BEST PRACTICES IN MATERIAL CHOICE FOR DESIGN AND CONSTRUCTION OF HYDROMETALLURGICAL EQUIPMENT

T. Johnson, J. Graham and D. Kelley

Ashland Performance Materials
5200 Blazer Parkway
Dublin, Ohio 43017

Keywords: Hydrometallurgy, FRP, solvent extraction, corrosion resistance, Derakane, epoxy vinyl ester resin, Vale, Voisey’s Bay, MolyCorp, Mountain Pass, El Boleo
Abstract

Hydrometallurgical processes can be exceptionally corrosive. This is particularly true in acid leaching processes for copper, cobalt, nickel and rare earth elements. In the last five years, several large hydromet plants have been built in North America (Vale - Long Harbour, Baja Mining – El Boleo and MolyCorp - Mountain Pass). Hundreds of storage tanks, extraction vessels and electrowinning cells along with miles of piping were designed and fabricated to withstand the aggressive environments inherent in these processes. One key element all three projects had in common was the extensive use of FRP in equipment design. As a material of construction, FRP provided equal if not improved durability relative to alternative corrosion resistant alloys at a considerably lower cost. This paper will highlight the extensive use of FRP in these three world scale projects and why it was chosen for each process.

INTRODUCTION

Fiberglass Reinforced Plastic (FRP) has been used to build corrosion resistant mineral processing equipment for more than 40 years. The operating conditions associated with mineral processing often require materials of construction that can withstand process acids and acid chlorides at temperatures up to 90°C. This service is not compatible with most common metallic materials of construction. Only expensive metal alloys offer the corrosion resistance required. The use of fiberglass reinforced plastics based on epoxy vinyl ester resins for the construction of electrowinning cells, storage and processing vessels, acid & abrasion resistant piping, ducting and acid plants offers both durable and cost-saving solutions for these applications. Today, more and more design engineers are specifying FRP composites for equipment used in hydrometallurgical processes.

Mineral processing continues to be an important high growth industry. According to Lucintel, the global mining industry will reach US $1,783 billion by 2017, with a compound annual growth rate (CAGR) of 7.4% (1). ResearchandMarkets.com estimates that the US metals & mining industry had total revenues of $201.5 billion in 2011, and will grow to a value of $273 billion by 2016 (6.3% CAGR) (2). Accenture reports that mining capital investments worldwide increased from $US 16 billion in 2001 to nearly $US 80 billion in 2011(3). Top investments in 2011 were made by Vale (US$ 22 billion), Rio Tinto (US$ 12 billion) and BHP Billiton (US$ 10 billion).

The last five years have seen particularly heavy investments in the North American mining industry. These investments include Vale’s Long Harbour (Newfoundland) complex processing nickel, cobalt and copper ores from the Voisey’s Bay mine along with Baja Mining’s El Boleo (Mexico) copper/cobalt mineral processing plant and MolyCorp’s Mountain Pass Rare Earth processing plant in California. One thing that all of these facilities have in common is the
aggressive hydrometallurgical processes they employ to extract metal(s) from the raw ore. Another key aspect all three have in common is their extensive use of FRP-based mineral processing equipment to withstand those same highly corrosive processes.

Figure1. Vale’s Long Harbour Nickel Processing Complex

**Long Harbour**

The Long Harbour Processing Plant is expected to process more than 50,000 MT/yr of nickel ore from the Voisey’s Bay mine in Labrador when it starts up in 2014. While the hydrometallurgical processes are indeed proprietary, they rely heavily upon hydrochloric acid at elevated temperatures to extract nickel metal from the ore. This is an environment not typically recommended for carbon steel or even most stainless steel alloys. Properly designed and fabricated FRP laminates based on epoxy vinyl ester resins, however, stand up to this environment quite well as is shown in the chart below.
Table 1. Epoxy Vinyl Ester Resin Chemical Resistance Compared to Alloys

<table>
<thead>
<tr>
<th>Materials</th>
<th>Sulfuric Acid</th>
<th>Hydrochloric Acid</th>
<th>Acid Chloride Salts</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRP made with Epoxy vinyl ester resins</td>
<td>100°C to 30%</td>
<td>80°C to 15%</td>
<td>100°C All conc.</td>
</tr>
<tr>
<td>2205 Stainless Steel</td>
<td>30°C to 30%</td>
<td>60°C to 1%</td>
<td>65°C to 2000 ppm @ low pH</td>
</tr>
<tr>
<td>Alloy C-276</td>
<td>100°C to 30%</td>
<td>80°C to 15%</td>
<td>65°C to 50M ppm @ low pH</td>
</tr>
</tbody>
</table>

Plasticon Canada, operating at the time as AC Plastiques Canada, was one of many fabricators chosen to support Vale’s Long Harbour project. With the invaluable support of ECC Corrosion (Wisconsin Rapids), Plasticon Canada provided a wide variety of FRP equipment including:

- 64 cylindrical FRP tanks with diameters varying between 5 ft and 20 ft and standing up to 30 ft tall;
- 6 rectangular FRP tanks, all approximately 36 ft x 17ft x 17 ft and each weighing between 35,000 and 45,000lbs;
- 4 FRP scrubbers with diameters varying between 12” and 72” and up to 30ft of height
- 18 FRP demisters with diameters varying between 18” and 108” and up to 18ft tall;
- 1 dual laminate CPVC/FRP scrubber 72” x 32 ft ;
- 3 FRP stacks up to 90 feet high;
- 13 clarifier circular FRP covers with diameters varying from 11.5ft to 100ft, weighing all together 117 tons;

The equipment was divided into several packages and awarded by well known hydrometallurgical process industry leaders such as FLSmidth (Salt Lake City) and Clean Gas Systems (New York). All of the equipment above was specified with FRP and dual laminates fabricated with epoxy vinyl ester resins due to the corrosive nature of the service.
The Denali group including Ershigs, Fabricated Plastics and Belco delivered a total of 64 FRP tanks to the Long Harbour project. All of this equipment was fabricated with epoxy vinyl ester resins. The storage vessels were designed for a variety of corrosive environments including hydrochloric acid, sodium hydroxide and boric acid. They were produced through a filament winding process routinely conducted at the Belco and Fabricated Plastics facilities. Vessels ranged in size up to 18 feet in diameter (5.5 meters) and over 27 feet in height (8.4 meters).
A number of the vessels, however, were even larger measuring diameters up to 13.4 meters (44 feet) and heights up to 15.65 meters (51 feet). Initially, Vale was unconvinced that such large vessels could be made from FRP. In the end, however, Ershigs was able to persuade Vale that it was indeed feasible to fabricate and transport vessels of this size. Part of that persuasive argument was to visit flue gas desulfurization (FGD) projects in the power industry where Ershigs and Augusta Fiberglass had each built even larger FRP structures. In fact, the current record for large diameter FRP structures is the six 119 foot diameter Jet Bubbling Reactors (JBR) located in major Power Generation Plants in the Southeast US. Once Vale toured one of these air pollution control facilities and inspected the enormous JBR scrubber, feasibility was no longer in doubt.

![Ultra-Large HCl Tanks](image)

Figure 4. Ultra-Large HCl Tanks

Corrosion Technology International (CTI), the largest polymer concrete electrolytic cell producer in the world, partnered with Capital Precast (CP), the largest pre-cast company in Newfoundland to produce 332 cells for the nickel, cobalt and copper electrowinning circuits. The nickel electrowinning (NiEw) and cobalt electrowinning (CoEW) cells each weighed in
excess of 10 MT making them the largest of their type ever manufactured. In addition to the cells, CTI/CP also designed and supplied structural beams for walkway support.

But the fabrication of FRP equipment for the Long Harbour project doesn’t stop there. Miles of acid and abrasion resistant piping was specially fabricated by Ershigs and others for the hydromet plant and Bateman delivered a host of mixer settlers to the site. In addition, Universal Fan made more than 70 large FRP exhaust fans. Many more vendors delivered FRP ducting, hoods, cooling towers and process vessels to the Long Harbour project. All in all, more than 10 million lbs of FRP was utilized in this world class mineral processing plant.

**El Boleo**

The Boleo project in Mexico on the Baja peninsula is another large hydrometallurgical site that specified a great deal of FRP equipment. When commissioned, the $1.4 Billion undertaking is expected to produce 60,000 MT/yr copper, 3100 MT/yr cobalt, 36,000 MT/yr zinc and 100,000 – 250,000 MT/yr manganese carbonate. While not nearly as large as the Long Harbour plant, Boleo required dozens of FRP processing vessels and storage tanks as well as miles of acid and abrasion resistant FRP piping.

![Figure 5. Boleo Hydrometallurgical Processing Plant](image)

A great many FRP tanks were built for the Boleo hydromet plant. Many were so large that they needed to be fabricated on site. Ershigs was commissioned to fabricate 9 tanks for the Boleo project. The tanks were 11.5 meters in diameter (38 feet) by 12.5 meters high (41 feet) with domed tops and flat bottoms. They were designed to withstand the corrosive acid environment used in the extraction of desired metals from the Boleo ore. Augusta Fiberglass
also provided FRP vessels to the Boleo project – twenty five in all. Some incorporated silicon carbide into the corrosion barrier to enhance their resistance to abrasion from ore slurries. Others had fire retardance built into the structural layers with brominated epoxy vinyl ester resin. The tanks ranged in size from 10 feet to 15 feet in diameter and from 11.5 feet to 41 feet in height. All of the Ershigs and Augusta vessels were fabricated with epoxy vinyl ester resins.

Figure 6. Tanks for Boleo Hydromet Plant

Fiber-Tech Industries and Structural Composite Technologies collaborated to fabricate the FRP components (designed by well-known FRP consultant Bob Yeates) required to protect the 6 Counter Current Decantation (CCD) vessels. These specially designed metal extraction vessels are more than 60 meters (200 feet) across. They possess a concrete base with a thick FRP liner (fabricated by Fiber-Tech) which gives the vessels considerable acid and abrasion resistance. Structural Composite Technologies delivered nearly 200 FRP launders to complete the CCD set up.
RPS Composites was awarded the contract for the acid and abrasion resistant piping needed for the Boleo facility. RPS Composites (with the help of Fiber-Tech Industries) is also designing, supplying, and installing FRP liners for 12 concrete settlers and 6 concrete tanks. In fact, over the last three years RPS has supplied more than 1.5 million lbs of FRP for mineral processing projects including –

- 30,000 fittings
- 150,000 feet of piping
- 7500 FRP wear pads & thrust collars
- 12,000 custom designed steel supports

Application environments included wet chlorine gas, hydrochloric acid, plating reagents, biocides, aqueous organic solutions, sodium hydroxide, boric acid and sodium chloride. FRP pipe systems were chosen for these applications because they offer significant advantages over alternative materials such as rubber lined carbon steel, stainless steels, and high nickel alloys. These advantages include lower installed costs, lower life cycle costs, and better resistance to a broad range of chemical environments.

Plásticos Industriales de Tampico (PITSA) was also awarded the fabrication of more than 500 metric tons of composite FRP conductive and non-conductive piping and accessories for the Boleo project. The conductive pipe and accessories is intended for organic flow service, fabricated with a conductive carbon veil and brominated epoxy novolac vinyl ester resins with 5% antimony added to meet ASTM 84 Class I fire retardant requirements.
Mountain Pass

The $1.42B Mountain Pass project began producing rare earth oxides in 2012 at a rate of 8,000 to 10,000 metric tons a year. That rate is expected to increase to 19,050 MT by mid 2013 with a potential to reach as much as 40,000 MT in 2014 depending upon market demand. At that point MolyCorp would be delivering nearly a third of the current global supply of rare earths.

![Figure 8. MolyCorp’s Mountain Pass Hydromet Facility](image)

The Mountain Pass hydromet plant not only needed to extract a variety of rare earth elements from the ore body, but it also needed to separate the individual elements once they were extracted. This necessitated not only the use of aggressive reagents but a large number of processing vessels as well. Once again, process design engineers turned to FRP for the complex chemistry needed to process the Mountain Pass ore. Dozens of FRP extraction and separation tanks were required to complete the hydromet process. Plas-Tanks Industries and Daniel Company fabricated most of the FRP tanks on this site. Plas-Tanks delivered 23 vessels ranging in size from 6,000 to 35,000 gallons using epoxy vinyl ester resins. Most of the tanks were 12 to 14 feet in diameter. The tallest was about 32 feet in height. The corrosive service included hydrochloric acid, sodium hydroxide and sodium hypochlorite (bleach). Daniel provided 17
vessels to the Mountain Pass project. Most of the tanks were 13’-6” in diameter and nearly 25 feet tall.

Figure 9. Reagent Storage Vessels

Figure 10. FRP Tanks for Mountain Pass Project
Mineral processing environments are some of the most aggressive in the world. Equipment design and construction is heavily tested by the reagents used in these metal extraction processes. Hydrometallurgical equipment is more durable when made from FRP fabricated with epoxy vinyl ester resins. These three world class hydromet projects attest to the value of FRP in aggressive mineral processing environments.

NOTICE

All statements, information and data presented herein are believed to be accurate and reliable but are not to be taken as a guarantee, express warranty or implied warranty of merchantability or fitness for a particular purpose or representation, express or implied, for which Ashland Inc. assumes legal responsibility, and they are offered solely for your consideration, investigation and verification.

References

2) “Metals and Mining in the United States”, ResearchandMarkets.com, November 2012
3) “Accenture Global Survey of the Metals and Mining Industry”, 2012