of an FRP composite laminate.

Fillers

Fillers, usually inorganic or inert materials, can favorably affect surface appearance, moldability and the cost of many composite parts. So that end-use performance properties may be fully derived from the base resin, fillers are rarely used in a corrosion resistant composite application. Occasionally, inert conductive fillers such as carbon black will be added to a resin in order to meet electrical conductivity requirements. Abrasion resistance of the composite can be improved through the use of hard, inert fillers such as silicon carbide.

Thixotropes

Resins can be thixed with products such as Cab-O-Sil® TS-720 or Aerosil® 202. However, it is recommended that these thix agents be used only to make putty because of the negative influence on some corrosion resistant environments of the composite. Wetting agents such as ethylene glycol and Triton X 100 should be added before the Cab-O-Sil. Recommend adding 0.4 phr wetting agent and

0.8phr of fumed silica. Add silica to vortex of high shear and mix for 15 minutes. Monitor temperature and keep temperature under 90F. If temperatures exceed 90F the hydrogen bonding will be destroyed resulting in loss of thixtropy.

Mold Releases

Mold Releases are used to ensure that the part comes off the mold. A variety of mold releases, such as Mylar films, are available. As a general rule for corrosion-resistant applications, mold releases are not added to the resin formulation but applied externally to the tooling.

Abrasion Resistant Additives

An abrasion resistant corrosion liner is necessary when operating conditions involve slurries or other applications with abrasive particles that can abrade the corrosion liner. When used correctly, silicon carbide and aluminum oxide have been effective in reducing liner deterioration caused by abrasion.

A mixture of resin and silicon carbide or aluminum oxide should be made and catalyzed based on resin weight.

The use of carbon veil in place of "C" glass veil or synthetic veil has also been shown to improve abrasion resistance. AOC Technical Service can be contacted for additional information on improving abrasion resistance

Air Release Agents

Air release agents can be added to the resin (0.05-0.2%) to decrease foaming. Excessive levels of air release agents can cause a laminate to be cloudy, therefore recommended levels should not be exceeded. Contact AOC Technical Service for additional information.

Wax Topcoats

Some resins are subject to surface inhibition when cured in the presence of air. Air inhibition affects the cure and corrosion resistance of the outermost resin layer, which results in an acetone sensitive, potentially tacky surface. A wax-containing topcoat approximately 2.0-3.5 mil applied to the outermost resin surface can help prevent air inhibition. As the resin cures, the wax migrates to the surface of the laminate, hardens and prevents air from reaching the laminate. In conditions under hot sunlight, the wax topcoat may be ineffective. A resin/wax solution should never be applied between laminate layers, this could result in poor secondary bonding and premature failure.

The wax/styrene solution is made by dissolving 20 grams of a fully refined paraffin wax (melting point = 130-140°F (54-60°C)) in 180 grams of warm styrene (110°F (43°C)). The solution is then added at the rate of 2% to the resin and mixed thoroughly. The resin solution should then be promoted and catalyzed as normal. Predissolved wax solutions are also available from fiberglass distributors.

Slide 9 Preparing the Resin

In order to fabricate equipment correctly, the resin must be prepared properly and in a safe manner. Below are several steps that should be followed when preparing the resin.

1. Estimate the amount of time required for fabrication. Remember to take into account resin and air temperature - warmer temperature - faster cure, cooler temperature - slower cure. The viscosity of the resin can also be affected by temperature.

2. If utilizing a neat resin and adding a thixotrope, the thixotrope should be added to the resin and agitated using a high shear mixer until the desired thixotrope index has been achieved. High shear agitation generates heat, therefore, this step should be done before adding any promoters.

3. Using the promoter / catalyst addition tables as guidelines, choose the appropriate additive levels to achieve a suitable working time.

4. Weigh the required amount of resin, cobalt, DMA, and if applicable, inhibitors (predissolved in styrene or other appropriate solvent) into separate containers. A conversion table is shown on slide 13 that may be helpful when measuring materials volumetrically.

5. Add the cobalt to the resin and mix thoroughly using an air driven mixer under slow to moderate agitation. During all mixing, care should be taken to minimize air entrapment in the resin. Excessive air bubbles in a laminate can cause a reduction of physical and corrosion properties.

6. Add the DMA or DEA and mix thoroughly.

7. Add any additional liquid materials such as inhibitors and mix thoroughly.

8. Add any pigments or fillers such as antimony trioxide, alumina trihydrate, etc. and mix thoroughly.

9. After all ingredients have been added, the drum should be mixed thoroughly.

10. After mixing in required promoters and fillers, a sample of resin should be removed and a gel time test performed. Again, refer to the designated promoter / catalyst table for recommended catalyst level.

11. The gel time can be lengthened by adding an inhibitor or shortened by adding additional cobalt or DMA, however, do not exceed the recommended levels for that resin.

12. Catalyze the resin as needed.

13. If the exotherm of cure is too hot, copper naphthenate can be added to control this. The gel time will not be effected if using a standard MEKP. If more than a combined 400 ppm copper naphthenate and inhibitor is added to the resin, a full cure may not be possible. Contact AOC Technical Service for further guidelines.

Slide 10 VIPEL Resin and Conversion Charts See below

Slide 11 Weight to Volume Conversion Tables for Cobalt Naphthenate 6% and DMA

Slide 12 Methyl Ethyl Ketone Peroxide and BPO Conversion Charts

Slide 14 CURE PROPERTIES OF VIPEL F010 SERIES MEKP 50% EXCEPT FOR PROMOTED VERSIONS.

Slide 15 CURE PROPERTIES OF VIPEL F010 SERIES using 98% BPO

Slide 16 CURE PROPERTIES OF VIPEL F013 SERIES using MEKP – 50%

SLIDE 17 GEL TIMES FOR VIPEL K022ACA USING MEKP

Slide 18 Gel times for VIPEL K022ACA using BPO

Slide 19 Gel times for VIPEL F085 using CHP

Slide 20 Standard Construction Corrosion Resistant Laminate

Slide 21 FIBERGLASS COMPOSITIONS (WT%)

Slide 22 Surfacing Veil

The purpose of surfacing veil, also referred to as surfacing mat or tissue, is to provide reinforcement for the resin rich inner liner of a corrosion barrier that prevents cracking and crazing. A second, is to prevent protrusion of the chopped strand mat fibers to the surface which could allow wicking of the environment into the laminate to occur.

The primary type of surfacing veil used in corrosion applications is "C"- glass veil. However, in applications where "C"-glass veil is not suitable, other veil types made from thermoplastic polyester or carbon fibers may be used. (We recommend using two 5mil carbon veil followed by 1 “C” veil. Use roller on the “C” veil side only).

"C"-glass veil is typically recommended for most corrosion environments. However, synthetic veil; such as NEXUS, is preferred in some environments such as those containing fluoride compounds. Carbon veil is often used in abrasive environments. When used properly, carbon veil has been shown to provide better abrasion resistance than either "C"-veil or synthetic veil. Carbon veil is also used to provide a conductive liner for static electricity control. For applications where conductivity is not desirable, the use of carbon veil should be reevaluated. Veils made with other types of glasses, such as "A" and "ECR',' are used less often in the corrosion industry but may be acceptable in certain applications. Thorough testing should be conducted in the specific environment before using "A" and "ECR" veil.

Slide 23 FIBERGLASS COMPOSITIONS (WT%)

1. Provides resin rich corrosion barrier and prevents cracking/crazing of resin rich barrier.
2. Types of veils depends upon resin, corrosion environment, and fabrication techniques.
3. Use of multiple veils depends upon corrosion and resin.

Slide 24 Chopped Strand Mat

Two primary types of chopped strand mat are used in the corrosion industry, "E" and "ECR" glass. Chopped strand fibers are generally (12.5 — 50mm) long and, after being chemically treated, are held together by a binder. Together, the glass fiber bundles form the chopped strand mat. Chopped strand mat is available in a variety of weights per square foot: 0.75 oz.,1.5 oz. and 2.0 oz. are used in corrosion applications.

Slide 25 Continuous Strand Roving

Most continuous strand roving comes as unwoven strands of glass wound into a cylindrical package for additional processing. Continuous strand roving is used in filament winding and pultrusion or can be chopped into fibers for spray-up applications to replace chopped strand mat.

Woven Roving

Woven roving consists of continuous glass fiber ravings that are woven together to form a heavy mat which is available in a variety of thicknesses and weights. Alternating layers of woven roving and chopped strand mat are used in the structural portion of hand lay-up laminates.

Slide 26 Biaxial & Uniaxial

Slide 27 Electron microscope view of glass fiber wet out after cure.

Slide 28 Corrosion Resistant Resin Guide

Slide 29 Chemical Resistance at RT

Slide 30 Heat Resistance

Slide 31 Resin Selection depends on the CHEMICALS, CONCENTRATION (MAX./ MIN.), TEMPERATURE (OPERATING-MAX./ MIN.), UPSETS. Does the composite need to be FLAME RETARDANT, require ABRASION resistant or INSULATION? What MANUFACTURING PROCESS should be used?

Slide 32 SUCCESSFUL APPLICATION, RESIN SELECTION, DESIGN / ENGINEERING, WRITING,SPECIFICATIONS, FABRICATION, INSPECTION

Slide 33 INSPECTION OF FRP EQUIPMENT , WHEN SHOULD IT BE DONE? DURING AND AFTER FABRICATION, WHEN RECEIVED AND INSTALLED, AFTER A PERIOD OF USE, CHANGING SERVICE

Slide 34 Typical FRP Fabrication Techniques - HAND LAY-UP , SPRAY-UP, FILAMENT WINDING CONTINUOUS PULTRUSION, RESIN TRANSFER MOLDING, LININGS

Slide 35 Hand Lay-up

Slide 36 Picture wetting out mat.

Slide 37 SPRAY-UP

Slide 38 Chopper Gun

Slide 39 Filament Winding

Slide 40 Picture of filament wing at Beetle Ardmore, OK

Slide 41 Fiberglass roving wet-out

Slide 42 Continuous Pultrusion

Slide 43 RESIN TRANSFER MOLDING

Slide 44 COMPRESSION MOLDING

Slide 45 LINING

Slide 46 INDUSTRY SPECIFICATIONS PIPE

Slide 47 INDUSTRY SPECIFICATIONS FOR FRP EQUIPMENT

Slide 48 INDUSTRY SPECIFICATION FOR FRP EQUIPMENTASME RTP-1, the standard for reinforced thermoset plastic corrosion resistant equipment code; and ASME B31.3 process piping code.

This is available at http://ww ASTM D3299 – Above Ground Vertical Filament Wound Tanks

ASTM D4097 – Above Ground Vertical Contact Molded Tanks

ASTM D2996 – Filament Wound pipe

ASTM D2310 – Machine-made Pipe

ASTM D3982 – Contact Molded Duct and Hoods

ASTM D4024 – Reinforced Thermosetting Plastic (RTP) Flanges

ASTM D6041 – Contact Molded Pipe and Fittings

ASTM D5364 - Chimney Liners

Slide 49 Trouble Shooting Guide for Curing Resins at Room Temperature

Slide 50 VISUAL ACCEPTANCE CRITERIA FOR CURED LAMINATES

Slide 51 VISUAL ACCEPTANCE CRITERIA FOR CURED LAMINATES

Slide 52 VISUAL ACCEPTANCE CRITERIA FOR CURED LAMINATES

Slide 53 Advantages - No Electrochemical Corrosion, High Strength and Stiffness for Low Weight, Tailored Mechanical Properties, Tailored Corrosion Resistance

Slide 54 FRP VERSUS STEEL

Slide 55 THANK YOU FOR SPECIFYING AOC VIPEL®, THE PROVEN CORROSION FIGHTER, www.corrosionresins.com; or contact: Corrosion@aoc-resins.com or Douglas Raine at douglas@fgbt.org