DERAKANE™ FABRICATION GUIDE

A GUIDE TO FABRICATING FRP COMPOSITES

INEOS Composites

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DERAKANE™ EPOXY VINYL ESTER RESINS

INEOS Composites Derakane™ epoxy vinyl ester resins provide excellent chemical and corrosion resistance coupled with outstanding heat performance and toughness – qualities that have made them the materials of choice for a wide range of fiber-reinforced plastic (FRP) applications. Derakane™ resins can be used with conventional fabricating techniques to produce durable and dependable structures that require little maintenance over a long service life.

This guide serves as an introduction to working with Derakane™ resins and selecting the most appropriate additives for room-temperature contact-molding-type applications. We developed this guide to help fabricators choose the most effective combinations of Derakane™ resins and reinforcements to produce corrosion-resistant composites for a variety of end use applications.

The FRP industry has a wide range of needs; therefore, the information that follows is general and intended to serve as a basic guide to working with these products. Advice on the selection of resins for specific corrosive services is beyond the scope of this guide. For additional guidance, we recommend the Resin Selection Guide for Chemical Resistance, Derakane™ Epoxy Vinyl Ester Resins. Specific material selection guidance and recommendations are available by contacting Derakane™ Technical Service at derakane@ineos.com.

For more information about Derakane™, Derakane™ Momentum™, and Derakane™ Signia™ resins, please contact your INEOS Composites sales representative or distributor, visit ineos.com/composites, or email us at derakane@ineos.com. We want to be your resource of choice and encourage you to reach out with questions or comments.

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CONTENTS

Section 1

Section 2

Section 3

Section 4

Section 5

Section 6

Section 7

Section 8

Section 9

Section 10

Section 11

Appendix A

Appendix B

Appendix C

Appendix D

SECTION 1

Thermoset Resins

Derakane™ resins are thermosetting resins. They cure by crosslinking between reactive polymers and a reactive diluent, typically styrene. This crosslinking is accomplished via a free radical polymerization reaction that is initiated by the addition of ingredients that readily form free radicals. Formation can be started with heat or by using additives that work at ambient temperatures.

Derakane™ resins begin as a viscous liquid. Once reactive additives are added, the liquid cures irreversibly into a solid polymer network. Cured resins are inherently heat and corrosion-resistant. However, without suitable reinforcement, they may not be strong enough for many applications. Outside of thinner film-coating applications, steps must be taken to add strength to epoxy vinyl ester resins.

Typically, reinforcement is accomplished by adding glass fibers to the resin before curing. The glass fibers strengthen the cured resin, but do not chemically react with it. The resin/glass fiber combination creates a very strong, corrosion and heat-resistant material referred to as FRP.

For consistently high-quality end products, all of the materials used in fabrication must be selected with care, precisely formulated, and used by well-trained workers who are familiar with the special techniques required when working with FRP.

SECTION 2

Reactive Additives

Materials that initiate free radical formation (initiators), cause free radical formation at room temperature (promoters) and adjust resin reactivity (accelerators, inhibitors and retarders) are listed in Table 2.1. Recommended initiator, promoter and inhibitor levels for specific resins can be found on their respective technical data sheet (TDS). Review the associated safety data sheet (SDS) for these additives prior to using them.

Appendix A and B include lists of suppliers for many of the products described in this section. They are not the only suppliers of these products; check with a local distributor for availability in your area.

Initiators	Promoters	Accelerators	Inhibitors	Retarders
Methyl ethyl ketone peroxide (MEKP)	Cobalt naphthenate (6%, 12%) (CoNap)	Dimethylaniline (DMA)	Tertiary butyl catechol (TBC)	2,4-Pentanedione (2,4-P)
Benzyl peroxide (BPO)	Cobalt octoate (CoOct)	Diethylaniline (DEA)	Toluhydroquinone (THQ)	
Cumene hydroperoxide (CuHP)		Dimethylacetoacetamide (DMAA)	Hydroquinone (HQ)	
		Diethylacetoacetamide (DEAA)		

Table 2.1: Common initiators, promoters, accelerators, inhibitors and retarders.

Initiators[1]

Initiators, sometimes erroneously referred to as catalysts, are organic peroxides that work with promoters to initiate the chemical reaction that causes a resin to gel. The amount of time from when the initiator is added until the resin begins to gel is referred to as the "gel time." Initiator and promoter levels can be adjusted to shorten or lengthen the gel time somewhat and accommodate both high and low temperatures. Figure 2.1 shows how a resin system's gel time shortens as the temperature increases.

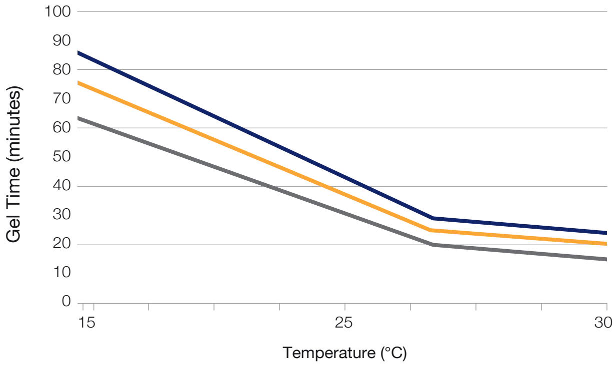


Figure 2.1: Gel time versus temperature.

Two primary types of initiators are recommended for curing Derakane™ resins at room temperature: methyl ethyl ketone peroxide (MEKP) and benzoyl peroxide (BPO). A third, less-common initiator, cumene hydroperoxide (CuHP), is often blended with MEKP and used to lower the exotherm (heat buildup) and extend the gel time of Derakane™ resins. CuHP with cobalt naphthenate/cobalt octoate (CoNap/CoOct 6%) can also be used with rapid cure resins, such as those in the Derakane™ 470 series, to reduce the exotherm temperature.

Fabricators can achieve a range of working times by varying the amount of initiator they use with a resin. However, they must do so with care. If the initiator level is too low, an incomplete cure may occur, which can result in degraded physical properties and reduced chemical resistance. On the other hand, if the initiator level is too high, laminates, and thick laminates in particular, can delaminate, burn, or discolor during curing. Excessive initiator levels may also result in reduced chemical resistance.

Choosing the proper initiator is critical to achieving the expected chemical resistance, and care must be taken not to select initiators that cure too fast or too slow. Under normal/dry conditions, a minimum of 0.1% CoNap/CoOct 6% is suggested for Derakane™ Signia™ resins. Elevated ambient humidity may require higher levels of CoNap/CoOct 6%.

Note: The promoters CoNap/CoOct 6% should never be mixed directly with a peroxide initiator such as MEKP. Direct mixing will result in a violent reaction, and possibly a fire or explosion.

MEKP

MEKP, commonly supplied at 9% active oxygen, is the most widely used initiator system. MEKP is used with promoters, usually 6% CoNap or 6% or 12% CoOct, and accelerators including dimethylaniline (DMA), diethylaniline (DEA), dimethylacetoacetamide (DMAA), or diethylacetoacetamide (DEAA). MEKP will not cure when used only with DMA, DEA, DMAA, or DEAA; a cobalt promoter must be used.

Typically, MEKP initiators are blends of MEKP isomers. MEKP performance varies by brand; common differences include variations in gel time, exotherm temperature, and cure time. In addition to variations due to isomer proportions, significant variations can arise based on resin.

An MEKP brand that works well with one resin may not work well with another. Different results are due primarily to the varying monomer and dimer contents of various peroxides. The following initiator brands have a high dimer content and have shown consistent reactivity and excellent resin cure development when used with Derakane™ resins:

- Luperox®[2] DHD-9
- Norox®[3] MEKP 925 H
- Butanox®[4] LPT-IN

Other brands may work as well, but should be thoroughly evaluated before use. For optimum results with standard Derakane™ resins, it is important to maintain the recommended ratio of MEKP to CoNap/CoOct 6% in the cure system. A minimum ratio of 3:1 (MEKP: CoNap/CoOct 6%) is required. A maximum ratio of 10:1 has also proven satisfactory. Using proportions outside of a 3:1 to 10:1 range may produce a poorly cured laminate with low Barcol hardness and inadequate corrosion resistance. The ratios can be made less critical by using DMA or DMAA as an accelerator.

Note: A minimum of 0.2% CoNap/CoOct 6% is suggested for all standard Derakane™ resins, except Derakane™ 470. A minimum of 0.05% CoNap/CoOct 6% is suggested for Derakane™ Momentum™ resins. Under normal/dry conditions, a minimum of 0.1% CoNap/CoOct 6% is suggested for Derakane™ Signia™ resins. Elevated ambient humidity may require higher levels of CoNap/CoOct 6%.

MEKP should be stored in a well-sealed container to prevent contamination by water. Water in the initiator will adversely affect resin cure. MEKP can be checked for excessive water content by mixing small amounts with equal parts of styrene. A haze in the mixture indicates excessive water.

Certain INEOS Composites resins employ alternate exotherm suppression technologies. Consult the resin TDS or contact our technical service team by phone or email (derakane@ineos.com) for information on local availability and/or alternative initiators.

Non-Foaming MEKP Substitutes for Derakane™ Resins

The use of Trigonox 239[4], CuHP, and Norox CHM-50[3], initiators can eliminate the foaming experienced when Derakane™ and Derakane™ Momentum™ resins are initiated with standard MEKP systems. Derakane™ Signia™ resins experience reduced foaming when initiated with standard MEKP systems.

At ambient temperatures with normal promoter/accelerator systems, Trigonox 239, CuHP and Norox CHM-50 initiators provide a rapid and complete cure with Derakane™ resins. The cure achieved is comparable to that of an MEKP-initiated system. The typical gel time formulations for Trigonox 239, CuHP and Norox CHM-50 are similar to those shown for MEKP with the different Derakane™ and Derakane™ Momentum™ resins.

These MEKP substitutes provide an added benefit when used to initiate Derakane™ 411 series resins: they lower peak exotherm temperatures by 20° to 30 °C (40° to 50 °F), based on 50 g mass, as compared to equivalent MEKP/CoNap/CoOct 6% initiated systems.

Note: Use of non-foaming MEKP initiators lowers the peak exotherm temperatures for Derakane™ 470 and other resins by only about 11 °C (20 °F).

Use the MEKP guidelines when developing formulations with Trigonox 239, CuHP and Norox CHM-50. When using Trigonox 239, CuHP or Norox CHM-50, the addition of 0.1 wt% CoNap/CoOct 6% above the CoNap/CoOct 6% levels recommended in the formulation tables should provide gel times comparable to those of MEKP.

BPO

The initiator BPO is available in powder, emulsion and paste forms for curing all Derakane™ resins. The paste form is the most widely used and is generally supplied in 40–50% active form. Pastes and emulsions are easier to use than powders. An aqueous BPO solution is not recommended for corrosion-resistant applications; our tests have shown that aqueous BPO solutions can compromise corrosion resistance in select environments. BPO pastes tend to settle on standing and should be mixed thoroughly just prior to use to ensure uniformity.

SAFETY NOTE: BPO powder requires special handling. Refer to the BPO SDS for specific safety instructions. BPO should never be mixed directly with DMA or DEA. Direct mixing will result in a violent reaction, and possibly a fire or explosion.

For room-temperature applications, BPO requires the addition of DMA or DEA. (DMAA and DEAA do not work with BPO.) For curing at temperatures above 70 °C (160 °F), BPO is used without DMA or DEA. Since BPO requires only DMA or DEA, it is used in the production of FRP where metallic promoters, such as cobalt, must be avoided. For optimal results with BPO, the ratio should be from 10 to 20 parts (preferably 10 to 15 parts) active BPO to one part DMA. DEA is a less active accelerator than DMA and can be used when longer gel times are required. Optimum ratios are from 4 to 12 parts active BPO to one part DEA.

BPO is not as widely used as MEKP because it is more difficult to mix into resins, may cause higher exotherm temperatures, and is more difficult to fully post cure. However, in sodium hypochlorite environments, a DMA or DEA/BPO cure system is required. The presence of metallic promoters, such as cobalt, in an MEKP cure system accelerates the breakdown of sodium hypochlorite to hypochlorous acid. Hypochlorous acid is much more aggressive toward FRP than sodium hypochlorite and will attack it prematurely.

Note: When cured with DMA or DEA/BPO, Derakane™ 510A or 510B resin will turn a bright yellow when exposed to the sun. This does not affect chemical resistance.

CuHP

CuHP is used less frequently than MEKP and BPO, but can be helpful in lowering laminate exotherm temperatures, especially in thick parts. The use of CuHP is standard with Derakane™ 470 resins and results in lower exotherm temperatures, less shrinkage and less warpage. In cool weather, a small amount of DMA may be used to accelerate curing. Mixing procedures are similar to those used with systems of MEKP and CoNap/CoOct 6%.

The following brands of CuHP have shown consistent reactivity when used to initiate Derakane™ 470 resins: Luperox CU90[2], Curox CuHP[3], and Trigonox[4] K-90. Other brands may work but should be thoroughly evaluated before use.

Promoters[1]

In addition to an initiator, a promoter is required to make a resin cure at room temperature. Safe work practices dictate that the promoter be thoroughly mixed into the resin before adding the initiator. The initiator then reacts with the promoter to cause the resin to gel. Promoter levels can also be adjusted to shorten or lengthen the gel time, as needed.

CoNap or CoOct[5]

Cobalt naphthenate 6%

The most common promoters are solutions of CoNap or CoOct. Cobalt solutions are dark blue or purple liquids and are most commonly used with MEKP and CuHP initiator systems. They are sold in solutions of 1%, 6%, 12% and 21% active cobalt in a solvent. Six percent CoNap is approximately half as reactive as 12% CoNap; therefore, if 0.2% of 6% CoNap is called for, 0.1% of 12% CoNap should be added to achieve approximately the same reactivity. Gel time tables for Derakane™ resins are based on a 6% cobalt solution, which is commonly used in the range of 0.2% to 0.4% by weight. Different brands have shown little difference in reactivity.

Note: Never mix a cobalt promoter directly with a peroxide initiator such as MEKP. Direct mixing will result in a violent reaction, and possibly a fire or explosion.

When used at temperatures below 25 °C (77 °F), cobalt promoters should be dissolved in styrene monomer prior to addition to the resin. Dilution in styrene will facilitate uniform mixing and dispersion of the cobalt. Please note that CoNap is acceptable for producing articles that come in contact with food in accordance with FDA regulation Title 21 CFR 177.2420. See **Appendix C** for additional information on formulating for FDA applications.

Accelerators

Accelerators are additives that can improve curing at room temperature. They are typically used in low concentrations ranging from 0.025% to 0.1%.

DMA

Dimethylaniline

DMA is a yellow amine liquid with a strong odor. DMA can be used with MEKP, non-foaming MEKP substitutes, BPO (ambient cure), and CuHP-type initiator systems. The addition of DMA may not be necessary with MEKP and CuHP systems. However, small amounts of DMA may be used in conjunction with cobalt promoters to improve Barcol hardness development and/or shorten the cure time at cool temperatures. With ambient-temperature BPO systems, DMA acts as a promoter and is required for the resin to cure.

When formulating Derakane™ Momentum™ resins with DMA, the resin should be used shortly after adding the DMA. Derakane™ Momentum™ resins mixed with DMA have poor stability and may gel quickly without the addition of an initiator.

DEA

DEA is another amine that can be used. DEA is approximately half as reactive as DMA; therefore, if 0.1% DMA is called for, 0.2% of DEA should be added to achieve the same reactivity.

When formulating Derakane™ Momentum™ resins with DEA, the resin should be used shortly after adding the DEA. Derakane™ Momentum™ resins mixed with DEA have poor stability and may gel quickly without the addition of an initiator.

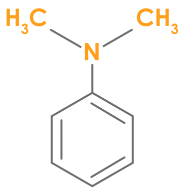
DMAA

DMAA is a low toxicity amide that can be used with MEKP, non-foaming MEKP substitutes, and CuHP-type initiator systems. Similar to DEA, DMAA is approximately half as reactive as DMA; therefore, if 0.1% DMA is called for, 0.2% of DMAA should be added to achieve the same reactivity.

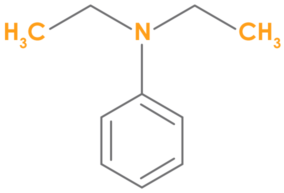
DEAA

DEAA also is a low toxicity amide that can be used with MEKP, non-foaming MEKP substitutes and CuHP-type initiator systems. DEAA is a clear, colorless liquid, so it is often used in color-critical applications. Similar to DEA and DMAA, DEAA is approximately half as reactive as DMA; therefore, if 0.1% DMA is called for, 0.2% of DEAA should be added to achieve the same reactivity.

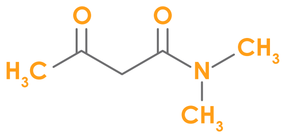
For improved stability, systems can be formulated with DMAA or DEAA rather than DMA or DEA.



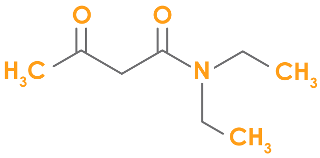
DMA



DEA



DMAA



DEAA

Note: When using BPO with Derakane™, Derakane™ Momentum™, or Derakane™ Signia™ resins, DMA or DEA should be used. DMAA and DEAA do not work in conjunction with BPO and Derakane™, Derakane™ Momentum™, or Derakane™ Signia™ resins.

SAFETY NOTE: DMA, DEA, DMAA, and DEAA should never be mixed directly with BPO. Direct mixing will result in a violent reaction, and possibly a fire or explosion.

CuNap

CuNap is a green liquid typically containing 6–8% copper. It is included in formulations to control the exotherm of resins intended for MEKP initiation. If low hydrogen peroxide containing MEKPs are used, the impact on the peak exotherm temperature is marginal. However, if standard MEKPs are used, CuNap will lower the exotherm temperature and lengthen the gel-to-peak time without affecting the gel time. Typical levels of CuNap recommended for exotherm control are 0–400 ppm. CuNap should be added to the formulation the same day the resin is initiated. Please review the suggested amounts for CuNap on the appropriate resin TDS.

Inhibitors

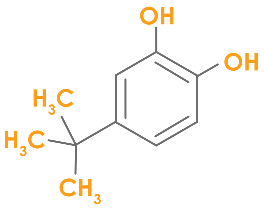
Inhibitors are used to lengthen resin gel times. Inhibitors are useful when very long gel times (1–2 hours) are required or when resin is curing quickly due to high temperatures.

Tertiary Butyl Catechol (TBC), Hydroquinone (HQ), and Toluhydroquinone (THQ)

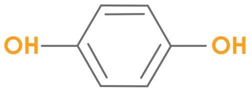
TBC, HQ, and THQ can be used with MEKP, BPO, and CuHP initiator systems. However, care should be taken not to add too much inhibitor, which could result in permanent undercure, low Barcol hardness, or reduced corrosion resistance. Recommended inhibitor levels vary from inhibitor to inhibitor and from resin to resin. A general guide for addition levels is a maximum of 0.30% of a 10% solution (300 ppm). For detailed instructions on adding inhibitors to specific resin systems, refer to the appropriate resin TDS or contact INEOS Composites Technical Service at derakane@ineos.com.

TBC is typically sold as a 10% solution. If using an 85% solution, it should be diluted in styrene to a 10% solution before being added to the resin. HQ and THQ are sold as solids and should be dissolved in methanol to make a 10% solution prior to addition to the resin. Inhibitors can also be dissolved in propylene glycol, which greatly reduces the flammability of the solution. Inhibitor solutions should be used as soon as possible to ensure their full effectiveness.

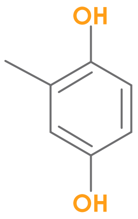
Note: Inhibitors and inhibitor solutions should not be mixed directly with promoters or peroxides.



Tertiary Butyl Catechol



Hydroquinone



Toluhydroquinone

Gel Time Retarder for Derakane™ Resins

2,4-Pentanedione (2,4-P) (Acetylacetone)

2,4-P can be used with Derakane™, Derakane™ Momentum™, and Derakane™ Signia™ resins that are cured with MEKP, CuHP, Trigonox 239, or CuHP and CoNap/CoOct 6% to slow time to gelation. Recommended levels of 2,4-P range from 0.05% to 0.30%. Gel times can be extended as much as tenfold without adverse effects on the final cure or the corrosion resistance of the finished product. The addition of 2,4-P can increase the exotherm temperature. This material can be formulated into high-build coatings to give an extended pot life or can be used for fabrication when very long gel times are required.

CAUTION: Gel time will not be delayed by addition of 2,4-P when a vinyl ester cure is initiated with BPO using DMA as an accelerator. Also, in many polyester systems, 2,4-P may act as an accelerator. TBC in the range of 0.01% to 0.03% (85–255 ppm) can be used to retard the gel time of BPO/DMA systems.

SAFETY NOTE: INEOS Composites does not manufacture or market the peroxides, promoters, accelerators or retarders used with our resins. Always refer to the manufacturer-supplied SDS when using these materials.

In order to avoid dangerous reactions, each additive should be mixed thoroughly into the resin before introducing another additive. For example, DMA and DEA should never be mixed directly with BPO. Direct mixing will result in a violent reaction, and possibly a fire or explosion.

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[1] WARNING: Promoters should always be mixed thoroughly into the resin before adding the initiator. If promoters and initiators are mixed directly together, an explosion may result.

[2] Registered trademark of Arkema LTD

[3] Registered trademark of United Initiators

[4] Registered trademark of AKZO Nobel Coatings Limited

[5] 6% CoOct can be substituted for 6% CoNap to obtain comparable gel times with Derakane™ resins.

Non-Reactive Additives

Thixotropes, fillers, clays, etc. are frequently used in the structural portion of laminates. They are generally unsuitable for use in corrosion-resistant liners. Contact INEOS Composites Technical Service with specific questions regarding the use of any filler in corrosion applications.

Thixotropes

Thixotropes, usually in the form of fumed silica, are used to thicken resin and reduce drainage, especially on vertical surfaces. Resins with these additives are generally used in hand lay-up and spray-up applications. Fabricators can purchase polyester resins with fumed silica in them or add it themselves.

The most efficient and effective thixotropes for use with Derakane™ resins are Cab-o-sil®[1] TS-720 and Aerosil®[2] R202. To ensure uniform dispersion, fumed silica should be mixed into the resin using a high speed, high shear dissolver or its equivalent.

In structural applications, the amount of thixotrope should be kept as low as possible to maximize the strength of the laminate. Thixotropes reduce corrosion resistance to some chemicals; therefore, they should never be used in corrosion-resistant liners. Contact INEOS Composites Technical Service before adding thixotropes to vinyl esters or other resins for use in corrosion-resistant applications. The use of fumed silica in hydrofluoric acid, sodium hypochlorite, fluoride-containing environments, and sodium/potassium hydroxide environments is especially detrimental; it is not recommended and will result in decreased corrosion resistance.

FRP fabricators should contact additive manufacturers for recommendations on safe handling and storage of thixotropic additives.

Antimony Oxides

Cured polyester and vinyl ester resins will burn in the presence of sufficient heat and oxygen. Halogenated polymer resins, however, are flame retardant, and the addition of antimony trioxide (Sb_2O_3) or antimony pentoxide (Sb_2O_5) can further enhance their flame retardance. Antimony acts as a synergist and reacts with halogens to improve the resin's flame retardance. (When added to non-halogenated resins, antimony does not make the resin flame retardant. It acts as filler only.)

In the U.S. composites industry, the flame and smoke properties of polyester and vinyl ester resins are usually rated according to the ASTM E84 tunnel test as performed under strictly controlled conditions. In this test, industry code officials, fire marshals, and resin suppliers have categorized red oak as having a flame spread of 100 and asbestos cement board as having a flame spread of zero.

A flame spread of less than or equal to 25 is considered Class I; greater than 25 but less than 75 is considered Class II. Some resin systems can obtain a Class I flame spread without the addition of antimony; others require the addition of 3–5% antimony trioxide or pentoxide to achieve a Class I rating. Flame spread values obtained on laminates made in the laboratory with and without antimony are listed on the specific resin TDS.

Figure 3.1: Laminates with antimony trioxide, antimony pentoxide and no antimony.

Antimony compounds can be added directly to the resin and dispersed using normal mixing equipment. Resin mixed with antimony should be stirred frequently to keep the materials in suspension. Once Nyacol®3 APE-1540 is added to Derakane™ resins, the mixture should be used within eight hours to minimize the effect of the additive on the gel time. If left overnight, resin with a cobalt promoter and Nyacol® APE-1540 may experience significant gel time drift and the resin may not cure properly. Nyacol® APE-3040 has been shown to have less impact on gel time and gel time drift in resin formulations. When added to resins containing a cobalt promoter, antimony trioxide may also affect gel times, but any noticeable change will occur at a much slower rate than with Nyacol® APE-1540.

Contact INEOS Composites Technical Service for specific recommendations on the addition of antimony. Please note that antimony trioxide and pentoxide do not lower smoke emission values.

Fillers

Alumina Trihydrate (ATH)

ATH is used to improve flame retardance and reduce the smoke emissions of specific resin systems. ATH is a fine, white, powdered filler which, when added in the proper amount, can improve the flame retardance 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, slowing the rate of burning.

ATH differs from antimony trioxide in several ways. As mentioned earlier, antimony trioxide is only effective with halogenated resin systems and is used in small percentages. ATH can be effective with both halogenated and non-halogenated resin systems, but requires much higher filler loadings to achieve the desired flame retardance. Consequently, ATH cannot be used in place of antimony trioxide. High levels of ATH 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 ATH to the corrosion liner reduces corrosion resistance significantly. Contact INEOS Composites Technical Service with specific questions.

Calcium Carbonate and Kaolin Clays


Antimony oxide, clay, calcium carbonate, fumed silica

Calcium carbonate and kaolin clays may also be used as fillers or extenders for polyester and vinyl ester resins. These materials increase the stiffness of the FRP while reducing the overall cost of the part. However, these fillers are not recommended in applications requiring corrosion resistance. Contact INEOS Composites Technical Service with specific questions.

Intumescent Coatings

Intumescent coatings can also be used to improve flame retardance and reduce smoke emissions of specific resin systems. Contact INEOS Composites Technical Service with specific questions.

Mold Release Agents

Wax or films of polyvinyl acetate (PVA), Mylar®4, or cellophane may be used as mold release agents to facilitate the removal of fabricated parts from metal, wooden, cardboard or plastic molds and mandrels. It is important to check the release characteristics of any mold release agent before using it in production.

Wax

Hard-based paraffin waxes and carnauba waxes have seen successful use as mold release agents during the fabrication of parts with Derakane™ resins. Several brands provide excellent results, including:

- Meguiar's Mirror Glaze®5
- Trewax®6
- Johnson's Traffic Wax®7
- TR®8 Mold Release

These products are generally available from local fiberglass supply distributors. Acrylic-based waxes have not been accepted for use as mold release agents because they tend to inhibit cure. Some silicone-based mold release agents have also been shown to inhibit laminate cures.

Optimal results are obtained by applying the wax to the mold or mandrel with a clean cloth, then vigorously buffing the surface to a hard, glossy, ultrathin film. Several coats of wax should be applied before a mold is used, then a single coating of wax after each release.

Excess wax left on the mold surface may inhibit curing, resulting in a hazy corrosion liner. Even though the surface beneath the wax may be fully cured, the hazy surface may give a low Barcol reading (see Section 8, Inspecting a Laminate). If this occurs, remove approximately 0.05–0.08 mm (2–3 mil) of the wax coating by sanding, then inspect the surface again using the Barcol hardness check described on page 51. If a high gloss surface is desired, overcoat the buffed wax surface of the mold with a PVA film.

Internal mold release agents may be used (typically at a level of 0.5%) in conjunction with waxed surfaces in specialized (elevated temperature) molding and filament winding applications. Contact INEOS Composites Technical Service with specific questions.

Films of Polyvinyl Alcohol (PVA)

Films of PVA, when properly applied, can provide excellent mold release for parts made with Derakane™ resins. PVA films may be sprayed or painted over waxed or polished metal molds. After application, the film must be allowed to dry thoroughly because any residual moisture can inhibit the cure of Derakane™ resins cured with MEKP or CuHP systems. Because PVA films are hydrophilic, in high humidity atmospheres it may be necessary to force-dry them.

Mylar and Cellophane

Films of Mylar and cellophane 2.5–15 cm (1–6 in) wide and 0.03–0.05 mm (1–2 mil) thick may be used as mold release agents to facilitate the removal of fabricated parts from metal, wooden, cardboard or plastic molds and mandrels. Mylar films 0.13–0.25 mm (5–10 mil) thick have excellent release characteristics and are used on bench tops for the production of parts and flat sheets.

Ultraviolet (UV) Protection

FRP parts fabricated with vinyl ester resins may display surface chalking and discoloration after long exposure to ultraviolet radiation. As long as the surface chalking and/or discoloration do not cause displacement of the fiberglass, both are considered cosmetic problems and should not affect the physical properties of properly fabricated equipment. However, cosmetic problems usually are not acceptable and may be reduced or eliminated by the following:

- Incorporating UV absorbers into the resin
- Pigmenting outer resin layers
- Painting the surface with epoxy polyamide paints and urethane topcoats
- Incorporating fillers

Three commonly used UV absorbers are:

- Cyasorb®[9] UV-9
- Cyasorb®[9] UV-24
- Tinuvin®[10] 326

These products are incorporated into the external coat at a level of 0.25–0.5%. For halogenated resin systems, the recommended level of UV stabilizer is 0.5%.

UV absorbers do not always provide effective protection for long term service, and they may also inhibit resin cure. Fabricators who wish to formulate a pigmented gelcoat should contact a pigment manufacturer.

REMINDER: Many inspectors require visual inspection of equipment before pigmented topcoats are applied. Do not apply paint or pigment unless the specifier has requested it.

If equipment is finished several days or weeks before the inspection, the need to grind the exterior before top coating can be avoided by using a polyamide epoxy coating. The only surface preparation required is the removal of dirt, dust, oil, grease and wax with a degreaser-type solvent and clean rags.

Mix and apply the polyamide epoxy paint according to the manufacturer's instructions, making sure that the air and surface temperatures are above 10 °C (50 °F) throughout application and cure. Apply a urethane topcoat to the polyamide paint to complete the UV protection. Do not apply the coating when the weather is humid or when rain is expected.

Polyamide epoxy paints and urethane topcoats are available from the companies listed in Table 3.1. These products have been used successfully on equipment fabricated with Derakane™ resins.

For non-pigmented equipment, a surfacing veil made with polyester fibers has been shown to significantly reduce fiber bloom. NEXUS®[11] veil, type 100-10, has provided consistent results.

Manufacturer	Website
Carboline	www.carboline.com
International	www.international-pc.com
PPG	www.ppg.com

Table 3.1: Sources for polyamide epoxy paints and urethane topcoats.

Wax Topcoats

Derakane™ and Derakane™ Momentum™ resins are subject to surface inhibition when cured in the presence of air. Derakane™ Signia™ resins are not air inhibited and do not require the use of a wax topcoat. 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 50–90 µm (2.0–3.5 mil) thick, 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. Under hot sunlight, the wax topcoat may be ineffective.

CAUTION: Never apply a resin/wax solution between laminate layers, as this could result in poor secondary bonding and premature failure.

The wax/styrene solution is made by dissolving 20 g of a fully refined paraffin wax (melting point = 55–60 °C [130–140 °F]) in 180 g of warm styrene (45 °C [110 °F]). Take appropriate care when warming styrene, as this temperature is above the flashpoint temperature of styrene. Add the solution to the resin at the rate of 2–4% and mix thoroughly, then promote and initiate the resin solution as normal. Pre-dissolved wax solutions are also available from FRP distributors.

Wax topcoats should be used as the final coating of Derakane™ and Derakane™ Momentum™ resin secondary lay-ups and on all repairs of surfaces exposed to a corrosive environment.

Surfactants and Antifoam Agents

Air bubbles in a laminate reduce its strength and may seriously affect its corrosion resistance. Air bubbles in the corrosion liner[12] can be more damaging than those in the structural layer. To minimize air bubbles, always follow these practices:

1. Avoid violent mixing, which mixes air into the resin. However, be sure that all ingredients are thoroughly mixed into the resin.
2. Apply resin to the mandrels first, then apply glass and roll it into the resin. Air bubble problems are inevitable when resin is applied to “dry” glass.
3. Roll the laminate from the center to the edges. Roll firmly but not too hard. Excessive pressure may fracture existing bubbles and make them more difficult to remove.
4. Eliminate all the bubbles from one ply before starting on the next.
5. Thoroughly clean rollers between uses.

The addition of certain surfactants and antifoam agents can improve the glass wet-out and air bubble release of resins. One of the most effective surfactants evaluated is BYK-A515[13]. When added to a resin at a level of 0.15%, this product significantly reduces the resin’s surface tension, thus improving glass wet-out and air bubble roll-out.

BYK-A555[13] antifoam agent at a level of 0.15% causes entrapped air bubbles to readily burst. At a level of 0.15%, BYK-A515 and BYK-A555 do not reduce the corrosion resistance of properly cured laminates.

Another widely used antifoam agent is SAG 47[14] silicone-based antifoam compound. The suggested maximum amount of SAG 47 for Derakane™ vinyl ester resin is 0.05 wt%.

Foamkill®[15] 8R and 8G, used in the 0.05–0.06 wt% range, are other effective air release agents.

Excessive levels of air release agents can cause clouding in the laminate. Do not exceed recommended levels. Please contact INEOS Composites Technical Service for additional information.

The compatibility between Derakane™ resins and glass fibers can be improved by adding 2,4-P to the resin at levels up to 0.05%. At such low levels, 2,4-P is unlikely to significantly affect the gel time of resin systems with a minimum of 0.3% CoNap (6% cobalt).

Abrasion-Resistant Additives

An abrasion-resistant corrosion liner may be necessary when operating conditions involve slurries or other applications with abrasive particles. Fast-flowing process streams containing solid particles can abrade the surface of FRP equipment such as tanks, piping and ducting. Particles that are less than 100 mesh (150 µm) in size are not a major abrasion threat, while liquid velocities of less than 2 m/sec (6 ft/sec) are not considered a problem for standard FRP systems.[16] However, when particle sizes get too large or flows get too fast, steps must be taken to minimize the abrasive effect.

To make the corrosion liner last longer, one practice is to double its thickness. A possibly more cost- and service-effective alternative is to incorporate hard, corrosion-resistant material in the veil portion of the corrosion liner or throughout the entire corrosion barrier. When used correctly, fine silica, silicon carbide and aluminum oxide have been effective at reducing liner deterioration caused by abrasion.

A mixture of resin and silicon carbide or aluminum oxide should be made and initiated based on resin weight. Table 3.2 shows the ability of different resins and abrasion-resistant additives to resist surface wear. Some abrasion-resistant additives may affect corrosion resistance; therefore, we recommend contacting INEOS Composites Technical Service for instructions on adding abrasion-resistant additives to specific resin systems.

The use of carbon veil in place of C-glass veil or synthetic veil has also been shown to improve abrasion resistance. Contact INEOS Composites Technical Service for additional information on improving abrasion resistance.

Laminate Description	Wear Index
Derakane™ 411 resin	388
Derakane™ 470 resin	520
Derakane™ 8084 resin	250
Derakane™ 411 resin *10% fine silica*	70
Derakane™ 411 resin *50% fine silica*	38
Derakane™ 411 resin *66% fine silica*	38
Derakane™ 411 resin *20% silicon carbide*	25
Derakane™ 411 resin *40% silicon carbide*	10
Derakane™ 411 resin *50% silicon carbide*	10

Table 3.2: Derakane™ resins taber abrasion testing.[17]

CS-17 Abrasive wheel, 1000 gm loading

Lists of suppliers for many of the additives described in this section are included in **Appendix A and B**. These are not the only suppliers of these products. Check with your local distributor for availability.

[1] Registered trademark of Cabot Corporation

[2] Registered trademark of Evonik Industries

[3] Registered trademark of Nyacol Nano Technologies, Inc.

[4] Registered trademark of DuPont Teijin Films

[5] Registered trademark of Meguiars Inc.

[6] Registered trademark of Trewax Company

[7] Registered trademark of S.C. Johnson and Sons, Inc.

[8] Registered trademark of T.R. Industries

[9] Registered trademark of Cytek Industries

[10] Registered trademark of BASF

[11] Registered trademark of Precision Fabrics

[12] Corrosion liner – Veil-Mat-Mat = 100–250 mil

[13] Registered trademark of BYK-Chemie USA

[14] Trademark of Momentive Performance Materials Inc.

[15] Registered trademark of Crucible Chemical Company

[16] Mallinson, John H., Corrosion Resistant Plastic Composites in Chemical Plant Design, Marcel Dekker, Inc., New York, New York, 1988.

[17] CS-17 Abrasive wheel, 1000 gm loading

SECTION 4

Reinforcements

Derakane™ resins are the top choice for quality and reliability when fabricating corrosion-resistant structures and equipment. However, for consistently high-quality end products, the glass reinforcement used in fabrication must be selected with care and used by workers who are well trained in the special techniques of FRP. This section is a basic guide to selecting reinforcements.

Standard Reinforcement Sequence for Corrosion-Resistant Equipment

The laminate sequence for standard corrosion-resistant equipment is based on the ASTM C581 Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used In Glass Fiber Reinforced Structures Intended for Liquid Service. This sequence is illustrated in Figure 4.1.

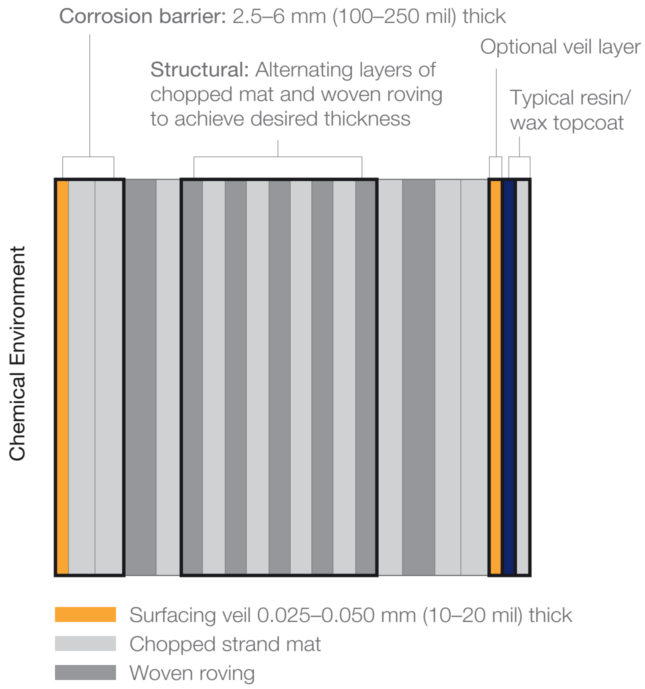


Figure 4.1: Typical laminate corrosion barrier and structural layer.

Generally, fabrication begins at the surface that will be exposed to the corrosive environment. The corrosion barrier's main function is to provide corrosion protection by minimizing penetration of the corrosive media into the structural portion of the laminate.

A resin-rich layer consisting of 95% resin and 5% reinforcement and approximately 0.025–0.050 mm (10–20 mil) thick is applied first. The reinforcement is in the form of a surfacing veil composed of C- or E-CR glass, a synthetic fabric, or carbon fiber. Two plies of surfacing veil can be used for more severely corrosive environments. The veil is followed by two or more layers of chopped strand mat or the equivalent chopped spray. This layer should consist of 20–30% glass. Together, the resin, veil, and chopped glass form the primary corrosion barrier or lining. This corrosion barrier should be 2.5–6 mm (100–250 mil) thick.

The remainder of the laminate, commonly referred to as the structural portion, contributes to the strength of the equipment. Compared to the corrosion barrier, the structural portion contains a higher glass percentage, generally 40–50%, and can include chopped strand mat, chopped strand, continuous strand, multidirectional, or unidirectional glass. Filament winding can also be used to construct the structural portion, in which case the glass content may be as high as 60%. The exact makeup of the structural portion depends on the engineering specifications for the equipment in question.

An optional veil layer can be applied to the exterior of the structure. A final wax topcoat or gelcoat can then be applied to the exterior of the equipment to prevent air inhibition.

Types of Reinforcement

This section provides general guidelines for fiberglass selection. For specific recommendations, please contact the glass manufacturer. Regardless of the glass type used, it is important to thoroughly evaluate it in a test laminate before beginning fabrication. In the test laminate, the glass should wet readily.

There are several forms of fiberglass reinforcement frequently used with Derakane™ resins:

- Surfacing veil
- Chopped strand mat/chopped strand
- Directional glass
- Woven materials
- Continuous strand

Fiberglass begins as molten glass and is formed into filaments by pulling it through bushings. A strand of glass roving is formed by gathering a large number of filaments together.

The surface of the glass is treated with sizing agents. Some types of glass then have a binder applied to them while others do not. Sizing agents and suitable binders facilitate further processing, maintain fiber integrity, and provide compatibility with various resin systems. After this treatment, the fibers are further processed into specific glass types such as surfacing veil, chopped strand, chopped strand mat, woven roving, biaxial mat, continuous strand, and unidirectional mat.

Much of the fiberglass used in the corrosion industry is either E-glass or E-CR glass. ASTM D578 discusses in detail the formulation differences between E-glass and E-CR glass, but the essential difference is the presence of boron. Boron, which is present in E-glass, leaches readily into acidic environments. Since boron is a network former in the glass structure, its loss results in a significant degradation of the glass reinforcement's performance. E-CR glass, on the other hand, is boron free. The leaching of other fiberglass components, which are not network formers, proceeds at a very slow rate, significantly improving the performance of the glass reinforcement.

The glass forms used most frequently with Derakane™ resins are discussed below.

Surfacing Veil

C-glass veil

The chemical resistance of a fiberglass composite is provided by the resin. The surfacing veil, also referred to as surfacing mat or tissue, provides reinforcement for the resin-rich inner liner of the corrosion barrier and also helps control its thickness. The surfacing veil also helps prevent protrusion of the chopped strand mat fibers from the surface, which could allow the corrosive environment to wick into the laminate.

C-glass veil is commonly used in a variety of corrosive environments. E-CR veil is gaining popularity due to its improved performance in corrosive environments, and particularly acidic environments, combined with its excellent electrical and mechanical properties.

In applications where a C-glass or E-CR glass veil is not suitable, thermoplastic polyester or carbon fiber veils may be used. Thermoplastic polyester or synthetic veil is preferred in some environments, most often those containing acidic fluoride compounds. Other environments where synthetic veil is preferred are noted in the Resin Selection Guide. When using synthetic veil with less-flexible resins, a non-apertured synthetic veil is recommended to minimize stress in the system. Both non-apertured and apertured synthetic veils can be used with more flexible resin systems such as vinyl esters.

Synthetic veil (apertured)

In severe environments, multiple plies of veil may be recommended. However, caution is advised. In applications requiring synthetic veil next to the chemical environment, a ply of C-glass veil may be placed behind the synthetic veil to minimize air entrapment and to assist in making lay-up easier.

Carbon veil is often used in abrasive environments. When used properly, carbon veil provides better abrasion resistance than either C-glass or synthetic veils. Carbon veil also is used to provide a conductive liner for static electricity control. When using carbon veil to provide a conductive liner, the specific liner should be evaluated to confirm that it meets the required degree of conductivity. For applications where conductivity is not desired, the use of carbon veil should be reevaluated. Carbon veil also offers improved thermal conductivity. Contact INEOS Composites Technical Service with specific questions.

Carbon veil

Chopped Strand Mat

Chopped strand mat

Chopped strand

Chopped strand mat used in the corrosion industry is generally made from either E-glass or E-CR glass. As discussed earlier, E-CR glass is advantageous in some corrosive environments. Chopped strand fibers are generally 12.5–50 mm (½– 2 in) long and, after chemical treatment, are held together by a binder. Together, the glass fiber bundles form the chopped strand mat.

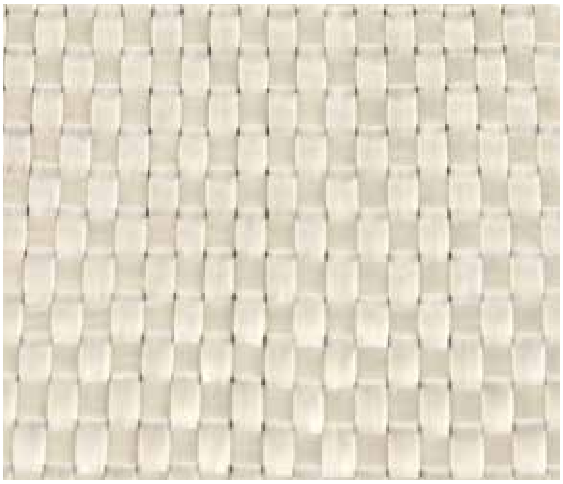
Two layers of chopped strand mat are frequently used with the surfacing veil to form the corrosion liner. Chopped strand mats are also used in the structural layer between layers of woven roving or as the sole reinforcement for the structural layer.

The following chopped strand mat thicknesses are used most often in corrosion applications:

- 225 g/m^2 (0.75 oz/ft^2)
- 300 g/m^2 (1.0 oz/ft^2)
- 450 g/m^2 (1.5 oz/ft^2)
- 600 g/m^2 (2.0 oz/ft^2)

Chopped strand mats vary in glass composition and sizing, so they should be thoroughly evaluated for laminate quality.

Woven Roving



Woven roving

Woven roving is a coarse fabric consisting of long, continuous glass fiber strands woven together to form a heavy mat. Woven roving is available in a variety of thicknesses and weights. Alternating layers of woven roving and chopped strand mat are commonly used in the structural portion of many hand lay-up vessels. In hand lay-up, the resulting laminates are generally 40–50% glass. Woven roving varies in glass composition and sizing, just as glass mat does. Therefore, Derakane™ laminates made with woven roving should be thoroughly evaluated for laminate quality.

Continuous Strand Roving

Continuous strand roving

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

Storage of Glass Fibers

Glass fiber products should be stored carefully so they remain clean and dry. Glass that is dirty or has absorbed water should not be used because the presence of dirt or moisture could inhibit resin/fiberglass compatibility, resulting in poor laminate quality.

SECTION 5

Resin Preparation

When fabricating with Derakane™ resins, it is important to correctly promote and initiate the resin to ensure an appropriate working time. Promoter and initiator addition tables for many Derakane™ resins are listed on the specific resin's TDS. These tables indicate the recommended promoter and initiator levels for addition at different temperatures to achieve desired working times. These tables serve only as guidelines, and the values should not be considered specifications.

Adjusting Promoter/Initiator Levels for Practical Applications

The promoter and initiator levels recommended on a resin's TDS represent laboratory conditions and often will need to be adjusted to accommodate actual working conditions in a fabricating shop or in the field. Many things can influence a resin's working time. High resin and shop temperatures, direct sunlight, and thick laminates can shorten a resin's gel time. Low resin and shop temperatures, heat sinks (metal molds), and fillers can lengthen gel times.

When the gel time is too short due to working conditions, promoter levels can be lowered to lengthen the gel time. Always use inhibitors in accordance with the recommendations on the appropriate resin TDS. If the information on the TDS is insufficient, please contact derakane@ineos.com for assistance.

Factors Affecting Resin Working Times

For successful bonding to glass fibers, resins should be used as soon as possible after initiators and other additives are mixed in. The manufacturer's working time refers to the time from when the promoters, accelerators, inhibitors, and initiators are mixed with the resin to when the resin begins to gel. The working times listed on the TDS are determined through lab testing using small batches of resin (~100 g) under controlled conditions.

Conditions that increase working time:

- Cooler temperatures
- Cool resin
- Large heat sinks (metal molds)
- High humidity (to the point of hurting cure)
- Brisk winds
- Addition of fillers

Conditions that decrease working time:

- High temperatures
- Warm resin
- Insulated heat sinks (wooden molds)
- Thick laminates
- Direct sunlight

A summary of some of the most common problems encountered with room-temperature cure systems and suggestions for minimizing these problems are shown in Appendix D.

Measuring Small Quantities of Additives

Be sure to accurately measure the quantities of initiators, promoters and accelerators you use to cure Derakane™ resins. Measurements can be made with disposable syringes, graduated cylinders or plastic squeeze bottles with graduated pour spouts. Actual gel times may vary due to subtle variations in curing agents and resins, slight variations in measuring small amounts of reactants, the size of the resin batch, and the environmental parameters mentioned above.

Preparing a Master Batch of Resin

A successful technique for obtaining consistent curing characteristics is to prepare a master batch containing the resin, promoters, accelerators, and inhibitors. Master batches of 20 kg (5 gal) to 200 kg (55 gal) are common. The master batch contains CoNap/CoOct 6%, amine (if required), and inhibitor (if required). It does not contain initiators. To fabricate equipment correctly, you must prepare the resin properly and in a safe manner.

Master batches should be carefully prepared by a designated, reliable technician and should be checked frequently for curing characteristics and uniformity. The master batch approach assures that the proper ratio of promoters and accelerators will be used each time. Master batches also give operators latitude in determining the amount of initiator needed and the time required for a specific job. A master batch formulation helps compensate for changes in temperature and other ambient conditions. Consult the resin TDS for recommended master batch formulations.

Steps to Follow When Preparing a Master Batch of Resin.

1. Estimate the amount of time required for fabrication. (A typical gel time is 25–30 minutes.) 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: warmer temperature = lower viscosity; cooler temperature = higher viscosity.
2. Using the promoter/initiator addition tables on the resin TDS as a guideline, choose the appropriate additive levels to achieve a suitable working time. Review the SDS for all additives and refer to the safety notes on page 21 of this guide.
3. Weigh the required amount of resin, cobalt, amine, and, if applicable, inhibitors (pre-dissolved in styrene or another appropriate solvent), in separate containers. The conversion Table 5.1, page 22 may be helpful when measuring materials volumetrically.
4. For open-top containers, add the cobalt to the resin and mix thoroughly using a high speed air-driven mixer under slow to moderate agitation. Gradually increase the mixing speed while ensuring that cobalt or other additives are not sticking to the sides of the container. With a high speed mixer, a mixing time of 15–20 minutes should be adequate. Bunghole mixers with small propellers may not provide adequate mixing. (See Step 8 if using a bunghole mixer.) During all mixing, take care to minimize air entrapment in the resin. Excessive air bubbles in a laminate can cause a reduction of physical and corrosion properties. Monitor the resin temperature throughout the mixing process, as hotter resin = shorter gel times.

Addition of 6% cobalt naphthenate

Note: A cobalt promoter should never be mixed directly with a peroxide initiator (such as MEKP). Direct mixing will result in a violent reaction, and possibly a fire or explosion.

5. Add the amine (DMA, DEA, DMAA, or DEAA) and mix thoroughly.

Note: Never mix amines directly with an inhibitor or an initiator. Direct mixing will result in a violent reaction, and possibly a fire or explosion. Always thoroughly mix the aniline into the resin before adding the inhibitors or initiator.

6. Add any additional liquid materials, such as inhibitors, and mix thoroughly.
7. Do not add pigments or fillers such as antimony trioxide, alumina trihydrate, etc., through a drum's bunghole. They need to be mixed thoroughly in an open-top container.
8. To ensure proper mixing with a bunghole mixer, remove at least 18 kg (40 lb) of resin and place in a large container. Mix all ingredients, except the initiator, into resin that you removed from the drum. Once thoroughly mixed, add the resin back into the drum using a funnel. The entire drum should then be mixed thoroughly with a screw-type air-driven mixer for about 20–25 minutes. A bunghole mixer with three collapsing paddles (top, middle and bottom) can also be used. Monitor the resin temperature throughout the mixing process: hotter resin = shorter gel times.
9. After you have mixed in the required promoters and fillers, remove a sample of the resin and perform a gel time test. Again, refer to the designated promoter/initiator table on the resin TDS for the recommended initiator level.

Typical gel timer

10. The gel time can be lengthened by adding an inhibitor or shortened by adding more cobalt or amine or initiator. Do not exceed the recommended additive levels for that resin.
11. Initiate the resin as needed. For each batch, the operator may vary the amount of MEKP (within prescribed limits) to get the desired gel time. The correct amount of MEKP should be measured carefully and mixed thoroughly into the resin. A minimum mixing time is 30 seconds, including time for scraping the sides and bottom of the mixing container. Take care to minimize air entrainment during mixing.
12. If the resin's exotherm temperature is too high, you can add CuNap to reduce it. The gel time will not be affected if using a standard MEKP. If you add more than a combined 400 ppm CuNap and inhibitor to the resin, a full cure may not be possible. For additional guidelines, email derakane@ineos.com.

SAFETY NOTE: Use proper safety precautions in all these operations. Always wear suitable eye protection and protective clothing when handling resins, promoters, accelerators and initiators. Observe good housekeeping practices to minimize contamination of the working area. Proper ventilation should be maintained to meet government standards. Whenever possible, use disposable containers for mixing. Dispose of used containers and resin waste properly in accordance with local regulations.

Weight-to-Volume Conversion

Additive	Conversion	Resin Quantity		
		4 liters (1 gal) (4 kg [8.8 lb])	20 liters (5 gal) (20 kg [44 lb])	200 liters (55 gal) (200 kg [450 lb])
6% Cobalt naphthenate[1] (phr)				
0.10	cc	4	21	212
	fl oz	0.15	0.7	7.2
0.20	cc	8	41	423
	fl oz	0.3	1.4	14
0.30	cc	12	62	634
	fl oz	0.4	2.1	22
0.40	cc	17	83	849
	fl oz	0.6	2.8	29
0.50	cc	21	104	1.1 L
	fl oz	0.7	3.5	36
Dimethylaniline (phr)				
0.025	cc	0.9	4.5	46
	fl oz	0.03	0.15	1.5
0.05	cc	2.1	10	106
	fl oz	0.07	0.35	3.6
0.075	cc	3.0	15	161
	fl oz	0.1	0.5	5.1
0.10	cc	4.1	21	212
	fl oz	0.015	1.7	7.0
Methyl ethyl ketone peroxide (phr)				
1.00	cc	36	178	1.8 L
	fl oz	1.2	6.0	61
1.25	cc	44	222	2.3 L
	fl oz	1.5	7.5	77
1.50	cc	53	266	2.7 L
	fl oz	1.8	9.0	92
1.75	cc	62	311	3.2 L
	fl oz	2.1	11	107
2.00	cc	71	355	3.7 L
	fl oz	2.4	13	122
Benzyl peroxide paste (50% active) (phr)				
1.00	cc	36	164	1.7 L
	fl oz	1.2	5.8	59
1.50	cc	49	245	2.5 L
	fl oz	1.7	8.6	88
2.00	cc	65	327	3.3 L
	fl oz	2.3	11.5	118
2.50	cc	82	409	4.2 L
	fl oz	2.9	14	147
3.00	cc	98	491	5.0 L
	fl oz	3.5	17	176

Table 5.1: Weight-to-volume conversion.

[1] In Europe, 6% CoOct can be substituted for 6% CoNap to obtain comparable gel times. If 12% CoOct is used, half as much 12% CoOct as 6% CoNap should be used to obtain comparable gel times.

Making a Test Laminate and Applying FRP Linings

Making a Test Laminate

The following outline is a guide to using Derakane™ resins in producing typical FRP laminates by hand lay-up.

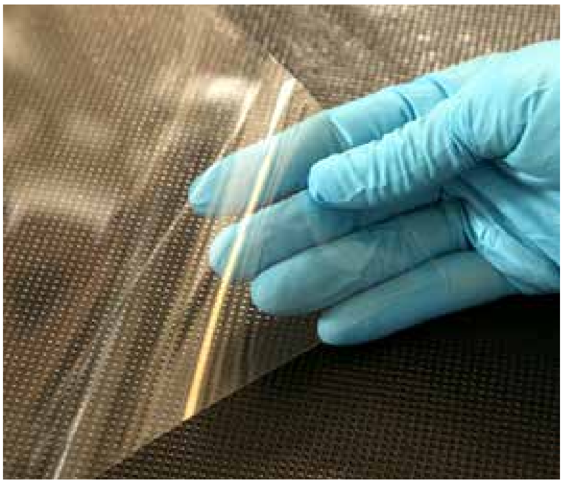
Three important factors could not be shown in a photo essay:

1. The precise, accurate formulation of materials
2. The variables involved in making a laminate to satisfy particular specification requirements
3. The expertise, skill and artistry of the worker making the laminate

We believe that these instructions can help FRP workers formulate materials properly and control the variables involved in meeting specification requirements. However, only the worker's experience and attention to detail can provide the craftsmanship. Put yourself, your experience, and your hands into these photos, remembering that what is shown here is only part of the complete picture.

Step 1: Cover Bench With a Release Sheet

After you have formulated a batch of resin and organized your work area and tools, lay a Mylar release sheet over the bench top.



Mylar release film

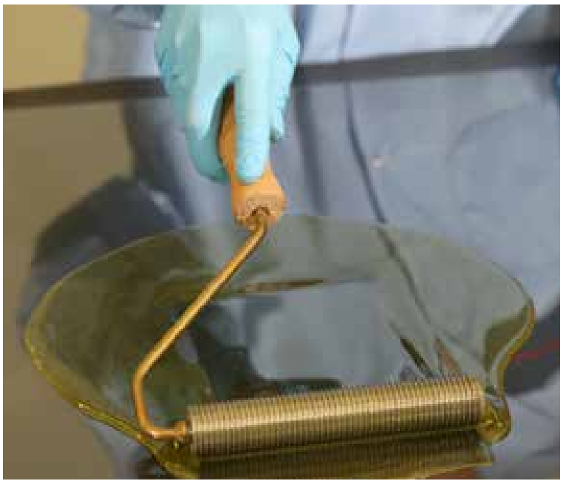
Step 2: Pour Resin Base

Pour initiated Derakane™ resin onto the release sheet.

Pour resin onto the release film

Step 3: Spread Resin Base

Spread the resin evenly using a roller or other spreading device (tongue depressor, paint brush, etc.).



Spread the resin with a serrated roller

Step 4: Apply Surfacing Veil

Carefully position the glass surfacing veil over the wet resin and roll the veil into the resin with a serrated roller.

Apply veil layer and roll with a serrated roller

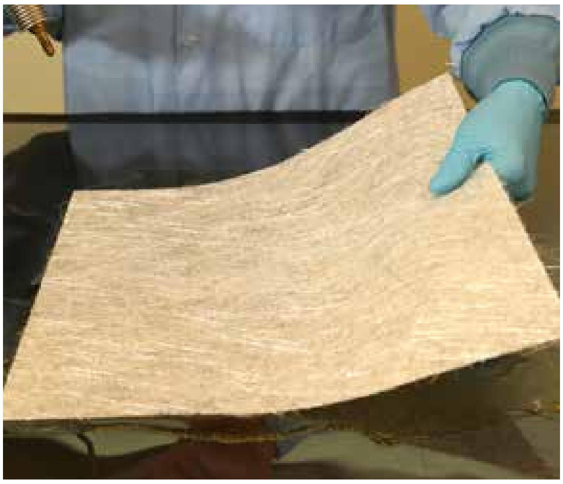
Step 5: Add More Resin

Apply additional initiated resin and roll again.

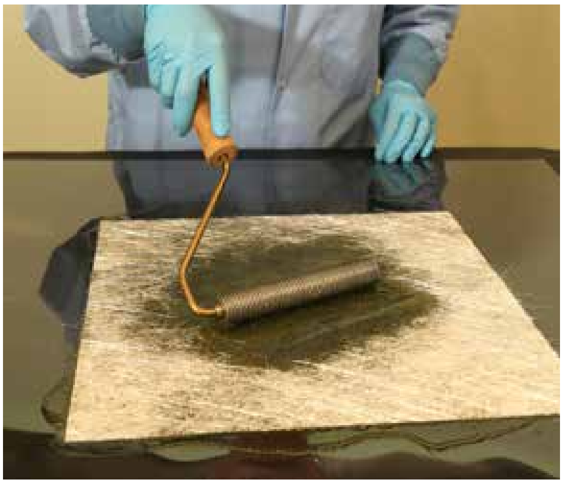
Pour additional resin onto veil and roll again

Step 6: Apply Layer of Chopped Strand Mat

Carefully place the first layer of chopped strand mat over the resin and roll it into the resin, adding more resin if necessary.



Apply layer of chopped strand mat



Roll with a serrated roller

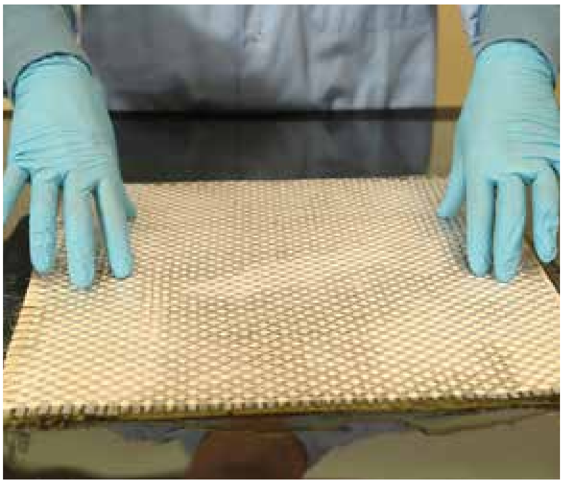
Step 7: Add Resin and Apply Second Mat

Spread initiated resin over the first chopped strand mat, then apply a second chopped strand mat and roll it into the resin, adding more resin if necessary.

Add additional resin and a second layer of chopped strand mat

Step 8: Apply Woven Roving

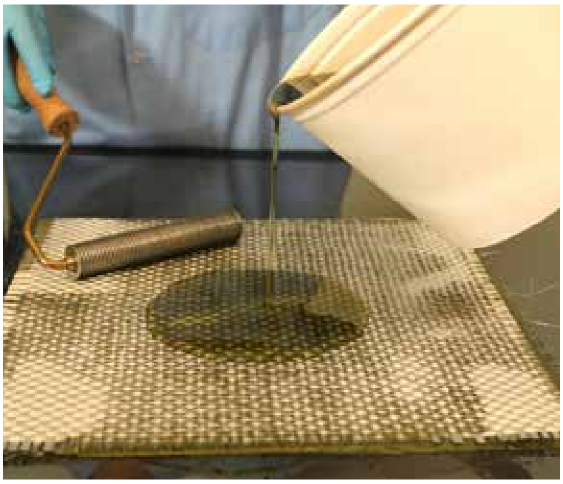
Spread a little more resin over the second chopped strand mat and apply a layer of woven roving.



Apply layer of woven roving

Step 9: Roll Roving Into Resin

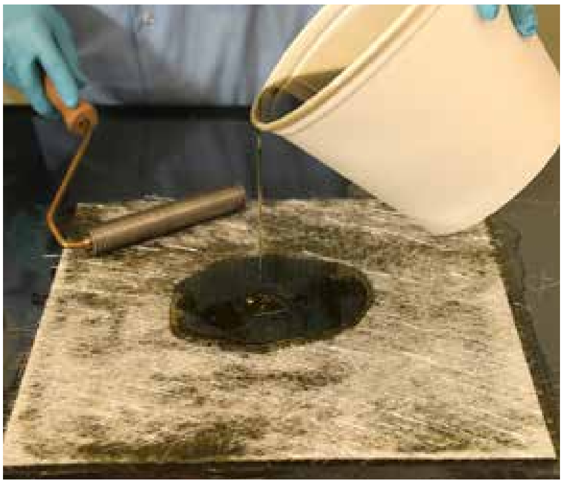
Using a serrated roller, carefully roll the woven roving into the resin.



Apply resin to woven roving layer

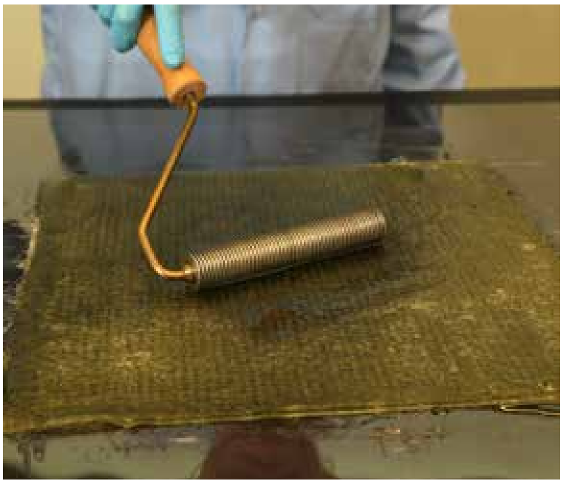
Step 10: Add Final Chopped Strand Mat

Apply a final layer of chopped strand mat and initiated resin and roll again.



Add additional resin and a final layer of chopped strand mat

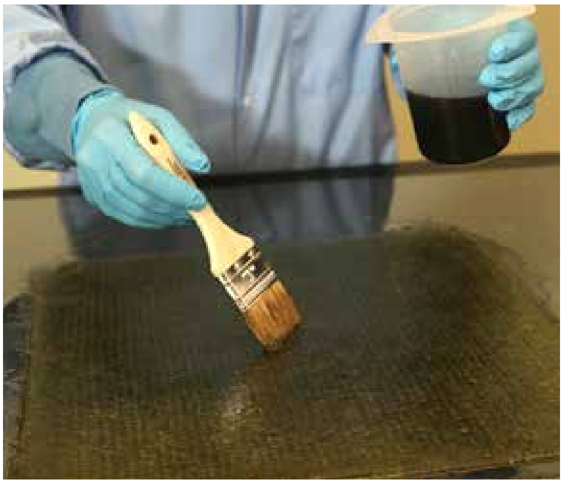
Step 10: Add Final Chopped Strand Mat (continued)



Roll final layer of chopped strand mat

Step 11: Finish with Wax Topcoat

Coat the surface with a protective wax topcoat. Allow the resin to gel and cure. The laminate is now ready for use. (For a more detailed explanation, refer to the following guide to making a laminate.)



Apply a resin/wax topcoat

Guide to Making a Laminate

The following outline is a guide to the use of Derakane™ epoxy vinyl ester resins in producing typical FRP laminates by hand lay-up.

A. Safety Considerations

1. Know the appropriate safety, handling precautions and procedures, and proper disposal methods for resins, glass, initiators, promoters and accelerators. Consult the SDSs for all products before beginning.
2. Wear clean, body-covering protective clothing, gloves and appropriate eye protection.
3. Avoid unnecessary contact with resins, initiators and other chemicals.
4. Good, general ventilation should be sufficient for most conditions. However, local exhaust may be required where there is little air circulation, such as in confined areas. Respiratory equipment – either air purifying or self-contained breathing apparatus – may be required when levels exceed peak concentration.
5. Keep yourself and your work area as clean as possible.
6. During lay-up, keep laminates away from open flames or sparks.
7. Wear a respirator when sanding.
8. Be aware that thick laminates may undergo an exothermic reaction (i.e., get hot and emit noxious odors).
9. Dispose of wastes properly.

B. Plan What You Need for the Job

1. Assemble the proper tools: release film, mixers, a spreading tool (brush, tongue depressor, etc.), serrated rollers, and cleaning solvents.
2. Assemble proper fabricating materials: resin, glass surfacing veil, chopped fiberglass mat, woven roving, promoter, initiator, etc.
3. Be sure that proper safety equipment is available and ready for use: safety glasses, clean gloves, protective clothing, fire extinguishers, etc.

C. Be Sure the Work Area Is Suitable for Safe Operation

1. Have a clean, well-lighted work area with adequate ventilation.

D. Prepare the Mold Surface

1. Prepare the mold surface for laminate release by:
    - Covering it with a sheet of release film (0.08–0.1 mm [3–5 mil]) and taping down edges, or
    - Waxing the mold surface and buffing it thoroughly
2. The release film should be wrinkle-free and should extend well beyond the edges of the laminate. Also, if wax is used, the waxed area should extend well beyond the edges of the laminate.

E. Cut the Glass Fiber

1. Cut glass fabrics larger than the desired laminate size to permit trimming. For example, to prepare a 30 x 30 cm (12 x 12 in) finished laminate, you should cut a 36 x 36 cm (14 x 14 in) piece of glass.
2. The sequence for applying layers of glass, from base to surface, is:
    a. One layer of surfacing veil > corrosion liner
    b. Two layers of chopped mat > corrosion liner
    c. One layer of woven roving > structural layer
    d. One layer of chopped mat > structural layer

    Repeat Steps C and D as required for desired thickness, always finishing with chopped mat.

    Note: Some specifications may require an additional surfacing veil on the exterior (atmospheric) side of the laminate.

F. Making a 6 mm (¼ in) Laminate

The following symbols are used here to indicate the application sequence:

V = standard 10 mil corrosion surfacing veil

M = chopped strand mat of 450 g/m^2 (1.5 oz/ft^2)

R = woven roving glass

The sequence VMMRMRM will produce a laminate approximately 6 mm (¼ in) thick with a corrosion liner on one side. The side next to the release film will have a hard, glossy surface and should have a high Barcol hardness value when cured. This 6 mm (¼ in) laminate should contain about 40% glass by weight and have the following physical properties:

- Flexural strength (ASTM D790) – approximately 193 MPa (28,000 psi)
- Tensile strength (ASTM D638) – approximately 138 MPa (20,000 psi)

G. Measuring and Mixing the Resin

1. The amount of resin required will depend on the size of the part. A test laminate of 30 x 30 cm (12 x 12 in) will require about three 200 gram batches of resin or one 600 gram batch
2. The proportion of initiator and accelerators to use with Derakane™ epoxy vinyl ester resins is determined by shop conditions such as temperature and humidity and by the time needed to make the lay-up.
3. MEKP initiator should be added immediately prior to making the laminate. When measuring and mixing resins, promoters and the initiator, wear appropriate eye protection, protective clothing and gloves as directed by the relevant SDSs. Mix thoroughly and scrape sides and bottom of the mixing vessel while mixing. This final mixing should take approximately 60 seconds.

H. De-Air Resin

1. Allow resin to stand for several minutes to de-air.

I. Apply Resin

1. Apply a thin layer of resin with a short-bristled brush or serrated roller over a 36 cm (14 in) square area of release film. It is important to apply the resin first and then roll the glass into the resin. This will decrease the likelihood of entrapping air bubbles and assure the saturation of the glass from the bottom up.

J. Apply the First Layer of Surfacing Veil

1. As you apply the surfacing veil, resin will bleed up through the glass. You may need to apply additional resin to wet the surfacing veil completely. This additional resin will help in wetting the next layer. When the surfacing veil loses its fibrous appearance, the glass is thoroughly wetted.
2. Use a serrated lay-up roller to work the resin through the glass and work out air bubbles. Rolling also compresses the glass and removes excess resin. Roll firmly but not too hard. Roll from the center out to the edges as this helps “push” the air bubbles out of the laminate.

    Note: The proper technique is an art. You will need to develop skill in rolling to produce FRP parts that provide optimal performance.

3. Apply additional resin and spread with the spreading device. Make sure that all air bubbles are removed from the current glass layer before you apply another layer of glass.
4. Place one ply of chopped fiberglass mat on the resin and roll. If necessary, apply additional resin to thoroughly wet the mat.

K. Apply Additional Resin and Glass Layers

Please keep the following points in mind:

1. A resin-saturated surfacing veil holds about 90% resin by weight.
2. A chopped strand mat is harder to saturate with resin than a surfacing veil and requires much more resin. Chopped strand mats hold about 75% resin by weight.
3. Woven roving typically holds 40–60% resin by weight. When saturated with resin, it becomes harder to hold in place.
4. In all layers, you should roll the glass reinforcement into the resin; do not roll the resin into the glass.
5. As you finish each layer, initiate a fresh batch of promoted resin. Be sure to keep your roller in the solvent, clean it frequently and dry it before each use.

L. Apply Woven Roving

1. When the mat is completely wet-out, apply additional resin, spread with the spreading device and apply a layer of woven roving. Woven roving is more difficult to wet-out than veil and mat; therefore, additional resin and rolling may be required to thoroughly wet the roving.
2. Repeat **Steps K and L** as necessary to build the laminate to the required thickness.

M. Apply a Final Chopped Strand Mat Layer

1. After you have applied all woven roving, apply a final layer of resin and chopped strand mat and roll thoroughly.

N. Apply a Final Coat of Resin

1. Once you have applied and rolled all the layers, apply a final coat of resin to cover the glass completely and seal the laminate.

O. Clean Up Thoroughly

1. Clean your tools, work area and yourself carefully and safely. Dispose of wastes properly.

P. Give Laminate Time to Gel and Cool

1. Let the laminate gel, exotherm and cool before removing it from the bench.

Q. Post Cure the Laminate

1. Once the laminate has thoroughly cured at room temperature, post cure the laminate as indicated in the following section.

Post Curing the Laminate

Depending on the end use application, a post cure may be recommended after fabrication. Proper cure depends on both a thorough base cure achieved by using recommended promoter and initiator levels and, when recommended, a thorough post cure. The post cure recommendations listed below are based on the European Standard EN13121-2:2003. This standard contains references to the thickness of the laminate/equipment being post cured and should be consulted to confirm recommended post cure times:

Standard HDT resins: Post cure for a minimum of four hours at 80 °C (180 °F) minimum

- Derakane™ 411 series resins
- Derakane™ 441-400 resin
- Derakane™ 510A, 510B, 510C resins
- Derakane™ 8084 resin

High HDT resins: Post cure for a minimum of four hours at 90 °C (200 °F) minimum

- Derakane™ 451 resin
- Derakane™ 455 resin
- Derakane™ 470 series resins
- Derakane™ 510N resin
- Derakane™ 515 resin

If the entire laminate thickness is to be post cured (e.g. for best mechanical properties), the method described in DIN 18820 standard may be followed. It recommends 80-100 °C (180-210 °F) for one hour per mm of thickness of the laminate (within 5 and 15 hours). However, this requires either a post cure in an oven or heating the interior with hot air (outside must be insulated).

When post curing a laminate, leave the release film attached. Removing the release film before post curing can produce a glossy surface, but the finish may have a slight orange-peel appearance. For additional information on post curing, please contact derakane@ineos.com.

Guide to Making a Conductive Lining

FRP is an inherently good insulator. A conductive lining in an FRP vessel or pipe provides a pathway through which the possible buildup of a potentially hazardous static charge can be grounded. This process of grounding will prevent the possible arcing that can occur when a charge buildup is present.

1. Apply a resin formulation containing 25 wt% graphite in conjunction with a 17 g/m^2 (0.5 oz/yd^2) carbon veil. We recommend testing a laminate sample with the graphite to ensure the cure is not affected.
2. The resin formulation containing graphite should only be used in the carbon veil layer. Following application of the carbon veil layer, a Nexus or C-glass veil and the usual corrosion-resistant lining should be applied with resin containing no graphite.
3. The use of graphite is not recommended in the normal corrosion-resistant lining and structural portion because the graphite has a slightly detrimental effect on secondary bonding strength. If graphite must be used throughout the FRP equipment, the overlay areas must be increased. The high loading of graphite in the resin formulation will have some detrimental effect on the corrosion-resistant properties of the cured resin laminate.
4. It is recommended that you place metal strips, such as Monel®[2], inside the resin layer containing graphite in areas next to flanges and that the Monel metal strips be tied to the flanges. The flanges should then be properly connected to ground. Copper, brass, zinc, and galvanized metal strips are not recommended because they have been found to prevent Derakane™ resins from curing properly.

Secondary Bonding

Secondary bonding can be a concern in many FRP applications. This is particularly true with Derakane™ 470 resin because of its high degree of reactivity. Derakane™ Signia™ resins are formulated for excellent secondary bonding, minimizing the need for surface preparation such as sanding or grinding.

To achieve a good secondary bond with Derakane™ and Derakane™ Momentum™ resins, it is necessary to prepare the surface properly. The entire surface must be sanded uniformly, giving at least a 0.05 mm–0.08 mm (2–3 mil) anchor pattern. This can be achieved by grinding the surface with a #16 or #24 sanding disc. When using the sanding disc, check the pad periodically to make sure there is no buildup of glass fiber and resin. If buildup occurs, it will impair proper sanding and the consequent formation of a good secondary bond.

After you have properly prepared the surface, you must keep it clean and dry until you can start laminating. Dust, moisture or traces of oil that can come in contact with the surface may act as a mold release or inhibit the cure and prevent a good secondary bond. Laminating should be done within a couple of hours of the surface preparation.

The addition of the surfactant BYK A515 at 0.1 wt% to Derakane™ or Derakane™ Momentum™ resins can improve their adhesion to primary laminates. The surfactant properties of the BYK A515 reduce the surface tension of epoxy vinyl ester resins, thus allowing the resins to flow more easily into laminate surface cavities. For structural walls on spas and hot tubs, the use of BYK A515 at a level of 0.2 wt% in Derakane™ resin laminates has been shown to improve the resin's adhesion to the smooth backing of polyacrylic sheets.

Note*: Solvent wiping of a primary surface before secondary laminating starts is not necessary. In fact, it can cause poor secondary bond formation.*

A solvent wipe is usually done to remove the dust accumulated during sanding. If you use a rag wetted with solvent to wipe off the primary surface, it is likely to have picked up contaminants that might act as a mold release and prevent a good secondary bond. Thorough dusting with a dry cloth is sufficient.

Applying a Test Patch

It is good practice to apply a test patch to check the soundness of the prepared surface before applying a laminate. To do this, first prime a 30 x 30 cm (12 x 12 in) area with 0.05–0.08 mm (2–3 mil) of initiated Derakane™ 8084 resin and allow it to cure until dry to the touch. Then apply four layers of 8 x 20 cm (3 x 8 in) 450 g/m^2 (1½ oz/ft^2) glass fiber mat, placing a piece of Mylar film under one end to prevent bonding, and allow to cure. After the test patch is cured, pry it off by placing a screwdriver under the Mylar film.

If the test patch is good, glass fibers will be pulled from the primary laminate. If fibers are pulled away, prime the remaining surface, allow it to cure and begin lamination. If the test patch separates cleanly and easily from the mat, wash the surface with hot water to remove contaminants and then sandblast the surface with #3 sand and allow it to dry. When the surface is completely dry, prime a 30 x 30 cm (12 x 12 in) area of the mat with initiated Derakane™ 8084 resin. When the primed area is cured, apply another test patch as described above. If the test patch is good, prime the remaining surface as described above and begin lamination after sandblasting. If the test patch separates cleanly and easily again, it is likely that the surface is too contaminated to accept a secondary bond.

Making a Laminate Lining

Subject to applicable codes and regulations on applications, reinforced Derakane™ resins can be used to line steel, FRP, concrete structures and equipment, such as tanks, ductwork, sumps, pits, floors and drains. Linings of Derakane™ epoxy vinyl ester resins are less permeable to moisture than polyester linings. Proper surface preparation is essential when lining any surface with an FRP laminate. Using the procedures illustrated in the following photo essay will provide a suitable bonding surface for most applications. After preparing the surface, you should apply a test patch to verify that it is ready for lining. Lining work should be performed by properly trained FRP professionals.

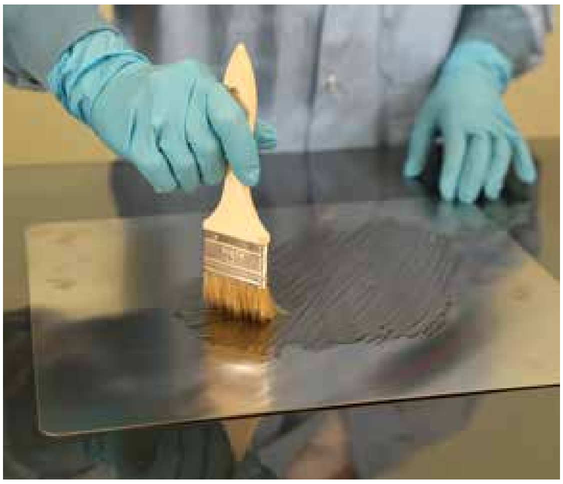
Lining a Metal Surface

Step 1: Clean and Sandblast

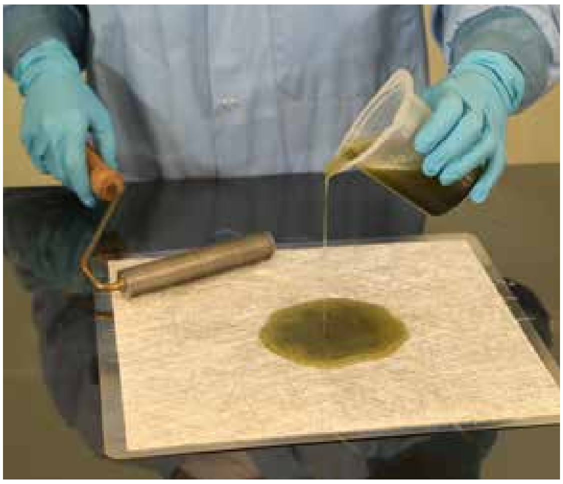
Steam clean or wash the metal with 1% sodium triphosphate to remove grease, oil and other contaminants. When the surface is dry, sandblast it to a bright metal finish. Do not wipe the surface with a solvent; instead, brush or (preferably) vacuum off the abrasive dust. The blasted metal surface should conform to SSPC-SP-5 or NACE No. 1 white metal blast profiles. Fill pits, cracks, holes and other irregularities with an initiated resin grout. The outside corners should have a 3 mm (⅛ in) minimum radius and inside corners should be filled to a 2.5 cm (1 in) radius. Feather FRP edges by grinding. Allow the resin grout to cure, then sand smooth and remove dust.

Step 2: Prime the Surface

The surface temperature of the equipment to be relined should not exceed 40 °C (100 °F). Immediately after you have removed the dust, apply 0.05–0.08 mm (2–3 mil) of initiated Derakane™ 8084 resin with a brush or roller to provide an anchor for the lining. The primer coat prevents surface corrosion prior to application of the laminating resin and also provides a bonding surface for the laminating resin. Allow the primer coat to cure under ambient conditions, 15–38 °C (60–100 °F), to a tack-free state before applying the laminating resin. Once the primer coat is dry to the touch, check the surface with a test patch as explained in the Secondary Bonding section on page 29 of this guide. No condensation should be allowed to form over the primer coat. If the lining application is delayed, cover the primed surface to protect it from contamination. If the delay is longer than three days and the primer coat has been allowed to develop a hard cure, the surface should be lightly sanded and another primer coat applied prior to applying the laminating resin.



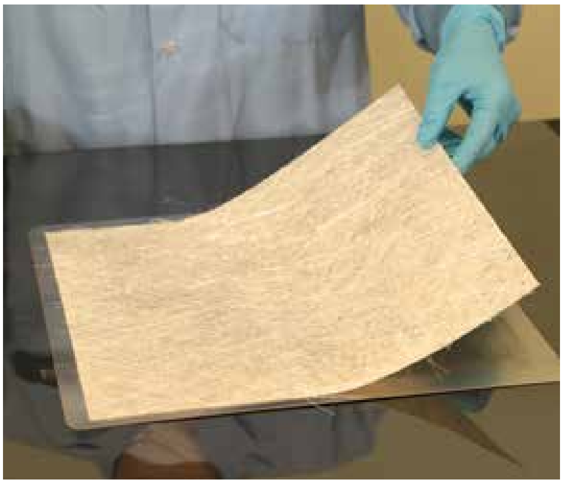
Apply a clear coat of primer resin to clean metal surface



Apply additional resin

Step 3: Apply Chopped Strand Mat

Cut two layers of 450 g/m^2 (1½ oz/ft^2) chopped strand mat and two layers of surfacing veil so that the full liner thickness can be applied in one lay-up, making allowance for staggered joints with at least a 5 cm (2 in) overlap. Apply initiated Derakane™ resin to the primed surface with a brush or roller, then lay a chopped strand mat over the resin and roll with a serrated roller until all air bubbles have been removed. Repeat until two bubble-free layers of chopped strand mat have been applied.

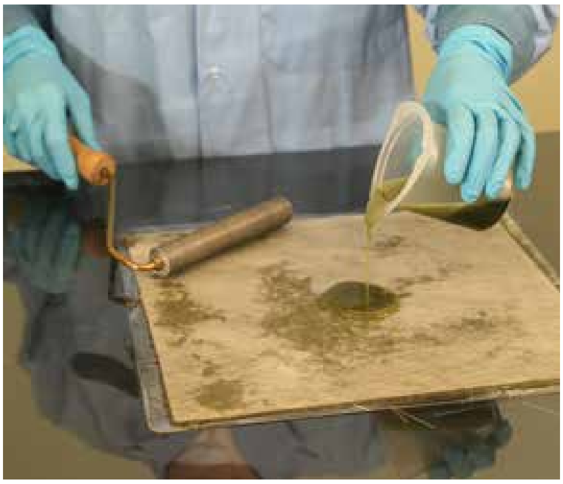


Apply a layer of chopped strand mat

Roll chopped strand mat, repeat with additional resin and another layer of chopped strand mat

Step 4: Apply Surfacing Veil

Using the same sequence of operations, apply two layers of surfacing veil with Derakane™ resin. The lining should now be at least 3 mm (⅛ in) thick.



Apply veil layer and additional resin

Roll veil layer, repeat with additional resin and another layer of veil

Note: If any layer of mat or surfacing veil is allowed to cure overnight, it must be wiped with clean, dry rags to remove any contaminants before the next layer is applied. If a layer or an overlap is allowed to cure for more than 72 hours at 20 °C (70 °F), it must be etched by grinding or sandblasting before the next layer can be applied.

Step 5: Inspect and Repair the Lining

Before top coating, inspect the lining for defects such as voids, dry glass or exposed fibers. A 20,000-volt spark tester is an effective tool for this inspection. Defects should be removed by grinding to the bare substrate. Then cover any low areas with two layers of chopped strand mat and two layers of synthetic veil applied with Derakane™ resin. The glass should overlap the surrounding area by at least 5 cm (2 in) and the sanded defect area should be built up to the original laminate thickness.

Step 6: Apply Topcoat

Once the laminate has passed inspection, apply a resin/wax topcoat to prevent air inhibition. When using Derakane™ Signia™ resins, a resin/wax topcoat may not be needed. See Wax Topcoats in Section 3 of this guide.

Apply resin/wax topcoat

Lining an FRP Surface

Step 1: Sandblast or Grit Blast the Surface

First, wash the eroded or damaged FRP lining to remove large amounts of dirt, etc., and then grind back until sound FRP in the structural layer is exposed. The FRP surface must be free of dirt, grease and other foreign matter. Do not wipe the surface with solvent; instead, brush or (preferably) vacuum off the abrasive dust. The exposed surface should have a 0.05–0.08 mm (2–3 mil) anchor pattern. Any portion of the structural layer removed during surface preparation should be restored before a liner is applied.

Step 2: Prime the Surface

The surface temperature of the equipment to be relined should not exceed 40 °C (100 °F). Immediately after the dust has been removed, apply 0.05 mm–0.08 mm (2–3 mil) of initiated Derakane™ 8084 resin with a brush or roller to provide an anchor for the lining. The primer coat prevents surface corrosion prior to the application of the laminating resin and also provides a bonding surface for the laminating resin. Allow the primer coat to cure under ambient conditions, 15–38 °C (60–100 °F), to a tack-free state before applying the laminating resin. Once the primer coat is dry to the touch, check the surface with a test patch as explained in the Test Patch section on page 30 of this guide. No condensation should be allowed to form over the primer coat. If the lining application is delayed, cover the primed surface to protect it from contamination. If the delay is longer than three days and the primer coat develops a hard cure, lightly sand the surface and apply another primer coat prior to applying the laminating resin.

Step 3: Apply Chopped Strand Mat

Cut two layers of 450 g/m^2 (1½ oz/ft^2) chopped strand mat and two layers of surfacing veil so that the full liner thickness can be applied in one lay-up, making allowance for staggered joints with at least a 5 cm (2 in) overlap. Apply initiated Derakane™ resin to the primed surface with a brush or roller, then lay a chopped strand mat over the resin and roll with a serrated roller until all air bubbles have been removed. Repeat until you have applied two bubble-free layers of chopped strand mat.

Step 4: Apply Surfacing Veil

Using the same sequence of operations, apply two layers of surfacing veil with Derakane™ resin. The lining should now be at least 3 mm (⅛ in) thick.

Note: If any layer of mat or surfacing veil is allowed to cure overnight, it must be wiped with clean, dry rags to remove any contaminants before the next layer is applied. If a layer or an overlap is allowed to cure for more than 72 hours at 20 °C (70 °F), it must be etched by grinding or sandblasting before the next layer can be applied. When using Derakane™ Signia™ resins, grinding may not be needed.

Step 5: Inspect and Repair the Lining

Before top coating, inspect the lining for defects such as voids, dry glass or exposed fibers. A 20,000-volt spark tester is an effective tool for this inspection. Defects should be removed by grinding to the bare substrate. Then cover any low areas with two layers of chopped strand mat and two layers of synthetic veil applied with Derakane™ resin. The glass should overlap the surrounding area by at least 5 cm (2 in). Build up the sanded defect area to the original laminate thickness.

Step 6: Apply Topcoat

Once the laminate has passed inspection, apply a resin/wax topcoat to prevent air inhibition. When using Derakane™ Signia™ resins, a resin/wax topcoat may not be needed. See Wax Topcoats in Section 3 of this guide.

Lining a Concrete Surface

Reinforced Derakane™ resins can be used to line concrete surfaces and equipment; however, the appropriate codes and regulations must be followed.

Step 1: Sandblast or Grit Blast the Surface

In the case of concrete, the Portland cement lattice should be removed to expose stone. Several sanding methods are acceptable; however, grit blasting and sandblasting are preferred. When lining a concrete structure, the concrete should be at least 28 days old and completely dry. Sandblast as you would a metal surface. After blasting, fill any cracks, pits, etc., with an initiated fumed silica-filled resin putty, allow to cure, and sand smooth. After all sanding is complete, thoroughly vacuum the surface to remove all dust and dirt.

Step 2: Prime the Surface

The surface temperature of the equipment to be relined should not exceed 40 °C (100 °F). Immediately after the dust has been removed, apply 0.05–0.08 mm (2–3 mil) of initiated Derakane™ 8084 resin with a brush or roller to provide an anchor for the lining.

The primer coat prevents surface corrosion prior to the application of the laminating resin and also provides a bonding surface for the laminating resin. The primer coat should be allowed to cure under ambient conditions, 15–38 °C (60–100 °F), to a tack-free state before applying the laminating resin. Once the primer coat is dry to the touch, check the surface with a test patch as explained in the **secondary bonding section of this guide**. Do not allow condensation to form over the primer coat. If the lining application is delayed, cover the primed surface to protect it from contamination. If the delay is longer than three days and the primer coat is allowed to develop a hard cure, sand the surface lightly and apply another primer coat prior to applying the laminating resin.

Step 3: Apply Chopped Strand Mat

Cut two layers of 450 g/m^2 (1½ oz/ft^2) chopped strand mat and two layers of surfacing veil so that the full liner thickness can be applied in one lay-up, making allowance for staggered joints with at least a 5 cm (2 in) overlap. Apply initiated Derakane™ resin to the primed surface with a brush or roller, then lay a chopped strand mat over the resin and roll with a serrated roller until all air bubbles have been removed. Repeat until you have applied two bubble-free layers of chopped strand mat.

Step 4: Apply Surfacing Veil

Using the same sequence of operations, apply two layers of surfacing veil with Derakane™ resin. The lining should now be at least 3 mm (⅛ in) thick.

Note*: If you allow any layer of mat or surfacing veil to cure overnight, you must wipe it with clean, dry rags to remove any contaminants before you apply the next layer. If a layer or an overlap is allowed to cure for more than 72 hours at 20 °C (70 °F), it must be etched by grinding or sandblasting before the next layer can be applied. When using Derakane™ Signia™ resins, grinding may not be needed.*

Step 5: Inspect and Repair the Lining

Before top coating, inspect the lining for defects such as voids, dry glass or exposed fibers. A 20,000-volt spark tester is an effective tool for this inspection. Remove defects by grinding to the bare substrate. Then cover the low area with two layers of chopped strand mat and two layers of synthetic veil, applied with Derakane™ resin. The glass should overlap the surrounding area by at least 5 cm (2 in). Build up the sanded defect area to the original laminate thickness.

Step 6: Apply Topcoat

Once the laminate has passed inspection, apply a resin/wax topcoat to prevent air inhibition. When using Derakane™ Signia™ resins, a resin/wax topcoat may not be needed. See Wax Topcoats in Section 3 of this guide.

Epoxy Vinyl Ester Resin Anchors for Concrete

For service temperatures of up to 80 °C (180 °F), Derakane™ 8084 resin can be used in a putty mix to produce anchors in concrete tank walls. To install the anchors, drill two-inch diameter holes two inches deep in the concrete on two-foot centers. Fill the holes with freshly initiated Derakane™ 8084 resin putty, leaving the surface of the anchor flush with the surface of the concrete wall.

[1] Registered trademark of Dixon Ticonderoga Co.

[2] Registered trademark of Special Metals Corporations

[3] Trademark of Blue Cub IP LLC

[4] Trademark of The Dow Chemical Company

SECTION 7

Joining and Repair Procedures

Introduction

This section covers materials and suggested methods for the general repair of all fiberglass-reinforced Derakane™ resin equipment, and for the butt and strap joining technique for fiberglass-reinforced pipe or duct.

The procedures outlined here are relatively quick and simple for field or shop work. However, it is recommended this work be performed by properly trained FRP professionals.

Please note that the minimum width of a joint or repair overlay and the number of plies of glass reinforcement required are related to the construction specifications; e.g., wall thickness and/or pressure rating, of the equipment being repaired. It is extremely important to follow vendor construction specifications and material requirements. When in doubt, contact the proper engineering or materials personnel or the equipment supplier.

1. Equipment Required

- Resin
- Promoters
- Initiator
- Solvent
- Fiberglass mat
- Woven roving
- Surfacing veil
- Fumed silica
- Styrene
- Wax
- UV absorber
- Release agents and films
- Hacksaws
- Saber saws
- Cut-off wheels or similar equipment
- Disc sanders
- Files
- Abrasive paper
- Work bench and pipe stands and/or jigs
- Scissors
- Stiff-bristled brushes
- Serrated rollers
- Unwaxed paper measuring cups or tubs
- Mixing sticks (tongue depressors)

2. General Information

Serrated rollers are far superior to common mohair or paint rollers for rolling resin-saturated fiberglass. Rapid dabbing with a stiff-bristled brush will remove entrapped air. The glass, resin, promoters, initiators, and other additives should be stored separately and according to the manufacturer's recommendations. The fiberglass reinforcement must be kept clean and dry. Before beginning the repair process, all materials should be at room temperature, 20°–30 °C (65°–85 °F). When repairing the joint, shop temperatures should also be 20°–30 °C (65°–85 °F). Repair work should not be done in rain, in snow or in an excessively humid environment. When working in a humid environment, all work should be done at a temperature >3 °C (5 °F) above the dew point. As the temperature approaches the dew point, water can condense on the surface of the part. The presence of water on the surface will affect resin cure and surface bonding detrimentally. Similarly, the glass must be kept dry and stored above the dew point.

3. Surface Preparation

Follow the surface preparation instructions as listed in Section 6, Secondary Bonding, of this guide.

4. Resin Preparation

SAFETY NOTE: Never mix the promoters CoNap/CoOct 6% directly with a peroxide initiator such as MEKP. Direct mixing will result in a violent reaction, and possibly a fire or explosion.

Use the same resin for repairing or joining that you would for fabricating original equipment. Weigh a sufficient amount of resin into a suitable container. (Avoid using more than 1 kg [1 qt] of resin at a time.) If required (and permitted), slowly add fumed silica and mix well to achieve a uniform consistency. If a high degree of flame retardancy is required, 3–5% antimony trioxide or pentoxide can be added to certain resins. Consult the specific resin TDS for guidance on appropriate amounts to add.

Use the resin weight to determine the amount of promoter, accelerator, inhibitor, and initiator required to achieve an acceptable working time. Table 5.1, Weight-to-Volume Conversion, in this guide may be helpful when measuring materials volumetrically. When determining a suitable working time, remember to take into consideration the resin, air, and part temperature. Refer to the promoter/initiator tables on the resin TDS for guidelines on additive levels. Weigh the required amount of promoter, accelerator, and, if applicable, inhibitor (pre-dissolved in styrene or other appropriate solvent) into separate containers.

Add the promoter to the resin and mix thoroughly. Add the accelerator to the resin and mix thoroughly. Add any additional liquid materials, such as inhibitors, and mix thoroughly. After thorough mixing, remove a sample of resin and perform a gel time test. If necessary, the gel time can be lengthened by adding inhibitor or shortened by adding additional promoter or accelerator; however, do not exceed the recommended levels for that resin. Initiate the resin as needed.

5. Resin Cure

Allow the resin to harden until sufficient cure is reached (see below). The time required will vary depending on weather conditions, temperature, and the amount of promoter and/or initiator used. An external heat source, such as an infrared heat lamp, will decrease curing time and may be necessary in cold weather. Generally, work should not be done at temperatures below 13 °C (55 °F) unless an external heat source is applied. Because most polyester and vinyl ester resins are flammable liquids, external heat sources should be used with caution. Take care when using an external heat source to prevent overheating the FRP, which can cause cracking, crazing and discoloration.

A Barcol hardness test and an acetone sensitivity test can be used to assist in determining the extent of cure of a laminate. See page 51 of this guide for a description of the Barcol hardness test and the acetone sensitivity test.

6. Joining Pipe or Duct

6.1. Preparation of Pipe or Duct

Cut the pipe or duct to the desired length, making sure that the ends are square and butt closely together.

Firmly support pipe sections; square the ends to be welded using a saber saw

Roughen the edges and prepare the surfaces as described in Section 6, Secondary Bonding, on page 29 of this guide.

Roughen the outside surfaces with a sander approximately 3 cm (1 in) farther in from the ends than the finished weld surface; where inside welds are possible, interior surfaces should be sanded prior to assembly

Immediately after you have removed the dust, apply 0.05–0.08 mm (2–3 mil) of initiated Derakane™ 8084 resin with a brush or roller to provide an anchor for the bonding surfaces.

Coat roughened end edges of pipe with a small amount of initiated resin

Any large voids may be filled with an initiated fumed silica-filled resin putty. The pipe components should be supported in position as rigidly as possible so that no movement occurs while making the joint. The primer coat prevents surface corrosion prior to the application of the joint repair and also provides a good bonding surface. Allow the primer coat to cure under ambient conditions, 15–38 °C (60–100 °F), to a tack-free state before joining the pipe or duct. Use a jig or other support system to hold the sections in position so that no movement occurs while making the joint or during curing.

6.2. Joining

Coat all the roughened edges with the resin mix, completely filling the joint and gently squeezing the sections together. For this step, it may be advantageous to add fumed silica to the resin to produce a paste or light putty that will readily fill small voids (3 mm [⅛ in] or less) and irregularities in the joint. It is often desirable to accelerate the curing time for this step by increasing the level of initiator. Remember to stay within the recommended levels as shown on the TDS. After joining, the interior surface should be relatively smooth, but a light bead of resin on the interior surface is desirable.

Butted sections may be “hot patched” or “tabbed” to hold them in alignment during the weld-cure period. A “hot patch” or “tab” consists of a 5 x 5 cm (2 x 2 in) square piece of fiberglass mat saturated with resin mix.

Apply “hot patches” or “tabs”

For this step, it is often desirable to speed up the cure of the resin by increasing the level of initiator. Remember to stay within the recommended levels as shown on the TDS. The “tab” resin and initiator should be mixed together in a small paper cup. Apply the prepared “hot patches” or “tabs” at intervals around the joint. The “hot patches” or “tabs” will cure in a matter of minutes and form a “tack weld” that secures the pipe sections in proper alignment.

Curing or hardening in a matter of minutes, the “patches” or “tabs” secure the pipe sections in the proper alignment

Discard the excess “tab” resin immediately after use to avoid contaminating the welding resin.

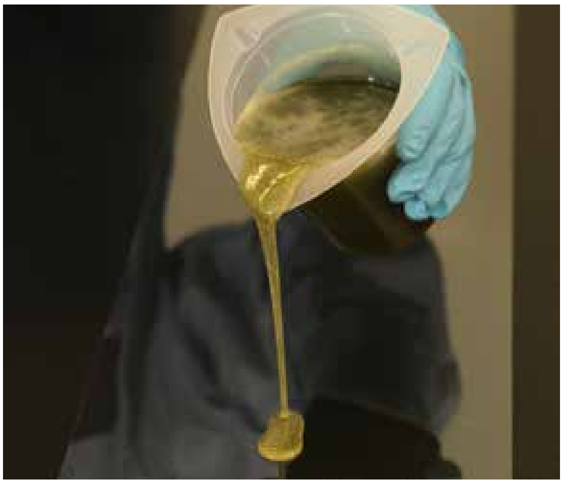
6.3. Preparation of Strapping

Table 7.1, page 40, serves as a guideline for determining fiberglass size and ply requirements; however, industry standards, such as ASME RTP-1 or EN13121-2:2003, or specific customer specifications should be consulted to determine the required size and quantity of fiberglass needed to provide a structurally sound repair.

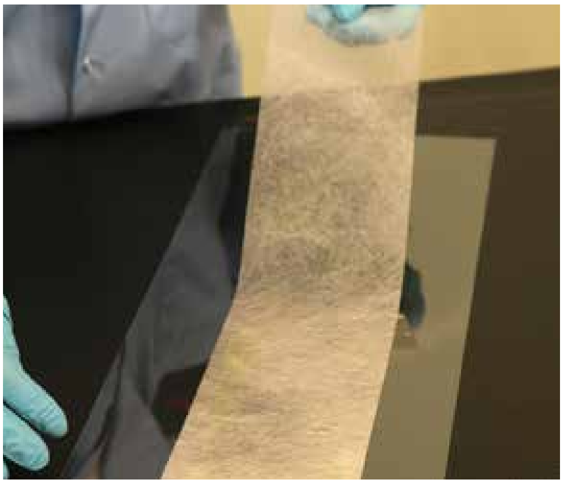
For the purpose of this photo series, each strip of fiberglass should be 5 cm (2 in) longer than the circumference of the pipe being repaired. Strips longer than 90 cm (36 in) may be cut in half to simplify application.

Lay out fiberglass mat strips on the work surface and cut each strip to the appropriate length

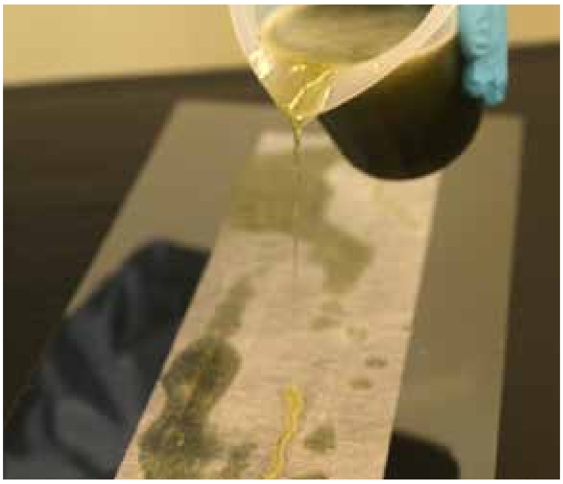
Subject to engineering review, Table 7.1 and Figure 7.1 can be used as guides in determining the minimum width of joint overlays, the number of plies of strapping needed, and the lay-up sequence. The thickness of the joint should be at least as thick as the pipe to be joined. Mix the appropriate amount of initiator with the required amount of resin that can be used immediately (about 1 kg [1 qt] of resin per 60 x 60 cm [2 x 2 ft] piece of mat). The resin will harden in about 20–30 minutes. Lay the widest section of fiberglass on a flat surface treated with release agent or covered with release film. Wet the entire surface with resin mix, using a brush and/or roller to spread the resin over the fiberglass.



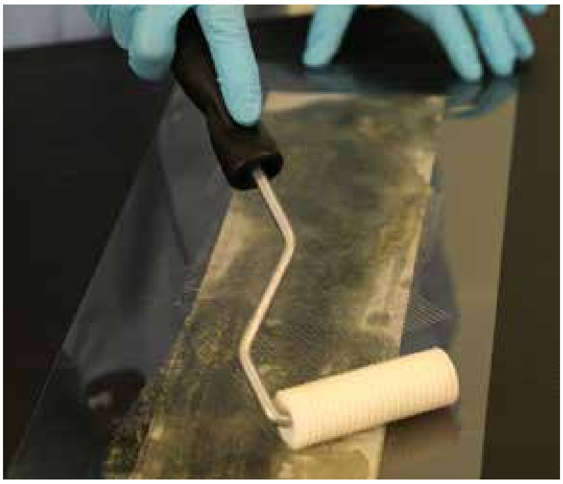
After thoroughly mixing in the initiator, pour the resin onto the release film



Apply the widest piece of fiberglass first



Spread the resin over the entire fiberglass strip

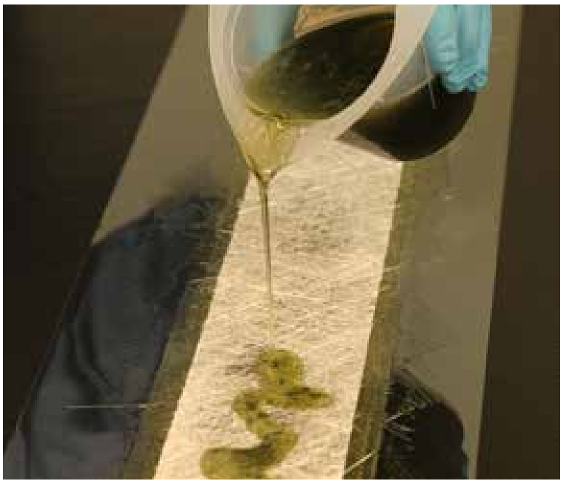


Work the resin into the fiberglass with a roller and/or brush (gloves are recommended)

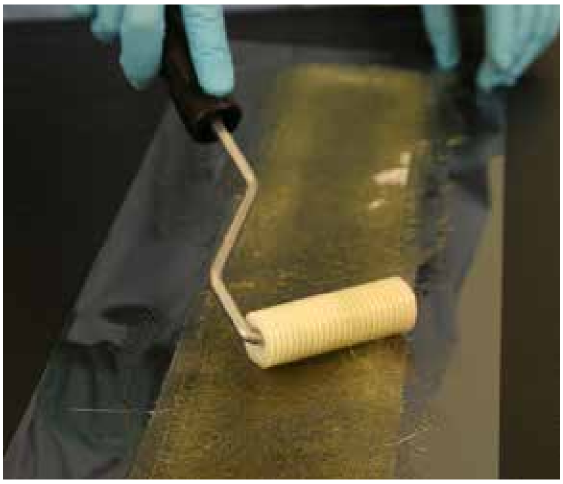
Position the next ply of fiberglass on top, offsetting it by about 3 cm (1 in) on the length. For the width, equal overlap is preferable but a slight offset (staggered) is acceptable.

Place the next-widest strip of fiberglass onto the first with one end of the second strip starting approximately 3 cm (1 in) in from the end of the first strip

Wet-out the layer with resin mix, removing as much air as possible with a brush and/or roller, being sure to roll outward, toward the edges of the laminate section.



Add additional resin



Work the resin into the second mat strip with a roller

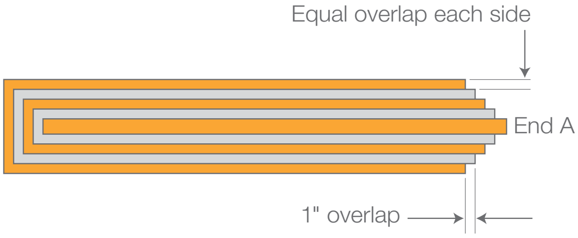


Figure 7.1: Fiberglass reinforcement for pipe repair.

Fiberglass mat impregnated with resin to form an integral unit for field weld or repair

Required Fiberglass Strapping and Sequence

Pipe Wall Thickness	Minimum Width of Overlays	Number of Plies of Fiberglass Strapping and Sequence*
3 mm (⅛ in)	—	3M; V
5 mm (3⁄16 in)	8 cm (3 in)	4M; V
6 mm (¼ in)	10 cm (4 in)	3M; 1WR; 2M; V
8 mm (5⁄16 in)	13 cm (5 in)	3M;1WR; 3M; V
10 mm (⅜ in)	15 cm (6 in)	3M; 1WR; 2M; 1WR; 2M; V
11 mm (7⁄16 in)	18 cm (7 in)	3M; 1WR; 2M; 1WR; 2M; V
13 mm (½ in)	20 cm (8 in)	3M; 1WR; 3M; 1WR; 3M; V
14 mm (9⁄16 in)	23 cm (9 in)	3M; 1WR; 3M; 1WR; 2M; 1WR; 1M; V
16 mm (⅝ in)	25 cm (10 in)	4M; 1WR; 4M; 1WR; 3M; 1WR; 1M; V
17 mm (11⁄16 in)	28 cm (11 in)	4M; 1WR; 4M; 1WR; 4M; 1WR; 1M; V
19 mm (¾ in)	30 cm (12 in)	4M; 1WR; 4M; 1WR; 4M; 1WR; 1M; V

Table 7.1: Required fiberglass strapping and sequence

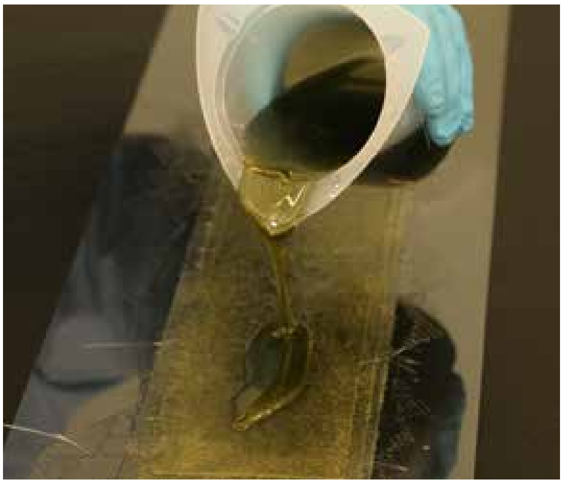
M = 450 g/m^2 (1.5 oz/ft^2) chopped strand mat

WR = 680 g (24 oz) woven roving

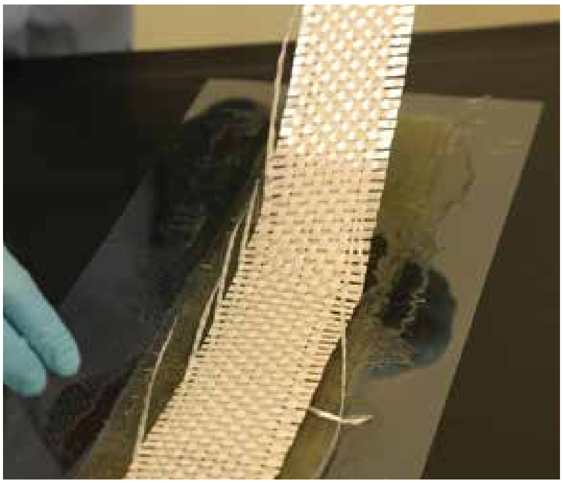
V = 0.025 mm (10 mil) “C” veil (optional)

*From surface of pipe outward

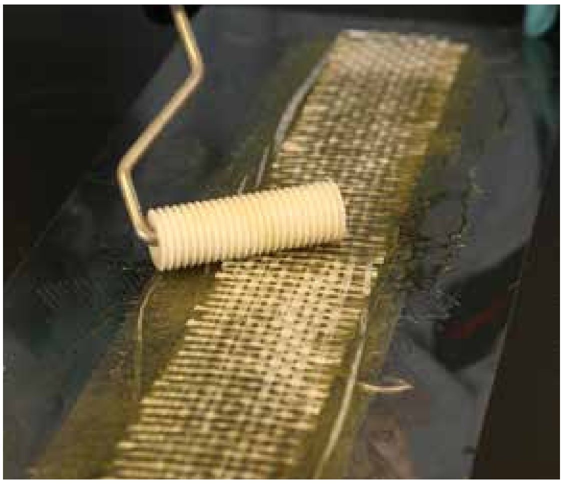
Wet-out the layer with resin mix, removing as much air as possible with a brush and/or roller, being sure to roll outward, toward the edges of the laminate section. Avoid excessive pressure, which will remove too much resin from the area. Repeat with the proper sequence of fiberglass until all the plies are saturated with resin and have formed into one integral unit (Figure 7.1, page 39).



Apply additional resin



Apply another strip of fiberglass



Work the resin into the fiberglass with a roller

When wetting each strip, it is best to be a little "lean" on resin at this stage rather than over wetting. If necessary, you may add more resin later. After laying the final strip, compress the strips together with glove-protected hands to remove large air bubbles and to make sure all layers are thoroughly wetted with resin.

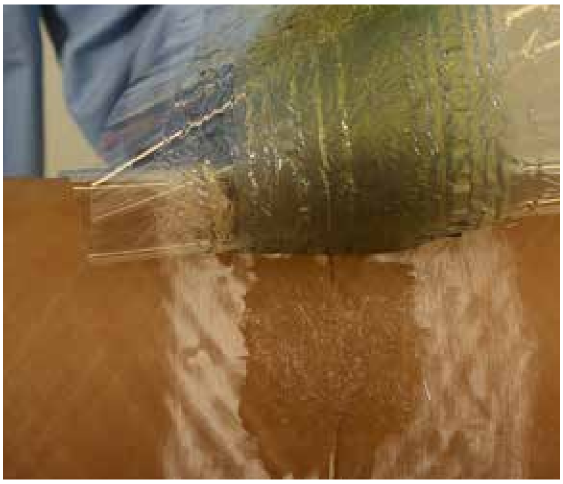
On very thick or large diameter joints, it may be easier to saturate two or three plies of fiberglass with resin at a time. This technique helps ensure removal of trapped air and facilitates the application of the strapping.

6.4. Application of Strapping

Apply resin mix on the prepared area of the pipe joint using a brush and/or roller. Pick up the entire strapping as prepared and center it carefully on the pipe joint.

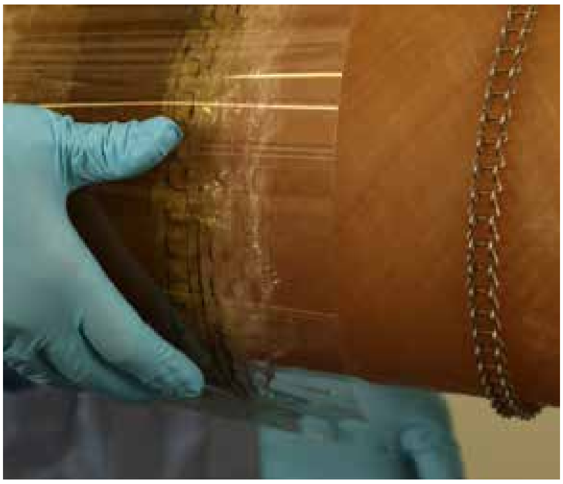
Pick up the completed weld strip

Apply the tapered end first with the narrowest ply placed directly against the pipe weld. Make sure to center the strapping and position it properly over the butt seam (Figure 7.2, page 42).



Carefully center the weld strip on the pipe joint and wrap the strip around the joint

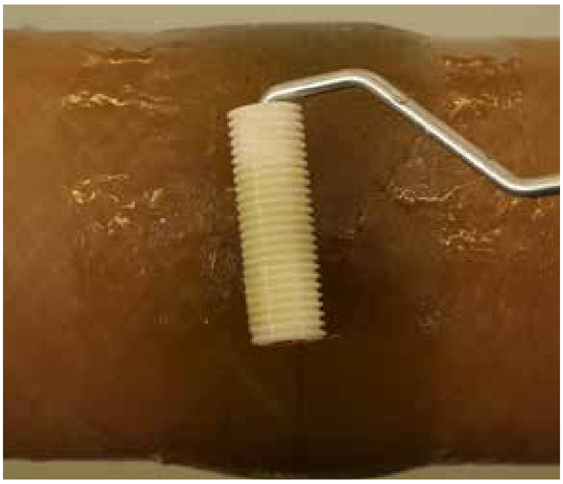
Carefully wrap the strapping around the joint using an even, forward pressure to form the entire joint with offset ends overlapping smoothly. Take care to avoid wrinkles on the under and back side of the weld.



Gently press the weld strip around the surface of the pipe joint until the ends overlap; lightly press out the air bubbles with gloved hands

If the strapping was assembled on release film, the film can be lifted with the strapping composite and will help in forming the strapping around the joint. Once the strapping is wrapped around the pipe, remove the release film before continuing to the next step. Roll out the strapping, being careful to smooth and blend the edges of the strapping into the pipe surface.

Any remaining air bubbles will appear as light spots. These should be removed by rolling toward the edge of the weld where they will be released and disappear.



Roll out the strapping; smooth and blend the edges into the pipe surface

All wrinkles and entrapped air should be removed by rolling from the center of the joint toward the outside edge. At this stage, additional resin may be applied if any fiberglass appears to be dry.

Add additional resin to any area that appears to be dry

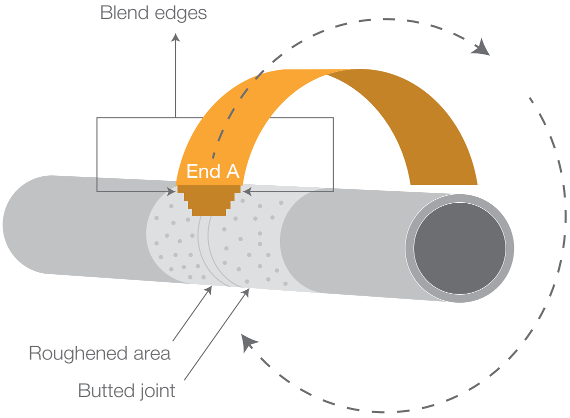
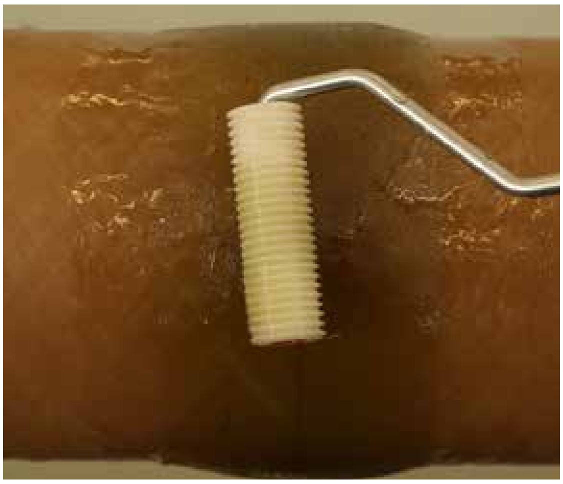


Figure 7.2: Strapping correctly positioned over center of butt seam

Finish the application of the weld with the roller. If the weld is not a straight butt joint, a little extra rolling and hand work may be necessary to shape the mat strips and eliminate bumps and ridges. Take care to prevent the strapping from sagging at the bottom of the joint during curing.

On large diameter equipment, it may be easier to saturate just a few fiberglass plies with resin at a time and apply strapping in two, three or four sections around the circumference to complete the wrapped joint.

Do not move or disturb the completed weld until it is completely cured and the surface is tack free. If the temperature is below 13 °C (55 °F), keep the weld area warm with heat lamps. For exterior installations, protect the weld from the weather.



Allow the weld joint to cure completely

After the weld area has cured, a topcoat of resin mix should be applied. Wax can be added to this layer of resin if desired. See page 13, Wax Topcoats, for guidelines on preparing a resin/wax topcoat. If the pipe or duct will be exposed to UV radiation, a suitable UV absorber may be added to the resin for this final coat. See page 12, Ultraviolet Protection, for recommended UV absorbers and levels. Determine the suitability of UV absorbers prior to beginning the joint repair.

7. Repair of Interior and Exterior Surfaces

In general, the above Steps 6.1–6.4, can be followed for repairing interior and exterior surfaces. Follow the surface preparation instructions listed in Section 6, Secondary Bonding, on page 29 of this guide. Mix the resin according to the instructions in Step 4, resin preparation, on page 35. Begin by placing the narrowest layer of fiberglass mat over the area to be joined/repaired and saturate the fiberglass with resin using a roller and/or brush. Roll the area from the center toward the outside edge, making sure to remove all wrinkles and entrapped air. Repeat with subsequent layers of fiberglass mat. Each layer of fiberglass must be larger than the underlying layer by 1–2 cm (½–1 in) all around. For the last layer, use only one ply of C-glass veil (or synthetic veil). Once the resin has cured, a final wax-containing topcoat should be applied over the veil layer, see page 13, Wax Topcoats. For exterior repairs, a wax topcoat may not be necessary. If the repaired area will be exposed to UV radiation, a suitable UV absorber may be added to the resin for this final coat. See page 12, Ultraviolet Protection, for recommended UV absorbers and levels. Allow the repaired joint to cure thoroughly.

8. Repair of Holes, Leaks, Cracks, etc.

The damaged area can be drained or plugged and then repaired with a new section, or a repair can be made using the “patch” technique. The surface must be prepared as described in Section 6, Secondary Bonding, on page 29 of this guide. For pipe and other equipment of similar diameter, the procedures outlined in Steps 6.1–6.4 on pages 36–41 are directly applicable; i.e., the wrap or strap technique is used to either join in the new section or “patch” the damaged area. Regardless of the repair technique you use, always consult the appropriate standards, such as ASME RTP-1 or EN13121-2:2003, or the pertinent customer specifications in order to achieve a structurally sound repair.

For large diameter vessels and large damaged areas, it may be necessary to apply a temporary backing of sheet metal or cardboard with a release agent before proceeding with repair according to the instructions listed in Sections 6 or 7. In any event, consult with an engineer to confirm that the proposed repair method is structurally sound and suitable for the intended application.

9. Installation of Nozzles

Consult the appropriate standards, such as ASME RTP-1 or EN13121-2:2003, or the pertinent customer specifications to determine the proper procedure required to provide a structurally sound nozzle installation. General procedures are outlined in Sections 6, 7, and 8. A generous filler of resin putty, as described in Step 6.2 on page 37, must be applied to all portions of the pipe neck on both sides of the wall. Once the resin putty has been allowed to cure, the interior surface must be finished with at least one layer of C-glass veil or synthetic veil. Once the veil layer has cured, apply a final, wax-containing topcoat over it.

10. Cleanup

All equipment should be cleaned immediately after use with a safety solvent. The solvent can also be used to clean work areas and/or small resin spills (less than 100 g).

Contact your materials supplier, equipment fabricator, or INEOS Composites Technical Service at derakane@ineos.com for assistance if there is any indication that procedures are not producing satisfactory results.

Your local INEOS Composites distributor can often provide complete joining and repair kits. They also can supply a complete line of INEOS Composites thermosetting resins.

SECTION 8

Inspecting a Laminate

FRP composite equipment should be inspected during fabrication, after all fabrication is completed and prior to putting the equipment into service. Inspection hold points during manufacturing may be specified. If possible, the inspection should be done at the fabricator's shop where, if any problems are found, they can easily be repaired. An additional inspection should be conducted immediately after installing the equipment to ensure that no mechanical damage occurred during transportation and installation. After installation, periodic inspections should be performed to monitor the integrity of the equipment and determine if and when the equipment needs to be repaired or replaced.

It is also recommended that the resin type, veil and glass type, method and location of fabrication, service conditions and date of installation be recorded when the equipment is installed. Keeping a record of this information is essential when the time comes to repair or re-line the equipment.

Visual Inspection

One of the simplest and most effective types of inspection is visual. Many imperfections in a laminate can be detected by simply holding a light behind the laminate and looking at it. Air bubbles, laminate uniformity, cracks, and wet-out are just a few of the things that can be detected by looking at a laminate. Table 8.1, Common Visual Defects Found in Cured Laminates, describes some common defects that can be detected visually, along with steps that can be taken to minimize these defects. For additional information on inspecting FRP parts and common laminate defects, refer to the following standards:

- ASTM C582 Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment
- ASTM D2563 Standard Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts
- FTPI 2007-1 Recommended Practice for the In-service Inspections of Aboveground Atmospheric Fiberglass Reinforced Plastic (FRP) Tanks and Vessels, which can be found at the FTPI's website: www.fiberglasstankandpipe.com.

Examine the laminate surface carefully. A smooth surface that is uniform in color is usually an indication of a well-fabricated laminate. There should be no dry spots or glass fibers protruding from the laminate surface.

Occasionally, a specification will require a section of the structure to be cut out and examined for liner and structural thickness, voids, interlaminar bonding, and overall uniformity of the laminate. Areas of high stress can also be detected and usually appear as minute cracks in the cross section.

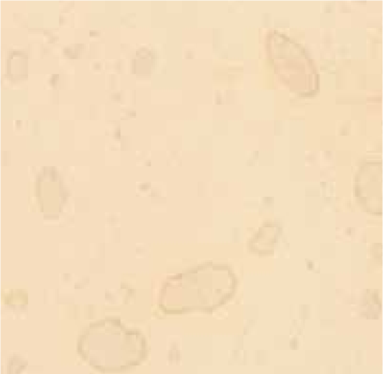
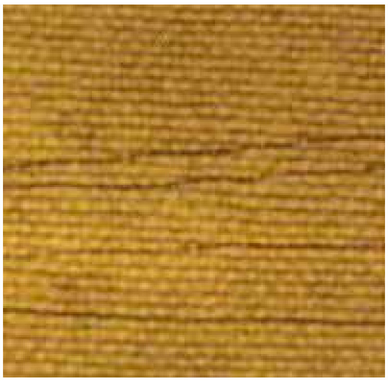
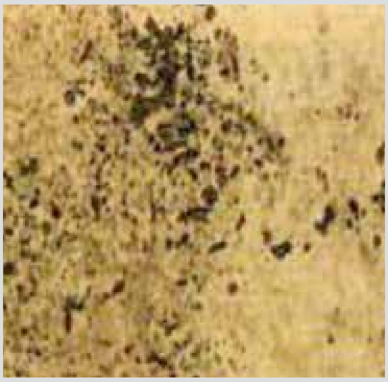
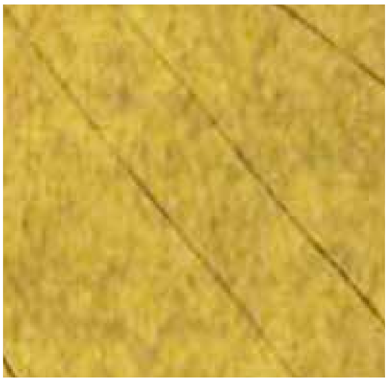
Defect	Description	Possible Causes	Possible Solutions
Air bubbles, voids 	Entrapped air in and between glass plies; non-interconnected spherical voids	Application of too many plies of glass at one time Inadequate rolling during lay-up Vigorous mixing causing incorporation of air into resin High viscosity resin used in combination with thick glass Poor or dirty surface	Apply fewer plies of glass at one time and roll thoroughly Reduce mixing speed Resin viscosity can be reduced by adding 3–5% styrene
Blisters 	Round, elevated areas of varying sizes on laminate surface; may occur individually or in a group	Too-rapid cure with high exotherm may cause separation of mat surfaces Presence of moisture in glass, resin, or filler	Reduce exotherm of resin system by laying up fewer plies at one time Reduce exotherm by lowering DMA or initiator level Ensure proper storage of resin, glass, and filler away from sources of moisture
Crack 	Cracks running along laminate either on or just below the surface, resulting in separation of material through entire thickness	Cracks may result from dramatic changes in the temperature conditions of the equipment (thermal shock cracking) Impact Resin shrinkage during cure Overly resin-rich areas	Monitor and minimize temperature fluctuations during equipment operation Avoid impact to the laminate surface Reduce resin content

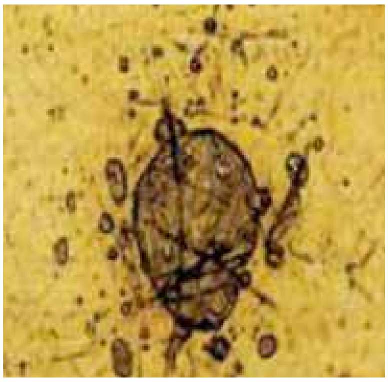
Table 8.1: Common Visual Defects Found in Cured Laminates

Defect	Description	Possible Causes	Possible Solutions
Crazing 	Pattern of fine cracks on or beneath surface	Isolated resin-rich area Impact Intermittent service causing temperature differences Wetting/drying cycling Resin shrinkage	Reduce resin content Monitor and minimize temperature fluctuations during equipment operations
Delamination 	Separation of glass layers, occurs particularly in areas of high stress; i.e., small diameter pipe, knuckle joints, etc.	Poor saturation of glass with resin Application of two layers of woven roving with no chopped mat in between Application of laminate to an FRP surface that has been allowed to cure several weeks Use of rapid cure systems in small radii areas	Ensure glass is completely saturated with resin and roll thoroughly Always use alternating layers of woven roving and chopped mat Before applying another FRP layer, lightly sand areas that have been cured for long periods of time In tight radii areas, use a low-exotherm system to reduce resin shrinkage and stress buildup
Dry spots 	Areas where dry glass fibers were not wetted thoroughly and are protruding from laminate, frequently along laminate edge	Not using enough resin to thoroughly saturate glass, occurs most often in molding operations	Thoroughly saturate glass with resin and roll thoroughly

Defect	Description	Possible Causes	Possible Solutions
Fish-eye 	Small globular mass of foreign material on or near the laminate surface that is not blended into surrounding material; particularly evident in transparent or translucent materials	Dirty glass Contamination of resin with foreign material	Ensure fabricating area is clean Properly store resin and glass to eliminate contamination
Jackstrawing 	Initially, laminate appears clear, but as curing occurs, white blemishes appear in the laminate; individual glass fibers become prominent and turn white, normally occurs in the structural area or chopped mat area of the laminate	Resin and glass fiber debond at the interface of the resin and glass, the sizing on the glass is not compatible and a high exotherm temperature causes the resin to shrink away from the glass fiber and debond, causing cloudy white appearance of laminate	Thoroughly evaluate compatibility of resin and glass before beginning fabrication Reduce resin exotherm Contact INEOS Composites Technical Service for assistance with selecting a glass compatible with specific resins
Pimple 	Small, sharp, or conical pimple-like raised area on laminate surface, usually resin rich	Dripping resin onto a laminate surface that has already begun to cure Rolling a laminate surface that has begun to cure	Thoroughly roll out laminate before resin begins to cure Do not continue rolling if resin is beginning to cure

Defect	Description	Possible Causes	Possible Solutions
Scorching/burning 	Discoloration of laminate as it cures	Generation of very high exotherm temperatures due to one (or a combination) of the following: hot working temperatures, high DMA and/or initiator levels, laying up too many plies at one time	Reduce DMA and/or initiator levels, particularly if working temperatures are high Reduce number of plies laid up at one time and allow to cure before applying additional layers
Pit or pinhole 	Small, regular or irregular crater on laminate surface, usually with nearly equal width and depth	Air bubbles that rise to surface and curing occurs before rolling out bubbles	Roll thoroughly between application of glass plies Reduce mixing speed to minimize incorporation of air into resin
Resin pocket 	Apparent accumulation of excess resin in a small, localized area	Improper lay-up (glass separates and void fills with resin)	Ensure proper lay-up sequence Roll thoroughly between application of glass plies

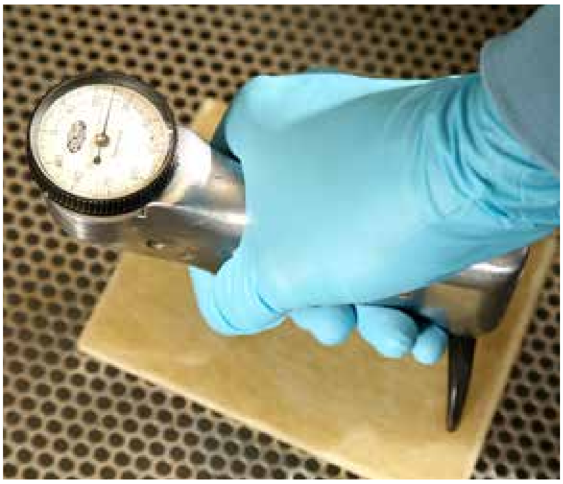
Defect	Description	Possible Causes	Possible Solutions
Scratch 	Shallow mark, groove, furrow or channel on laminate surface	Improper handling or storage of cured part	Properly store cured part away from sharp objects or rough surfaces that could damage surface of part
Spotty cure	Laminate surface is soft in some areas, while cured hard in others	Incomplete or inadequate mixing of promoters and/or initiator	Adjust mixing to achieve a small vortex and good movement of resin surface Mix thoroughly after addition of each additive Dissolve cobalt in small amount of styrene before adding to resin
Tacky surface	Laminate surface is tacky to the touch or fails to pass acetone sensitivity test (see page 51)	Incomplete cure caused by air inhibition Cobalt level too low	Apply a resin/wax topcoat to tacky surface (see page 51) Do not use a resin/wax topcoat if additional bonding is to be done to the surface Increase cobalt level

Defect	Description	Possible Causes	Possible Solutions
Worm holes 	Elongated void in surface or covered by thin film of cured resin	Usually found in small diameter pipe where cure occurs from the outside and progresses toward the mandrel	In tight radii areas, use a low exotherm system to reduce resin shrinkage and stress buildup
Wrinkle 	Crease or wrinkle of glass on or near the laminate surface	Wrinkling of veil (particularly synthetic veil) or glass can occur when laminating over uneven surfaces or when using stiff, heavy glass in corners Fold in the release film on the mold	Use 300 g/m^2 (1 oz/ft^2) or 450 g/m^2 (1½ oz/ft^2) mat where wrinkling is a problem Reduce resin viscosity by adding 3–5% styrene

Barcol Hardness

Barcol hardness values serve as an indication of completeness of cure; high values indicate a thorough cure and low values indicate an incomplete cure. Barcol hardness values will vary from one resin system to another and will depend on the type and number of veil layers. Generally, a well-fabricated, well-cured laminate will have a minimum Barcol hardness reading of 30. Please contact INEOS Composites Technical Service for additional information.

To check Barcol hardness of FRP equipment, refer to ASTM D2583 Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor. A brief instructional summary of how to check Barcol hardness is described below.



Barcol Impressor

To test for Barcol hardness, use the Barcol tester #934.1[1] to take readings on both the inside and outside surfaces of the part (10 to 12 readings in all). Reject the highest and lowest readings and average the remaining values to obtain an average Barcol hardness value.

Some key points to remember when testing Barcol hardness:

- Calibrate the Barcol tester with both high and low hardness discs and check it frequently
- Use the Barcol tester at room temperature (about 25 °C [77 °F])
- When using the tester, keep it level and be certain the point is perpendicular to the laminate surface
- Clean or replace Barcol points frequently
- Be sure to take measurements at secondary bonds such as flanges and internal connections; values at these points are critical
- Laminates with a high glass content may give abnormally high Barcol values when the point hits glass
- Contacting a synthetic veil may cause a drop of two to three points
- Adding graphite or carbon black can significantly reduce Barcol hardness; values of approximately 20 instead of 30 are typical
- Undercured laminates due to incorrect initiator ratios may cause low Barcol readings
- Incomplete initiator mixing may cause widely varying readings
- Heavy residual wax on the surface may cause low Barcol readings; lightly sand off 0.03–0.05 mm (1–2 mil) of wax and test again
- Testing a curved surface may cause a low Barcol reading

According to ASTM C581, the recorded Barcol value must be at least 90% of the published Barcol hardness value for that resin system in order for the equipment to be accepted. EN13121-2:2003 requires a minimum of 80% of the published value. Barcol values for INEOS Composites resins are indicated on the individual TDS or can be obtained from an INEOS Composites Technical Service Representative.

Acetone Sensitivity

An acetone sensitivity test can be used in conjunction with the Barcol hardness test to determine the extent of cure of a laminate. This test consists of using your finger to rub four to five drops of acetone on the laminate surface until the acetone evaporates. The laminate surface should be free of mold release, wax, dust, and dirt. If the surface of the laminate remains tacky or soft after evaporation, the laminate is air inhibited and is not thoroughly cured. In some instances, post curing the FRP part can further cure a laminate and improve Barcol hardness and acetone sensitivity test results.

Fabrication Methods

Fabrication Standards

The fabrication of FRP equipment is governed by various standards that provide guidelines and requirements for composition, performance, construction, design and testing methods of such equipment. The American Society of Testing Materials (ASTM), the National Bureau of Standards (NBS), and the American Society of Mechanical Engineers (ASME) publish numerous standards for the fabrication of various types of FRP structures. Some common standards are listed below.

1. ASTM C581: Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service
2. ASTM C582: Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment
3. ASTM D883: Standard Terminology Relating to Plastics
4. ASTM D1598: Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
5. ASTM D1599: Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
6. ASTM D1600: Standard Terminology for Abbreviated Terms Relating to Plastics
7. ASTM D2105: Standard Test Method for Longitudinal Tensile Properties of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube
8. ASTM D2143: Standard Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe
9. ASTM D2310: Standard Classification for Machine-Made “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
10. ASTM D2517: Standard Specification for Reinforced Epoxy Resin Gas Pressure Pipe and Fittings
11. ASTM D2562: Standard Practice for Classifying Visual Defects in Parts Molded from Reinforced Thermosetting Plastics
12. ASTM D2563: Standard Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts
13. ASTM D2924: Standard Test Method for External Pressure Resistance of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
14. ASTM D2925: Standard Test Method for Beam Deflection of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Pipe Under Full Bore Flow
15. ASTM D2992: Standard Method for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
16. ASTM D2996: Standard Specification for Filament-Wound “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
17. ASTM D2997: Standard Specification for Centrifugally Cast “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
18. ASTM D3262: Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe
19. ASTM D3299: Standard Specification for Filament Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks
20. ASTM D3517: Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe
21. ASTM D3567: Standard Practice for Determining Dimensions of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
22. ASTM D3647: Standard Practice for Classifying Reinforced Plastic Pultruded Shapes According to Composition
23. ASTM D3754: Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe
24. ASTM D3917: Standard Specification for Dimensional Tolerance of Thermosetting Glass-Reinforced Plastic Pultruded Shapes
25. ASTM D3918: Standard Terminology Relating to Reinforced Plastic Pultruded Products
26. ASTM D3982: Standard Specification for Contact Molded “Fiberglass” (Glass Fiber Reinforced Thermosetting Resin) Ducts

27. ASTM D4021: Standard Specification for Glass Fiber-Reinforced Polyester Underground Petroleum Storage Tanks (Withdrawn 1999, no replacement)
28. ASTM D4024: Standard Specification for Machine Made “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Flanges
29. ASTM D4350: Standard Test Method for Corrosivity Index of Plastics and Fillers
30. ASTM D4385: Standard Practice for Classifying Visual Defects in Thermosetting Reinforced Plastic Pultruded Products
31. ASTM D5364: Standard Guide for Design, Fabrication, and Erection of Fiberglass Reinforced Plastic (FRP) Chimney Liners with Coal-Fired Units
32. ASTM D5685: Standard Specification for Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe Fittings
33. ASTM D6041: Standard Specification for Contact-Molded Fiberglass (Glass-Fiber-Reinforced Thermosetting Resin) Corrosion Resistant Pipe and Fittings
34. ASTM F412: Standard Terminology Relating to Plastic Piping Systems
35. ASME/ANSI RTP-1: An American National Standard for Reinforced Thermoset Plastic Corrosion-Resistant Equipment
36. API 15LR: Low Pressure Fiberglass Line Pipe and Fittings
37. AWWA C950-13: Fiberglass Pressure Pipe

European and International Standards

1. EN 13121: GRP Tanks and Vessels for Use Above Ground
2. EN 13923: Filament Wound FRP Pressure Vessels: Materials, design, manufacturing and testing
3. ISO 1268: Fiber-Reinforced Plastics: Methods of producing test plates
4. ISO 10406: Fiber-Reinforced Polymer (FRP) Reinforcement of Concrete
5. ISO 10467: Plastics Piping Systems for Pressure and Non-Pressure Drainage and Sewage: Glass-Reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin
6. ISO 10639: Plastics Piping Systems for Pressure and Non-Pressure Water Supply: Glass-Reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin
7. ISO 14484: Performance Guidelines for Design of Concrete Structures Using Fiber-Reinforced Polymer (FRP) Materials
8. ISO 14692: Petroleum and Natural Gas Industries: Glass-Reinforced Plastics (GRP) piping
9. ISO 24817: Petroleum, Petrochemical and Natural Gas Industries: Composite repairs for pipework: Qualification and design, installation, testing and inspection

Standards are also used for classifying smoke and flame retardant properties of FRP equipment. The most frequently referred to fire and smoke standards are listed below.

1. ASTM D635: Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
2. ASTM D2863: Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastic (Oxygen Index)
3. ASTM E84: Standard Test Method for Surface Burning Characteristics of Building Materials
4. ASTM E162: Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source
5. ASTM E662: Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials
6. ASTM E906: Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using a Thermopile Method
7. UL 94: Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
8. EN 13501: Fire Classification of Construction Products and Building Elements
9. EN 45545: Railway Applications: Fire Protection on Railway Vehicles

Fabrication Processes

FRP is made with reinforcement material such as glass or carbon fibers, along with resin and additives. The reinforcement material provides strength and structure, while the resin holds the fibers in place and protects them from corrosion and abrasion.

The fabricator applies the resin and fiber materials in layers by one of several fabricating techniques. This “layering” process gives the fabricator freedom to mold intricate shapes. Fabricators today have the technical sophistication to custom design and build pieces of equipment tailored to demanding design considerations. The fabricating technique chosen depends on factors like size, shape and complexity of the equipment, performance and appearance requirements, volume, and cost. This section describes the most commonly utilized fabricating methods used with vinyl ester resin systems.

Hand Lay-Up

The hand lay-up process requires little capital investment and is the oldest, simplest, and most labor-intensive fabrication method. Hand lay-up is well suited for low volume production of equipment and can be used for both the corrosion barrier and the structural portion.

This process uses a room-temperature cure system where initiated resin is applied to the surface of a mold, and then fiberglass – usually veil, followed by chopped mat and/or woven roving – is placed on top of the resin. The fiberglass is then saturated with the resin by rolling the surface with a roller. This rolling action also assists in removing air bubbles that can detrimentally affect laminate performance. Following rolling, more resin and fiberglass are applied to build up the corrosion barrier and the structural portion of the laminate. Each consecutive layer is applied in the same manner as the first.

FRP parts fabricated using various fabrication processes.

Spray-Up

Spray-up is a faster process and is less labor intensive than hand lay-up. Several drawbacks to spray-up include the possibility of more air entrapment and difficulty in controlling variables such as thickness and resin-to-glass ratios. As with hand lay-up, spray-up can be used for the corrosion barrier and the structural portion of equipment. Approval by end users may be required for the use of spray-up in the corrosion barrier. The spray-up process is a room-temperature cure process in which continuous strand roving is fed through a chopper gun, combined with initiated resin and sprayed onto a mold surface. The surface is then rolled to remove air bubbles. Additional layers of resin/glass are applied and rolled to reach the desired thickness.

One-Part System

For spray-up and chopper gun applications, accelerators and promoters are added directly to a drum and mixed thoroughly into the resin with an appropriate mixer. Collapsing-propeller-type agitators give good results. A minimum of 25 minutes of mixing is needed to ensure the accelerators and promoters are thoroughly mixed into the resin. Typical percentages of promoters and accelerators for Derakane™ resins are listed on the specific resin TDS.

The initiator, usually an MEKP (9% oxygen), is then added with an injection-type initiator gun. A 10–20 minute working time is recommended. There should be no moisture or oil in either the air line or the initiator line. The operator should run a small amount of resin through the gun to check the gel time before fabricating parts.

Two-Part System

A two-part system can also be used. In this method, two containers are used; one contains resin with twice the required amount of promoters and no initiator, while the other contains resin with twice the required amount of initiator and no promoters. Resin is then drawn from both containers and mixed during the spraying process, resulting in a resin with the proper mix of promoter and initiator. Mix only as much resin as you will use within four hours. Two-part systems are most commonly used for BPO/DMA systems. Resin used with the two-part system must be stable when promoted and then initiated with high levels of additives. Please follow suppliers' recommendations for use, maintenance, purging, etc., of spray guns and other equipment.

Filament Winding

Filament winding is an excellent process for fabricating round equipment such as tanks, pipes, ducts, etc. Filament winding is less labor intensive than both hand lay-up and spray-up and produces very uniform structures in terms of thickness, resin-to-glass ratio, etc. Filament winding is recommended only for the structural portion of FRP equipment. The corrosion barrier should be fabricated using either hand lay-up or spray-up.

Filament winding process.

Filament winding typically uses a room-temperature cure system but generally involves very long gel times. Continuous-strand glass or roving is pulled through guides impregnated with resin and fed onto a rotating mandrel in a helical pattern. This produces the structural portion of the equipment that is typically 60% glass. The wind angle formed by this pattern has a direct bearing on the physical strength of the part. Chopped mat and/or roving may also be applied to accelerate the build-up of the structural portion.

1. **Glass**: Continuous roving is the primary reinforcement used for filament winding. The following continuous rovings have been used successfully with Derakane™ resins:
   - Hybon®1 2000 Series
   - Type 30
   - R099 625 & 673

   Higher-yield rovings generally wet-out more easily, but more strands are required to achieve the desired glass content. Continuous rovings are sized to reduce damage to the glass during fabrication. Glass suppliers also add coupling agents to improve compatibility and adhesion of the resin to the glass. Surfacing veils and chopped-strand mats are applied on the inside mandrel surface of filament-wound pipe to provide a resin-rich corrosion liner for enhanced chemical resistance. This liner is usually applied to the mandrel by hand. This technique is similar to hand lay-up on a flat surface. The resin is applied to the mandrel surface first, and then the glass veil or mat is applied and wetted through by the resin. Applying the liner usually requires two people who unroll the veil or mat onto the mandrel in a helical pattern.

2. **Peroxide initiators**: Elevated temperature peroxide initiators are used when the fabrication equipment is capable of applying heat to the uncured laminate. Many peroxides are commercially available for use in elevated-temperature curing of vinyl ester resins.

   Peroxide initiators are generally chosen for their ability to provide the best combination of rapid cycle time and laminate quality. The activation temperature of the peroxide is an indication of how rapidly it will initiate a resin. Table 9.1 provides 10-hour half-life temperatures for four of the peroxide initiators commonly used with Derakane™ resins. Ideally, peroxides with a lower 10-hour half-life temperature will provide shorter gel times at any given resin temperature.

   By using different initiator systems, fabricators can achieve a wide range of gel times over a broad temperature range. In addition, certain blends of peroxides may offer advantages such as reduction of peak exotherm temperature or other special properties.

Peroxide	10-Hour Half-Life Temperature
Perkadox 16-40XPS [bis(4-tert-butyl cyclohexyl) peroxydicarbonate]	43 °C (109 °F)
Dibenzoyl peroxide (BPO)	72 °C (162 °F)
Tert-butyl perbenzoate (TBPB)	106 °C (223 °F)
Cumene hydroperoxide (CuHP)	159 °C (318 °F)

Table 9.1: 10-hour half-life temperatures of peroxide initiators

4. **Room-temperature cure**: Derakane™ epoxy vinyl ester resins can also be formulated for room-temperature cure. Promoter and initiator systems recommended for these formulations are essentially the same as those used for hand lay-up. Various inhibitors and/or retarders may be used in combination with a cobalt-promoted system to increase the room-temperature gel time. See the specific resin TDS for information on suitable inhibitors and retarders.
5. **Internal mold release agents**: Internal mold release agents may be used (typically at a level of 0.5%) in conjunction with waxed surfaces in specialized (elevated temperature) molding. One brand that works well with Derakane™ resins is Zelec®[2] UN release agent.

Fabricating Thick FRP Sections

Derakane™ resin systems are designed to work successfully in the fabrication of thick parts where exotherm temperatures are a concern. When laminating a thick section, first formulate the promoter package to achieve the desired gel time needed for the application (see the appropriate resin TDS for specific formulations). Second, fabricate a test laminate to see if the exotherm of the resin is too high, resulting in burnt sections of the part. If this is the case, CuNap can be added to some formulations at a level of up to, but no more than, 400 ppm (see the appropriate resin TDS for specific formulation examples and CuNap charge levels). As a result, the resin system will maintain the same gel time characteristics but the peak exotherm temperature will be much lower, eliminating the concern of burning. The resin should be used within a day of charging the copper. Copper causes the gel characteristics to drift over time.

Finishing Processes

There are a variety of methods available to finish the exterior surface of FRP equipment. In many cases, a topcoat of resin containing a dissolved wax is sprayed, rolled, or brushed onto the surface of the FRP equipment. This wax forms a film preventing air inhibition of the resin. Air inhibition can lead to a tacky surface. However, care must be taken if there is any future laminating to be done, such as the addition of manways or nozzles, because the wax will interfere with secondary bonding. The wax must be removed prior to subsequent laminations. This is typically accomplished by surface grinding.

If the equipment needs to be a certain color, you may gelcoat or paint it. These coatings have the added advantages of providing opacity for light-sensitive contents and weather protection for FRP equipment used outdoors.

[1] Registered trademark of PPG Industries

[2] Registered trademark of Stepan Company

SECTION 10

Health, Safety and Regulatory Information

Safety Data Sheets (SDS)

Safety data sheets (SDS) contain health and safety information that assists handlers in developing appropriate procedures to protect employees and customers. Before handling INEOS Composites products, all personnel should read and understand the SDS for the specific resins being used. SDSs for all Derakane™ resins are available through your INEOS Composites sales representative or by request via derakane@ineos.com.

The information provided on the SDS applies only to Derakane™ resins and not to other products used in formulating such as initiators, promoters, accelerators, inhibitors, solvents, and other additives. Specific safety and handling procedures for these additives should be requested from the product manufacturer. When various materials are used in combination, formulators should follow the most stringent safety and handling procedures applicable to the products being used.

Monomers

Derakane™ resins must be diluted with styrene or other monomers to obtain a workable viscosity. The most hazardous ingredient in these mixtures is the styrene or other monomer. (The polymer contained in the resin is typically non-hazardous.)

Styrene has a pungent odor that is detectable at levels of less than 1 ppm. Even thoroughly cured parts may have a residual styrene odor.

Styrene is subject to regulations that may impact facilities using Derakane™ resins. Current regulations should be reviewed before using Derakane™ resins.

For the most current and comprehensive information on styrene health effects, visit www.styrene.org for information pertaining to North America, or www.styreneforum.org for styrene information worldwide. Practical information for European fabricators can be found at www.upresins.org/safe-handling-guides. Other monomers used in Derakane™ resins pose different hazards. As always, consult the product SDS for details.

Flammability

Derakane™ liquid resins are classified as flammable due to the presence of styrene and other monomers. The red FLAMMABLE label is required on drums because the resins have a flash point under 38 °C (100 °F). Liquid resin should be stored away from heat sources such as space heaters, open flames, and spark-producing equipment. Smoking in the fabrication area should be strictly prohibited.

The flash point is the minimum temperature at which the material gives off a vapor in sufficient quantity to ignite in air, as tested by one of the approved methods. Because the flash point of styrene is approximately 27 °C (80 °F), flammable concentrations of vapors may be present when liquid Derakane™ resins are being used in the FRP shop. Note that other materials in the shop (e.g., acetone) may also contribute to flammable concentrations of vapors.

The lower flammable limit is the minimum concentration of a vapor in air that will burn when exposed to an ignition source. Conversely, the upper flammable limit is the maximum concentration of a vapor that will burn when exposed to an ignition source. These limits are specific for a given temperature and are usually given for 25 °C (77 °F).

The flash point and flammable limits of styrene in air are listed in Table 10.1. It is important to prevent the formation of explosive or combustible mixtures and to take precautions to avoid ignition of any such mixtures. Resin-handling areas should be well ventilated and equipment selected based on safety requirements of the area. All equipment, drums, tank trucks, and hose connections must be grounded for the safe discharge of static electricity. Do not use cutting or welding torches on empty resin drums; they may contain flammable vapors.

Consult the Derakane™ resin SDS and your site safety plan for additional information regarding the proper handling of Derakane™ liquid resins.

Flash Point	**23–29 °C (74–84 °F)**
Flammable limits in air	
Lower limit	1.1% (based on styrene)
Upper limit	6.1% (based on styrene)

Table 10.1: Flash point and flammable limits of styrene-containing resins in air

Resin Spills

Resin spills of less than 100 grams can be wiped up with a paper towel or cloth and the area washed with soap and water. For spills of greater than 100 grams, consult the SDS for proper containment and cleanup procedures.

Disposal

Carefully follow all applicable regulations when disposing of any hazardous material. Consult the product SDS and the local regulatory agency for proper disposal procedures. In some areas, completely cured resin parts may be considered non-hazardous; however, it is recommended that the proper regulatory agency be contacted to confirm the proper method of disposal for cured resin parts.

Health Concerns

Review the appropriate product SDS for guidance on topics including skin contact, eye contact, inhalation, ingestion, and chronic health effects.

We encourage our customers and potential users of INEOS Composites products to review the application of our products from the standpoint of human health and environmental quality. To help ensure that INEOS Composites products are not used in ways for which they are not intended or tested, INEOS Composites personnel can assist customers in dealing with certain safety and environmental considerations. Your INEOS Composites sales representative can arrange the proper contacts.

Resin Storage

Storage Temperatures

The storage life of Derakane™ resins decreases at higher temperatures. For maximum stability, Derakane™ resins should be stored at temperatures below 25 °C (77 °F). Derakane™ resins should be kept away from all sources of heat that might create localized hot spots.

For storage of drums, it is highly recommended that all material is stored at stable temperatures below 25 °C (77 °F). Avoid exposure to heat sources such as direct sunlight or steam pipes. To avoid contamination of product with water, do not store outdoors. Keep sealed to prevent moisture pick-up and monomer loss. Rotate stock.

When Derakane™ resins are stored below 13 °C (55 °F), separation may be observed. All polymer solutions have a temperature at which they may either crystallize (giving a hazy appearance) or separate into two layers. Polymers are known to exist in supersaturated solutions for long periods of time so separation may or may not occur. If separation occurs, the resin should be brought back into a homogenous solution by gradually warming to 25 °C (77 °F). Depending on the degree of separation/haziness, mixing, as well as warming may be required. Resin stored below 13 °C (55 °F) is acceptable for use and only requires this additional mixing and/or warming if phase separation/haziness is visually apparent.

Resin Stability

The stability of Derakane™ resins is limited even when stored according to the above recommendations. Resin age is not an appropriate measure of suitability for use. INEOS Composites does not acknowledge "shelf life" as a property. See the document "Fitness for Use Guidelines," available from INEOS Composites Technical Service.

Inventory Rotation

To minimize potential warranty problems, maintain your Derakane™ resin inventory on a first-in, first-out basis; i.e., always use the oldest resin first.

Aerating the Resin

Because inhibitors in Derakane™ resins work by reacting with oxygen to prevent premature crosslinking, periodic replenishing of the dissolved oxygen will extend the resin's shelf life. Because flammable vapor mixtures may be formed in the process, this operation should be done only in well-ventilated areas free from ignition sources.

The recommended way to replenish dissolved oxygen is by using an air-powered drum mixer with both the bung and vent caps removed. Another possible way is to bubble small amounts of clean, dry air into the drum through a dip pipe.

Note: *The dip pipe should not contain any zinc or copper alloy since these materials could change the reactivity of the resin.*

Note: *Derakane™ Momentum™ resins do not require periodic aeration to maintain storage life. These resins should not be reaerated.*

Note: *Derakane™ Signia™ resins do not require periodic aeration to maintain storage life; however, aeration is not detrimental to the overall stability of the resin.*

For increased safety, a 2:1 mixture by volume of nitrogen and air may be used to keep gas from exiting the drum during sparging below the styrene/gas flammability limits. Both the drum and the sparging line should be grounded. Oxygen can also be replenished by opening the bung and the vent in the head space above the resin. After this is completed, close the drum tightly and roll it on its side to mix air into the resin.

Any steps to extend the shelf life of Derakane™ resins must be taken before they begin to gel. If the resin has begun to gel, discard it in accordance with approved disposal procedures. (Gelled resin will not cure properly and finished products made with it may have unsatisfactory chemical resistance.)

Bulk Storage

Derakane™ resins are frequently stored in bulk storage tanks. A properly designed bulk storage system should do the following:

- Eliminate flammability hazards
- Protect resin against temperature extremes
- Prevent contamination, including exclusion of ambient moisture/humidity
- Retard polymerization in infrequently used lines

Follow these procedures to ensure proper bulk storage of Derakane™ resins:

1. Maintain resin temperature below 25 °C (77 °F) in an electrically grounded vessel. Continuous monitoring of the bulk resin temperature is recommended.
2. Periodically recirculate the resin in the storage tank and process lines to prevent polymer buildup in stagnant sections.
3. Keep resin properly aerated by circulating the contents of the storage tank to ensure complete turnover of the resin. This can be controlled with Step 2. Derakane™ Momentum™ and Signia™ resins do not need to be aerated.
4. Use proper materials for containing, transferring and storing the resin. Alloys containing copper or zinc can adversely affect the reactivity of the resin and should not be used. Rubber parts should also be avoided because styrene monomer is an excellent solvent for most rubbers except Viton®[1] fluoroelastomer. Please contact INEOS Composites Technical Service for additional information on best practices for bulk resin storage.
5. Check resin gel time and viscosity periodically to ensure continued high resin quality.

Storage of Promoted Resin

Derakane™ resin that has been promoted in the shop with CoNap/CoOct 6% and/or DMA/DEA or modified with other additives may have reduced stability compared to unmodified Derakane™ resins. Pre-acceleration of Derakane™ Momentum™ resins is typically done using cobalt promoter only. Should an amine accelerator be required for lower-temperature use or for better surface cure, and if the resin is to be used beyond one day, DEAA is the preferred accelerator for longer-term stability. Because of the possibility of reduced stability and to ensure consistent properties, any formulating of resin required for fabrication should be delayed until shortly before use. Formulated resin should be used as quickly as possible to prevent problems.

Because additives can have a destabilizing effect on Derakane™ resins, the stated commercial warranties do not apply to resins that have been modified from their "*as received*" condition.

Product Stewardship

We encourage our customers and potential users of INEOS Composites products to review the application of our products from the standpoint of human health and environmental quality. To help ensure that INEOS Composites products are not used in ways for which they are not intended or tested, INEOS Composites personnel can assist customers in dealing with certain safety and environmental considerations. Your INEOS Composites sales representative can arrange the proper contacts.

INEOS Composites product literature, including Safety Data Sheets, should be consulted prior to use of our products. These may be obtained from your INEOS Composites sales representative, by visiting ineos.com/composites, or by sending a request by email to derakane@ineos.com.

APPENDIX A

Trade Names and Material Suppliers

Trade Name	Type	Manufacturer	Website
Surfacing veils			
NEXUS®	Polyester	Precision Fabrics Group	www.precisionfabrics.com
Avelle® APC	Polyester	Xamax Industries	www.xamax.com
M524-E-CR25A	"C" Glass	Owens Corning	www.ocvreinforcements.com
Freudenberg T-1777; T-1773	"C" Glass, PAN	Freudenberg	www.freudenberg-nw.com
		Fiberglass Florida (S. America)	www.fiberglassflorida.com
Mats			
M113	E-glass	Owens Corning	www.ocvreinforcements.com
Advantex® M723A	E-CR glass	Owens Corning	www.ocvreinforcements.com
Chopped mat		Fiberglass Florida (S. America)	www.fiberglassflorida.com
		Jushi	www.jushi.com
Woven roving			
318, 322, 324		Owens Corning	www.ocvreinforcements.com
Hybon® woven roving		Nippon Electric Glass	www.neg.co.jp/en/
Woven roving		Fiberglass Florida	www.fiberglassflorida.com
		Jushi	www.jushi.com
		Owens Corning	www.ocvreinforcements.com
Continuous roving			
Hybon® 2000 Series		Nippon Electric Glass	www.neg.co.jp/en/
Advantex® Type 30		Owens Corning	www.ocvreinforcements.com
Continuous roving		Fiberglass Florida (S. America)	www.fiberglassflorida.com
		Jushi	www.jushi.com
Gun roving			
OC® Multi-End Rovings		Owens Corning	www.ocvreinforcements.com
Initiators			
Luperox® DDM-9, DHD 9	MEKP	Arkema	www.arkema-americas.com
Norox® MEKP 925/925H/ KP925H	MEKP	United Initiators	www.united-initiators.com
Cadox® L-50a	MEKP	Akzo Nobel	www.akzonobel.com/polymer
Butanox® M-50	MEKP	Akzo Nobel	www.akzonobel.com/polymer
Butanox® LPT-IN	MEKP	Akzo Nobel	www.akzonobel.com/polymer
Luperox® AFR 40	BPO	Arkema	www.arkema-americas.com
Benox® L-40LV	BPO	United Initiators	www.united-initiators.com
Cadox® 40E	BPO	Akzo Nobel	www.akzonobel.com/polymer
Cumene hydroperoxide	CuHP	Chemtura Corporation	www.chemtura.com
Luperox® CU80	CuHP	Arkema	www.arkema-americas.com
Norox® CuHP	CuHP	United Initiators	www.united-initiators.com
Trigonox® K-90	CuHP	Akzo Nobel	www.akzonobel.com

Products listed above are registered trademarks or trademarks of the corresponding companies.

Trade Name	Type	Manufacturer	Website
Initiators: non-foaming MEKP substitutes			
Trigonox 239		Akzo Nobel	www.akzonobel.com/polymer
Norox CHM-50		United Initiators	www.united-initiators.com
Promoters			
6% Cobalt naphthenate		Akzo Nobel Dura Chemical Corporation Ltd.	www.polymerchemistry.akzonobel.com www.durachemicals.com
6% Cobalt octoate		Akzo Nobel Dura Chemical Corporation Ltd.	www.polymerchemistry.akzonobel.com www.durachemicals.com
Accelerators			
Dimethylaniline	DMA	Lanxess (China) Sigma-Aldrich	www.lanxess.com www.sigmaaldrich.com
Diethylaniline	DEA	Lanxess (China) Sigma-Aldrich	www.lanxess.com www.sigmaaldrich.com
Dimethylacetoacetamide	DMAA	Eastman	www.eastman.com
Diethylacetoacetamide	DEAA	Parchem	www.parchem.com
Inhibitors			
Tertiary butyl catechol	TBC	Solvay	www.solvay.com
Hydroquinone	HQ	Eastman Fisher Scientific	www.eastman.com www.fishersci.com
Toluhydroquinone	THQ	Eastman	www.eastman.com
2, 4-Pentanedione	2,4-P	Sigma-Aldrich Akzo Nobel	www.sigmaaldrich.com www.akzonobel.com
Antimony oxides			
Antimony trioxide		Sigma-Aldrich Parchem	www.sigmaaldrich.com www.parchem.com
Antimony pentoxide		Sigma-Aldrich Nyacol®	www.sigmaaldrich.com www.nyacol.com
Intumescent coatings			
Intumescent coatings		Akzo Nobel	www.international-pc.com/products/fire-protection/fire-protection.aspx
Fumed silica			
CAB-O-SIL TS-720 or M-5		Cabot Corporation	www.cabotcorp.com
Aerosil R200 or R202		Evonik Industries	www.aerosil.com
Fumed silica		HM Royal	www.hmroyal.com

Products listed above are registered trademarks or trademarks of the corresponding companies.

Trade Name	Type	Manufacturer	Website
UV stabilizers: for polyester resins			
Cyasorb 5411		Cytek Industries	www.cytek.com
Cyasorb UV-9		Cytek Industries	www.cytek.com
UV stabilizers: for vinyl ester resins			
Cyasorb UV-9		Cytek Industries	www.cytek.com
Tinuvin 328		BASF	www.basf.com
Uvinul M-40		BASF	www.basf.com
Air release agents			
BYK A515, A555		BYK	www.byk.com
SAG 47		Momentive	www.momentive.com
Abrasion-resistant additives			
Silicon carbide		Electro Abrasives	www.electroabrasives.com
		Penn-United Technologies Inc.	www.pennunited.com
		St. Gobain	www.sic.saint-gobain.com
		ESK	www.esk-sic.com/en/
Aluminum oxide		Sigma-Aldrich	www.sigmaaldrich.com
		Almatis	www.almatis.com
Quartz flour		Quarzwerke GmbH	www.quarzwerke.com
Air inhibitors/suppressants			
Fully refined paraffin wax		HM Royal (China, S. America)	www.hmroyal.com
		Moore & Munger (China, S. America)	www.mooremunger.com
BYK S750		BYK	www.byk.com
BYK P9928 (foam suppressant)		BYK	www.byk.com
Exotherm suppressant			
Copper naphthenate		Parchem	www.parchem.com
		Dura Chemical Corporation Ltd.	www.durachemicals.com
Wetting agents			
Tween 20		Sigma-Aldrich	www.sigmaaldrich.com
BYK R605		BYK	www.byk.com

Products listed above are registered trademarks or trademarks of the corresponding companies.

APPENDIX B

Equipment Suppliers

Equipment	Website
Chopper guns/RTM supplies	
Magnum Venus Products	www.mvpind.com
Graco	www.graco.com
Binks	www.binks.com
Barcol hardness testers	
Barcol Impressor	www.barcol-impressor.com
Paul N. Gardner Co. Inc.	www.gardco.com
Viscometers	
Brookfield	www.brookfieldengineering.com
Gel timers	
Bibby Scientific	www.bibby-scientific.com
Portable heaters	
Master Heaters	www.masterheaters.com
Pumps and mixers	
Magnum Venus Products	www.mvpind.com
Rollers, laminating accessories	
Magnum Venus Products	www.mvpind.com

APPENDIX C

Food Contact and FDA/USDA Compliance

Food Contact

Special attention to additives is necessary when fabricating for FDA-regulated applications. Certain Food and Drug Administration (FDA) regulations (21 CFR § 177.2420) contain a list of FDA-approved additives and should be referenced before adding promoters, inhibitors, initiators or other additives to resins to be used in FDA-regulated applications.

Derakane™ 411, 411C and 441-400, including Momentum™ and Signia™ series resins, when properly formulated and cured, are compliant with the Federal Food, Drug and Cosmetic Act (U.S.), as amended, and applicable FDA regulations (e.g., 21 CFR § 177.2420). These resins may be used as articles or components of articles intended for repeated use in contact with food, subject to certain limitations described in that regulation. Additive levels should not exceed levels listed in 21 CFR 177.2420.

Note: *It is the responsibility of the customer/user to test the finished laminate or coating to determine its compliance with 21 CFR § 177.2420 and all other appropriate regulations.*

Derakane™ 411, 411C and 441-400 including Momentum™ and Signia™ series resins are chemically acceptable in processing or storage areas for contact with meat or poultry food products prepared under federal inspection and used at temperatures below 121 °C (250 °F). This acceptance has been given by the United States Department of Agriculture. Initiator levels should not exceed levels set out in the FDA regulations in 21 CFR § 177.2420.

Note: *Derakane™ 411 resin is available with different styrene levels. Achievement of appropriate complete cure (using recommended initiator levels, etc.), together with careful attention to the special five-step, post-fabrication techniques listed below, will enhance the fabricator's ability to comply with applicable regulations.*

Fabricating for FDA/USDA Compliance

Attention to the following procedure can help in achieving FDA compliance:

1. Use a promotion formulation and initiator that will yield a resin laminate with low residual styrene after a room-temperature cure. FDA regulations (21 CFR § 177.2420) list the following approved initiators, promoters and accelerators: MEKP, CuHP, BPO, CoNap/CoOct 6%, DMA and DEA, subject to quantity limitations stated in the regulation.
2. Thoroughly clean the part to remove any dust or dirt prior to post curing.
3. Post cure with dry heat for four hours at 80 °C (180 °F). The purpose is to reduce residual styrene to the range of 0.01–0.2%.
4. After post curing, steam-treat the part or steep it in hot water for 8–16 hours at 70 °C (160 °F) or higher. Use only hot water in FRP-lined metal vessels. This should remove all residual styrene from the laminate surface.
5. Wash the part thoroughly with detergent and rinse it thoroughly before placing it in service.

APPENDIX D

Troubleshooting Guide

Troubleshooting Guide for Curing Derakane™ Resins at Room Temperature

Problem	Check Points	
	MEKP or CuHP	BPO
Resin gels too slowly or will not gel at all	Review promoter/initiator levels. No less than 1.0 weight per hundred of resin (phr) MEKP or CuHP is required. Minimum 0.2 phr of CoNap/CoOct 6% is required. Increase levels if necessary but not above those recommended for that resin system.	Review additive levels. DEA is recommended for most applications. For some cold weather or thin laminate conditions, DMA may be considered. DMAA and DEAA do not work with BPO cures.
	Reduce or eliminate inhibitor.	Reduce or eliminate inhibitor.
	Check resin, shop and mold temperature. Cool temperatures cause slower gelling. Adjust formulation based on temperature conditions.	Check resin, shop and mold temperature. Cool temperatures cause slower gelling. Adjust formulation based on temperature conditions.
	Review 2,4-P addition. 2,4-P is typically added in small amounts and can have significant impact on gel time if too much is added.	Check active level of BPO. Some BPO is not 100% active. Levels may have to be adjusted to find required level of BPO.
	Review other additives. Antimony trioxides, fillers, and pigments may retard gelling and need to be added just before initiator or increase initiator/promoter concentrations.	Review other additives. Antimony trioxides, fillers, and pigments may retard gelling and need to be added just before initiator or increase initiator/promoter concentrations.
	Review addition sequence.	Review addition sequence.
	CoNap/CoOct 6% may be difficult to mix into resin, especially if resin is cool. Dissolve cobalt in a small amount of styrene before adding to resin.	BPO is difficult to mix and requires good agitation. If using BPO in powder form, consider switching to a solution for ease of mixing.
	Check fittings on equipment. Bronze, copper and zinc may inhibit cure.	BPO requires good agitation to ensure proper mixing of all additives.

Problem	Check Points	
	MEKP or CuHP	BPO
Barcol hardness development is slow/poor; spotty cure	Review other additives. Some pigments and flame retardants may retard Barcol hardness development.	Review other additives. Some pigments and flame retardants may retard Barcol hardness development.
	Reduce or eliminate inhibitor.	Reduce or eliminate inhibitor.
	Ensure proper mixing of all additives.	Ensure proper mixing of all additives.
	If surface is tacky or acetone-sensitive, a wax topcoat may be necessary.	If surface is tacky or acetone-sensitive, a wax topcoat may be necessary.
	Review levels of peroxide and CoNap/CoOct 6%. Increase promoter/initiator levels, but not above those recommended for that resin system.	Review BPO level. BPO is often sold in concentrations other than 100%. Check to make sure that you are adding the correct amount based on the concentration of your solution. The minimum BPO level is 1.0%.
	For thin laminates, the amount of CoNap/CoOct 6% can be increased. The use of 2,4-P will increase the gel time and increase the exotherm to assist in the development of Barcol hardness.	Ratio of active BPO to DMA or DEA is critical. For optimum cure, the BPO level must be between four and 12 times the DEA level. If DMA is used, then the level should be between 10 and 20 times the level of BPO.
	Review peroxides. Do not use levels of peroxide below 1.0%. MEKP peroxides generally provide the quickest Barcol hardness development, followed by activated cumyl hydroperoxides (such as Trigonox 239 and then CuHP).	Consider post curing the part. BPO-cured systems often exhibit depressed Barcol hardness values prior to post cure. Post cure is not optional with BPO cure systems.
	If an MEKP is already used, ensure that it has a high dimer content. Low dimer content peroxides generally do not develop Barcol hardness as efficiently.	
	If weather is hot, formulators often reduce peroxide levels too far to get a good cure. Use 1.0% minimum.	

Problem	Check Points	
	MEKP or CuHP	BPO
Resin gels too quickly	Check resin, shop and mold temperature; warm temperatures cause resin to gel faster. Adjust formulation based on temperature conditions.	Check resin, shop and mold temperature; warm temperatures cause resin to gel faster. Adjust formulation based on temperature conditions.
	Add inhibitor.	Add inhibitor.
	Consider adding 2,4-P to retard the gel time.	Consider addition of TBC up to a level of 300 ppm to retard the gel time.
	Reduce cobalt, DMA, or initiator levels, but not below those recommended for that resin system. MEKP or CuHP can be lowered to 1.0 phr and CoNap/CoOct 6% to 0.2 phr to increase the gel time.	Reduce DMA and/or BPO levels while maintaining the recommended ratios and a minimum of 1.0% BPO.
		Check active level of BPO. Some BPO is not 100% active. Levels may have to be adjusted to find required level of BPO.
Resin generates too much exotherm when curing	Reduce DMA and/or initiator levels, but not below those recommended for that resin system.	Reduce DMA and/or BPO levels but not below those recommended for that resin system.
	If using DMA, switch to DEA for more manageable exotherm temperatures.	If using DMA, switch to DEA for more manageable exotherm temperatures.
	Lay up fewer plies at one time to reduce amount of heat generated during exotherm. Allow to exotherm before adding additional plies.	BPO is a hot system. Lay up fewer plies at one time and allow to exotherm before adding additional plies. Add up to 0.03 phr TBC-85 per 100 parts of resin.
	Copper naphthenate can be added to Derakane™ resins to lower the exotherm, refer to the TDS for recommended levels.	
	Use CuHP with Derakane™ 470 resins.	
	Use Trigonox 239 and CuHP with Derakane™ 411 series resins.	
	Use a 50/50 blend of MEKP/CuHP.	

Problem	Check Points	
	MEKP or CuHP	BPO
Resin gel time drifts after sitting overnight	Check resin, shop, and mold temperature. Adjust formulation based on temperature conditions.	Add additional DMA or BPO while maintaining the recommended ratios.
	If the resin container is left open, the resin can absorb high amounts of water even in an air-conditioned building. High water levels will greatly extend gel times and may prevent the resin from curing properly. This scenario is especially prevalent in the hot, humid summer months. Add additional promoter, accelerator or initiator to restore the resin to its original gel time.	If BPO was added to the resin the previous day, some gel time drift may have occurred. Add TBC, up to 300 ppm, to the resin to slow down the gel time. If this is unsuccessful, consider blending the BPO initiated resin with neat resin to dilute the faster reactivity resin. Adjust the formulation based on new reactivity.
	If Nyacol APE-1540 was added to a flame retardant resin, the Nyacol material can absorb the CoNap/CoOct 6% to such an extent that there is not enough free CoNap/CoOct 6% to promote the gelling reaction. Add additional CoNap/CoOct 6% and, if needed, accelerator to restore the resin to its original gel time.	
	If Nyacol APE-1540 is used, consider the use of Nyacol[1] APE-3040. Nyacol APE-3040 does not exhibit the same level of gel time drift in cobalt promoted systems.	
Resin foams, resulting in entrapped air in the laminate	Use Trigonox 239, CuHP, or MCP with all Derakane™ resins. For greater control with Derakane™ 470 resin, use CuHP.	BPO systems generally do not produce gas so any problems with entrapped air may be due to fabrication. Consider the use of an air release additive to alleviate any problems.
	Consider initiating your resin to allow for 10 minutes of "*degassing*" prior to fabrication.	See Section 3, Non-Reactive Additives, for recommended antifoam agents.
	See Section 3, Non-Reactive Additives, for recommended antifoam agents.	

Troubleshooting Guide for Curing Derakane™ Signia™ and Derakane™ Momentum™ Resins at Room Temperature

Problem	Check Points	
	MEKP or CuHP	BPO
Resin gels too slowly or will not gel at all	Reduce or eliminate inhibitor.	Reduce or eliminate inhibitor.
	Check resin, shop and mold temperature. Cool temperatures cause slower gelling. Adjust formulation based on temperature conditions.	Check resin, shop and mold temperature. Cool temperatures cause slower gelling. Adjust formulation based on temperature conditions.
	Review other additives. Antimony trioxides, fillers, and pigments may retard gelling and need to be added just before initiator or increase initiator/promoter concentrations.	Review other additives. Antimony trioxides, fillers, and pigments may retard gelling and need to be added just before initiator or increase initiator/promoter concentrations.
	Review promoter/initiator levels. No less than 1.0 weight per hundred of resin (phr) MEKP or CuHP is required. No less than 0.05 phr of CoNap/CoOct 6% is required. Increase levels if necessary but not above those recommended for that resin system.	Review additive levels. DEA is recommended for most applications. For some cold weather or thin laminate conditions, DMA may be considered. DMAA and DEAA do not work with BPO cures.
	Review addition sequence. CoNap/CoOct 6% may be difficult to mix into resin, especially if resin is cool. Dissolve cobalt in a small amount of styrene before adding to resin.	Review addition sequence. BPO is difficult to mix and requires good agitation. If using BPO in powder form, consider switching to a solution for ease of mixing.
	Review 2,4-P addition. 2,4-P is typically added in small amounts and can have significant impact on gel time if too much is added.	BPO requires good agitation to ensure proper mixing of all additives.
	Check fittings on equipment. Bronze, copper and zinc may inhibit cure.	Check active level of BPO. Some BPO is not 100% active. Levels may have to be adjusted to find required level of BPO.

Problem	Check Points	
	MEKP or CuHP	BPO
Barcol hardness development is slow/poor; spotty cure	Reduce or eliminate inhibitor.	Reduce or eliminate inhibitor.
	Ensure proper mixing of all additives.	Ensure proper mixing of all additives.
	If surface is tacky or acetone-sensitive, a wax topcoat may be necessary.	If surface is tacky or acetone-sensitive, a wax topcoat may be necessary.
	Review other additives. Some pigments and flame retardants may retard Barcol hardness development.	Review other additives. Some pigments and flame retardants may retard Barcol hardness development.
	Review levels of peroxide and CoNap/CoOct 6%. Increase promoter/initiator levels, but not above those recommended for that resin system. If the mold or resin is cold, the addition of DEA should be considered.	Review BPO level. BPO is often sold in concentrations other than 100%. Check to make sure that you are adding the correct amount based on the concentration of your solution. The minimum BPO level is 1.0%.
	For thin laminates, the amount of CoNap/CoOct 6% can be increased. The use of 2,4-P will increase the gel time and increase the exotherm to assist in the development of Barcol hardness.	Ratio of active BPO to DMA or DEA is critical. For optimum cure, the BPO level must be between four and 12 times the DEA level. If DMA is used (less preferred), then the level should be between 10 and 20 times the level of BPO.
	Review peroxides. Do not use levels of peroxide below 1.0%. MEKP peroxides generally provide the quickest Barcol hardness development, followed by activated cumyl hydroperoxides (such as Trigonox 239) and then CuHP.	Consider post curing the part. BPO-cured systems often exhibit depressed Barcol hardness values prior to post cure. Post cure is not optional with BPO cure systems.
	If an MEKP is already used, ensure that it has a high dimer content. Low dimer content peroxides generally do not develop Barcol hardness as efficiently.	
	If weather is hot, formulators often reduce peroxide levels too far to get a good cure. Use 1.0% minimum.	
	Check fittings. Bronze, zinc and copper may inhibit cure. *Note: The use of MEKP with Derakane™ Momentum™ 470-300 resin is generally not recommended due to the high reactivity of novolac-based epoxy vinyl ester resins.*	

Problem	Check Points	
	MEKP or CuHP	BPO
Resin gels too quickly	Add inhibitor.	Add inhibitor.
	Consider addition of TBC-85 up to a level of 300 ppm to retard the gel time.	Consider addition of TBC-85 up to a level of 300 ppm to retard the gel time.
	Check resin, shop, and mold temperature; warm temperatures cause resin to gel faster. Adjust formulation based on temperature conditions.	Check resin, shop, and mold temperature; warm temperatures cause resin to gel faster. Adjust formulation based on temperature conditions.
	Reduce cobalt, DMA, or initiator levels, but not below those recommended for that resin system. MEKP or CuHP can be lowered to 1.0 phr and CoNap/CoOct 6% to 0.05 phr to increase the gel time.	Reduce DEA and/or BPO levels while maintaining the recommended ratios and a minimum of 1.0% BPO.
	Consider adding 2, 4-P to retard the gel time.	Check active level of BPO. Some BPO is not 100% active. Levels may have to be adjusted to find required level of BPO.
		Use an MEKP/CHP blend such as Norox MCP-75.
Resin generates too much exotherm when curing	If using DMA, switch to DEA for more manageable exotherm temperatures.	If using DMA, switch to DEA for more manageable exotherm temperatures.
	Reduce or eliminate DEA. Adjust the MEKP or CuHP to a minimum of 1.0 phr.	Reduce DEA and/or BPO levels but not below those recommended for that resin system.
	If using MEKP, consider using CuHP with Derakane™ Momentum™ 470 resin and an activated CuHP for Derakane™ Momentum™ 411-350 and Derakane™ Momentum™ 510C-350 resins.	BPO is a hot system. Lay up fewer plies at one time and allow to exotherm before adding additional plies. Add up to 0.03 phr TBC-85 per 100 parts of resin.
	Lay up fewer plies at one time to reduce amount of heat generated during exotherm. Allow to exotherm before adding additional plies.	
	Copper naphthenate can be added to Derakane™ resins to lower the exotherm, refer to the TDS for recommended levels.	

Problem	Check Points	
	MEKP or CuHP	BPO
Resin gel time drifts after sitting overnight	Check resin, shop, and mold temperature. Adjust formulation based on temperature conditions.	Check resin, shop, and mold temperature. Adjust formulation based on temperature conditions. Add additional DEA or BPO while maintaining the recommended ratios.
	If the resin container is left open, the resin can absorb water even in an air-conditioned building. High water levels can extend gel times and can prevent the resin from curing properly. This scenario is especially prevalent in the hot, humid summer months. Derakane™ Momentum™ resin may exacerbate this situation due to the low CoNap/CoOct 6% levels in the formulation. Add additional promoter, accelerator or initiator to restore the resin to its original gel time.	Consider using DMA instead of DEA for faster gel times, keeping in mind the recommended ratios.
	If Nyacol[1] APE-1540 was added to a flame retardant resin, the Nyacol material can absorb CoNap/CoOct 6% to such an extent that there is not enough free CoNap/CoOct 6% to promote the gelling reaction. Add additional CoNap/CoOct 6% and, if needed, accelerator, to restore the resin to its original gel time.	If BPO was added to the resin the previous day, some gel time drift may have occurred. Add TBC-85, up to 300 ppm, to the resin to slow down the gel time. **Note**: *The pre-promotion of Derakane™ Momentum™ resin with BPO is generally not recommended due to the high reactivity of this resin family. It is preferred that the BPO be added immediately prior to use.*
	If Nyacol APE-1540 is used, consider the use of Nyacol[1] APE-3040. Nyacol APE 3040 does not exhibit the same level of gel time drift in cobalt-promoted systems. **Note**: *The pre-promotion of Derakane™ Momentum™ resins with CoNap/CoOct 6% and DMA/DEA is generally not recommended due to the high reactivity of this resin family. It is preferred that CoNap/CoOct 6% and DMA/DEA be added immediately prior to use.*	

Problem	Check Points	
	MEKP or CuHP	BPO
Resin foams, resulting in entrapped air in the laminate	**See Section 3, non-reactive additives**, for recommended antifoam agents.	See Section 3, Non-Reactive Additives, for recommended antifoam agents.
	The use of an activated CuHP with Derakane™ Momentum™ 411-350 and Derakane™ Momentum™ 510C-350 resin will reduce foaming when used in a CoNap/CoOct system.	BPO systems generally do not produce gas so any problems with entrapped air may be due to fabrication. Consider the use of an air release additive to alleviate any problems.
	The use of CuHP with Derakane™ Momentum™ 470-300 will reduce foaming when used in a CoNap/CoOct 6% system.	
	If an MEKP is preferred, select a peroxide that has a low hydrogen peroxide content as hydrogen peroxide contributes to foaming in the resin.	
	Consider initiating your resin to allow for 10 minutes of "*degassing*" prior to fabrication.	

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[1] Nyacol Nano Technologies, Inc.

GLOBAL PRESENCE

Global Headquarters
INEOS Composites

North America
Dublin, OH USA
Tel: +1 614 790 9299
Americascustomer.composites@INEOS.com

Regional Centers

Asia Pacific
Shanghai, P.R. China
Tel: +86 21 2402 4688
ASIAcustomer.composites@INEOS.com

Europe
Barcelona, Spain
Tel: +34 93 206 5120
EMEAcustomer.composites@INEOS.com

India
Mumbai
Tel: +91 22 6148 9696
EMEAcustomer.composites@INEOS.com

Latin America
Araçariguama, São Paulo, Brazil
Tel: +55 11 4136 6477
Americascustomer.composites@INEOS.com

INEOS Composites

ineos.com/composites