



DESIGN AND CONSTRUCTION OF nyb FRP FANS

INTRODUCTION

Fiberglass-reinforced plastic (FRP) made from chemical-grade polyester or vinyl ester resin resists corrosion as well as, or in some cases better than, high-priced materials such as titanium or high-nickel alloys. In general, FRP (also known as RTP, or reinforced-thermoset plastic) is widely used in handling the fumes of acids and of many inorganic and organic chemicals where service temperatures do not exceed 250°F.

COMMON USES FOR FRP FANS

Potential applications for FRP fans include any process in which corrosive fumes must be captured, moved, cleaned, or vented. FRP fans are most often used in fume-scrubber systems where the scrubber itself may be constructed of FRP or an exotic alloy, but where FRP is the preferred fan material. Galvanizing and etching processes often have FRP exhaust hoods and ducts, and many of the fans used to convey fumes in such systems are also built of FRP. Wastewater-treatment plants and laboratory exhaust systems are other applications for which FRP fans are being used with increasing frequency.

When FRP is the selected material for an air-handling system, it is logical that the fan also be made of FRP. For example, the acids used in the pickling of stainless steel are necessarily those that attack stainless steel. In such a system, the acid-holding tanks, fume-control hoods, ducts, scrubbers, and fans are often made of FRP because FRP resists acid corrosion and costs less than metal alloys having comparable resistance.

In summary, FRP fans may be an economical alternative to stainless steel or other metal-alloy fans when corrosion is a concern and temperature is below 250°F. In addition to the economic advantage, FRP fans often provide better performance than special alloys in handling airstreams that are particularly corrosive to metals.

COMPARISON OF FRP FANS TO FANS OF OTHER MATERIALS

A comparison of the corrosion resistance and economics of fans made of various materials leads to these generalizations:

Coated steel fans vary greatly in the degree of corrosion protection provided and cost. Coatings run the scale from little-different-than-ordinary machinery enamel to baked-on phenolics applied to sandblasted metal. Costs for coated fans run from about one-third that of FRP fans for the least-resistant coated-steel fans to about half the cost for the baked phenolic-coated fans.

Coated fans, regardless of the inherent corrosion resistance of the coating, have the potential of coating failure and resultant rapid deterioration of the base metal. Failures occur when coatings are physically damaged, and when corrosive attack permeates the coating to attack the metal. Refer to Engineering Letter 16 for additional information on corrosion-resistant coatings for fan equipment.

Stainless steel is susceptible to attack by chlorides and resultant physical failure by stress cracking. Residential hot-water heaters are never made of stainless steel because the combination of small amounts of chlorine in the water, modest temperatures, and the stresses caused by changes in water pressure results in rapid failure of the stainless steel.

As noted earlier, stainless steel is also much more susceptible to corrosive attack by most acids than is FRP. Refer to Engineering Letter 14 for additional information on the use of stainless steel in fan construction.

Costs for fans made of 316L stainless vary from about three-fourths that of FRP fans for small Class I fans to almost twice the price of FRP fans for large Class III fans.

Fans made of Monel®, titanium, and the high-nickel alloys may be more or less corrosion resistant than FRP depending on the chemistry and temperature involved. Figure 1 shows the effect of simultaneously submerging a coupon of a high-nickel alloy (Hastelloy® C-276), 316 stainless steel and FRP (Derakane® 510A40) in a bath of nitric and hydrochloric acid (aqua regia). While the 316 stainless was destroyed and the 276 alloy severely corroded, the FRP was untouched.

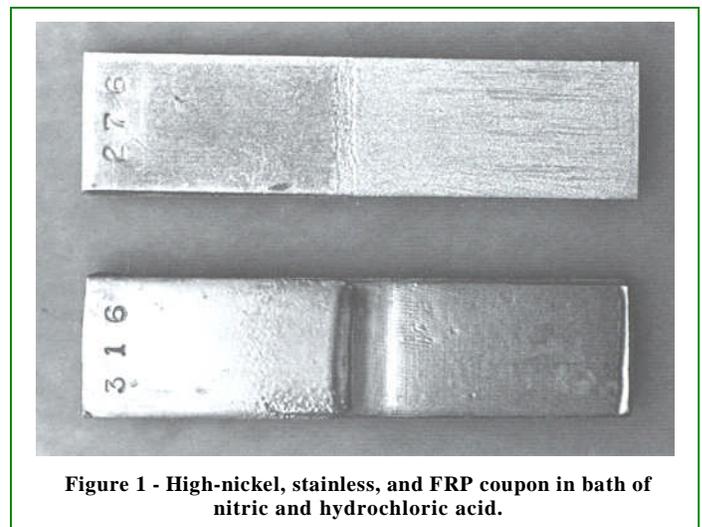


Figure 1 - High-nickel, stainless, and FRP coupon in bath of nitric and hydrochloric acid.

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Fans made of rigid polyvinyl chloride (PVC) have good all-around corrosion resistance and generally cost less than fans made of FRP. However, PVC has two significant physical weaknesses that severely limit its use in fans: PVC becomes quite brittle at temperatures below freezing, and PVC loses its strength so rapidly with increasing temperatures that even ordinary summer rooftop operating conditions are marginal. Wheels sag and go out of balance and strike housings. PVC is a thermoplastic material that "remembers" its original shape at about 150°F., and needs to reach only about 300°F. for it to have the zero strength needed for vacuum forming.

Numerous users have disavowed the use of PVC fans because of their experiences with failures resulting from PVC's low-temperature brittleness and high-temperature weakness.

The use of PVC equipment involves some safety considerations as well. PVC does not burn, but because it is a low-temperature thermoplastic it collapses early in a fire and will drip molten PVC. Thus, rather than containing a potential fire within the duct system, as fire-retardant FRP will do, PVC tends to expand the fire into other areas, even though it is not inherently combustible. In addition, PVC releases highly toxic hydrochloric acid fumes when exposed to flame even though it is a self-extinguishing material.

PVC, like FRP, is an insulating material and inherently spark-resistant. However, unlike FRP, it cannot be made electrically conductive to control static electricity.

UNDERSTANDING FRP

The term FRP describes a broad spectrum of fiber-reinforced plastic materials. For example, cabinets for office machines might be made of non-corrosion-resistant plastics reinforced with mica and loosely called FRP. However, the FRP used in making process vessels and equipment such as fans is composed of about 30% by weight of glass or other fibers that have been given a coating (sizing) to enhance their bonding with the resin, and about 70% by weight of corrosion-resistant polyester or vinyl ester resin.

The fibers provide physical strength, and the resin provides the corrosion resistance and rigidity that make FRP a workable solid. Sometimes, non-glass-fiber materials are used in FRP to impart special properties. For example, graphite fibers add tensile strength, and aramid fibers (Kevlar[®]) add toughness. But FRP for process equipment usually has glass fibers because they are more economical and easier to work with; graphite fibers, for example, are more difficult to handle and do not bond as well as glass.

Glass fibers are available in a variety of forms, including continuous -strand roving, woven roving, continuous -strand mat, chopped-strand mat, chopped fibers, and milled fibers. **nyb** uses all of the above except woven roving and continuous-strand mat in the construction of its FRP products.

Continuous-strand roving is used in the chopper guns for spray-molding of non-moving parts such as housings, inlet cones, inlet boxes, damper frames, and outlet transitions.

Chopped-strand mat, consisting of Type E glass of 1 1/2 ounces per square foot in weight, is used in hand lay-up of housings and Fume Exhauster wheel blades among other products. Castings such as FPB and RFE wheels and seal housings are made with chopped fibers. Milled fibers are primarily used to make putty for filling cracks, turning sharp angles into smooth radii, and encapsulating wheel hubs.

The corrosion resistance of FRP depends on the resin. Resins used in FRP for process equipment are formulated for maximum corrosion resistance, and are consequently two or three times as costly as those used in everyday products such as boat hulls or auto body parts.

FRP fan manufacturers normally use two types of resin in the construction of their products. Polyester is the resin of choice for non-moving components such as housings and inlet cones because it provides excellent corrosion resistance for most FRP applications at a relatively low cost. Unfortunately, this type of resin cannot withstand the dynamic stresses inherent in rotating parts such as wheels. Therefore, FRP wheel construction dictates the use of vinyl ester resins which are much stronger and more flexible than polyester resins.

The strength and elasticity of vinyl ester resins enable FRP wheels to achieve maximum safe speeds comparable to similar-sized steel wheels at 70°F. As with steel and other alloys, the strength and flexibility of vinyl ester is compromised at elevated temperatures, resulting in safe speed derate factors above 150°F. Refer to specific product bulletins for maximum safe speeds and applicable derate factors.

FIRE RETARDANCE OF FRP RESINS

Since many FRP applications involve a mixture of combustible chemicals and air, **nyb** FRP fans are made of fire-retardant resins. Fire retardance is measured by the ASTM E-84 test method, which determines flame spread ratings~ by comparing the rate at which flame spreads when material is fired in a long, narrow furnace with flowing air. (The test is also called the "tunnel test" and is recognized by Underwriters' Laboratory and the National Fire Protection Association.) Completely incombustible materials, such as cement board, are rated zero flame spread. Red oak is used as the comparative value of a combustible material and is rated at 100. A flame-spread rating of 25 or lower is considered non-combustible. (Resin systems rated at 25 or less are often referred to as Class I.)

A flame-spread rating of 50 means that the material will gradually, but steadily, extinguish itself. (Resin systems rated at 26 to 50 are often referred to as Class II. Class III and IV denote less fire-resistant ratings.)

Resins for chemical duty can be made fire retardant by formulating the resins to include adequate molecularly bound halogens, such as chlorine or bromine, or by the use of smaller amounts of halogens but with the addition of antimony trioxide. The first method is more costly but provides a clear resin that improves quality control of the product being manufactured since the workers and the inspectors can see into the finished

product. Antimony trioxide is a white pigment which produces an opaque product that reduces the ability to visually check product quality. Further, antimony additives can reduce the corrosion resistance and strength of the resin. **nyb** uses resins that are fire retardant without the use of antimony trioxide.

STANDARD nyb RESINS

Housings and other non-moving parts are made with an Ashland Chemical Company resin, Hetron® 92FR. This is a chloroendic, halogenated polyester resin known for its ease of fabrication. It is well suited for high temperature applications, and is highly fire retardant with an ASTM E-84 tunnel test rating of 25 or less, meeting requirements for ASTM E-84 Class I performance. This satisfies the most stringent concern for the containment of ventilation-system fires. Hetron 92FR is a clear resin that does not require the use of antimony trioxide to achieve its rating. The clarity makes it possible to maintain extremely high standards of quality control.

All **nyb** FRP wheels are made with Derakane 510A40, a brominated epoxy vinyl ester resin manufactured by Ashland Chemical Company. This resin offers the flexibility, low shrinkage, and excellent secondary bonding necessary to withstand the vibrational stress and fatigue of dynamic loading inherent in rotating wheels. Derakane 510A40 has an ASTM E-84 tunnel test rating of 25, offering Class I fire retardance without the use of additives which could compromise its superior toughness and corrosion resistance.

As with Hetron 92FR, the clarity of Derakane 510A40 enables the fabricator and inspectors to locate and eliminate air inclusions in the laminate, thus maintaining high standards of quality control of a critical fan component.

Since additives tend to adversely affect a resin's chemical resistance, **nyb** FRP products do not contain ultraviolet (UV) inhibitors. These additives have a tendency to inhibit resin cure and lose their effectiveness after long exposure to ultraviolet radiation. In order to prevent UV degradation, **nyb** applies a coating to the exterior surfaces of all FRP components. Years of successful outdoor service prove that this method of protection is superior to adding UV inhibitors to the resin.

Corrosion resistance is the main concern when selecting a resin. **nyb's** standard housing resin has very good corrosion resistance to a broad spectrum of corrosive environments. When necessary, the entire FRP airstream may be constructed of the more corrosion-resistant vinyl ester resin. The data on corrosion resistance to various chemicals, presented in Engineering Letter 18, were derived from tests of these resins.

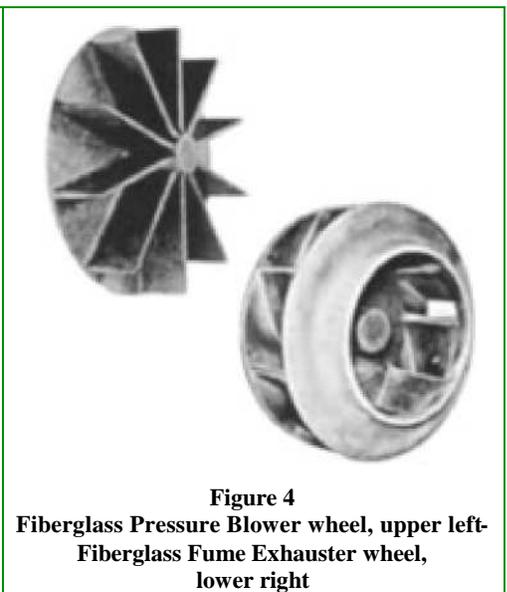
CONSTRUCTION OF FRP FANS

The fabrication of FRP is similar to the casting of metal. A pattern is used to make a mold for the FRP part. In a fan, the airstream surfaces of the housing should be smooth to minimize resistance and prevent build-up of airborne contaminants. Thus, male molds are required rather than female ones. The smooth outside surface of the mold shapes the inside surface of the housing.

Parts made with male molds must be removable, so FRP fan housings are usually made in two halves with matching flanges. In larger fans, these two halves are bonded together by means of FRP filler between the flanges, as shown in Figure 2. A lamination laid over the joint on the inside of the housing provides a smooth surface. The joined flanges form a ridge that adds rigidity to the housing. The inlet subassembly is bolted into place to allow access for installation of the wheel.

Smaller FRP fan housings are also molded in halves, but they are typically bolted together as shown in Figure 3. Removing the inlet side of the housing allows installation or removal of the fan wheel.

Fan wheel construction is also different for large and small FRP fans. Small wheels, such as **nyb's** Fiberglass Pressure Blower, are made by casting or press-forming in fully enclosed molds; Figure 4 shows an example. Larger wheels, such as **nyb's** Fume Exhauster, are made by assembling and bonding molded parts (wheel blades, frontplates, and backplates) with layers of laminate construction so as to make strong, smooth joints. See Figure 4. All FRP wheels are oven-cured for several hours to improve physical strength and corrosion resistance of the FRP laminate.



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Metal parts that are incorporated in the FRP parts, shafts, wheel hubs, and studs, are encapsulated in FRP so no metal is exposed to the gas stream. Shafts are encapsulated in an FRP sleeve that extends through a close-fitting opening in the side of the housing. (Shaft seals that can be lubricated are available as an option.) Bolts used to fasten smaller fan housing halves together are of 316 stainless steel.

Neoprene foam gasketing is used between bolted housing sub-assemblies and under access doors, inspection ports, and shaft seal assemblies.

FRP fan wheels are permanently bonded to the fan shafts, the shafts encapsulated in FRP, and the assembly balanced as a unit. After the fan is assembled it is test run as a final check to guarantee smooth operation.

Exterior surfaces of completed **nyb** FRP fans are coated with gray epoxy enamel.

APPLICABLE STANDARDS FOR FRP FANS

The purchaser of FRP fans should consider the importance of two published standards: one, ASTM D4167, covers the construction of FRP fans; the other, AMCA Standard 210, describes how fans are to be tested for air performance. The AMCA Certified Ratings Program is the method by which manufacturers certify their products' aerodynamic performance.

The ASTM standard is concerned with the structural reliability of the fan. If the fan in a fume-control system fails, the entire process may come to a halt. The importance of reliability has led to development of a standard for FRP fans American Society for Testing and Materials (ASTM) D4167, Standard Specification for Fiber-Reinforced Plastic Fans and Blowers. This standard defines minimum specifications for construction of major fan elements. Here are six of the details:

1. Fan housing construction must conform to the ASTM C582 specification which applies to all FRP process equipment. (**nyb** standard construction with optional veil complies with ASTM C582.) The same resin must be used throughout the housing unless the manufacturer and user agree to use different resins in different layers of the laminate. (**nyb** does not back up the corrosion barrier with less costly resin. **nyb** uses premium quality resin throughout.) The structural rigidity of the housing (or a prototype) is tested by running the fan with the inlet closed and the outlet open. Inward flexing may be no greater than 0.5% of the fan-wheel diameter.
2. Fasteners, hubs, and shafts exposed to corrosives must be either corrosion resistant or encapsulated in a material that is.
3. The ASTM standard prohibits the use of additives in fan wheel resins that obscure visual inspection of wheel parts, including the use of antimony trioxide. **nyb** standard construction provides fire retardance without the use of additives.
4. Safe wheel operating speed is determined either by past experience or by destructive testing i.e., running the fan wheel at increasing speeds until it fails, and applying a safety factor to the failure speed.

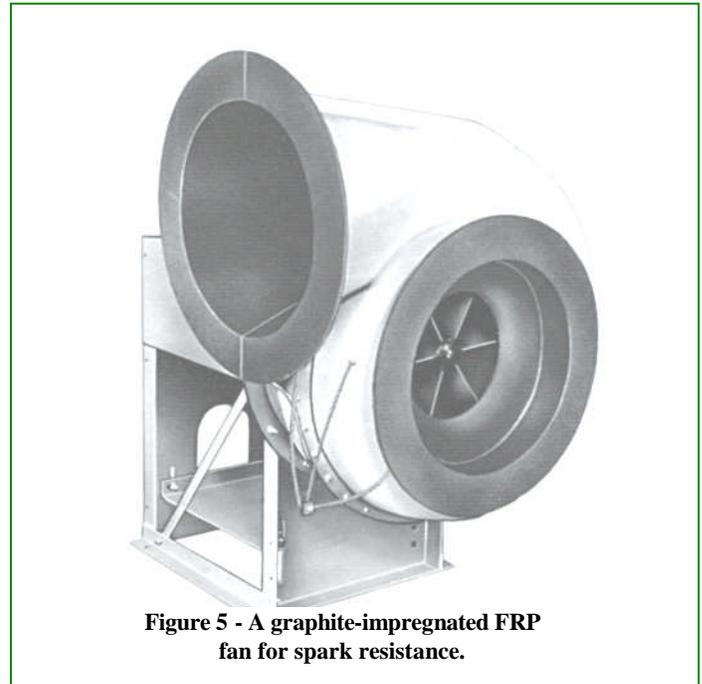


Figure 5 - A graphite-impregnated FRP fan for spark resistance.

5. Spark resistance. FRP is spark-resistant in the sense that contact of FRP parts does not generally produce sparks. However, FRP fans handling dry air can develop electrostatic charges on wheel and housing surfaces because FRP is a non-conductor. Still, an FRP fan can be made spark-resistant by incorporating graphite flakes in the wheel and housing airstream surfaces to make them conductive, and grounding the surface layers of the housing as shown in Figure 5. ASTM D4167 defines acceptable resistivity as no greater than 100 megohms between all points on the airstream surfaces and ground.
6. Dynamic balance is achieved either by balancing the wheel-shaft assembly as a separate unit or by balancing the wheel once it is installed in the fan (**nyb** does both). Unbalance is corrected by adding FRP weights.

The Air Movement and Control Association (AMCA) Certified Ratings Program is concerned with accurate performance ratings. The manufacturer submits published performance ratings to AMCA and fans for test in the AMCA Laboratory. Deviations are determined by plotting actual performance against the fan's cataloged performance .

Manufacturers displaying the AMCA Certified Ratings Seal on their products, and in their literature, have agreed to a system of check testing in the AMCA Laboratory. If a product fails to perform within the tolerances specified by the program, the manufacturer must either republish the literature with correct ratings or republish without the seal.