

Fiber-Reinforced Polymer (FRP)

Resin and Corrosion Barrier Selection – The Testing Behind the Recommendation

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ABSTRACT

Corrosion challenges exist in many industries including the chemical and mineral processing industry as well as in the oil and gas production industry. Many of these corrosion challenges can be solved using equipment fabricated with fiber-reinforced polymer (FRP). FRP has been used for over 60 years in these industries to control corrosion problems where stainless steel or higher nickel alloys are required because of the severity of the chemical environment. The use of the correct FRP material provides a product resistant to the chemical environment with a long service life and often at a more economical price. FRP corrosion resistant equipment consists of a chemical resistant resin reinforced with fiberglass. In order to determine the proper resin and corrosion barrier construction for a specific chemical service, resin coupons are evaluated in the laboratory (per ASTM C581) as well as in the field. Corrosion coupons are immersed in a specific chemical environment in the laboratory or they are sent to a customer who places them in their specific process. After extended exposure, the FRP coupons are evaluated visually and by physical testing to determine if that resin and corrosion barrier construction is suitable for the specific chemical environment. Case histories are also used to confirm the use of a resin in a specific chemical environment. The details of resin selection, corrosion barrier construction, including veil selection, coupon testing and evaluation will be discussed in this paper. A variety of examples and case histories where these materials have been successfully used in the chemical and mineral processing and oil and gas production industries will also be discussed.

Key words: fiber-reinforced polymer (FRP), chemical processing, oil and gas industry, mineral processing, corrosion resistant, resin, resin coupons, case history

INTRODUCTION

Fiber-reinforced polymer (FRP) equipment has been used in a variety of chemical industries for over 60 years. It is critical to choose the correct FRP material for the specific chemical environment. In the chemical processing industry, vinyl ester resins are used in a variety of applications including strong acid and caustic environments, chlor-alkali environments, chlorine, bleach, and fertilizer applications. FRP equipment is used in the oil and gas industry to handle crude oil, fire water storage and

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underground fuel storage. Regardless of the chemical application, the process for evaluating the resin involves specific testing per ASTM C-581^[1], Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service. This paper will discuss the ASTM C-581 procedure including the importance of resin selection, corrosion barrier construction, veil selection, and coupon evaluation. Case histories supporting the use of FRP in various chemical and mineral processing industries as well as the oil and gas industry will also be presented.

What Is FRP?

FRP is a product that consists of a thermoset resin and glass fiber reinforcement. The resin not only locks the glass fibers into place but it also provides the chemical resistance, heat resistance, flame retardance, and toughness for the FRP vessel. These resins, generally a polyester or vinyl ester resin, are thermoset resins that rely on the chemical reaction of a low molecular weight monomer like styrene to generate cross-linked three-dimensional networks. Once cured, they cannot be reheated or reshaped. This is unlike a thermoplastic material that consists of long tangled chains of polymer molecules that can be reheated and reshaped.

Glass Fibers

The glass fibers provide the physical strength and modulus of the FRP part. The type of glass fiber used as well as the orientation of the fibers affects the mechanical properties of the FRP. Since FRP is non-isotropic, their properties differ greatly based on the orientation of the glass fibers which allows for more flexibility and optimization in the design of FRP equipment.

Laminate / Corrosion Barrier

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

The veil layer of the corrosion barrier consists of a resin-rich layer with 90 - 95% resin and 5 - 10% reinforcement that is approximately 0.025 - 0.050 mm (10 - 20 mils) thick, Figure 1. The reinforcement is in the form of a surfacing veil composed of C- or E-CR glass, a synthetic fabric, or carbon fiber. Two plies of surfacing veil can be used for more severely corrosive environments. Since the veil layer is the first line of defense against the chemical environment, the proper veil selection is critical. C-glass veil is the veil of choice for most acidic environments such as sulfuric acid, citric acid, and acetic acid. In hydrochloric acid, two layers of C-glass veil are recommended for maximum corrosion resistance. Once exception is hydrofluoric acid (HF) where a synthetic veil is recommended. In HF, the fluoride attacks C-glass veil so synthetic veil is recommended to prevent degradation of the veil surface and to provide a long service life. In caustic environments, such as sodium hydroxide, a synthetic veil has been shown to provide better resistance than C-glass veil. Certainly, veil selection is critical in designing and fabricating FRP equipment that will provide a long service life.

The veil layer is followed by two or more layers of chopped strand mat or the equivalent chopped spray. This layer should consist of 20 - 30% glass. Together, the resin, veil, and chopped glass form the primary corrosion barrier or lining, 2.5 - 6 mm (100 - 250 mils) thick. The composition of the corrosion barrier depends on the chemicals present, their concentration, and the process operating temperatures.^[1]

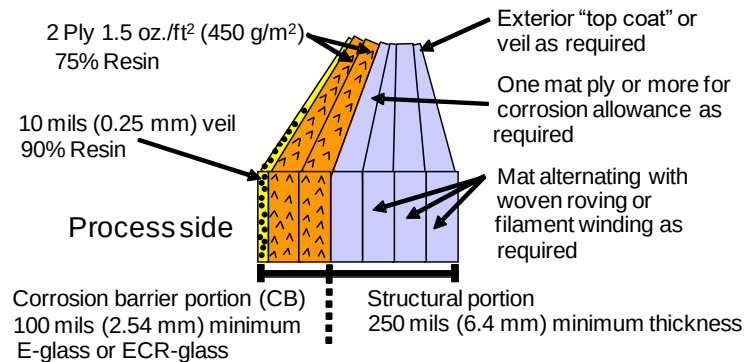


Figure 1: Typical FRP Laminate Construction

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

Proper resin selection and laminate design greatly influence the performance and longevity of process equipment. When designing FRP equipment, the first critical step is selecting the proper resin for the chemical service. When choosing a resin, the design engineer should consult the Resin Selection Guide of a knowledgeable resin manufacturer whose products are well established and backed with experience and case histories. If the chemical environment in question is not represented in the Resin Selection Guide, the designer should contact the resin supplier directly for a resin recommendation. If a chemical environment has not been previously evaluated, reputable resin manufacturers can work with the design engineer to conduct ASTM C-581 based corrosion testing in the specific chemical environment.

EXPERIMENTAL PROCEDURE

ASTM C581 Coupon Construction

In order to evaluate resins in a specific environment, FRP coupons, Figure 2, are fabricated that are representative of FRP equipment used in the field. The coupon consists of a layer of glass veil followed by two to three layers of chopped strand mat (450 g/m² (1.5 oz/ft²)). Coupon construction is completed by applying a second veil layer on top of the chopped strand mat. The coupon represents the corrosion barrier of FRP equipment. To prevent exposure of the cut edges, a resin/fumed silica mixture is applied to seal the edges of the coupon.^[2]

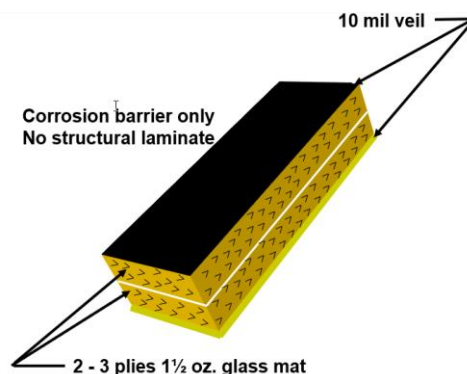


Figure 2: ASTM C581 Coupon