# The Use of FRP (Fiberglass-Reinforced Plastic) in Phosphate Fertilizer and Sulfuric Acid Processes

Don Kelley
Ashland Performance Materials
5200 Blazer Parkway
Dublin, OH 43017

ABSTRACT

The demand for corrosion resistant composites made from epoxy vinyl ester resins increased significantly starting in 2006 when nickel prices increased from $6/lb to $15/lb. This price increase continued in 2007 when nickel hit a high of $24/lb. With a 30-year reputation for low maintenance and relatively stable cost, FRP provides process engineers with a reliable, cost effective construction material that can be employed in numerous applications that are corrosive to stainless steel at a price much lower than high alloy clad steel. Although some other materials may be cost competitive with FRP, their use typically results in higher life cycle costs due to maintenance.

The purpose of this paper will be to compare FRP with high nickel alloy in "wet process" phosphoric acid and sulfuric acid environments. Relative cost and corrosion data will be presented to provide the information necessary for process engineers to facilitate future decisions concerning material of construction.

Keywords: *corrosion, epoxy vinyl ester resin, fertilizer, fiberglass-reinforced, high nickel alloy, plastic, phosphate, phosphoric acid, reinforced thermoset plastic, sulfuric, vinyl ester resin*

## INTRODUCTION

The cost of high nickel alloys increased significantly in 2006 and 2007, making corrosion resistant process equipment made with high nickel alloy very expensive relative to other materials. This has created a great demand for alternative, less expensive materials that have similar corrosion resistance. Prior to 2006, high nickel alloy was the material of choice for many "wet process" phosphoric acid and sulfuric acid environments found in phosphate fertilizer production plants. These environments often contain high chloride and fluoride levels that are highly corrosive to stainless steel.

Since phosphate fertilizer production plant capacity is expected to increase by at least 15% over the next four years, there will be a significant need for new corrosion resistant equipment in these plants. The cost of new equipment will depend greatly on the materials of construction. Materials such as high nickel alloy will be very expensive, and will create a demand for less expensive materials such as FRP that have proven performance in phosphate fertilizer processes.

FRP has a long history of success in a number of phosphate fertilizer processes including the sulfuric acid process. Typical applications include phosphate/ sulfuric acid reaction vessels, scrubber systems for both fertilizer and sulfuric acid processes, and pipes for phosphoric acid and gypsum transport. Fertilizer process equipment made from FRP is relatively inexpensive and has case histories dating back to 1973 to prove its successful use in fertilizer systems.

Alternative materials, besides high nickel alloy, include rubber-lined carbon steel, acid brick-lined carbon steel and resin coated carbon steel which can be used in "wet process" phosphoric and sulfuric acid environments. However, these materials do not all have the same service life expectancy, nor do they have the same cost. In this paper, FRP will be used as a reference material compared to other materials for service life and cost in phosphate fertilizer production.

## FRP COST VERSUS OTHER MATERIALS OF CONSTRUCTION

With the rising cost of nickel, FRP has become a very competitive material of construction. The total installed cost for FRP ranges from about $100 to $150 per square foot in North America (prices may vary in other countries). It is less expensive than 2205 stainless steel (Table 1) and much less expensive than C-276 alloy clad carbon steel but has a longer service life in high chloride and fluoride applications

TABLE 1
COST COMPARISON OF CONSTRUCTION MATERIALS*

| Construction Material | Installed Cost | Cost Ratio |
|---|---|---|
| Shop Fabricated FRP | $100 / Sq. Ft. | 1.00 |
| Field Fabricated FRP | $150 / Sq. Ft | 1.50 |
| 2205 stainless steel ¼ inch plate | $188 / Sq. Ft. | 1.88 |
| C-276 clad carbon steel | $330 / Sq. Ft. | 3.30 |

**Cost obtained from a major FRP supplier in North America.*

## FRP CHEMICAL RESISTANCE VERSUS METALS

Chemical resistance is a key predictor of service life in phosphate fertilizer processes. Compared to metals (Table 2), FRP made from epoxy vinyl ester resin has as good or better chemical resistance than Alloy C-276 and is superior to 2205 stainless steel. FRP has unusual resistance to chlorides and is superior to alloys in high chloride environments. Based on more than 30 years of experience and testing in "wet process" fertilizer systems, FRP made from epoxy vinyl ester resin has the chemical resistance necessary for long-term service life.

TABLE 2
EPOXY VINYL ESTER RESIN CHEMICAL RESISTANCE COMPARED TO METAL

| Materials | Sulfuric Acid | Hydrochloric Acid | Acid Chloride Salts |
|---|---|---|---|
| FRP made with epoxy vinyl ester resin | 100°C to 30% | 80°C to 15% | 100°C All conc. |
| 2205 Stainless Steel | 30°C to 30% | 60°C to 1% | 65°C to 2000 ppm @ low pH |
| Alloy C-276 | 100°C to 30% | 80°C to 15% | 65°C to 50M ppm @ low pH |

## FIBERGLASS-REINFORCED PLASTIC (FRP)

FRP is a laminate of E-glass fiber and thermoset resin as shown in Figure 1. Corrosion resistant FRP is made from a premium thermoset resin. The corrosion barrier (CB), on the process side of the laminate, has high resin content for corrosion resistance. The structural layers have high glass content for strength and stiffness.

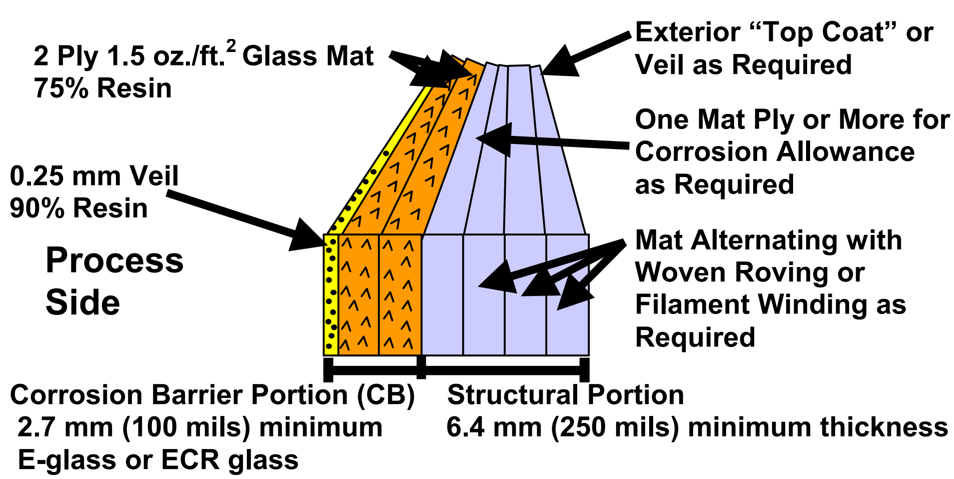


FIGURE 1: Typical Corrosion Resistant FRP Laminate Construction

For most wet applications, the maximum operating temperature is 100°C (212°F) with excursions up to 120°C (248°F). Dry environments can operate at 177°C (350°F) with excursions up to 204°C (400°F). Because not all resins are suitable for processes that have thermal cycling or high temperature excursions, it is important to consult the resin manufacturer when choosing a resin for these types of applications.

## PHOSPHATE FERTILIZER CASE HISTORIES

Case histories of FRP in phosphate fertilizer production include reaction vessels, absorber towers, slurry piping, ductwork, and stacks. The use of FRP in phosphate fertilizer environments dates back to the early 1970s and includes absorber towers, ductwork, and chimneys. More recently, FRP pipe based on epoxy vinyl ester resin is commonly used for abrasive slurry. With an abrasion-resistant liner, FRP pipe based on epoxy vinyl ester resin has been successful in numerous plant sites.

The corrosion resistance properties of fiber-reinforced plastic (FRP) made it the material of choice for the replacement of two rubber lined steel tanks used to process phosphoric acid. The 24'-high x 30'-diameter FRP tanks (Figure 2) were fabricated using epoxy vinyl ester resin. The tanks, operating between 60°-71°C (140°-160°F), process 42% phosphoric acid solution for granular fertilizer production. After the phosphoric acid has settled in the tanks, the solution is agitated to remove gypsum solids.

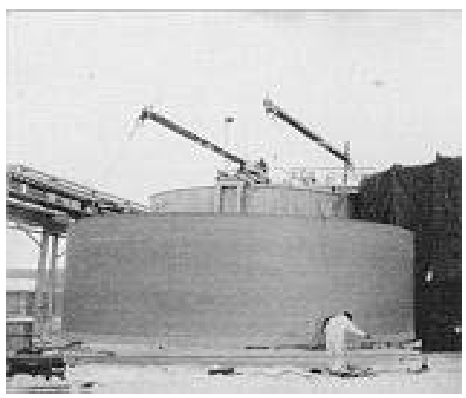

FIGURE 2: FRP Reaction Vessel for Phosphate Rock and Sulfuric Acid

A gas scrubbing system (Figure 3) at a fertilizer plant was made of FRP based on vinyl ester resin to resist attack from aggressive flue gases consisting of hydrochloric acid, hydrofluoric acid, and phosphate dust at 60°C (140°F). Stainless steel could not withstand the highly corrosive mixture of acid and dust which is formed in the scrubbers.

Service life of the FRP components is considered 50 years for this process. Three series of two scrubbers wash flue gases from a rotary drying unit. One series of two scrubbers performs a similar function at the output of the cooling. Cleaned outlet air from the scrubbers collects in a manifold and is released into the atmosphere through a chimney.

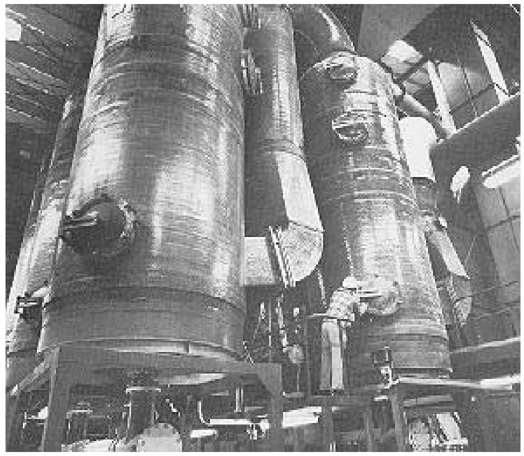

Figure 3. Gas Scrubbing System

In another pollution control process (Figure 4), 120°C (250°F) gas containing fluorides and ammonia is transported through FRP ducts to a scrubbing tower and is reacted with sulfuric acid at 68ºC (155°F).

Figure 4. Scrubber in Diammonium Phosphate Process

Waste gases from phosphate fertilizer production, containing droplets of phosphoric acid and traces of fluorine at 60-70°C (140°F-158°F) are handled by a FRP scrubber and chimney pollution control system (Figure 5) installed in 1974.

Figure 5. Scrubber Including Chimney for Fertilizer Process Waste Gases

Another scrubbing tower in a phosphate fertilizer process has been in service since 1973. Operating at 100°C (212°), the scrubber handles a combination of 40% phosphoric acid (H3PO4), ammonia, air, water and fertilizer dust.

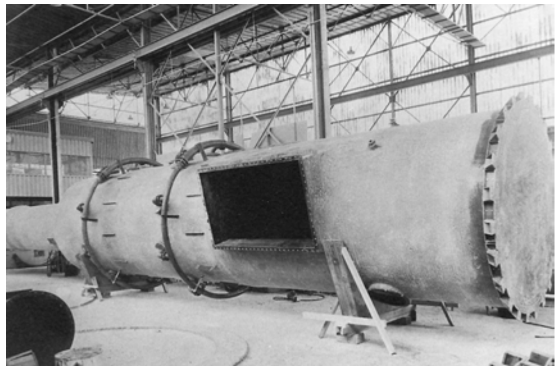

Figure 6. Phosphate Fertilizer Process Scrubber for 100°C (212°) Dust Laden Fumes

A large FRP fan (Figure 7), designed to handle P2O5 fumes from the reaction of phosphate rock and H2SO4 at 80ºC was installed in 1993.


Figure 7. Phosphate Fertilizer Process Fan for 80°C (182°) P2O5 Fumes

The western edge of the Sahara, Morocco possesses 75 per cent of the world's known phosphate reserves. To upgrade phosphate rock from nearby mines to more commercially valuable phosphoric acid, a vast refining plant in Jorf Lasfar uses an abrasion resistant FRP piping system to transport phosphoric acid and gypsum slurry.

The plant, built in 1986, is believed to be one of the largest phosphoric acid facilities in the world with a capacity of 1.3 million tons annually. The complex also includes one of the world's largest plants for producing the sulfuric acid that is used to extract phosphoric acid from phosphate rock.

Filament wound abrasion resistant FRP pipe (Figure 8) transport phosphoric acid through production, as well as to and from storage tanks. Two 1.5 meter (5 feet) diameter lines, each 6.5 km (4 miles) long, also carry a suspension of abrasive gypsum away for disposal.

Figure 8. Abrasion Resistant FRP Pipe for Phosphate Fertilizer Process Slurry

As seen above, FRP can be used extensively for pollution control in phosphate fertilizer processes. It can also be used to recover acid that would be otherwise lost as fumes. The unit pictured below (Figure 9) condenses phosphoric acid at 85% concentration out of waste air. Average process temperature is 85°C, rising to a maximum of 95°C.

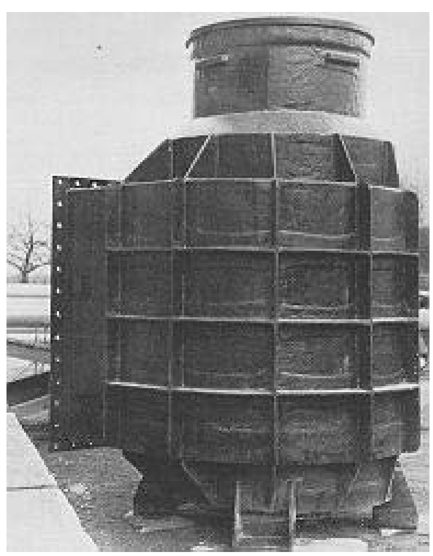

Figure 9. FRP Separator Recovers Phosphoric Acid from Waste Fumes

Venturi scrubbers (Figure 10) can also be made from FRP for cleaning phosphate fertilizer fumes containing ammonia and hydrogen sulfide at 65–90ºC (150°F-195°F)

Figure 10. Venturi Scrubber for Ammonia and Hydrogen Sulfide

## CONCLUSIONS

FRP made with DERAKANE® or HETRON® epoxy vinyl ester resin is an ideal material of construction for phosphate fertilizer reaction vessels, ductwork, absorber towers, stacks, and gypsum slurry piping with the following advantages:

- Proven performance for over 30 years
- Much lower cost than Alloy C-276 clad carbon steel
- Less maintenance than other materials

## NOTICE