Choosing the Correct Plastic Material for Tanks

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When designing tanks for chemical and fluid handling services, engineers have a variety of material options. Choosing the correct material from metals, plastics, coatings, and combinations thereof can majorly affect the lifetime of the tank. Plastic tanks can be specified over metals due to their corrosion resistance, lightweight properties, and ease of fabrication. This article examines some plastics most commonly used for tank constructions, both as liners inside metal or fiberglass tanks, as well as freestanding ones.

Corrosion is a challenging problem for engineers and maintenance professionals worldwide, particularly with tanks. Short-term tank corrosion issues include compromising product purity and minor leaks. More serious problems can cause complete component failure, releasing potentially dangerous chemicals into the surrounding areas.

Polymers or plastic materials are often employed as liners or even standalone parts to combat the issue of corrosion. Unlike metals, plastics are not susceptible to corrosion and rusting. However, not all plastics are alike and it is important to understand the characteristics, advantages, and limitations of each material. This article explores plastics commonly used for tanks and linings to prevent corrosion. For harsh environments with aggressive chemicals and elevated temperatures, fluoropolymers can be utilized. Specifically, polyvinylidene fluoride (PVDF) and PVDF copolymers are discussed, showing new advancements and fabrication techniques that have changed the way engineers and plant designers handle their corrosion challenges.

Plastic Materials—A Variety of Choices

Changes in a polymer's molecular backbone allow for a profoundly large number of possibilities in creating plastic resins. From varying elements to changing the structure and branches, small differences in polymer makeup can account for large changes in material performance. Commonly used families of polymer plastics include polyolefins, polyurethanes, polystyrenes, polyvinyls, polyesters, and fluoropolymers. These resins fall into the category of thermoplastics—meaning they can be re-melted and re-processed. Thermoplastics are most often processed via melt processing techniques, such as extrusion, injection, or compression molding. The temperature profiles and processing conditions vary depending on the material of choice and it is important for processors to consult with resin suppliers on optimal conditions.

When making a choice on what lining is best for the application, examining the innate performance properties of the material is crucial. Table 1 compiles some of the mechanical properties of commonly used lining materials at 23 °C.

In many instances, plastics are used in standalone constructions for tanks, wet benches, and cabinets, so the inherent strength of the material is especially important. Besides the mechanical properties, chemical resistance, permeation, and temperature are other areas engineers should consider when designing with plastics. When commodity materials face challenges in harsh thermal or chemical environments, fluoropolymers can provide new solutions.

For areas where plastics are used as linings, there are two principal reinforcement materials, metal and fiberglass. Common metal substrates include aluminum, carbon steel (CS), and stainless steel (SS) (Types 304 SS [UNS S30400] and 316 SS [UNS S31600]). One important characteristic of a plastic is that a liner in these systems has low permeability. This minimizes the risk of chemicals moving through the liner and becoming trapped between the liner and the outer shell, causing issues with blistering and delamination. Figure 1 shows the permeation rates of oxygen gas through various plastic materials. Oxygen is representative of a small molecule, thereby showing tough testing conditions.

PVDF Copolymers—Flexibility for Linings

PVDF copolymers are flexible versions of PVDF. Synthesized by reacting a co-monomer hexafluoropropylene (HFP) with the vinylidene fluoride (VF2) monomer, PVDF copolymers have varying degrees of flexibility, depending on the concentration of the HFP. Other common co-monomers can include tetrafluoroethylene (TFE) and its derivatives, ethylene tetrafluoroethylene (ETFE), and polytetrafluoroethylene (PTFE). The HFP is not an additive, plasticizer, or stabilizer to the material. Instead, it is directly reacted chemically with the VF2, ensuring that the resin retains its flexibility over time and does not leach out into the chemical media.

While added flexibility is a benefit, especially for tank fabrication, there are other advantages to PVDF copolymers. First, PVDF copolymers have a higher fluorine content. This higher degree of fluorine in PVDF copolymers gives a broader range of chemical resistance. While PVDF homopolymers are rated for continuous use in chemicals from <1 up to 12 pH, the PVDF copolymers extend the upper range to 13.5 pH. Common chemicals handled by PVDF and PVDF copolymers include strong acids, chlorides, and deionized or high-purity water. It is the added ductility and elongation that give the PVDF copolymers increased resistance to harsher chemicals. Higher flexibility also allows tank fabricators to thermoform and manipulate the sheets easier. Table 2 shows the mechanical properties of PVDF copolymers.

TABLE 1. PROPERTIES OF PLASTIC LINING MATERIALS[1]

	Flex Modulus (psi)[2]	Tensile (psi)[3]	Hardness (Shore D)[4]	Abrasion (mg/1,000 Cycles)[5]
PVC	320,000	6,500	80	12-20
PVDF	300,000	7,500	78	5-9
ECTFE	240,000	7,000	75	5-9
PP	200,000	5,000	60	15-20
ETFE	170,000	6,500	70	55-65
PFA	85,000	4,000	55	25-35
FEP	80,000	3,000	55	70-80
PTFE	72,000	3,000	50	500-1,000

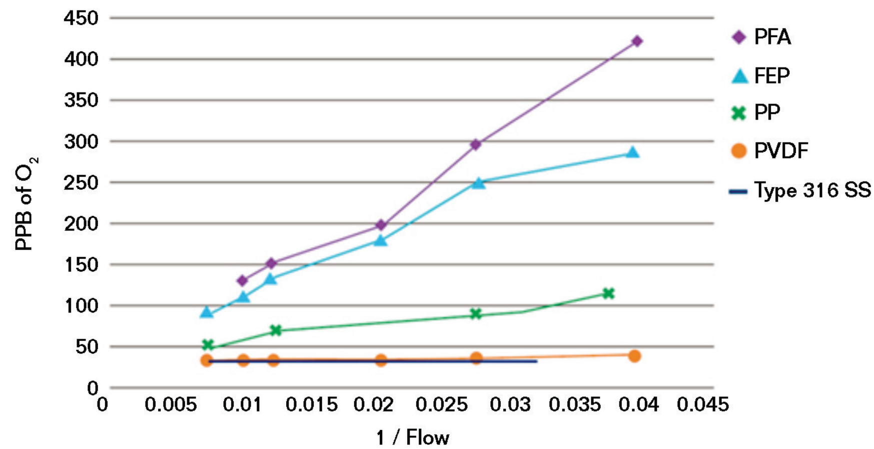

FIGURE 1 Oxygen permeation of tank materials.[6]

TABLE 2. MECHANICAL PROPERTIES OF PVDF COPOLYMERS[7]

	Melt Point (°C)	Flex Modulus (psi)[2]	Tensile (psi)[3]	Hardness (Shore D)[4]	Abrasion (mg/1,000 Cycles)[5]	Impact[8]
PVDF 740	170	300,000	7,500	78	5-9	2-4
PVDF Flex 2850	157	170,000	5,500	75	6-9	4-10
PVDF Flex 2800	142	100,000	4,000	65	16-19	10-20
PVDF Flex 2500	120	35,000	2,200	55	28-33	No Break

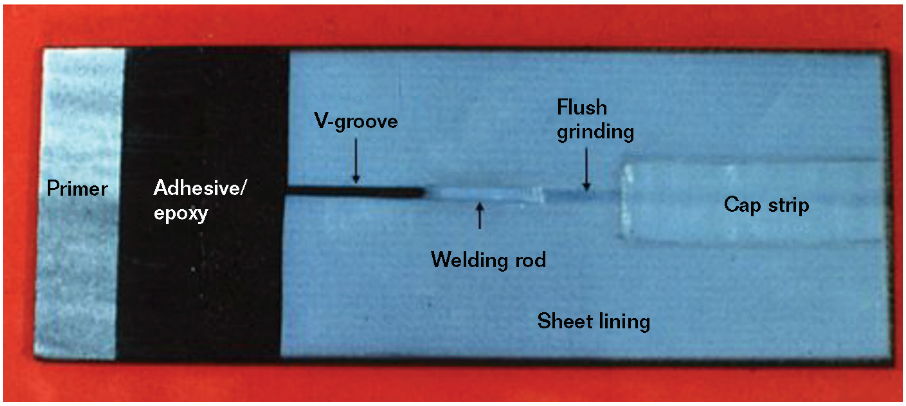

FIGURE 2 Tank-lining steps. Image courtesy of Electro Chemical Engineering & Manufacturing.

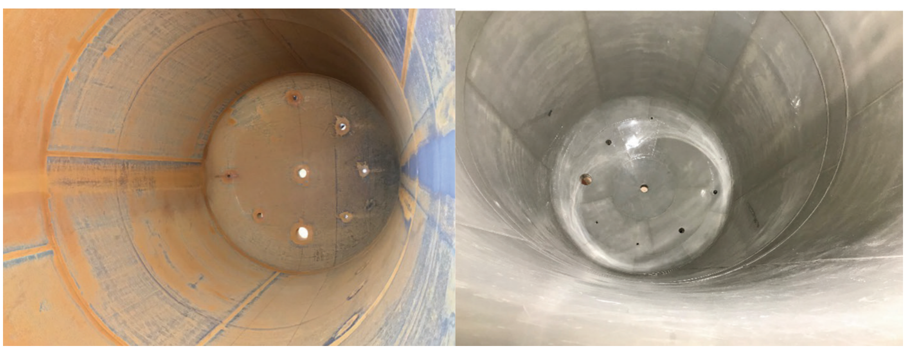

FIGURE 3 Before (left) and after (right) lining a steel tank with PVDF copolymer sheets. Images courtesy of Electro Chemical Engineering & Manufacturing.

Three main grades of resins are used for tanks made with PVDF. The first is PVDF 740 homopolymer used for vessels that are freestanding. The rigid homopolymer grade is available in thick sheets of PVDF (>1 in [25.4 mm]) that can be thermoformed and welded to create tanks. Common grades for liners are PVDF copolymers: PVDF Flex 2850 and PVDF Flex 2800. Copolymers are recommended in situations where high torque or high stress occurs, such as in over-the-road trailers that carry aggressive chemicals, like sulfuric, hydrochloric, hydrobromic, or other acids.

PVDF Sheets

In order to fabricate a tank using plastic materials, it is first necessary to process plastic into a sheet. Sheets of PVDF or any other thermoplastic resin are most commonly manufactured by either compression molding or extrusion. Standard thicknesses of liners are 60, 90, or 120 mils. Since PVDF has a relatively low melting point at 170 °C, it can be processed on standard equipment used to run polyolefins. Copolymer grades of PVDF may have an even lower melting temperature.

Because fluoropolymers have inherently non-stick properties, it would be very difficult to adhere a sheet directly to a metal or fiberglass tank. Because of this, sheets are available with fabric or glass backing. The fabric backing is co-extruded onto the sheets as they are being processed, allowing for a strong bond. A common peel test used by some suppliers of the sheets is ASTM D1781[9] in order to ensure a robust and strong bond without a chance of delamination.

Tank-Lining Process

The process of lining a tank can be similar for each plastic material. Most often, the liners are applied to CS or SS. Plastic liners, such as the ones described in Table 1, offer advantages to engineers and designers. When Hastelloy†, Inconel†, titanium, or other exotic metals are thought to be the only choice, using a less expensive metal with a fluoropolymer lining may provide users with a substantial cost savings and equivalent performance over the lifetime of the tank.

Depending on the chemical and temperature environment, the thickness of the sheet can vary. While thinner sheets are easier to form around the vessel, the thicker sheets offer better permeation resistance. Consultation with the tank fabricators is recommended.

Application, adhesion, and welding could be slightly modified per the material. Whether the tank is new or used, the lining process can be similar. Figure 2 shows a plan view of the application steps, starting with the primer on the left, and finishing on the right with a cap strip to protect the welded sheets. The following sections describe those steps in further detail, as well as a visual overview in Figure 3.

Cleaning and Blasting

Whether the tank is new or has been in service, the inside of the tank should be thoroughly cleaned before work can start. Typically, an abrasive blast is used to clean the interior of the tank and create an anchor point. A typical anchor profile is 3 to 5 mils to allow for good adhesion of the plastic sheet to the metal. Different types of media are available, ranging from fine, course, and extra course, and are usually made of crushed glass or other mineral abrasive. Harder metals may require harder blasting materials. Additionally, fabricators use standards, such as NACE No. 2/SSPC-SP10[10] to ensure a white metal blast.

Coating and Priming of Tank

Once the tank is blasted, a primer can be applied to hold the blast and prevent oxidation prior to the lining process. This is a necessary procedure since there could be some time lag before fabrication can be completed.

Thermoforming Sheets

While the tank is being prepped, the sheets and parts for nozzles and heads can

†Trade name.

be formed. This takes immense detail to understand all the dimensions of the tank while trying to minimize the amount of welding that needs to be done later. Corner angles, nozzle head size, and flanging all need to be considered before thermoforming parts. Once the dimensions are very well documented, the plastic parts can be heated appropriately per the material specifications in order to warm up the plastic and physically form the part. Since plastics have different melt temperatures and mechanical properties, the thermoforming temperatures and times must be adjusted to the specific material being employed. For PVDF, thermoforming should take place between two molding plates. PVDF homopolymers thermoforming temperature is recommended at 150 to 160 °C. For PVDF copolymers, thermoforming is recommended to take place ~15 °C below the melting point of the material.

Applying Plastic to Metal

As previously described, a fabric-backed sheet is used to bond the thermoplastic liner to the metal. In addition, an adhesive is added to provide adhesion to the metal. Some manufacturers have used solvent-based elastomeric adhesive in the past, but some have developed proprietary, higher temperature flexible epoxy adhesives. Before the sheets are applied to the metal, they should be annealed to alleviate stresses. A typical annealing time and temperature for PVDF can be 135 °C for 2 h. Other materials may have different annealing temperatures.

Welding

Welding can be freehand with a welding rod and heat gun. The operators should be cognizant of hazards with welding and take precautions to wear proper personal protective equipment. There are standards such as AWE G1 committee and/or DVS 2207-15[11] for welding of PVDF or tank fabricators who have developed their own welding procedures for linings. When using butt fusion or welding rod, there can be a cap applied to distribute stress of the weld over a wider joint. However, some organizations have developed a flow fusion technique to give smooth weld lines and no discontinuities. This technique takes two sheets of the plastic sheet and heats them up under pressure to allow the sheet to flow into each other seamlessly. The material cools and then has a solid material between the sheets connecting the two.

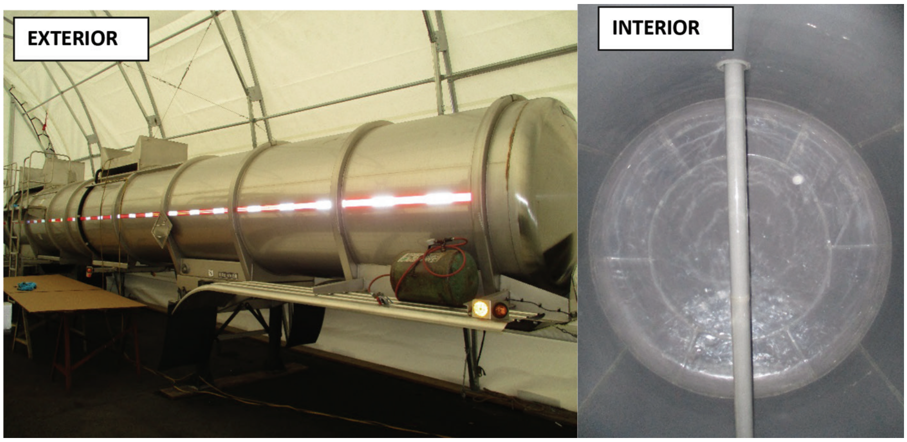

FIGURE 4 Over-the-road trailers carrying aggressive chemicals can be lined with PVDF copolymers. (Images courtesy of Electro Chemical Engineering & Manufacturing.)

Testing

Once the tank is fully lined and all welding is complete, a spark test followed by a helium leak test is performed to identify pinholes. Pinholes are minute imperfections where fluoropolymer material is not present. If a pinhole is identified, it should be fixed and filled with plastic to cover any area that is missing material.

Overall, the process of lining a tank can take several weeks depending on the size of the tank. Additionally, solutions exist for lining over-the-road trailers with PVDF copolymer linings, like in Figure 4. Should a leak or other defect occur in the tank over time, methods to repair can be relatively straightforward. These procedures are well documented and should be discussed with an experienced tank fabricator.

Dual Laminate Tanks

Tanks that have fiberglass as the reinforcement material are also commonly made with plastic liners. Unlike metal tanks, these dual-laminate tanks start with building the tank from the inside-out. Keeping the same fabric-backed sheets, thermoforming, and annealing recommendations, plastic liners are formed into the desired tank geometry. Next, the fiberglass is applied to the exterior, or fabric side of the sheet using a wet layup process. Dual laminate tanks can often be a more lightweight, cost-effective solution for users seeking a structurally strong tank.

Conclusions

PVDF and other plastics are commonly used to fabricate tanks. Available in standalone and lined configurations, tanks that have thermoplastics as the contact layer with the containment media can greatly extend the service life of the system. It is important that the proper plastic liner is used, as materials can vary greatly in temperature performance, chemical and permeation resistance, and ease of fabrication. Engineers and designers who specify plastic liners for corrosion control have come to appreciate their utility in both new tank designs as well as in retrofitted tanks.

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Continued on page 40

Continued from page 39

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