



A Guide To Fabricating Composites With **HETRON[®]** and **AROPOL[™]** Resins



Ashland Specialty Chemical Company is the leading supplier of resins
for corrosion resistant and flame retardant composites

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S E C T I O N 1

Product Description

The development and manufacture of HETRON and AROPOL polyester and vinyl ester resins have been a continuing process since 1954. They have been used to fabricate thousands of different types of corrosion resistant FRP equipment. Many versions of HETRON and AROPOL resins have been developed for ease of handling during hand lay-up, spray-up, filament winding, pultrusion, centrifugal casting and most other methods of commercial fabrication. Ashland Specialty Chemical Company provides a variety of thermoset resins for corrosion resistant applications. Table 1 summarizes the different types of resins.

TABLE 1

Resin Type	Resin Number	Fabrication Applications	Fume Service	Liquid / Fume Service	Flame Retardance (based on the ASTM E-84 Tunnel Test)		Thixed	Promoted	F-Cat
					Class I	Class II			
Chlorendic Polyester	HETRON® 72	High viscosity base resin, bulk molding compound (BMC), sheet molding compound (SMC), coating formulations	X	X		X – with 5% antimony trioxide			
	HETRON® 92	Pultrusion, BMC, SMC, molded electrical sheet, vacuum bagging, Mil Specification	X		X – with 3% antimony trioxide	X			
	HETRON® 92FR	Hand lay-up, spray-up	X		X			X	
	HETRON® 92AT	Hand lay-up, spray-up	X		X – with 3% antimony trioxide	X		X	
	HETRON® 197	Hand lay-up, spray-up, press molding, pultrusion, vacuum bagging		X		X – with 5% antimony trioxide			
	HETRON® 197-3	Hand lay-up, spray-up, filament winding		X		X – with 5% antimony trioxide	X		
	HETRON® 197P	Hand lay-up, spray-up, filament winding		X		X – with 5% antimony trioxide	X	X	
Bisphenol A Fumarate Polyester	HETRON® 700	Hand lay-up, spray-up, filament winding, press molding, pultrusion, coating formulations, FDA applications		X					
Isophthalic Polyester	HETRON® 99P	Hand lay-up, spray-up, filament winding, fire retardant	X		X – with 3% antimony trioxide	X	X	X	
	AROPOL™ 7241T-15* series	Hand lay-up, spray-up, filament winding, FDA applications		X			X	X	
	AROPOL™ 7334T-15* series	Hand lay-up, spray-up, filament winding, FDA applications		X			X	X	
Furan	HETRON® 800	Hand lay-up, spray-up, filament winding, flake glass coating		X					
Vinyl Ester	HETRON® 922	Hand lay-up, spray-up, filament winding, flake glass coatings, FDA applications		X					
	HETRON® 922L	Hand lay-up, spray-up, filament winding, flake glass coatings, applications requiring lower viscosity than Hetron 922, FDA applications		X					
	HETRON® 942/35	Hand lay-up, spray-up, filament winding, flake glass coatings, less than 35% styrene, FDA applications		X					
	HETRON® 970/35	Hand lay-up, spray-up, filament winding, flake glass coatings, applications requiring maximum solvent resistance, less than 35% styrene		X					
	HETRON® 980	Hand lay-up, spray-up, filament winding, flake glass coatings, higher temperature resistance than Hetron 922		X					
	HETRON® 980/35	Hand lay-up, spray-up, filament winding, flake glass coating, less than 35% styrene		X					
	HETRON® FR992	Hand lay-up, spray-up, filament winding, flake glass coatings		X	X – with 3% antimony trioxide				
	HETRON® FR998/35	Hand lay-up, spray-up, filament winding, flake glass coatings, less than 35% styrene		X	X				
Miscellaneous Fire Retardant	HETRON® 604T-20	Hand lay-up, spray-up, filament winding	X		X – with 3% antimony trioxide	X	X	X	
	HETRON® FR620T20	Hand lay-up, spray-up, filament winding	X		X	X	X	X	
	HETRON® 625P	Hand lay-up, spray-up, filament winding			X	X	X	X	
	HETRON® 692TP-25	Hand lay-up, spray-up, filament winding	X		X	X	X	X	
	MODAR 814**	RTM, hand lay-up, spray lay-up, filament winding			X – with ATH	X – with ATH			
	MODAR 816**	RTM, hand lay-up, spray lay-up, filament winding			X – with ATH	X – with ATH			

* Corrosion Resistant isophthalic based products

** Please contact Ashland Technical Service for more information on MODAR products

P promoted system

T-XX thixed system with a room temperature gel (RTG) of XX minutes using 1.25% of an MEKP catalyst

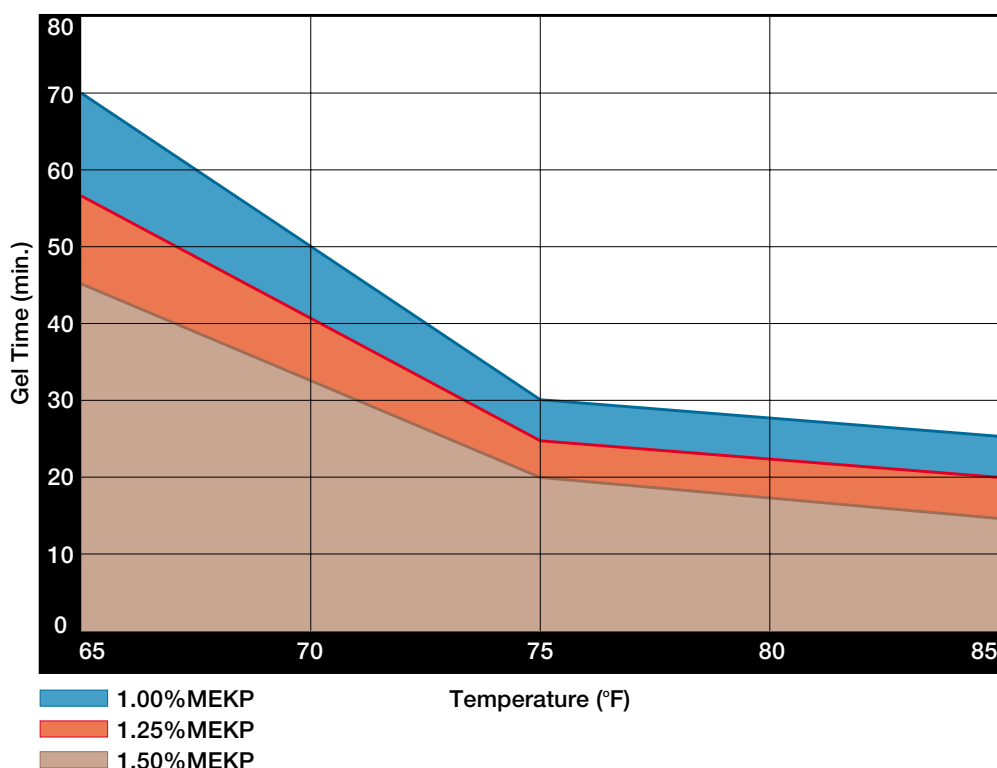
SECTION 2

Catalysts, Promoters and Inhibitors

Catalysts, also referred to as initiators, are organic peroxides that work together with promoters to initiate the chemical reaction that causes a resin to gel and harden. The amount of time from which the catalyst is added until the resin begins to gel is referred to as the “gel time.” Catalyst and promoter levels can be adjusted, to a certain extent, to shorten or lengthen the gel time and accommodate both high and low temperatures. For example, Figure 1 shows how the gel time of a prepromoted resin system shortens with increasing temperature.

If a longer gel time is required, inhibitors can be added to a resin system to lengthen the gel time. However, care should be taken not to decrease or increase promoter / catalyst levels beyond what is recommended for that particular resin. If the level of catalyst is too low, incomplete cure may occur which could result in decreased physical properties and chemical resistance. On the other hand, levels that are too high could cause the laminate, particularly thick laminates, to delaminate, burn, or discolor during curing. In addition, if promoter or catalyst levels are too high, the result can be undercure. Promoter, catalyst and inhibitor levels for specific resins are listed in Appendix A.

Figure 1.
Gel Time vs.
Temperature



CATALYSTS¹

There are two primary types of catalysts recommended for curing HETRON and AROPOL resins at room temperature: methyl ethyl ketone peroxide (MEKP) and benzoyl peroxide (BPO). A third, less common, catalyst type is cumene hydroperoxide (CHP) which is often recommended for blending with MEKP. In other processes, such as pultrusion, different types of catalysts are used. Catalysts for the pultrusion process are heat activated and are not used with promoters.

The proper choice of a catalyst is critical to achieving expected chemical resistance. Care must be taken not to select catalysts that are too fast or slow in curing. Unusually fast or slow cure times could result in reduced corrosion resistance in the final cured product.

Methyl Ethyl Ketone Peroxide (MEKP)

MEKP is the most widely used catalyst system. MEKP is used with promoters, usually 6% cobalt naphthenate or 6% or 12% cobalt octoate and dimethylaniline (DMA) or diethylaniline (DEA)¹. The MEKP used most often is supplied at 9% active oxygen.

Many resin producers require the use of special MEKPs that contain very low levels of hydrogen peroxide. This is because the vinyl ester resins they produce can foam when they come in contact with hydrogen peroxide. Ashland's Flexible-Catalyzation (F-Cat), High Performance epoxy vinyl ester resins (EVERs) do not foam when catalyzed with standard MEKPs. The use of standard MEKPs allows for much greater control of the exotherm during cure. Ashland Technical Service should be contacted for information on alternative catalysts for use with HETRON and AROPOL resins and appropriate exotherm control. See Appendix B for the contact in your area.

Benzoyl Peroxide (BPO)

BPO requires the addition of DMA or DEA for room temperature curing. For curing at elevated temperatures, greater than 160°F, BPO is used without DMA or DEA. BPO is not as widely used as MEKP primarily because it is more difficult to mix into the resin system than MEKP, it may cause higher exotherm temperatures, and it is more difficult to fully post cure. However, the following is an application where a BPO system is definitely recommended over a MEKP cure system.

- In sodium hypochlorite environments improved corrosion resistance is observed with DMA/BPO cure system. HETRON FR992 cured with BPO/DMA will turn a bright yellow when exposed to the sun. This does not effect chemical resistance.

BPO is available as a powder, a paste or an aqueous dispersion. The aqueous dispersion is not recommended for corrosion applications. Our tests show that aqueous BPO solutions compromise corrosion resistance in selected environments. The paste form is the most widely used type with polyesters and vinyl esters. BPO crystals are also available, however they are used less frequently. The paste is generally supplied in a 50% active

form and the crystals in 98% active form. To achieve the same gel time with paste and crystals, half the amount of crystals should be used as paste. For example, 2.0 grams of paste will react to give the same gel time as 1.0 gram of the crystals. BPO crystals are shock sensitive and must be predissolved in styrene prior to addition to the resin.

Cumene Hydroperoxide (CHP)

CHP is used less frequently than MEKP or BPO but can be helpful in lowering laminate exotherm temperatures, such as those seen in thick parts. CHP should be used with HETRON 970/35 vinyl ester resin. When using CHP with other resins beside HETRON 970/35 resin, care must be taken to ensure that a thorough cure is obtained, particularly at ambient temperatures. A post cure is recommended to insure a thorough cure. CHP can also be used with MEKP in ratios such as a 50/50 mixture. Whenever CHP is used as the only catalyst (except with HETRON 970/35), it is recommended that Ashland Technical Service be contacted for specific instructions.

T-butyl Peroxybenzoate

TBPB is a secondary catalyst that can be used in addition to MEKP, BPO, or CHP. The addition of TBPB assists in achieving a higher degree of cure. We recommend TBPB at 0.2%, based on resin. The addition of TBPB to resin will shorten the pot life. Please consult Ashland Technical Service for more information on TBPB.

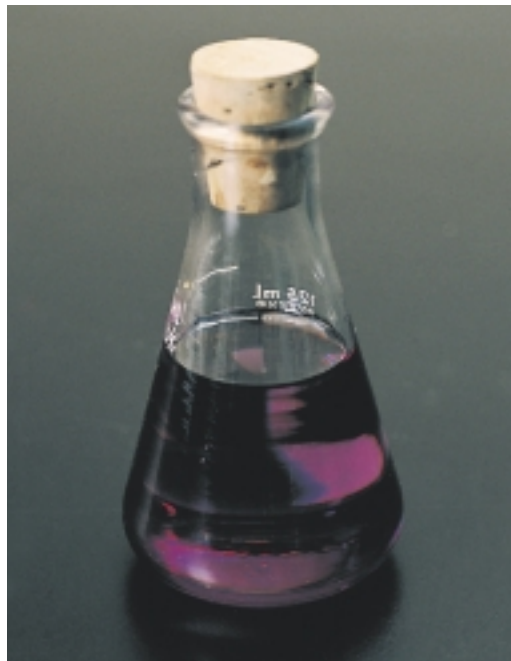
PROMOTERS¹

In addition to a catalyst, at least one promoter is required to make a resin cure at room temperature. Generally, the promoter is mixed in thoroughly before adding the catalyst. The catalyst then reacts with the promoter to cause the resin to gel. Promoter levels can also be adjusted to shorten or lengthen a gel time as needed.

Cobalt Naphthenate or Octoate²

Cobalt solutions are blue or purple liquids that are used with MEKP and CHP catalyst systems.

When used at temperatures below 70°F (24°C), it is recommended that cobalt be cut in styrene monomer prior to addition to the resin. Dilution in styrene will prevent small particles of cobalt from forming and will facilitate uniform mixing. Please note that selected grades of Cobalt Naphthenate are acceptable according to FDA regulations.

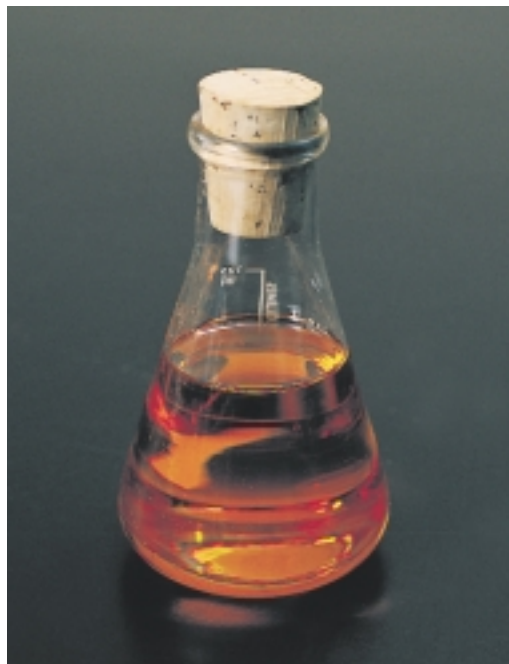


Cobalt naphthenate

Dimethylaniline (DMA)

Dimethylaniline is a yellow amine liquid with a strong odor. DMA can be used with MEKP, BPO (ambient cure), and CHP catalyst systems. The addition of DMA is not required with MEKP and CHP systems. However, small amounts of DMA may be used in conjunction with cobalt to improve Barcol development and/or shorten the cure time at cool temperatures. With ambient temperature BPO systems, the addition of DMA is required.

Diethylaniline (DEA) is another amine that can also 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.



Dimethylaniline

Copper Naphthenate

Copper naphthenate is available as a green paste that typically contains 6 - 8% elemental copper. It is included in a formulation to control the exotherm of blends intended for MEKP catalyzation. If low hydrogen peroxide containing MEKPs are used, the impact on the peak exotherm is marginal. However, if standard MEKPs are used, copper naphthenate will lower the exotherm and lengthen the time from gel to peak, without effecting the gel time. Typical levels of copper recommended for exotherm control are 0 – 400 ppm. Copper naphthenate should be added to the formulation the same day the resin is catalyzed. Please review the suggested amounts for Copper Naphthenate in Appendix A.

INHIBITORS

Inhibitors are used to lengthen the gel time of vinyl ester and polyester resins. Inhibitors are useful when very long gel times (1-2 hours) are required or when resin is curing quickly due to high temperatures. Some common inhibitors include tertiary butyl catechol (TBC), hydroquinone (HQ), and toluhydroquinone (THQ).

TBC is typically sold as an 85% solution but should be further diluted in styrene to a 10% solution before addition to the resin. HQ and THQ are sold as solids and should be dissolved in methanol to a 10% solution to be added to the resin. Inhibitors can also be dissolved in propylene glycol, which greatly reduces the flammability of the solution. It is recommended that inhibitor solutions be used as soon as possible to insure their full effectiveness.

TBC, HQ, and THQ can be used with MEKP, BPO, and CHP catalyst systems. However, care should be taken not to add too much inhibitor, which could result in permanent under-cure, low Barcol, or reduced corrosion resistance. Recommended inhibitor levels vary from inhibitor to inhibitor and from resin to resin. A general guide for addition levels is up to 0.30% of a 10% solution, however, Ashland Technical Service should be contacted for instructions on adding inhibitors to specific resin systems.

Special attention to additives is necessary when fabricating for FDA applications. Title 21 CFR 177.2420 contains a list of FDA approved additives and should be referred to before adding promoters, inhibitors, catalysts or other additives to resins to be used in FDA applications.

Included in Appendix C and D are lists of suppliers for many of the products described in this section. These are not the only suppliers of these products. Check with a local distributor for suppliers in your area.

Safety

Ashland Specialty Chemical Company does not manufacture cobalt, DMA, DEA, inhibitors or catalysts. Care should be taken to insure that each product is handled safely. The material safety data sheet and safety instructions on each product should be obtained from the manufacturer and read and understood before working with the products.

¹ WARNING – Promoters should always be mixed thoroughly into the resin before adding the catalyst. If promoters and catalysts are mixed directly together, an explosion could result.

² 6% Cobalt octoate can be substituted for 6% cobalt naphthenate to obtain comparable gel times with HETRON and AROPOL resins.

SECTION 3

Thixotropes, Antimony Oxides and Other Additives

Thixotropes

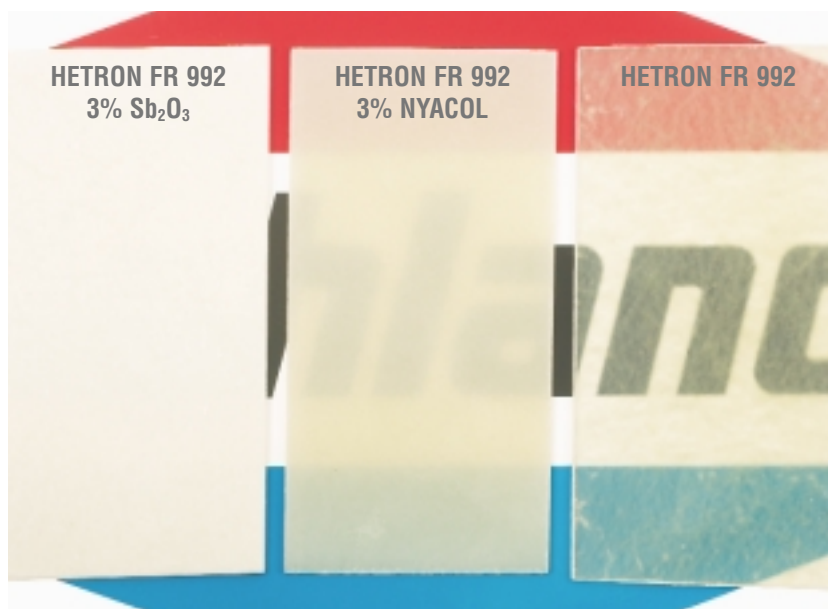
Thixotropes, usually fumed silica, are used to thicken resin and reduce drainage, especially on vertical surfaces. Resins with these additives are generally used in hand lay-up and spray-up applications.

Polyester resins can be purchased with fumed silica already in the resin or the customer may add it. Ashland Technical Service should be contacted before adding thixotropes to vinyl esters or other resins that are to be used in corrosion applications. The use of fumed silica in hydrofluoric acid, sodium hypochlorite, and sodium hydroxide environments is not recommended and could result in a decrease in corrosion resistance.

To insure uniform dispersion, fumed silica should be mixed into the resin using a high shear dissolver or equivalent.

Antimony Oxides

Cured polyester and vinyl ester resins will burn if provided with a sufficient amount of heat and oxygen. However, certain resins are flame retardant due to the incorporation of halogens in the backbone of the polymer. This improves the flame-retardant properties of the laminate. With most flame-retardant resins, adding antimony trioxide or antimony pentoxide can increase the degree of flame retardancy of the resin. Antimony acts as a synergist and reacts with the halogens to improve the resin's flame retardant properties. The addition of antimony to non-halogenated resins does not make the resin flame retardant, but instead acts only as filler.



Laminates containing antimony trioxide, antimony pentoxide, and no antimony oxide..

In the U.S. composites industry, the flame and smoke properties of polyester and vinyl ester resins are most often rated according to the ASTM E-84 tunnel test as performed under strictly controlled conditions. In this test, industry code officials, fire marshals, and resin suppliers have categorized red oak as a flame spread of 100 and asbestos cement board a flame spread of zero. A flame spread of less than or equal to 25 is considered a Class I and less than 75 but greater than 25 is a 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. Laminates made from HETRON 197 require 3-5% antimony trioxide or pentoxide to achieve a Class II rating. Flame spread values of specific resins with and without antimony are listed in Table 1 or refer to the specific data sheet of the resin in question.

The use of some grades of antimony pentoxide have been shown to increase the gel time of flame-retardant vinyl ester resins over time. Because of this, when antimony pentoxide is added to the resin, it should be used within 8 hours to minimize gel drift. Ashland Technical Service should be contacted for specific recommendations regarding antimony pentoxide. Please note that antimony trioxide and pentoxide do not lower smoke emissions.

FILLERS

Alumina Trihydrate

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

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

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

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

Other Fillers

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. These fillers are not, however, recommended in applications requiring corrosion resistance. Contact HETRON Technical Service for specific recommendations.

Intumescent Coatings

Intumescent coatings are also used to improve flame retardancy and reduce smoke emissions of specific resin systems.

Ultraviolet Stabilizers

FRP structures that are placed outdoors may experience surface chalking and/or discoloration. This chalking and/or discoloration is a surface phenomenon only and should not be detrimental to properly fabricated equipment. Polyester resins are inherently more ultraviolet (UV) stable than vinyl ester resins and the addition of UV stabilizers to the outermost resin layer may reduce UV degradation. The recommended level of UV stabilizers for use with polyester and vinyl ester resins is 0.25-0.5%. For halogenated resin systems, the recommended level of UV stabilizer is 0.5%.

Another option for decreasing UV degradation is HETROLAC® 105 protective lacquer. HETROLAC 105 is a very low viscosity lacquer containing UV absorber. HETROLAC 105 lacquer improves weather resistance of new FRP, restores gloss and luster to weathered FRP. For more information on HETROLAC 105 lacquer, consult the technical data sheet or contact Ashland Technical Service.

Air Release Agents

Air release agents can be added to the resin (0.05-0.5%) to decrease foaming. Excessive levels of air release agents can cause a laminate to be cloudy, therefore recommended levels should not be exceeded. Contact Ashland Technical Service for additional information.

Wax Topcoats

Some resins are subject to surface inhibition when cured in the presence of air. Air inhibition affects the cure and corrosion resistance of the outermost resin layer, which results in an acetone sensitive, potentially tacky surface. A wax-containing topcoat approximately 2.0-3.5 mil (51-89 µm) 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. In conditions under hot sunlight, the wax topcoat may be ineffective. A resin/wax solution should never be applied between laminate layers, this could result in poor secondary bonding and premature failure.

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

Abrasion Resistant Additives

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

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

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

Included in Appendix C and D are lists of suppliers for many of the additives described in this section. These are not the only suppliers of these products, check with a local distributor for suppliers in your area.

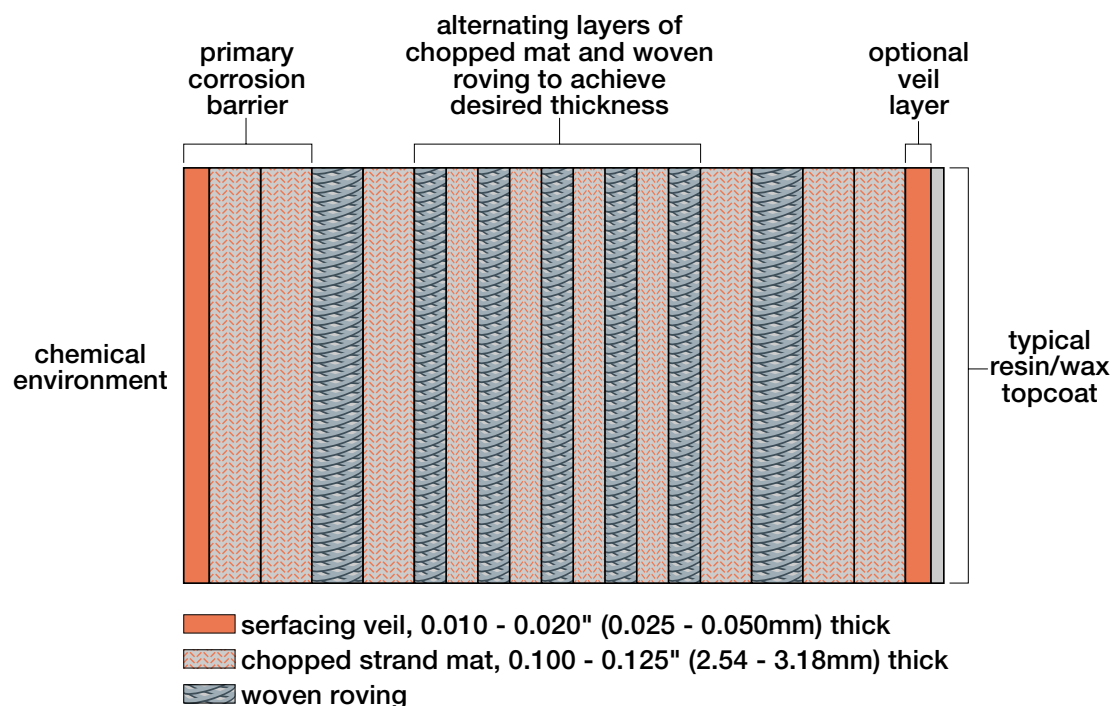
SECTION 4

Reinforcements

Standard Reinforcement Sequence for Corrosion Resistant Equipment

Laminate sequence for standard corrosion resistant equipment is based on the ASTM C581/582 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 2.

Figure 2. Laminate Corrosion Barrier and Structural Layer



Generally, fabrication begins at the surface that will be exposed to the corrosive environment. A resin rich layer consisting of 95% resin and 5% reinforcement is applied first. The reinforcement is in the form of a surfacing veil comprised of C-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 be at least 100 – 125 mil (2.5 – 3.1 mm) thick and should consist of 20 – 30% glass. Together, the resin, veil, and chopped glass form the primary corrosion barrier that minimizes permeation of the corrosive media into the structural portion of the laminate.

The remainder of the laminate, commonly referred to as the structural portion, provides strength and consists of alternating layers of chopped strand mat and/or chopped strand, and woven roving. This portion of the laminate should be 40-50% glass. The

structural portion of the laminate can also be filament wound where this layer typically has a minimum of 60% glass. The thickness of this layer will vary depending on the equipment being fabricated. A final wax topcoat or gelcoat is then applied to the exterior of the equipment to prevent air inhibition.

Types of Reinforcements

The following discussion provides general guidelines for fiberglass selection, however, the glass manufacturer should be contacted for specific recommendations. Regardless of glass type, each should be thoroughly evaluated in a test laminate before beginning actual fabrication. In the test laminate, the glass should wet readily and no glass fibers should be visible in the final cured laminate.

There are four basic forms of fiberglass commonly used with HETRON and AROPOL resins. They are:

- Surfacing veil
- Chopped strand mat
- Woven roving
- Continuous strand roving

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

The surface of the glass is treated with sizings and binders to facilitate further processing, maintain fiber integrity, and provide compatibility with various resin systems. After this treatment, the fibers are further processed into the specific glass types that are described below.

Surfacing Veil

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

The primary type of surfacing veil used in corrosion applications is "C" – glass veil. However, in applications where "C"-glass veil is not suitable, other veil types made from thermoplastic polyester or carbon fibers may be used.



"C"-glass veil

“C”-glass veil is typically recommended for most corrosion environments. However, synthetic veil is preferred in some environments such as those containing fluoride compounds. Synthetic veil is preferred in other environments, which are noted in the resin selection guide. When using synthetic veil with less flexible resins such as chlorendic polyesters, a non-apertured synthetic veil type 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.

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 has been shown to provide better abrasion resistance than either “C”-veil or synthetic veil. Carbon veil is also used to provide a conductive liner for static electricity control. For applications where conductivity is not desirable, the use of carbon veil should be reevaluated. Veils made with other types of glasses, such as “A” and “ECR”, are used less often in the corrosion industry but may be acceptable in certain applications. Thorough testing should be conducted in the specific environment before using “A” and “ECR” veil.

Chopped Strand Mat

Two primary types of chopped strand mat are used in the corrosion industry, “E” and “ECR” glass. Chopped strand fibers are generally $\frac{1}{2}$ ” – 2” (12.5 – 50mm) long and, after being chemically treated, are held together by a binder. Together, the glass fiber bundles form the chopped strand mat. Chopped strand mat is available in a variety of thicknesses: 0.75 oz., 1.5 oz. and 2.0 oz. (225 g/m², 450 g/m², 600 g/m²) are used most often in corrosion applications.



NEXUS® synthetic surfacing veil



Carbon veil



Chopped strand mat

Woven Roving

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



Woven roving

Continuous Strand Roving

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



Continuous strand roving

S E C T I O N 5

Resin Preparation

FDA Compliance

Several HETRON and AROPOL resins are manufactured with raw materials that are listed as acceptable in FDA regulation Title 21 CFR 177.2420 for repeated use in contact with food subject to user's compliance with the prescribed limitations of that regulation. The raw materials used in the manufacture of the following resins are listed as acceptable in FDA regulation Title 21 CFR 177.2420 for repeated use in contact with food subject to user's compliance with the prescribed limitations of that regulation:

HETRON 700, 922, 922L, 922L-25, and 942/35 resins

AROPOL 7241T-15, 7334T-15 resins

When fabricating equipment for FDA compliance, contact Ashland Technical Service for additional resins that meet these requirements.

When fabricating such equipment, there are several steps that should be followed in order to reduce residual styrene. Prior to exposure, all fabricated equipment should be post cured at 180°F (82°C) for 4 hours. The surface of the equipment should then be washed with a mild detergent and water and rinsed thoroughly with water.

Promoter and Catalyst Addition

When fabricating with HETRON and AROPOL resins, it is important to promote and catalyze the resin correctly in order to insure an appropriate working time. Promoter and catalyst addition tables for many HETRON and AROPOL resins are shown in Appendix A. These tables indicate levels to be added at different temperatures to achieve desired working times. These tables serve only as guidelines and the values should not be considered specifications. One of the most effective ways to control the exotherm without effecting the gel time is to add up to 400 ppm of copper naphthenate to the solution. This should be done as close to the time of catalyzation as possible. Over time copper naphthenate and cobalt will react with one another. If a low hydrogen peroxide catalyst is used (BPO, CHP, or any of the 'non foaming' MEKP's), the gel time will be affected substantially. HETRON FCat epoxy VERs will not foam with standard MEKP's.

Adjusting Promoter / Catalyst Levels for Practical Applications

The levels given in Appendix A represent laboratory conditions and will most often have to be adjusted to accommodate actual working conditions in a fabricating shop or in the field. Many things can influence the working time of a resin. High resin and shop temperatures, direct sunlight, and thick laminates can cause the gel time of a resin to shorten. Low resin and shop temperatures, heat sinks (metal molds), and fillers can cause the gel time to lengthen.

When the gel time is too short due to working conditions, promoter levels can be adjusted in order to lengthen the gel time. An inhibitor should be in accordance with those recommended in the appropriate table.

A summary of some of the most common problems encountered with room temperature cure systems and suggestions for minimizing these problems is shown in Appendix E. Also, Ashland Technical Service can be contacted for assistance in adjusting gel times.

Preparing the Resin

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

1. Estimate the amount of time required for fabrication. Remember to take into account resin and air temperature – warmer temperature – faster cure, cooler temperature – slower cure. The viscosity of the resin can also be affected by temperature.
2. If utilizing a neat resin and adding a thixotrope, the thixotrope should be added to the resin and agitated using a high shear mixer until the desired thixotrope index has been achieved. High shear agitation generates heat, therefore, this step should be done before adding any promoters.
3. Using the promoter / catalyst addition tables as guidelines, choose the appropriate additive levels to achieve a suitable working time.
4. Weigh the required amount of resin, cobalt, DMA, and if applicable, inhibitors (predissolved in styrene or other appropriate solvent) into separate containers. A conversion table is shown in Appendix F that may be helpful when measuring materials volumetrically.



Adding 6% cobalt naphthenate

5. Add the cobalt to the resin and mix thoroughly using an air driven mixer under slow to moderate agitation. During all mixing, care should be taken to minimize air entrapment in the resin. Excessive air bubbles in a laminate can cause a reduction of physical and corrosion properties.
6. Add the DMA or DEA and mix thoroughly.
7. Add any additional liquid materials such as inhibitors and mix thoroughly.
8. Add any pigments or fillers such as antimony trioxide, alumina trihydrate, etc. and mix thoroughly.
9. After all ingredients have been added, the drum should be mixed thoroughly.
10. After mixing in required promoters and fillers, a sample of resin should be removed and a gel time test performed. Again, refer to the designated promoter / catalyst table for recommended catalyst level.
11. The gel time can be lengthened by adding an inhibitor or shortened by adding additional cobalt or DMA, however, do not exceed the recommended levels for that resin.
12. Catalyze the resin as needed.
13. If the exotherm of cure is too hot, copper naphthenate can be added to control this. The gel time will not be effected if using a standard MEKP. If more than a combined 400 ppm copper naphthenate and inhibitor is added to the resin, a full cure may not be possible. Contact Ashland Technical Service for further guide-lines.

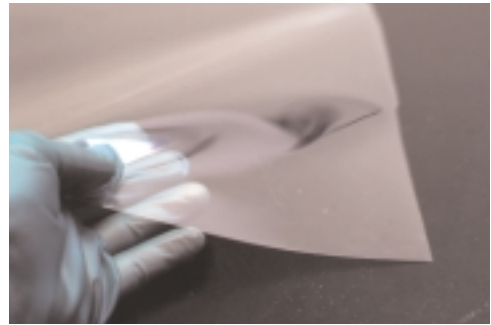


Typical gel timer

Making a Test Laminate

Below is a step-by-step procedure for making a standard test laminate. Materials that will be needed include release film, a spreading device, a serrated roller, resin, glass surfacing veil, chopped fiberglass mat, woven roving, and a cleaning solvent. Before beginning the laminating process, the fiberglass should be cut to the required size and the required amount of resin should be properly formulated. Do not catalyze the resin until you are ready to begin laminating.

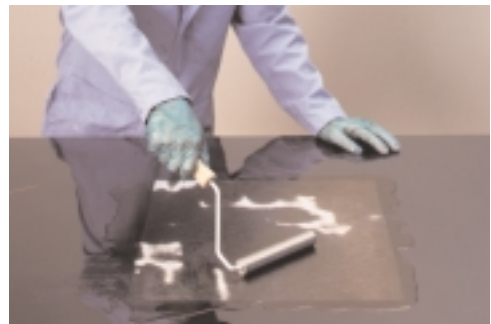
1. The surface should be prepared by spreading a release film on the bench top for protection.



2. At this time, catalyze the amount of resin to achieve the desired resin-to-glass ratio and pour some onto the release film and spread with the spreading device (tongue depressor, paint brush, etc.). When laminating, veil and glass should be applied to a resin rich mold surface. Air bubbles form readily when glass is applied to a dry surface.



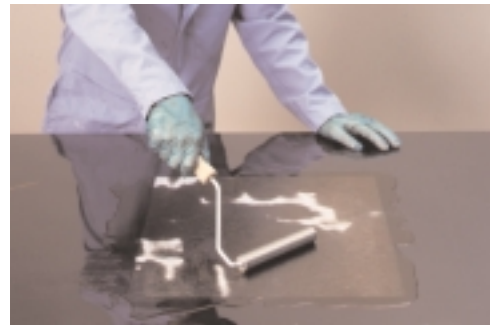
3. Carefully position the surfacing veil over the resin and roll with the roller until the veil is entirely wet out. When rolling out a laminate, roll firmly but not too hard and roll from the center out to the edges. This helps “push” the air bubbles out of the laminate.



4. Apply additional resin and spread with the spreading device. Make sure that all air bubbles are removed from the current glass layer before applying another layer of glass.



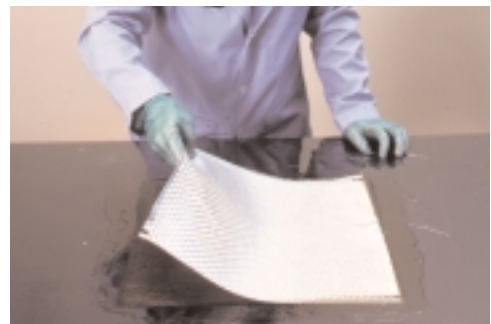
5. Place one ply of chopped fiberglass mat on the resin and roll with the roller. If necessary, apply additional resin to thoroughly wet the mat.



6. Apply a second ply of chopped fiberglass and roll thoroughly. Again, additional resin can be added if necessary.



7. When the mat is wet out completely, 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.
8. Repeat steps six and seven as necessary to make the laminate the required thickness.
9. After all woven roving has been applied, apply a final layer of resin and chopped strand mat and roll thoroughly. When rolling is completed, place the roller in a cleaning solvent and allow the laminate to cure thoroughly. When the laminate is thoroughly cured at room temperature, post cure as indicated in the following section.

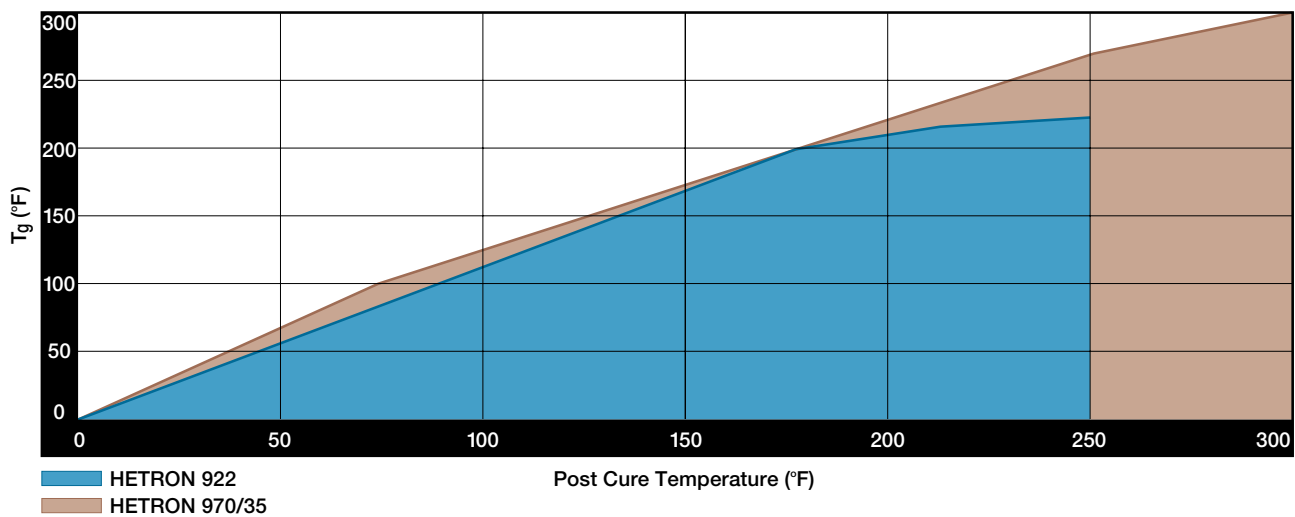


Post Curing the Laminate

After fabricating FRP equipment, it is important to post cure the equipment in order to insure that optimum cure has been achieved. Figure 3 illustrates how the post cure temperature affects the ultimate glass transition temperature (T_g) of a resin.

Ideally, a laminate should be post cured for two hours at a temperature above the heat deflection temperature (HDT) of the resin. The HDT of most HETRON and AROPOL resins is between 200° and 300°F; therefore, a post cure of two hours at 280°F is suitable for most systems. Laminates made with HETRON 970/35 should be post cured at 300°F for two hours since it has an HDT of 297°F. Ashland Technical Service can be contacted for additional information on post curing.

Figure 3. Glass Transition Temperature (T_g) vs. Post Cure Temperature



S E C T I O N 6

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 C 581 - Standard Test Method for Chemical Resistance of Thermosetting Resins Used in Glass Fiber Reinforced Structures
2. ASTM C 582 – Standard Specification for Reinforced Plastic Laminates for Self-Supporting Structures for Use in a Chemical Environment.
3. ASTM D 2105 – Standard Test Method for Longitudinal Tensile Properties of Reinforced Thermosetting Plastic Pipe and Tube.
4. ASTM D 2143 – Standard Test Method for Cyclic Pressure Strength of Reinforced Thermosetting Plastic Pipe
5. ASTM D 2310 – Standard Classification for Machine-Made Reinforced Thermosetting Resin Pipe
6. ASTM D 2517 – Standard Specification for Reinforced Epoxy Resin Gas Pressure Pipe and Fittings
7. ASTM D 2562 – Standard Practice for Classifying Visual Defects in Parts Molded from Reinforced Thermosetting Plastics.
8. ASTM D 2563 – Standard Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts.
9. ASTM D 2924 – Standard Test Method for External Pressure Resistance of Thermosetting Resin Pipe
10. ASTM D 2925 – Standard Test Method for Beam Deflection of Reinforced Thermosetting Plastic Pipe Under Full Bore Flow
11. ASTM D 2992 – Standard Method for Obtaining Hydrostatic Design Basis for Reinforced Thermosetting Resin Pipe and Fittings

12. ASTM D 2996 – Standard Specification for Filament-Wound Reinforced Thermosetting Resin Pipe
13. ASTM D 2997 – Standard Specification for Centrifugally Cast Reinforced Thermosetting Resin Pipe
14. ASTM D 3262 – Standard Specification for Reinforced Plastic Mortar Sewer Pipe
15. ASTM D 3299 – Standard Specification for Filament Wound Glass-Fiber Reinforced Thermoset Resin Chemical Resistant Tanks
16. ASTM D 3647 – Standard Practice for Classifying Reinforced Plastic Pultruded Shapes According to Composition
17. ASTM D 3917 – Standard Specification for Dimensional Tolerance of Thermosetting Glass Reinforced Plastic Pultruded Shapes
18. ASTM D 3918 – Standard Definitions Terms Relating to Reinforced Pultruded Products
19. ASTM D 3982 – Standard Specification for Custom Contact-Pressure-Molded Glass-Fiber Reinforced Thermosetting Resin Hoods
20. ASTM D 4021 – Standard Specification for Glass Fiber-Reinforced Polyester Underground Petroleum Storage Tanks
21. ASTM D 4350 – Standard Test Method for Corrosivity Index of Plastics and Fillers
22. ASTM D 4385 – Standard Practice for Classifying Visual Defects in Thermosetting Reinforced Plastic Pultruded Products
23. ASTM D 5364 – Standard Guide for Design, Fabrication, and Erection of Fiberglass Reinforced Plastic Chimney Liners with Coal-Fired Units
24. NBS PS 15-69 – Voluntary Product Standard for Custom Contact-Molded Reinforced-Polyester Chemical-Resistant Process Equipment (out of print)
25. ASME/ANSI RTP-1 – An American National Standard for Reinforced Thermoset Plastic Corrosion Resistant Equipment

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

1. ASTM D 635 – Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self Supporting Plastics in a Horizontal Position
2. ASTM D 2863 – Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastic (Oxygen Index)

3. ASTM E 84 – Standard Test Method for Surfacing Burning Characteristics of Building Materials
4. ASTM E 162 – Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source
5. ASTM E 662 – Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials
6. ASTM E 906 – Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products
7. UL 94 – Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

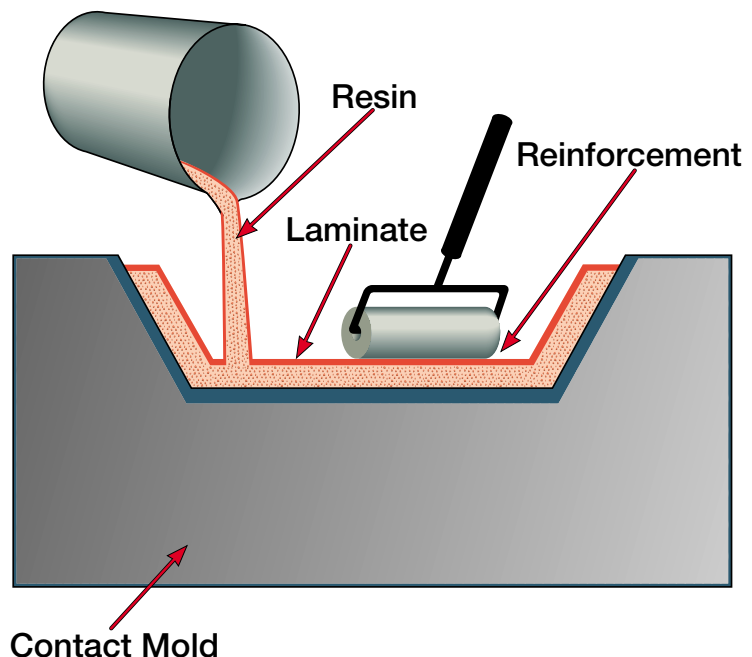
FABRICATION PROCESSES

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 catalyzed resin is applied to the surface of a mold and fiberglass, usually veil, chopped mat or 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.

Hand Lay-Up



Spray-Up

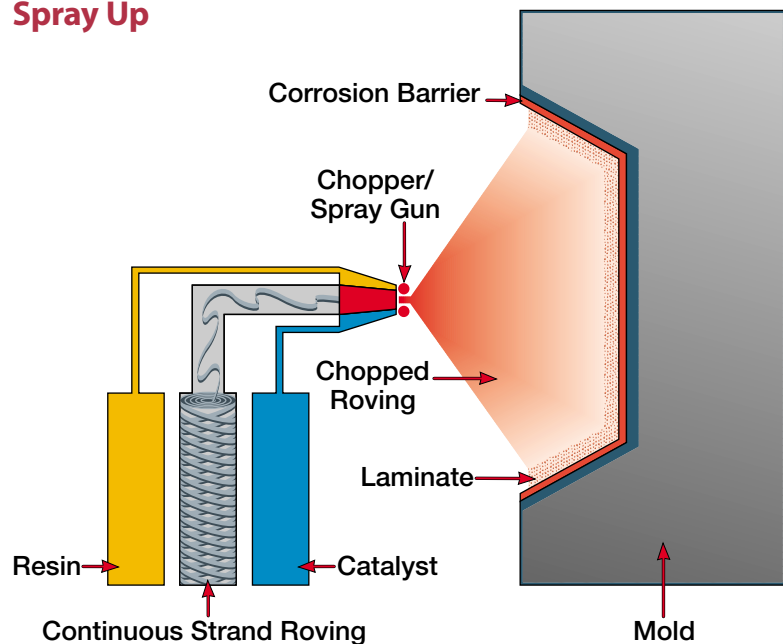
Spray-up is a faster process and is less labor intensive than hand lay-up. Several drawbacks to spray-up include the possibility of more air entrapment and a difficulty in controlling variables such as thickness and resin-to-glass ratios. As with hand lay-up, spray-up can be used for the corrosion barrier and the structural portion of equipment. The spray-up process is a room temperature cure process where continuous strand roving is fed through a chopper gun, combined with catalyzed 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.

A two-pot system can also be used. In this method, two containers are used, one contains resin with twice the required amount of promoters and no catalyst and the other contains resin with twice the required amount of catalyst and no promoters. Resin is then drawn from both containers and mixed during the spraying process. Resin used with the two pot system must be stable when promoted and catalyzed with high levels of additives.



A typical spray gun

Spray Up

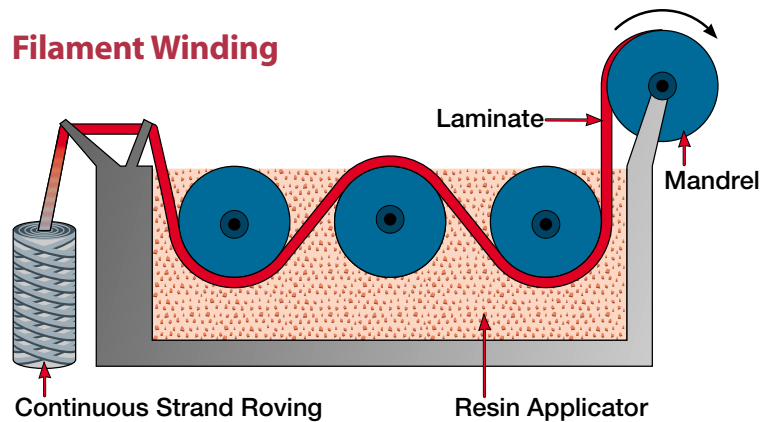


Filament Winding

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 as far as thickness, resin to glass ratio, etc. Filament

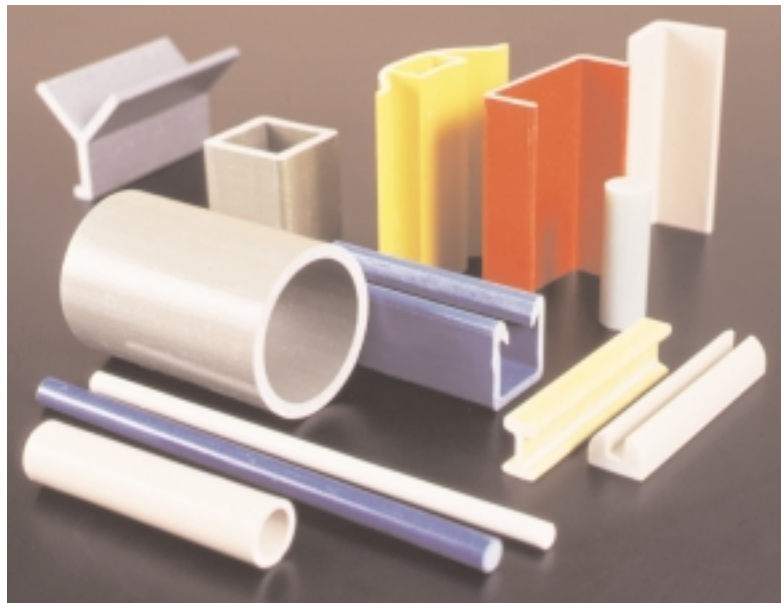
winding is recommended only for the structural portion of FRP equipment. The corrosion barrier should be fabricated using either hand lay-up or spray-up.

Filament winding typically uses a room temperature cure system but generally with very long gel times. A resin rich corrosion barrier is applied to a mandrel and allowed to cure. Continuous strand glass or roving is then pulled through guides, impregnated with resin and guided 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.



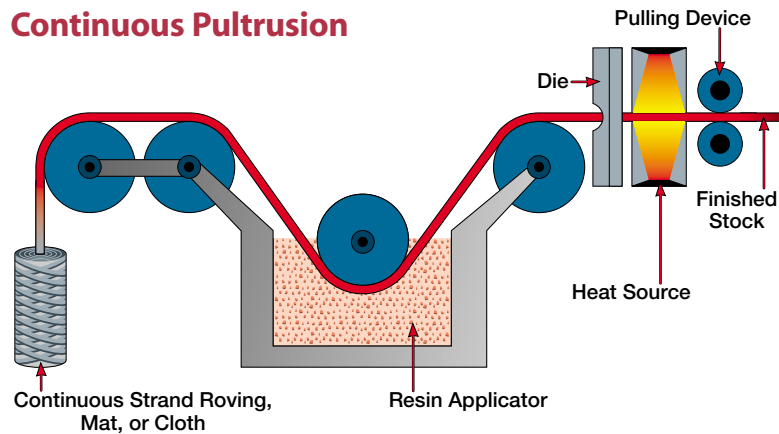
Pultrusion

Pultrusion is a continuous process that produces parts with a constant cross-section such as I-beams, channels, solid rods, and rails. The process utilizes glass, resin, filler, peroxides, pigments, and release agent. The glass reinforcement is fed from spools into a resin bath where the glass substrate is thoroughly impregnated with the resin mixture. The wet fibrous material then proceeds through forming guides where excess resin is removed from the glass. If the substrate is thin, it proceeds to a heated die where the resin mixture gels and cures into its final shape. A thick substrate proceeds through an R.F. preheating



Examples of pultruded profiles

chamber where the temperature of the resin is brought close to the gelation point of the system. From here, the material proceeds through a heated metal die where the resinous mass begins to cure. The glass/resin matrix solidifies into the exact shape of the cavity of the die being used. Grippers or caterpillar pads then pull the cured material to a cut off station where it is cut to the desired length. Pultrusion can produce unfilled parts with glass contents as high as 75% and with very high strengths.



Centrifugal Casting

Centrifugal casting is used in fabricating cylinders with a constant thickness. Molds used in centrifugal casting are often buffed and polished to a mirror finish. Glass and catalyzed resin are applied to the inside of a rotating mold. This rotation evenly distributes the glass and resin against the mold surface.

Resin Transfer Molding

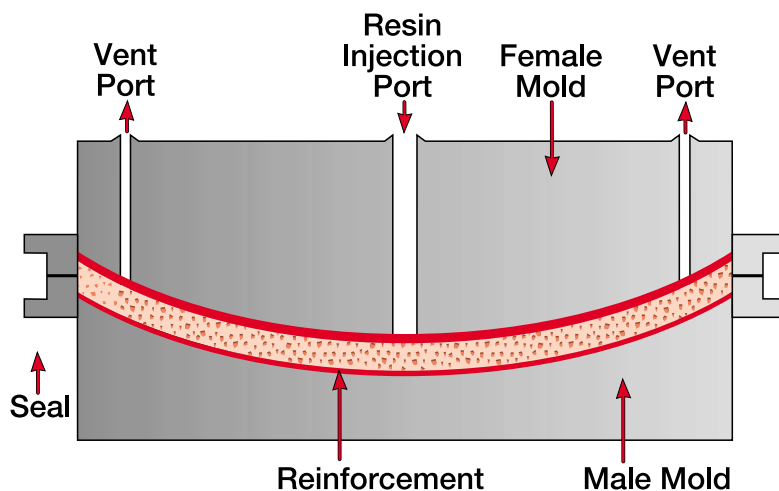
Resin transfer molding (RTM) is a mechanical process using a closed mold system. Catalyst and resin are pumped in under pressure from two separate containers into a closed mold containing glass reinforcement, usually continuous strand mat. The resin is pumped into the mold until excess resin escapes through vent tubes placed at the far end of the flow pattern. The system is then allowed to cure for a specific period of time after which the mold is opened and the part is removed.



A part made by RTM

RTM requires low viscosity resin, typically less than 250 cps, which can be pumped easily and readily fills the mold and wets the glass. Fillers may also be incorporated into the resin mix for certain applications. RTM uses either room temperature or elevated temperature catalyst systems. RTM is suitable for medium volume production and provides a process that is less expensive than compression molding and faster than spray-up.

Resin Transfer Molding



Linings

In some cases, the lining of an FRP structure may be eroded away but the structural portion of the equipment may be in acceptable condition. In these cases, the existing equipment can be relined to extend its life span. An FRP lining can also be put in existing steel equipment or applied over concrete. Whether lining an existing structure or putting in a new lining, the surface must be properly prepared in order to insure good bonding between the fiberglass lining and the existing structure.

The eroded or damaged FRP lining should first be washed to remove large amounts of dirt, etc. and then ground out back to the structural layer. In lining a steel tank, the surface should be sandblasted to "white metal". The blasted metal surface should conform to SSPC-SP-5 or NACE No.1 white metal blast profiles. In the case of concrete, the portland cement lattice should be removed to expose stone. Several sanding methods are acceptable, however, grit blasting and sand blasting are the preferred methods. When lining a concrete structure, the concrete should be at least 28 days old and completely dry. Sandblasting should be performed the same as with metal. After blasting, any cracks, pits, etc. should be filled in with putty, allowed to cure, and then sanded smooth. After all sanding is complete, the surface should be thoroughly vacuumed to remove all dust and dirt.

The surface of the equipment to be relined should not exceed 100°F (38°C). A uniform primer coat of resin, 1-3 mil (25-76 µm) thick, is then applied using a paintbrush or other suitable equipment. 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, 60-100°F (15-38°C) to a tack free state before applying the laminating resin. The laminating procedure should follow the primer application as soon as possible. No condensation should be allowed

to form over the primer coat. If the primer coat is allowed to develop a hard cure, the surface should be lightly sanded and another primer coat applied prior to applying the laminating resin.

Fabricating Thick Sections

HETRON® epoxy vinyl ester 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 appendix D for specific formulations). Second, fabricate a test laminate to see if the exotherm of the resin is going to be too high, resulting in burnt sections of the part. If this is the case, add copper naphthenate to the formulation up to, but no more than 400 ppm (see appendix D for formulation examples and copper naphthenate 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 for 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 as the wax will interfere with secondary bonding. It must be removed prior to subsequent laminations. This is typically accomplished by surface grinding.

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

S E C T I O N 7

Inspecting a Laminate

FRP composite equipment should be inspected after all fabrication is completed and prior to putting the equipment into service. 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 done immediately after installing the equipment to insure that there has been no mechanical damage as a result of transportation and installation. After installation, periodic inspections should be performed in order 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 of fabrication, service conditions and date and place of installation be recorded when the equipment is installed. Keeping a record of this information is essential when the time comes to repair or reline 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 the laminate. Air bubbles, laminate uniformity, cracks, and wet out are just a few of the things that can be detected by looking at a laminate. The table in Appendix G describes some common defects that can be detected visually and steps that can be taken to minimize these defects. For additional information on inspecting FRP parts and common laminate defects, refer to ASTM C 582 Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment or ASTM D 2563 Standard Recommended Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts.

The surface of the laminate should also be carefully examined. A surface that is smooth and 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.

Barcol Hardness

Barcol hardness values serve as an indication of degree of cure with high values indicating thorough cure and low values indicating incomplete cure. Barcol 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 reading of 30. Please contact Ashland Technical Service for additional information.

According to ASTM C 581, the recorded Barcol value must be at least 90% of the published Barcol value for that resin system in order for the equipment to be accepted. Barcol values for HETRON and AROPOL resins are indicated on the individual product data sheets or can be obtained from an Ashland Technical Service Representative.

To check Barcol hardness of FRP equipment, refer to ASTM D 2583 Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor.

Usually high or low Barcol values can be attributed to several factors:

High Barcol Values

1. Laminate surface with high glass content, Barcol tester may be measuring glass.

Low Barcol Values

1. Laminate surface with resin/wax topcoat, sand off small area of wax coat and measure Barcol again.
2. Laminate fabricated with synthetic veil.
3. Undercured laminate possibly due to incomplete catalyst mixing or incorrect catalyst ratios.
4. Testing a curved surface.



Barcol hardness impressor

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 rubbing four to five drops of acetone with a finger on the laminate surface until the acetone evaporates. The laminate surface should be free of mold release, wax, dust, and dirt. After evaporation, if the surface of the laminate remains tacky or soft, 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.

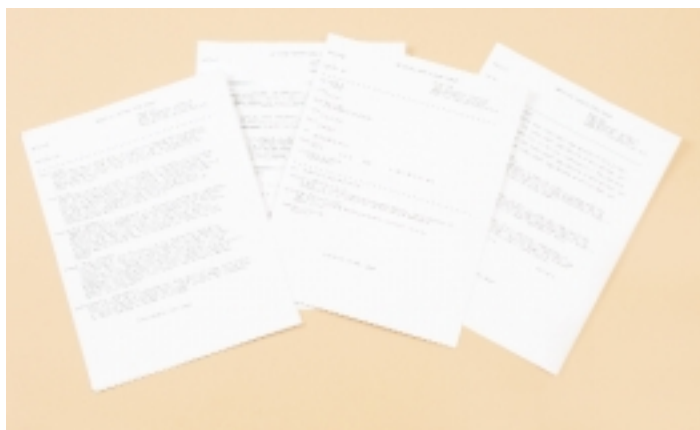
SECTION 8

Health, Safety, and Regulatory Information

Material Safety Data Sheets

Material safety data sheets (MSDS) are available from Ashland Specialty Chemical Company on all HETRON and AROPOL resins. The MSDS contains health and safety information to assist handlers in developing appropriate product handling procedures to protect employees and customers. The MSDS should be read and understood by all personnel before handling Ashland Specialty Chemical Company products in their facility.

HETRON and AROPOL resins are polymers that are diluted with styrene, or other monomers, to obtain a workable viscosity. The most common hazardous ingredient in the resins is styrene or other monomers. The polymer contained in the resin is typically non-hazardous.



Material safety data sheet

Styrene has a pungent odor that is easily detected due to the very low odor detection level of less than 1 ppm.

This is why even thoroughly cured parts may have a residual styrene odor.

Styrene is subject to a number of federal and state regulations that have the potential to impact facilities using HETRON and AROPOL resins. Current regulations should be reviewed for each facility before using HETRON or AROPOL resins.

For the most current and comprehensive information on styrene health affects see the following web sites: www.styrene.org or www.styreneforum.org. Other monomers used in HETRON and AROPOL resins pose different hazards. As always, consult the product MSDS for details.

Flammability

HETRON and AROPOL liquid resins are flammable due to the presence of styrene or other monomers. 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.

Sparks from static electricity can also cause fires. One of the most effective ways to prevent electrostatic sparking is to properly ground and bond in-plant equipment and containers. Do not use cutting or welding torches in empty resin drums. They may contain flammable vapors which could be ignited.

In the event of a fire involving HETRON or AROPOL resins, the fire should be extinguished using foam, dry powder, or carbon dioxide.

When HETRON and AROPOL resins burn, toxic gases such as carbon monoxide and hydrogen bromide (brominated resins only) may be given off. For this reason, caution should be used to avoid inhalation of the fumes. If necessary, a self-contained breathing apparatus should be worn while extinguishing the fire. Consult the MSDS and your site safety plan for more details.

HEALTH CONCERNS

Skin Contact

Protective gloves and clothing should be worn at all times while handling HETRON and AROPOL resins. Prolonged or repeated skin contact causes skin irritation and may damage the skin. If resin comes in contact with skin, it should be washed off immediately with large amounts of water and soap. If the skin is damaged, seek immediate medical attention. If irritation symptoms persist, seek medical attention.

Eye Contact

Eye protection should be worn at all times while handling HETRON and AROPOL resins. Exposure to liquid or vapor may cause eye irritation. If symptoms such as stinging, tearing, redness, and swelling develop and persist, seek medical attention.

Inhalation

Inhalation of styrene vapors from HETRON and AROPOL resins should be minimized with ventilation or other engineering controls. Exposure over the recommended limits may cause respiratory irritation and central nervous system (CNS) effects. Symptoms of CNS depression include headaches, nausea, drowsiness, etc. If inhalation symptoms develop, immediately move the individual away from exposure and into fresh air. Seek immediate medical attention.



Protective clothing, such as safety glasses, safety shoes, and gloves should be worn when handling HETRON and AROPOL resins.

Ingestion

Swallowing any amount of HETRON or AROPOL resin may be harmful. Seek medical attention and, if possible, do not leave the person unattended.

Chronic Health Effects

In 1987, the International Agency for Research and Cancer (IRAC) classified styrene as a group 2B (possibly carcinogenic to humans). This classification was not based on styrene itself, but upon that of styrene oxide, a metabolite of styrene. The potential for styrene exposure to cause cancer in humans has been questioned by many organizations. Current information on this topic is available on the websites previously mentioned in this section.

Resin Spills

Very small resin spills of less than 100 grams can be wiped up with a paper towel or cloth. Spills greater than 100 grams and less than 10 gallons should be cleaned up by applying sand or another appropriate absorbent material on the spilled resin. After the resin is absorbed, the material can be shoveled into a container and properly disposed of. The sticky residue should be removed using hot, soapy water. Large resin spills, greater than 10 gallons, should be contained using a dike. The spilled resin should be removed using containers and properly disposed of.

Storage

Resin in drums should be stored below 80°F (27°C) and away from direct heat sources such as sunlight and steam pipes. If stored at temperatures above 80°F (27°C), storage life will decrease. Bulk quantities of resin should be stored in stainless steel tanks or tanks lined with epoxy or phenolic coatings. When storing resins, bubbling dry air or a mix of 5% oxygen and 95% nitrogen into the bottom of the tank may be desirable to keep inhibitors activated and maximize shelf life. Containers should be sealed to prevent moisture pickup and monomer loss.

Disposal

Local, state and federal regulations should be carefully followed when disposing of any hazardous material. Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters. In some states, completely cured resin parts may be considered non-hazardous, however, it is recommended that the proper local or state agency be contacted to confirm the proper method of disposal for cured resin parts. For assistance with your waste management needs—including disposal, recycling and waste stream reduction, contact Ashland Distribution Company, IC&S Environmental Services Group at 800-637-7922

APPENDIX A

Promoter and Catalyst Addition Tables

Table 1A – Typical Gel Times for HETRON 922 Resin with MEKP¹

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Catalyst	Gel Time (minutes) Delta X-9	Gel Time (minutes) DDM-9	Gel Time (minutes) HiPoint 90
65 (18)	0.3	0.15	1.25	14.3	21.3	21.9
	0.3	0.075	1.25	23.8	30.7	29.4
	0.3	0.05	1.25	38.3	39.3	39.4
75 (24)	0.3	0.075	1.25	14.8	17.4	16.8
	0.3	0.05	1.25	21.3	23.3	22.5
	0.3	0.025	1.25	33.0	34.4	35.7
85 (29)	0.2	0.075	1.25	15.3	17.9	18.3
	0.2	0.05	1.25	22.2	23.7	24.2
	0.2	0.025	1.25	36.7	37.7	40.8

Table 2A – Typical Gel Times for HETRON 922 Resin with BPO³

Temperature °F (°C)	DMA ⁴	Catalyst (50% BPO Paste)	Gel Time (minutes)
65 (18)	0.70	2.0	17.3
	0.50	2.0	23.5
	0.30	2.0	37.6
75 (24)	0.50	2.0	15.5
	0.30	2.0	25.0
	0.15	2.0	49.0
85 (29)	0.30	2.0	17.7
	0.20	2.0	24.8
	0.10	2.0	36.2
	0.30	2.0	17.9

Table 3A – HETRON 922 Resin and Different Levels of Copper at 77°F

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Copper (PPM)	Catalyst (Delta X-9)	Gel Time (minutes)	Gel to Peak (minutes)	Peak Exotherm
77 (25)	0.30	0.075	0	1.25	15.6	9.4	322°F
	0.30	0.075	100	1.25	16.0	8.0	284°F
	0.30	0.075	200	1.25	15.8	11.2	248°F
	0.30	0.075	300	1.25	16.6	10.9	228°F

Table 4A – Typical Gel Times for HETRON 942/35 Resin with MEKP¹

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Catalyst	Gel Time (minutes) Delta X-9	Gel Time (minutes) DDM-9	Gel Time (minutes) HiPoint 90	Gel Time (minutes) HiPoint 90/CHP ⁵ (50/50)
65 (18)	0.35	0.2	1.25	9.3	17.9	18.0	45.6
	0.3	0.2	1.25	13.2	21.0	21.5	53.2
	0.3	0.1	1.25	19.2	26.3	26.3	61.1
	0.3	0.05	1.25	28.1	39.0	39.4	69.7
75 (24)	0.3	0.05	1.25	15.4	17.7	16.4	34.5
	0.3	0.02	1.25	28.2	32.1	30.4	69.4
	0.2	0.02	1.25	52.4	55.4	55.9	111.6
85 (29)	0.4	0.04	1.25	9.2	11.1	11.0	21.3
	0.3	0.03	1.25	18.1	19.6	18.8	40.5
	0.2	0.03	1.25	29.1	32.0	29.6	55.5
	0.1	0.03	1.25	53.3	58.1	49.5	80.9

Table 5A – Typical Gel Times for HETRON 942/35 Resin with BPO³

Temperature °F (°C)	DMA ⁴	Catalyst (50% BPO Paste)	Gel Time (minutes)
65 (18)	0.50	2.0	16.9
	0.40	2.0	19.3
	0.30	2.0	23.1
	0.20	2.0	35.2
75 (24)	0.40	2.0	11.7
	0.30	2.0	15.1
	0.20	2.0	21.0
	0.10	2.0	44.8
85 (29)	0.30	2.0	11.4
	0.20	2.0	18.5
	0.10	2.0	41.2
	0.05	2.0	176.1

Table 6A – HETRON 942/35 Resin and Different Levels of Copper at 77°F

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Copper (PPM)	Catalyst (Delta X-9)	Gel Time (minutes)	Gel to Peak (minutes)	Peak Exotherm
77 (25)	0.30	0.05	0	1.25	13.4	6.3	335°F
	0.30	0.05	100	1.25	11.5	7.1	304°F
	0.30	0.05	200	1.25	12.4	10.0	277°F
	0.30	0.05	300	1.25	11.1	10.3	259°F

Table 7A – Typical Gel Times for HETRON 980/35 Resin with MEKP¹

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Catalyst	Gel Time (minutes) Delta X-9	Gel Time (minutes) DDM-9	Gel Time (minutes) HiPoint 90
65 (18)	0.55	0.05	1.25	16.2	18.0	18.0
	0.4	0.05	1.25	24.9	27.5	30.6
	0.4	0.025	1.25	39.1	40.2	42.0
75 (24)	0.4	0.025	1.25	20.0	20.6	20.5
	0.3	0.025	1.25	24.9	26.7	26.4
	0.2	0.025	1.25	34.5	35.9	35.4
85 (29)	0.3	0.025	1.25	19.7	20.7	21.4
	0.25	0.025	1.25	22.1	23.5	26.5
	0.2	0.015	1.25	34.6	35.9	40.5

Table 8A – Typical Gel Times for HETRON 980/35 Resin with BPO³

Temperature °F (°C)	DMA ⁴	Catalyst (50% BPO Paste)	Gel Time (minutes)
65 (18)	0.40	2.0	12.8
	0.30	2.0	24.9
	0.20	2.0	35.7
75 (24)	0.30	2.0	13.6
	0.20	2.0	24.7
	0.10	2.0	52.1
85 (29)	0.30	2.0	11.6
	0.20	2.0	17.5
	0.10	2.0	37.9

Table 9A – HETRON 980/35 Resin and Different Levels of Copper at 77°F

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Copper (PPM)	Catalyst (Delta X-9)	Gel Time (minutes)	Gel to Peak (minutes)	Peak Exotherm
77 (25)	0.30	0.02	0	1.25	28.2	14.0	328°F
	0.30	0.02	100	1.25	24.0	13.8	312°F
	0.30	0.02	200	1.25	24.5	16.5	284°F
	0.30	0.02	300	1.25	24.6	22.0	254°F

Table 10A – Typical Gel Times for HETRON FR 992 Resin with MEKP¹

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Catalyst	Gel Time (minutes) Delta X-9	Gel Time (minutes) DDM-9	Gel Time (minutes) HiPoint 90	Gel Time (minutes) HiPoint 90/CHP ⁵ (50/50)
65 (18)	0.2	0.1	1.25	16.2	27.1	26.0	60.8
	0.2	0.075	1.25	19.5	30.6	30.9	68.8
	0.2	0.05	1.25	26.9	40.0	33.4	76.1
	0.15	0.05	1.25	35.7	50.9	47.9	112.4
75 (24)	0.3	0.04	1.25	10.7	12.4	12.7	26.9
	0.2	0.04	1.25	16.2	20.5	19.1	39.8
	0.15	0.04	1.25	21.6	27.3	25.7	53.5
	0.1	0.04	1.25	29.6	37.1	35.8	73.7
85 (29)	0.3	0.05	1.25	7.7	7.9	8.3	18.4
	0.2	0.05	1.25	10.7	11.5	12.1	23.7
	0.1	0.05	1.25	20.0	25.1	23.5	47.8
	0.1	0.05	1.25	29.1	34.6	30.1	62.4

Table 11A – Typical Gel Times for HETRON FR 992 Resin with BPO³

Temperature °F (°C)	DMA ⁴	Catalyst (50% BPO Paste)	Gel Time (minutes)
65 (18)	0.50	2.0	20.6
	0.30	2.0	26.0
	0.20	2.0	36.2
	0.10	2.0	70.1
75 (24)	0.30	2.0	16.3
	0.20	2.0	23.6
	0.10	2.0	47.7
85 (29)	0.30	2.0	11.3
	0.20	2.0	15.9
	0.10	2.0	27.3
	0.05	2.0	59.4

Table 12A – HETRON FR 992 Resin and Different Levels of Copper at 77°F

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Copper (PPM)	Catalyst (Delta X-9)	Gel Time (minutes)	Gel to Peak (minutes)	Peak Exotherm
77 (25)	0.10	0.04	0	1.25	22.6	10.5	341°F
	0.10	0.04	100	1.25	20.2	10.2	317°F
	0.10	0.04	200	1.25	20.2	14.2	310°F
	0.10	0.04	300	1.25	20.6	15.9	288°F

Table 13A – Typical Gel Times for HETRON FR 998/35 Resin with MEKP¹

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Catalyst	Gel Time (minutes) Delta X-9	Gel Time (minutes) DDM-9	Gel Time (minutes) HiPoint 90	Gel Time (minutes) HiPoint 90/CHP ⁵ (50/50)
65 (18)	0.25	0.025	1.25	11.6	15.2	14.6	36.7
	0.35	0.01	1.25	15.8	16.4	16.1	42.9
	0.25	0.01	1.25	24.5	27.3	26.8	66.1
	0.35	—	1.25	34.8	36.7	38.3	86.0
75 (24)	0.15	0.05	1.25	6.6	10.1	9.3	21.4
	0.3	—	1.25	20.5	21.5	22.4	46.8
	0.15	—	1.25	31.4	35.0	35.2	76.1
	0.1	—	1.25	51.8	57.6	56.9	115.0
85 (29)	0.3	—	1.25	18.0	18.7	18.7	40.8
	0.2	—	1.25	22.0	22.3	23.1	49.2
	0.1	—	1.25	37.5	41.3	41.0	84.6

Table 14A – Typical Gel Times for HETRON FR 998/35 Resin with BPO³

Temperature °F (°C)	DMA ⁴	Catalyst (50% BPO Paste)	Gel Time (minutes)
65 (18)	0.20	2.0	14.1
	0.20	2.0	20.0
	0.15	2.0	27.0
	0.10	2.0	43.0
75 (24)	0.20	2.0	14.1
	0.15	2.0	20.1
	0.10	2.0	31.4
	0.05	2.0	76.5
85 (29)	0.20	2.0	10.3
	0.15	2.0	12.3
	0.10	2.0	17.7
	0.05	2.0	46.0

Table 15A – HETRON FR 998/35 Resin and Different Levels of Copper at 77°F

Temperature °F (°C)	6% Cobalt ² Naphthenate	DMA ⁴	Copper (PPM)	Catalyst (Delta X-9)	Gel Time (minutes)	Gel to Peak (minutes)	Peak Exotherm
77 (25)	0.10	—	0	1.25	28.3	13.5	320°F
	0.10	—	100	1.25	31.5	15.2	307°F
	0.10	—	200	1.25	32.8	17.4	286°F
	0.10	—	300	1.25	33.1	21.9	279°F

Table 16A – Typical Gel Times for HETRON 922L Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate	Dimethylaniline ⁴ (phr)	MEKP ¹ (phr)
65 (18)	10 - 20	0.30	0.075	1.25
	20 - 30	0.30	0.025	1.25
	30 - 40	0.30	0.010	1.25
75 (24)	10 - 20	0.30	0.025	1.25
	20 - 30	0.10	—	1.25
	30 - 40	0.05	—	1.25
85 (29)	10 - 20	0.30	0.010	1.25
	20 - 30	0.05	—	1.25
	30 - 40	0.025	—	1.25

Table 17A – Typical Gel Times for HETRON 922L Resin with BPO³

Temperature °F (°C)	Gel Time (minutes)	Dimethylaniline ⁴ (phr)	BPO ³ (phr)
75 (24)	10 - 15	0.25	2.00
	20 - 25	0.15	2.00
	30 - 35	0.10	2.00

Table 18A – Typical Gel Times for HETRON 992L-25 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	MEKP ¹ (phr)
65 (18)	40 - 50	1.50
	50 - 60	1.25
	65 - 75	1.00
75 (24)	15 - 25	1.50
	25 - 35	1.00
85 (29)	10 - 20	1.50
	20 - 30	1.00

Table 19A – Typical Gel Times for HETRON 970/35 Resin with CHP⁵ and TBC-85⁶

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate (phr)	Dimethylaniline ⁴ (phr)	TBC-85 ⁶ (phr)	CHP ⁵ (phr)
65 (18)	10 - 20	0.50	0.40	—	2.50
	20 - 30	0.40	0.10	—	2.00
	30 - 40	0.20	0.05	—	1.50
75 (24)	10 - 20	0.20	0.15	—	1.50
	20 - 30	0.10	0.05	—	1.00
	30 - 40	0.10	0.05	0.02	1.00
85 (29)	10 - 20	0.15	0.05	—	1.50
	20 - 30	0.10	0.025	0.02	1.00
	30 - 40	0.10	0.02	0.03	1.00

Table 20A – Typical Gel Times for HETRON 970/35 Resin with BPO³

Temperature °F (°C)	Gel Time (minutes)	Dimethylaniline ⁴ (phr)	BPO ³ (phr)
65 (18)	10 - 20	0.20	2.00
	20 - 30	0.15	1.75
	30 - 40	0.10	1.25
75 (24)	10 - 20	0.15	2.00
	20 - 30	0.10	2.00
	30 - 40	0.07	2.00
85 (29)	10 - 20	0.10	2.00
	20 - 30	0.10	1.25
	30 - 40	0.05	2.00

Table 21A – Typical Gel Times for HETRON 980 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate (phr)	Dimethylaniline ⁴ (phr)	MEKP ¹ (phr)
65 (18)	10 - 20	0.30	0.10	1.25
	20 - 30	0.30	0.05	1.25
	30 - 40	0.20	0.05	1.25
75 (24)	10 - 20	0.30	0.05	1.25
	20 - 30	0.20	0.05	1.25
	30 - 40	0.20	0.025	1.25
85 (29)	10 - 20	0.20	0.05	1.25
	20 - 30	0.30	—	1.25
	30 - 40	0.30	—	1.25

Table 22A – Typical Gel Times for HETRON 980 Resin with BPO³ and HQ⁷ as an Inhibitor

Temperature °F (°C)	Gel Time (minutes)	Dimethylaniline ⁴ (phr)	HQ ⁷ (phr)	BPO ³ (phr)
65 (18)	30 - 40	0.30	—	2.00
	40 - 50	0.25	—	2.00
	50 - 60	0.20	—	2.00
	70 - 80	0.15	—	2.00
75 (24)	15 - 25	0.30	—	2.00
	20 - 25	0.25	—	2.00
	25 - 35	0.20	—	2.00
	35 - 45	0.15	—	2.00
85 (29)	15 - 25	0.25	—	1.50
	20 - 25	0.20	—	1.50
	25 - 35	0.15	—	1.50
	45 - 55	0.10	—	1.50
95 (35)	15 - 25	0.25	—	1.00
	25 - 30	0.20	—	1.00
	30 - 40	0.15	—	1.00
	40 - 50	0.25	0.005	1.00
	50 - 60	0.20	0.005	1.00
	70 - 80	0.10	0.005	1.00

Table 23A – Typical Gel Times for HETRON FR990 ZX Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate (phr)	Dimethylaniline ⁴ (phr)	MEKP ¹ (phr)
77 (25)	5 - 15	0.30	0.10	1.50
	10 - 20	0.20	0.10	1.50
	15 - 25	0.30	—	1.50
	20 - 30	0.10	0.10	1.50
	25 - 35	0.10	—	1.50

Table 24A – Typical Gel Times for HETRON 92 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate (phr)	MEKP ¹ (phr)
75 (24)	10 - 15	0.50	1.00
	15 - 25	0.30	1.00
	25 - 35	0.20	0.90
	40 - 50	0.10	1.00
85 (29)	10 - 15	0.30	1.00
	15 - 20	0.20	0.90
	20 - 25	0.10	1.00
	25 - 35	0.20	0.50
95 (35)	10 - 15	0.20	0.90
	15 - 20	0.10	1.00
	20 - 25	0.20	0.70

Table 25A – Typical Gel Times for HETRON 92FR Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	MEKP ¹ (phr)
65 (18)	30 - 35	1.25
	35 - 40	1.00
75 (24)	15 - 20	1.50
	20 - 25	1.00
85 (29)	5 - 10	1.50
	10 - 15	1.00

Table 26A – Typical Gel Times for HETRON 197 and 197-3 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate (phr)	Dimethylaniline ⁴ (phr)	MEKP ¹ (phr)
55 (13)	3 - 6	0.70	0.20	1.90
	15 - 25	0.70	—	1.50
	35 - 45	0.40	—	15.0
65 (18)	3 - 6	0.60	0.10	1.25
	15 - 25	0.60	—	1.25
	35 - 45	0.40	—	1.25
75 (24)	10 - 15	0.60	—	1.25
	20 - 25	0.40	—	1.25
	30 - 40	0.20	—	0.90
	55 - 65	0.15	—	0.90
85 (29)	10 - 20	0.40	—	1.25
	30 - 40	0.20	—	0.90
	40 - 50	0.19	—	0.65
95 (35)	10 - 15	0.40	—	1.25
	15 - 25	0.20	—	0.90
	25 - 35	0.20	—	0.65

Table 27A – Typical Gel Times for HETRON 197 and 197-3 Resins with BPO³

Temperature °F (°C)	Gel Time (minutes)	Dimethylaniline ⁴ (phr)	BPO ³ (phr)
65 (18)	40 - 50	0.25	2.00
	50 - 60	0.20	2.00
	75 - 85	0.15	2.00
75 (24)	25 - 30	0.25	2.00
	30 - 35	0.20	2.00
	35 - 45	0.15	2.00
	50 - 60	0.10	2.00
85 (29)	20 - 25	0.15	1.50
	30 - 35	0.10	1.50
	70 - 80	0.05	1.50
95 (35)	20 - 25	0.15	1.50
	25 - 30	0.15	1.00
	30 - 40	0.10	1.00
	40 - 50	0.05	1.50
	55 - 65	0.05	1.00

Table 28A – Typical Gel Times for HETRON 197P Resin with MEKP¹ and HQ⁷ as an Inhibitor

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate (phr)	MEKP ¹ (phr)
65 (18)	25 - 35	—	1.50
	35 - 40	—	1.25
	40 - 50	—	1.00
75 (24)	10 - 15	0.010	1.25
	15 - 20	—	1.25
	20 - 25	—	1.00
	30 - 40	0.006	1.25
	45 - 55	0.008	1.25
85 (29)	5 - 10	—	1.50
	15 - 20	—	1.00

Table 29A – Typical Gel Times for HETRON 604T20 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	MEKP ¹ (phr)
65 (18)	25 - 35	1.75
	40 - 50	1.25
75 (24)	10 - 20	1.75
	25 - 35	1.00
85 (29)	5 - 15	1.75
	15 - 25	1.00

Table 30A – Typical Gel Times for HETRON 700 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	6% Cobalt ² Naphthenate (phr)	Dimethylaniline ⁴ (phr)	MEKP ¹ (phr)
65 (18)	30 - 40	0.50	0.10	1.25
	40 - 50	0.40	0.10	1.25
	60 - 65	0.30	0.10	1.25
75 (24)	20 - 30	0.50	0.10	1.25
	30 - 35	0.40	0.10	1.25
	40 - 45	0.30	0.10	1.25
	50 - 55	0.20	0.10	1.25
85 (29)	15 - 20	0.40	0.10	1.25
	20 - 25	0.30	0.10	1.25
	25 - 30	0.20	0.10	1.25
	45 - 50	0.10	0.10	1.25
95 (35)	15 - 20	0.30	0.10	1.25
	25 - 30	0.20	0.10	1.25
	35 - 40	0.10	0.10	1.25
	45 - 50	0.10	0.10	1.00

Table 31A – Typical Gel Times for HETRON 700 Resin with BPO³

Temperature °F (°C)	Gel Time (minutes)	Dimethylaniline ⁴ (phr)	BPO ³ (phr)
65 (18)	25 - 35	0.50	2.00
	35 - 45	0.40	2.00
	50 - 60	0.30	2.00
75 (24)	15 - 20	0.60	2.00
	20 - 30	0.50	2.00
	30 - 40	0.40	2.00
	40 - 50	0.30	2.00
	50 - 60	0.20	2.00
85 (29)	25 - 35	0.40	2.00
	35 - 45	0.30	2.00
	50 - 60	0.20	2.00
	65 - 75	0.10	2.00
95 (35)	15 - 20	0.40	2.00
	20 - 30	0.30	2.00
	35 - 45	0.20	2.00
	60 - 70	0.10	2.00

Table 32A – Typical Gel Times for HETRON 800 Resin with HETRON 803L-1 Catalyst

Temperature °F (°C)	Gel Time (minutes)	HETRON 803L-1 (phr)
65 (18)	15 - 20	5.0
	25 - 30	3.0
	30 - 35	2.5
75 (24)	10 - 15	4.0
	15 - 20	2.5
85 (29)	5 - 10	4.0
	10 - 15	2.5

Table 33A – Typical Gel Times for AROPOL 7241T-15 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	MEKP ¹ (phr)
60 (15)	10 - 15	1.90
	25 - 30	1.25
	50 - 60	0.65
70 (21)	10 - 15	1.90
	15 - 20	1.25
	45 - 50	0.65
80 (27)	5 - 10	1.90
	10 - 15	1.25
	20 - 30	0.65
90 (32)	5 - 10	1.25
	10 - 15	0.65

Table 34A – Typical Gel Times for AROPOL 7334T-15 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	MEKP ¹ (phr)
65 (18)	30 - 35	1.25
75 (24)	15 - 20	1.25
85 (29)	10 - 15	1.25

Table 40D – Typical Gel Times for AROPOL 7334T-15 Resin with MEKP¹

Temperature °F (°C)	Gel Time (minutes)	MEKP ¹ (phr)
65 (18)	30 - 35	1.25
75 (24)	15 - 20	1.25
85 (29)	10 - 15	1.25

Copper Conversion Table

ppm	55 gallon drum (450 lbs) fl. oz. / cc's or grams	5 gallon pail (40 lbs) cc's or grams
50	0.35 / 10	0.9
100	0.7 / 20	1.8
150	1.0 / 31	2.7
200	1.4 / 41	3.6
250	1.7 / 51	4.5
300	2.1 / 61	5.4

Notes:

- 1 Methyl Ethyl Ketone Peroxide, 9.0% active oxygen
- 2 In Europe, 6% cobalt octoate can be substituted for 6% cobalt naphthenate to obtain comparable gel times. If 12% cobalt octoate is used, half as much 12% cobalt octoate as 6% cobalt naphthenate should be used to obtain comparable gel times.
- 3 Benzyl Peroxide Paste, 50% active
- 4 Dimethyl Aniline
- 5 Cumene Hydroperoxide
- 6 TBC-85 is tertiary butyl catechol, 85% solution
- 7 Hydroquinone

APPENDIX B

Ashland Specialty Chemical Technical Service Contacts

Country/Region	Company/Contact Address/Phone/Fax
UNITED STATES	<i>Ashland Specialty Chemical Company</i> HETRON® Technical Service 5200 Blazer Pkwy Dublin, Ohio 43017 phone: 800.327.8720 fax: 614.790.6157 e-mail: hetron@ashland.com
AUSTRALIA	<i>Huntsman Chemical Company Australia</i> Sommerville Road P.O. Box 62 West Footscray VIC 3012 phone: 61.3.316.3172 fax: 61.3.316.3579
BRAZIL	<i>ARA Quimica, S.A.</i> Alameda Rio Negro, 1084 Salas M3/M5 Barueri, São Paulo CEP 06454-000, BRAZIL phone: 55.11.4195.6777 fax: 55.11.4195.1317 e-mail: www.araquimica.com.br
CHINA	<i>Ashland Chemical</i> Holiday Inn Office Building 45 North Zhongshan Road Room 1205 Nanjing, CHINA 210008 phone: 86.25.331.8982 fax: 86.25.331.8760 e-mail: ashland@public1.ptt.js.cn
EUROPE	<i>Ashland Composite Polymers Division</i> Via delle Groane, 126 20024 Garbagnate (MI) ITALY phone: 39.02.3978.8446/8447 fax: 39.02.3978.8413
SAUDI ARABIA	<i>Saudi Industrial Resins, Ltd.</i> Manufacturing Facility P.O. Box 7764 Al Farsi Center, 9th Floor Jeddah, SAUDI ARABIA 21472 phone: 966.2.651.8920 fax: 966.2.651.7072
SPAIN	<i>Ashland Chemical Hispania, S.A.</i> Manufacturing Facility Partida Povet 37 APDO Correo 26 12580 Benicarló, SPAIN phone: 34.964.471.316 fax: 34.964.473.697

APPENDIX C

North American Suppliers

Reinforcements			
C-Glass Veil	Owens Corning	419.248.8000	www.owenscorning.com
NEXUS Veil	Precision Fabrics Group Inc.	800.284.8071	www.precisionfabrics.com
Chopped Mat / Woven Roving	Vetrotex (CertainTeed)	800.433.0922	www.vetrotexcertainteed.com
	Owens Corning	419.248.8000	www.owenscorning.com
	PPG Industries, Inc.	412.434.3131	www.ppg.com
Catalysts			
MEK Peroxide			
HIPOINT 90	Witco Corporation	800.494.8737	www.witco.com
LUPERSOL DDM-9	Elf-Atochem North American Inc.	800.558.5575	www.atofina.com
BUTANOX M-50	Akzo Nobel	800.227.7070	www.akzo-nobel.com
NOROX MEKP-9	The Norac Company, Inc.	626.334.2908	www.norac.com
CADOX M-50	Akzo Nobel	800.227.7070	www.akzo-nobel.com
Benzyl Peroxide			
LUPERCO ATC paste	Elf-Atochem North American Inc.	800.558.5575	www.atofina.com
Cumene Hydroperoxide			
Cumene Hydroperoxide	Elf-Atochem North American Inc.	800.558.5575	www.atofina.com
Promoters			
6% Cobalt / 12% Cobalt	OMG Americas, Inc.	216.781.0083	www.omgi.com
Dimethyl Aniline / Diethyl Aniline	Buffalo Color Corporation	800.631.0171	www.buffalocolor.com
Inhibitors			
Tertiary Butyl Catechol (TBC)	Union Carbide Chemicals	800.447.4369	www.dow.com
Hydroquinone (HQ)	Eastman Chemical Products, Inc.	615.240.4111	www.eastman.com
Toluhydroquinone (THQ)	Eastman Chemical Products, Inc.	615.240.4111	www.eastman.com
Antimony Oxides			
Antimony Trioxide	Hoechst Celanese Corporation	704.554.3148	www.vectran.com
Antimony Pentoxide	PQ Corporation	610.651.4200	www.pqc corp.com
Intumescent Coatings			
Intumescent Coatings	PPG Industries, Inc.	412.434.3131	www.ppg.com
Fumed Silica			
CAB-O-SIL TS-720 or M-5	Cabot Corporation	217.253.3370	www.cabot-corp.com
AEROSIL R200 or R202	Degussa Corporation	201.641.6100	www.degussa.com
UV Stabilizers			
For Polyester Resins			
CYASORB 5411	Cytec Industries	800.486.5525	www.cytec.com
CYASORB UV-9	Cytec Industries	800.486.5525	www.cytec.com
For Vinyl Esters			
CYASORB UV-9	Cytec Industries	800.486.5525	www.cytec.com
TINUVIN 328	Ciba Geigy Corporation	800.431.1900	www.ciba.com
UNIVINUL M-40	BASF Corporation	800.669.2273	www.basf.com
Air Release Agents			
BYK A515	BYK Chemie	203.265.2086	www.byk.com
SAG 47	OSi Specialties	800.523.5862	www.osispecialties.com
Abrasion Resistant Additives			
Silicon Carbide	Exolon – ESK Company	800 962-1100	www.exolon.com
Aluminum Oxide	Degussa Corporation	201.641.6100	www.degussa.com
Air Inhibitors/ Suppressants			
Fully Refined Paraffin Wax	H M Royal	800.257.9452	www.hmroyal.com
Fully Refined Paraffin Wax	Moore & Munger	800.423.7071	www.mooremunger.com
BYK S750	BYK Chemie	203.265.2086	www.byk.com
Exotherm Suppressant			
Copper Naphthenate	OMG Americas, Inc.	216.781.0083	www.omgi.com
Wetting Agents			
Tween 20	ICI Chemicals	302.887.3000	www.ici.com
BYK R605	BYK Chemie	203.265.2086	www.byk.com

Check out suppliers on-line for international contacts!

APPENDIX D

Equipment Suppliers

Chopper Guns/RTM Supplies		
Magnum Venus Products	800.448.6035	www.venus-gusmer.com
Glas-Craft	317.875.5592	www.glascraft.com
Binks	888.992.4657	www.binks.com
Barcol Hardness Testers		
Barber Colman Company	815.637.3222	www.barber-colman.com
Viscometers		
Brookfield	800.628.8139	www.brookfieldengineering.com
Gel Timers		
Techne	800.225.9243	www.techneusa.com
Portable Heaters		
Master Heaters	800.446.1446	www.masterheaters.com
Vogelzang International Corporation		www.vogelzang.com
Pumps & Mixers		
Magnum Venus Products	800.448.6035	www.venus-gusmer.com
Rollers, Laminating Accessories		
Magnum Venus Products	800.448.6035	www.venus-gusmer.com

APPENDIX E

Trouble Shooting Guide for Curing Resins at Room Temperature

Defect	Check Points	
	MEKP or CHP	BPO
Resin gelling too quickly	<p>Reduce cobalt, DMA, or catalyst levels but not below those recommended for that resin system.</p> <p>Add inhibitor.</p> <p>Check resin, shop and mold temperature; warm temperatures cause resin to gel faster.</p>	<p>Reduce DMA and/or BPO levels but not below those recommended for that resin system.</p> <p>Add inhibitor.</p> <p>Check resin, shop and mold temperature; warm temperatures cause resin to gel faster.</p>
Resin exotherm too high during curing	<p>Reduce DMA and/or catalyst levels but not below those recommended for that resin system.</p> <p>Lay up fewer plies at one time to reduce amount of heat generated during exotherm and allow to exotherm before adding additional plies.</p> <p>Use a 50/50 blend of MEKP/CHP.</p>	<p>Reduce DMA level but not below that recommended for that resin system.</p> <p>DMA/BPO is a hot system. Lay-up fewer plies at one time and allow to exotherm before adding additional plies.</p>
Resin gelling too slowly or will not gel at all	<p>Increase promoter/catalyst levels, not above those recommended for that resin system.</p> <p>Reduce or eliminate inhibitor.</p> <p>Check resin, shop and mold temperature; cool temperatures cause resin to gel slower.</p> <p>Check other additives. Antimony trioxides, fillers, and pigments may retard gel time. Mix fillers in just before adding catalyst.</p> <p>Check mixing. Cobalt may be difficult to mix into resin, especially if resin is cool. Dissolve cobalt in a small amount of styrene before adding to resin.</p> <p>Check fittings on equipment. Bronze, copper and zinc may inhibit cure.</p>	<p>Increase promoter/catalyst levels, not above those recommended for that resin system.</p> <p>Reduce or eliminate inhibitor.</p> <p>Check resin, shop and mold temperature; cool temperatures cause resin to gel slower.</p> <p>Check other additives. Antimony trioxides, fillers and pigments may retard gel time. Mix fillers in just before adding catalyst.</p> <p>Check active level of BPO. Some BPO is not 100% active. Levels may have to be adjusted to five required level of BPO.</p> <p>Insure proper mixing of all additives.</p>
Resin not getting hard after gelation or spotty cure.	<p>Increase promoter/catalyst levels but not above those recommended for that resin system.</p> <p>Reduce or eliminate inhibitor.</p> <p>If surface is tacky or acetone sensitive, a wax topcoat may be necessary.</p> <p>Insure proper mixing of all additives.</p> <p>Check fittings on equipment. Bronze, copper and zinc may inhibit cure.</p>	<p>Increase promoter/catalyst levels but not above those recommended for that resin system.</p> <p>Reduce or eliminate inhibitor.</p> <p>If surface is tacky or acetone sensitive, a wax topcoat may be necessary.</p> <p>Insure proper mixing of all additives.</p>

APPENDIX F

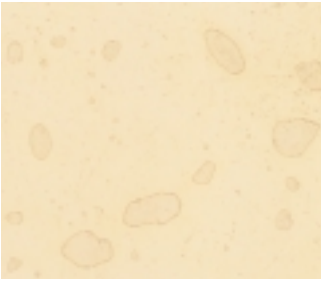


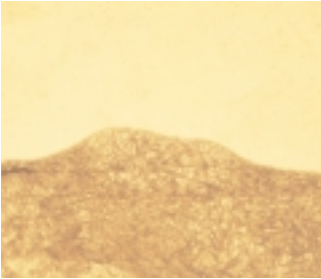
Weight to Volume Conversion Tables





Additive (phf)	Conversion	Resin Quantity		
		1 Gallon (8.8 lbs, 4 kg)	5 Gallons (44 lbs, 20 kg)	55 Gallons (450 lbs, 200 kg)
6% Cobalt Naphthenate ¹				
0.10	fl. oz.	0.15	0.7	7.2
	cc	4	21	212
0.20	fl. oz.	0.3	1.4	14
	cc	8	41	423
0.30	fl. oz.	0.4	2.1	22
	cc	12	62	634
0.40	fl. oz.	0.6	2.8	29
	cc	17	83	849
0.50	fl. oz.	0.7	3.5	36
	cc	21	104	1.1L
Dimethylaniline				
0.025	fl. oz.	0.03	0.15	1.5
	cc	0.9	4.5	46
0.05	fl. oz.	0.07	0.35	3.6
	cc	2.1	10	106
0.075	fl. oz.	0.1	0.5	5.1
	cc	3.0	15	151
0.10	fl. oz.	0.15	0.7	7.0
	cc	4.1	21	212
Methyl Ethyl Ketone Peroxide				
1.00	fl. oz.	1.2	6.0	61
	cc	36	178	1.8L
1.25	fl. oz.	1.5	7.5	77
	cc	44	222	2.3L
1.50	fl. oz.	1.8	9.0	92
	cc	53	266	2.7L
1.75	fl. oz.	2.1	11	107
	cc	62	311	3.2L
2.00	fl. oz.	2.4	13	122
	cc	71	355	3.7L
Benzyl Peroxide Paste (50% active)				
1.00	fl. oz.	1.2	5.8	59
	cc	36	164	1.7L
1.50	fl. oz.	1.7	8.6	88
	cc	49	245	2.5L
2.00	fl. oz.	2.3	11.5	118
	cc	65	327	3.3L
2.50	fl. oz.	2.9	14	147
	cc	82	409	4.2L
3.00	fl. oz.	3.5	17	176
	cc	98	491	5.0L

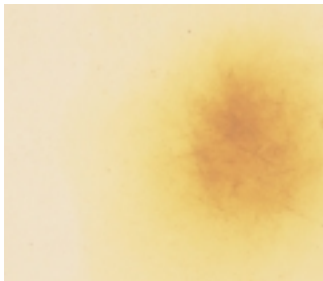

¹ In Europe, 6% cobalt octoate can be substituted for 6% cobalt naphthenate to obtain comparable gel times. If 12% cobalt octoate is used, half as much 12% cobalt octoate as 6% cobalt naphthenate should be used to obtain comparable gel times.

APPENDIX G

Visual Acceptance Criteria for Cured Laminates

Defect	Description	Possible Causes	Possible Solutions
Air bubbles, Voids 	Entrapped air in and between glass plies	Application of too many plies of glass at one time Inadequate rolling between applications Vigorous mixing causing incorporation of air into resin High viscosity resin used in combination with thick glass	Apply fewer plies 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 at 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 catalyst level Insure proper storage of resin, glass, and filler, away from sources of moisture
Crack 	Cracks running along laminate either on or just below the surface	Overly resin-rich areas Cracks may result from dramatic changes in the temperature conditions of the equipment (thermal shock cracking) Resin shrinkage during cure	Reduce resin content Monitor and minimize temperature fluctuations during equipment operation
Delamination 	Separation of glass layers, occurs particularly in areas of high stress; i.e., small-diameter pipe, knuckle joints, etc.	Inadequate 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	Insure 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 build-up

Defect	Description	Possible Causes	Possible Solutions
Dry Spots 	Areas where dry glass fibers are protruding from laminate	Not thoroughly saturating glass with resin	Thoroughly saturate glass with resin and roll thoroughly
Fish-eye 	Mass of foreign material on or near the laminate surface; mass is not blended into surrounding material	Dirty glass Contamination of resin with foreign material	Insure 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	Incompatibility between resin and glass binder; as resin cures, binder “phases out,” causing white cloudy appearance of laminate	Thoroughly evaluate compatibility of resin and glass binder before beginning fabrication Contact Ashland Technical Service for assistance in selecting a glass compatible with specific resins
Pimple 	Small, raised area on laminate surface	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
<p>Scorching/Burning</p> 	<p>Discoloration of laminate as it cures</p>	<p>Generation of very high exotherm temperatures due to one or a combination of the following -</p> <p>hot working temperatures, high DMA and/or catalyst levels, laying up too many plies at one time</p>	<p>Reduce DMA and/or catalyst levels particularly if working temperatures are high</p> <p>Reduce number of plies laid up at one time and allow to cure before applying additional layers</p>
<p>Spotty Cure</p>	<p>Laminate surface is soft in some areas while cured hard in others</p>	<p>Incomplete or inadequate mixing of promoters and/or catalyst</p>	<p>Adjust mixing to achieve a small vortex and good movement of resin surface</p> <p>Mix thoroughly after addition of each additive</p> <p>Dissolve cobalt in small amount of styrene before adding to resin</p>
<p>Tacky Surface</p>	<p>Laminate surface is tacky to the touch or fails to pass acetone sensitivity test (see page 24)</p>	<p>Incomplete cure caused by air inhibition</p> <p>Cobalt level too low</p>	<p>Apply a resin/wax topcoat to tacky surface (see page 12)</p> <p>Do not use a resin/wax topcoat if additional bonding is to be done to the surface</p> <p>Increase cobalt level</p>
<p>Wrinkle</p> 	<p>Crease or wrinkle of glass on or near the laminate surface</p>	<p>Wrinkling of veil (particularly synthetic veil) or glass can occur when laminating over uneven surfaces or when using stiff, heavy glass in corners</p>	<p>Use 1 oz. (300 g/m²) or 1 1/2 oz. (450 g/m²) mat where wrinkling is a problem</p> <p>Reduce resin viscosity by adding 3 - 5% styrene</p>

RESPONSIBLE CARE

Ashland Specialty Chemical has a strong commitment to our customers, our employees, and to the communities in which we operate and do business. We believe in maintaining our operations in a totally safe and an environmentally responsible manner. We've focused our efforts on conserving resources and minimizing hazardous materials in both our working environment and at our customers'. In addition, we also participate in the industry's Responsible Care* initiative of the American Chemistry Council.

*Responsible Care is a service mark of the American Chemistry Council.

QUALITY PLUSSM

Batch to batch uniformity of Ashland's HETRON & AROPOL resin systems not only means easier molding but also consistent performance and quality.

Ashland Specialty Chemical Company adopted a continuous improvement process called Quality Plus in the early 1980's. Ashland Specialty Chemical became a quality leader in many industries we serve; continuous improvement has become an important part of every employee's training and thinking. Driven from the top down, this process still guides all of our operations and activities, and the way we do business.

Notice: All precautionary labels and notices should be fully read and understood by all supervisors personnel and employees before using. For additional safety and health information, contact Ashland Specialty Chemical Company. Purchaser has the responsibility for determining any applicability of a compliance with federal, state and local laws and/or regulations involving use, particularly in making consumer products.

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