Composite
Polymer Design
ADVANCED

INFUSION PRODUCTS GUIDE

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I. Why Epoxy?

Composite Polymer Design manufactures a variety of epoxy resin systems that are well suited to the infusion process. Before delving into specifics, let's take a moment to consider why you should select an epoxy.

A. Adhesion to Reinforcement

The supreme advantage of epoxy is its excellent adhesion to almost any surface. Epoxy adheres tenaciously to a broad range of substrates, particularly those that are frequently used as reinforcement in composite parts and structures.

1. Carbon Fiber

Carbon fiber commonly has an epoxy binder. This binder further promotes the adhesion of epoxy to the substrate and makes an epoxy the ideal resin system for the fabrication of carbon fiber composites.

2. Kevlar®

Kevlar® typically does not have a binder. In this case, the superior adhesion characteristics of epoxy make it preferable to other organic polymers for the fabrication of Kevlar® composites.

3. Fiber Glass

More so than carbon fiber and Kevlar® composites, fiber glass composites are susceptible to attack by water vapor. Water vapor attacks the interface between resin and reinforcement, and leads to degradation of the composite structure. In the long term, epoxy provides a barrier against water vapor that is superior to other organic polymers and can be used to fabricate more durable fiber glass composites. Fiber glass is available with a wide variety of binders. A number of these binders have been formulated to promote the adhesion of specific organic polymers to fiber glass. As such, it is important to select a grade of fiber glass with an epoxy compatible binder when using an epoxy resin system to construct fiber glass composites.

4. Core Material

Where core material has been incorporated into the design of a laminate to produce a light weight composite structure, using an epoxy resin system can provide further weight savings. The superior adhesion characteristics of epoxy eliminate the need for a resin rich mat between the structural reinforcement and the core material.

B. Versatility

Epoxy resin systems can be formulated with various curing agents, diluents, fillers and other additives to produce an almost unlimited range of properties. The tremendous versatility of epoxy makes it possible to tailor the handling and mechanical properties of an epoxy resin system to what is needed.

C. Low Shrinkage

Epoxy resin systems exhibit little shrinkage during cure and allow for the precise reproduction of mold surfaces. The dimensional stability provided by an epoxy resin system gives rise to the fabrication of composite parts and structures with lower ingrained stress levels. As a result, finished pieces are stronger and more durable than those produced using organic polymers that exhibit higher values of shrinkage.

D. Chemical Resistance

Properly cured epoxy resin systems have excellent chemical resistance to acids, bases and solvents. In contrast to other organic polymers, epoxy resin systems are particularly resistant to caustic substances.

E. No Volatile Loss

Epoxy resin systems formulated for the fabrication of structural composites are typically 100 percent solids. No byproducts, volatile or otherwise, are formed as these systems polymerize. By and large, there are no VOC issues associated with the handling of epoxy resin systems.

II. Selecting An Epoxy Resin System For Infusion

Several issues need to be weighed when selecting an epoxy resin system for the infusion process. The considerations that need to be made fall into two categories, end product requirements and processing requirements.

A. End Product Requirements

End product requirements are those requirements that apply to the function and/or use of the composite part or structure to be manufactured.

1. Operating Temperature

One requirement that is paramount to the selection of an epoxy resin system is the operating temperature or service temperature of the article to be manufactured. The heat deflection temperature (HDT) of the epoxy resin system selected must be greater than or equal to this intended operating temperature.

a. Less Than 210°F

If the intended operating temperature of a composite part or structure is less than 210°F, one of the Composite Polymer Design (CPD) room temperature infusion systems found in Table 1 should be considered.

b. Between 210°F and 310°F

If the intended operating temperature of a composite part or structure is between 210°F and 310°F, one of the CPD medium temperature infusion systems found in Table 2 should be considered.

c. Greater Than 310°F

If the intended operating temperature of a composite part or structure is greater than 310°F, one of the CPD high temperature infusion systems found in Table 3 should be considered.

2. Other Physical Properties

Other physical properties, such as the desired compressive, flexural and tensile strengths, should be taken into account when selecting an epoxy resin system for infusion. Please refer to the physical properties listed in the lower half of Table 1, Table 2 and Table 3 to determine if one of the CPD infusion systems meets your end product requirements. In the event that one of these systems does not meet your end product requirements, Composite Polymer Design can custom tailor an epoxy resin system to meet your needs.

B. Process Requirements

Process requirements are those requirements that apply to the act of manufacturing a composite part or structure.

1. Cure Cycle

The first process requirements that should be considered when selecting an epoxy resin system for infusion is the desired cure cycle. Please review the capabilities of your equipment, tooling and ancillary materials when choosing a cure cycle. In particular, please consider the temperature your mold will have to withstand.

a. Room Temperature Cure

Composite Polymer Design offers a variety of two part epoxy resin systems that can be cured at room temperature, 68-77°F (20-25°C).

b. Elevated Temperature Cure

CPD also offers one part and two part epoxy resin systems that must be cured at an elevated temperature.

2. Post Cure Cycle

The second process requirement that should be considered when selecting an epoxy resin system for infusion is the post cure cycle. Not all epoxy resin systems require a post cure. However, it is typically the case with epoxy that a post cure is required to develop ultimate properties. As with choosing a cure cycle, it is important to review the capabilities of your equipment, tooling and ancillary materials when choosing a post cure cycle. Again, in particular, please consider the temperature your mold will have to withstand.

a. Supported

In the first stage of a post cure cycle, a composite part or structure made using an epoxy resin system typically needs to be supported. That is, it should remain in the mold to reduce the likelihood of any deformation that may occur as a result of thermal shock. A supported post cure is usually conducted at temperatures less than or equal to 150°F to avoid damaging the mold.

b. Unsupported

Prior to the latter stages of a post cure cycle, a composite part or structure made using an epoxy is typically removed from the mold and post cured free standing. An unsupported post cure is usually conducted at temperatures in excess of 150°F, but should not exceed the heat deflection temperature of the epoxy resin system.

3. Viscosity

Another process requirement to consider when selecting an epoxy resin system for infusion is viscosity. Composite Polymer Design offers a variety of low viscosity resins that have been formulated specifically for infusion. One advantage of using an epoxy versus other organic polymers is that epoxy resin systems exhibit a latent build in viscosity. That is, they typically remain low in viscosity much longer than other organic polymers, extending the work life without compromising gel time.

a. Input Resin Temperature

The input resin temperature is the temperature of the resin at the point it is being infused. Typically, the input resin temperature is equivalent to the ambient temperature of the shop or facility in which the resin system is being used. In some instances, the input resin temperature is raised in order to further reduce the viscosity of an epoxy resin system. Composite Polymer Design reports viscosity at 77°F (25°C). As a crude guide, heating to 100°F (38°C) will reduce the viscosity of an epoxy resin system by approximately 45%, heating to 120°F (49°C) will reduce the viscosity by approximately 70% and heating to 140°F (60°C) will reduce the viscosity by approximately 85%.

b. Mold Temperature

Ideally, the mold temperature should be the same as the input resin temperature in order to maintain a consistent viscosity.

4. Work Life

The work life required to infuse a composite part or structure should also be considered when selecting an epoxy resin system for infusion. Composite Polymer Design does not report the work life of the epoxy resin systems it manufactures, because work life generally varies with mass and temperature. Rather, CPD reports the gel time of each of its resin systems in a 150 gram mass at 77°F (25°C).

a. Mass Dependent

The work life of an epoxy resin system is mass dependent. In a large mass, the work life of an epoxy resin system will be reduced and in a small mass, the work life will be prolonged.

b. Temperature Dependent

The work life of an epoxy resin system is also temperature dependent. At an elevated temperature, the work life of an epoxy resin system will be shortened and at a reduced temperature, the work life will be extended. As a crude guide, heating to 100°F (38°C) will reduce the work life of an epoxy resin system by approximately 60%, heating to 120°F (49°C) will reduce the work life by approximately 80% and heating to 140°F (60°C) will reduce the work life by approximately 90%.

5. Demold Time

The final process requirement that should be considered when selecting an epoxy resin system for infusion is the demold time. Demold time is the point at which the resin system has cured to a degree that a composite part or structure is strong enough to be removed from the mold. In many cases, a composite part or structure will be removed from the mold following the supported stage of a post cure cycle and in others it will be removed from the mold after a satisfactory time at room temperature.

a. Mass Dependent

Much like the work life, the demold time of a composite part or structure made using an epoxy resin is mass dependent. In a large mass, the demold time will be reduced and in a small mass, the demold time will be prolonged.

b. Temperature Dependent

The demold time of a composite part or structure made using an epoxy resin is also temperature dependent. At an elevated temperature, the demold time will be shortened and at a reduced temperature, the demold time will be extended.

c. Type of Structural Reinforcement

Another factor that impacts demold time is the type of structural reinforcement used to build a composite part or structure. Fiber glass is a good conductor of heat, while carbon fiber and Kevlar® are better insulators. This means that, all other factors being equal, the demold time of fiber glass composites will be greater than the demold time of a carbon fiber or Kevlar® composites.

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The information contained in this guide is believed to be reliable. We do not guarantee the accuracy of the information or make any warranty of merchantability or any warranty of fitness for a specific purpose or use. In no event shall Epoxical, Inc. be liable for incidental or consequential damages.

Table 1 – CPD Room Temperature Infusion Systems

System	4281/4284	2110/9260	4281/4286	2110/9218	2110/9227	2110/9297
Elevated Temperature Cure Required In Mold[1]	No	No	No	No	No	No
Post Cure Required[1]	No	No	No	Yes	No	No
Post Cure Recommended[1]	Yes	Yes	Yes	Yes	Yes	Yes
Handling Properties						
Resin Viscosity at 77°F, cps	900	1,200	900	1,200	1,200	1,200
Hardener Viscosity at 77°F, cps	8	30	12	40	20	30
Mixed Viscosity at 77°F, cps	150	300	220	290	300	300
Mix Ratio By Weight	100:22	100:28	100:22	100:30	100:28	100:26
Mix Ratio By Volume	100:27	3:1	100:27	2.3:1	3:1	3.1:1
Gel Time at 77°F, 150g, min.	40	50	70	85	130	290
Physical Properties						
Color	Amber	Amber	Amber	Amber	Amber	Amber
Shore Hardness	86D	84D	86D	86D	84D	82-85D
Tensile Strength, psi	8,600	10,800	8,900	12,600	10,300	11,700
Tensile Modulus, psi	348,000	425,000	363,000	499,000	421,000	468,000
Tensile Elongation, %	5.9	7.2	5.7	5.8	7.2	6.9
Compressive Strength, psi	18,800	14,600	18,200	16,700	13,800	16,200
Flexural Strength, psi	15,400	18,400	15,500	19,500	17,500	19,000
Flexural Modulus, psi	413,000	479,000	418,000	494,000	469,000	492,000
HDT, Post Cured, °F	180	200	210	210	190	200
Izod Impact, Notched, ft-lb/in	1.16	1.12	1.15	1.06	1.09	1.18
Shrinkage, in/in	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

[1] Tooling must be able to withstand the temperatures it will be exposed to during the cure cycle and the supported stage(s) of a post cure cycle.

Table 2 – CPD Medium Temperature Infusion Systems

System	4310/9239	4310/9234	4310/9235	4310/9231
Elevated Temperature Cure Required In Mold[1]	No	No	No	Yes
Post Cure Required[1]	Yes	Yes	Yes	Yes
Post Cure Recommended[1]	Yes	Yes	Yes	Yes
Handling Properties				
Resin Viscosity at 77°F, cps	1,200	1,200	1,200	1,200
Hardener Viscosity at 77°F, cps	15	15	20	100
Mixed Viscosity at 77°F, cps	400-600	400-600	400-600	500-700
Mixed Viscosity at 100°F, cps	200-300	200-300	200-300	250-350
Mix Ratio By Weight	100:20	100:25	100:26	100:35
Mix Ratio By Volume	4:1	3.2:1	3:1	2.33:1
Gel Time at 77°F, 150g, min.	60	110	130	500
Gel Time at 100°F, 150g, min.	25	40	50	180
Minimum Recommended Cure Temperature[2] (In Mold)	68°F	68°F	68°F	150°F
Physical Properties				
Color	Amber	Amber	Amber	Amber
Shore Hardness	85D	87D	88D	89D
Tensile Strength, psi	11,800	12,600	11,900	7,100
Tensile Modulus, psi	424,000	419,000	427,000	367,000
Tensile Elongation, %	4.6	4.1	3.9	2.5
Compressive Strength, psi	15,800	16,700	15,400	13,500
Flexural Strength, psi	17,200	19,500	18,900	14,100
Flexural Modulus, psi	446,000	454,000	448,000	411,000
HDT, Post Cured, °F	259	312	314	310
Izod Impact, Notched, ft-lb/in	1.22	1.28	1.25	0.54
Shrinkage, in/in	<0.002	<0.001	<0.001	<0.001

[1] Tooling must be able to withstand the temperatures it will be exposed to during the cure cycle and the supported stage(s) of a post cure cycle.
[2] A post cure at temperatures in excess of the minimum recommended cure temperature is required to develop ultimate properties.

Table 3 – CPD High Temperature Infusion Systems

System	4310/9232	4303/4303	4307/4303	2134/4307	2135/9529	4305
Elevated Temperature Cure Required In Mold[1]	No	Yes	Yes	Yes	Yes	Yes
Post Cure Required[1]	Yes	Yes	Yes	Yes	Yes	Yes
Post Cure Recommended[1]	Yes	Yes	Yes	Yes	Yes	Yes
Handling Properties						
Resin Viscosity at 77°F, cps	1,200	1,800	3,500	7,500	7,700	NA
Hardener Viscosity at 77°F, cps	40	200	200	200	800	NA
Mixed Viscosity at 77°F, cps	620	750	1,800	1,800	5,500	5,700
Mixed Viscosity at 100°F, cps	340	NA	NA	860	1,700	2,900
Mixed Viscosity at 120°F, cps	NA	200	500	380	600	500
Mixed Viscosity at 140°F, cps	NA	100	250	270	320	200
Mix Ratio By Weight	100:20	100:107	100:88	100:92	100:6	NA
Mix Ratio By Volume	4:1	100:103	100:82	100:89	13.8:1	NA
Gel Time at 77°F, 150g, min.	75	NA	NA	1,440	720	NA
Gel Time at 100°F, 150g, min.	35	NA	NA	NA	240	NA
Gel Time at 120°F, 150g, min.	NA	>180	>180	360	90	>480
Gel Time at 140°F, 150g, min.	NA	>120	>120	NA	45	>240
Gel Time at 170°F, 150g, min.	NA	120-240	120-240	NA	NA	NA
Minimum Recommended Cure Temperature[2] (In Mold)	68°F	170°F	170°F	160°F	150°F	250°F
Physical Properties						
Color	Brown	Brown	Brown	Brown	Brown	Brown
Shore Hardness	88D	87D	87D	90D	92D	87D
Tensile Strength, psi	12,900	12,100	10,500	12,200	10,200	8,600
Tensile Modulus, psi	431,000	486,000	451,000	472,000	470,000	527,000
Tensile Elongation, %	3.1	2.4	2.5	2.3	2.8	2.1
Compressive Strength, psi	16,900	25,600	14,700	21,300	27,100	NA
Flexural Strength, psi	17,900	20,500	15,300	17,900	15,600	NA
Flexural Modulus, psi	448,000	536,000	354,000	488,000	485,000	NA
HDT, Post Cured, °F	356	375	375	385	450	425
Izod Impact, Notched, ft-lb/in	1.23	1.01	1.06	1.01	1.06	NA
K_{IC}, MPa*m $^{1/2}$ (Fracture Toughness)	NA	NA	1.02	NA	NA	NA
G_{IC}, KJ/m^2 (Strain Energy Release Rate)	NA	NA	0.70	NA	NA	NA
Shrinkage, in/in	<0.001	<0.005	<0.005	<0.003	<0.003	<0.002

[1] Tooling must be able to withstand the temperatures it will be exposed to during the cure cycle and the supported stage(s) of a post cure cycle.

[2] A post cure at temperatures in excess of the minimum recommended cure temperature is required to develop ultimate properties.