TECHNICAL ARTICLE SERIES

The Plastic Alternative

ARTICLE # TL-116

INDUSTRY: General

ENTITY: Various

SOLUTION(S) PUMPED: Bromine, Hydrofluoric acid, Corrosive slurries, Hot brine

PUMP TYPE(S): CHEM-GARD Horizontal Centrifugal Pump, FLEX-I-LINER Sealless Self-Priming Peristaltic Pumps, Nonmetallic Tank Pump Systems, SUMP-GARD Thermoplastic Vertical Pump

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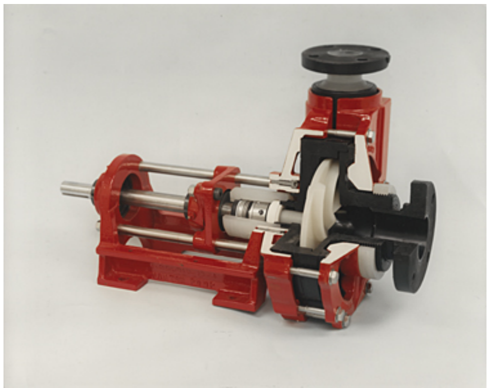


Cut-away of polypropylene centrifugal pump with PVDF impeller to extend service life in abrasive applications

A PVDF impeller, stainless steel shaft sleeved in PVDF and ceramic sleeve bearings

The Plastic Alternative

While chemical inertness is the major reason for specifying a plastic pump, users can take advantage of other benefits as well

Reprinted from PUMPS AND SYSTEMS
By Ken Comerford

A variety of nonmetallic materials are available to meet your needs.

Not so long ago system designers would consider the use of plastic pumps only if available metal pumps were completely unsuitable. Plant engineers had learned to live with costly downtime and excessive maintenance due to corrosion. Extensive research activities concentrated on published corrosion rates for a long list of metals and exotic alloys in an endless array of chemical solutions at varying temperatures. Specific metal selection for a given application was left to the user's discretion, based on what were considered to be "allowable" rates of attack.

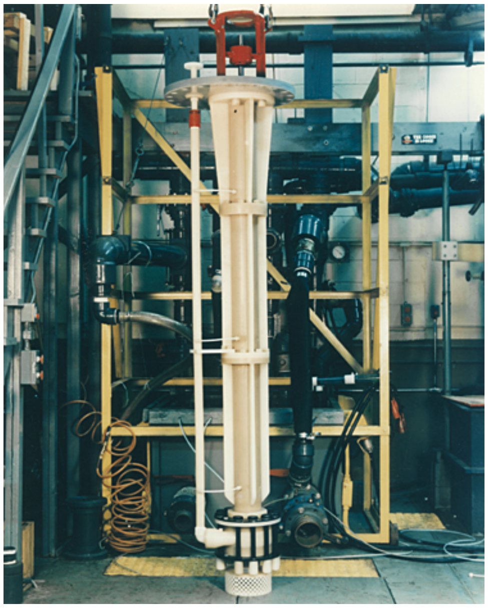
Unlike metals, with their anticipated corrosion rates in mils penetration per year, plastics are either inert to or not suitable for a given fluid. Selection, therefore, tends to be less complicated. In a recent study of plant engineers and consultants who indicated they were using or specifying plastic pumps, the number one reason given for their selection of a specific pump was superior corrosion resistance.

Although there are many other reasons for specifying plastic pumps, chemical inertness is the major one. No other reason comes close. The benefits that accrue because of this resistance explains why plastic pumps are being used today in almost every facility handling corrosive, hazardous, toxic, and other aggressive liquids, and slurries.

CURRENT DESIGN PARAMETERS

Today plastic pumps are being produced for flows in excess of 2,000 gpm, with heads to 280 ft, and for use at temperatures from below freezing to 275° F. Recent developments have made it possible to incorporate many design features directly related to the unique properties of plastics into pumps that conform to ANSI specification B71.3 for horizontal process pumps.

With the successful introduction of these pumps, it was only natural that vertical centrifugal designs would follow. This is particularly significant in light of the need for deep sumps in the wastewater field. The advantage of lightweight, chemically inert plastics has stimulated a host of creative engineering approaches, and these sump pumps are now available in lengths up to 20 ft.



PVDF sump pump for handling bromine has cast iron bolts encapsulated in ECTFE, and Acme threads protected by PVDF sealing nuts, isolating the bolts from the corrosive solution. Heavy sheeting of PVDF protects the underside of the CPVC cover plate, and the stainless steel shaft is sleeved in thick sectioned PVDF.

ADVANTAGES OF PLASTIC PUMPS

Although the main advantage of plastic pumps is corrosion control, there are many other benefits in applications that do not exceed their temperature and pressure limitations.

- extended service life
- superior abrasion resistance
- freedom from contamination
- low maintenance
- broader range of usefulness
- low weight saves money
- low cost

PLASTIC MATERIAL OPTIONS

Although the materials handbooks list hundreds of nonmetallic formulations with varying properties, for pump users the choice for most applications narrows down to eight rigid plastics and eight elastomeric materials. Choosing a specific material for use in an application begins with a review of data published in handbooks and "corrosion" tables. However, experience with actual conditions is important. For this reason, we strongly recommend that pump specifiers consult with manufacturers before recommending nonmetallic materials for a new application. There is literally no substitute for experience when it comes to material selection.

Take the basic consideration that limits the use of plastic pumps — operating temperature. Although handbooks and specification sheets prepared by material suppliers may show suitability of some plastics at temperatures to 500° F, plastic pump manufacturers will generally not recommend their product for continuous duty at temperatures above 275-300°F. The dynamics of pump operation, which include turbulence, start-stop, wet-dry, abrasive particulates, and similar situations, suggest that textbook laboratory test data be tempered by actual experience.

RIGID PLASTICS

The rigid plastics most widely used for pump construction are broadly divided into two groups —thermoplastics and thermosets. Thermoplastics have linear molecular chains that flow over each other and separate when heated, then solidify into predetermined shapes upon cooling. Reheating permits reforming without significant change in properties. Thermosets, when heated, form permanent crosslinks between linear chains, creating a rigid structure that cannot flow again. Some thermosets are molded from liquid components that react to certain chemicals at room temperature to create tightly crosslinked chain structures. In either case, once the reaction is complete the plastic cannot be reformed or remelted.

Thermoplastic materials are the group most widely used for corrosion and abrasion resistance. Because they are homogeneous in structure, they offer greater resistance to a broad range of aggressive solutions. They also provide greater purity and can be used with ultrapure water, pharmaceuticals, and foods.

Thermosets, on the other hand, offer greater tensile and impact strength. In this respect they are more closely related to metal. Because they are composites, however, their abrasion resistance is limited and they are subject to wicking and product contamination.

The various rigid nonmetallics used most frequently for pumping corrosive and abrasive fluids or fluids requiring freedom from contamination are described below.

PVC (POLYVINYL CHLORIDE)
This relatively low-cost, impact-resistant thermoplastic material resists attack by strong acids, alkalies, salt solutions, alcohol, and many other chemicals. It is not recommended for use with solvents such as ketones, chlorinated hydrocarbons, and aromatics. It imparts no tastes or odors to fluids being handled. Generally used at ambient temperatures, PVC is not suggested for pump service above 140°F.

CPVC (CHLORINATED POLYVINYL CHLORIDE)
With physical and chemical resistance similar to PVC, this material is suitable for use at temperatures up to 210° F. It offers greater impact strength and abrasion resistance than PVC and is often recommended when high mechanical strength is required at elevated temperatures.

PP (POLYPROPYLENE)
This widely used pump material is the lightest of the engineered thermoplastics. It has a specific gravity of 0.90 and offers an excellent strength-to-weight ratio. Polypropylene is recommended for handling a broad range of acids, bases, and solvents, but is not suggested for use with strong oxidizing acids, chlorinated hydrocarbons, or aromatics. Temperature limitations fall between PVC and CPVC with a high of 185° F for continuous service. Because of its low cost and availability, it is universally recommended for water and wastewater.

PE (POLYETHYLENE)
This ultra-high-molecular-weight polyethylene is very similar in mechanical and chemical resistance to the lighter-weight and lower-cost polypropylene. It is also impermeable to water and resistant to acids, alkalies, and organic solvents. Polyethylene retains good physical properties at low temperatures and at temperatures to 200° F.

PVDF (POLYVINYLIDENE FLUORIDE)
Because of its high density (specific gravity = 1.8). this strong, tough, abrasion-resistant fluorocarbon material resists distortion and retains its high physical properties over a broad temperature range, from -40 to 275° F. PVDF is inert to most acids, alkalies, and solvents, as well as chlorine, bromine, and other halogens. Its high hardness and low coefficient of friction recommend it for abrasion-resistant applications. In its natural state, PVDF is widely specified for ultrapure water, reagent-grade chemicals, and similar applications where freedom from contamination is important.

ECTFE (ETHYLENE CHLOROTRIFLUOROETHYLENE)
ECTFE is very similar to PVDF, but slightly superior in terms of broad chemical inertness, abrasion resistance, and use where fluid contamination cannot be tolerated. It offers excellent resistance to oxidizing acids, hydroxides, metal etchants, electroplating chemicals, and other aggressive fluids. ECTFE has superior barrier properties that minimize shedding. This makes it ideal for ultrapure water applications.

Recommended for temperatures to 275°F.

PTFE (POLYTETRAFLUOROETHYLENE)
Commonly referred to as Teflon®, this crystalline polymer is one of the most chemically inert and most expensive compounds available for industrial service. Although it has useful mechanical properties at temperatures as high as 500° F, when incorporated as a component material in plastic pumps, operating temperature of the other fluid contact parts tend to limit its use to 275° F. In addition, the physical properties of the material —relatively low tensile strength, wear resistance, and creep resistance —limit its usefulness.

FRP/GRP (FIBERGLASS/GLASS REINFORCED POLYESTER)
This group of thermoset materials consists of polyesters reinforced with glass or other fibers to provide high strength and impact resistance. Depending on the particular formulation, FRP/GRP composites resist a broad range of corrosive fluids at temperatures up to 230° F. Their application is more critical than the thermoplastics with respect to specific resistances of individual formulations, and their structure limits their use in abrasive applications.

ELASTOMERIC MATERIALS

A variety of flexible materials is required for proper function of pump components such as flexible liners, tubing, gaskets, and seals. When used in contact with the pumped fluid, they must combine the required chemical resistance with unique mechanical properties. Here is a brief review of those most frequently specified in conjunction with plastic pumps.

NATURAL RUBBER
This material offers satisfactory resistance to acids and alkalies as well as to oxygenated solvents. It has good abrasion resistance and may be successfully used at low temperatures. However, oxidizing acids will attack it, and it tends to absorb and swell in vegetable, mineral, and animal oils.

BUTYL RUBBER
Good resistance to corrosive chemicals and outstanding resistance to dilute mineral acids are offered by this synthetic elastomer. Unlike natural rubber, it provides resistance to vegetable and mineral oils. It is not recommended for use with petroleum solvents or aromatic hydrocarbons.

NORDEL®
This DuPont synthetic elastomer performs well at low and high temperatures and resists attack from a wide range of acids, alkalies, detergents, phosphates, ketones, alcohols, and glycol. It does not tend to absorb fluids or swell. Nordel is not suitable for use with aromatic hydrocarbons.

BUNA-N
This nitrile rubber has good resistance to acids, as well as alkalies. It is inert to aliphatic hydrocarbons, petroleum, and both mineral and vegetable oils. Buna-N has excellent water-swell resistance. Major limitations to its use are solvents such as acetone, methyl ethyl ketones, and chlorinated hydrocarbons.

NEOPRENE

Introduced by DuPont in 1932, this synthetic rubber provides excellent resistance to oils, greases, and many other petroleum products. Its use is limited, however, to non-aromatic hydrocarbons, and it will not withstand chlorinated solvents. Neoprene is widely used for its resistance to alkalies, dilute mineral acids, or inorganic salt solvents; but it is not suggested for acid and salt solutions that are highly oxidizing, or for contact with esters or ketones.

HYPALON®

The ability of this DuPont synthetic rubber to resist attack by oxidizing chemicals such as concentrated sulfuric acid and hypochlorite solutions, as well as its ability to withstand long term weathering, is well documented. Hypalon is especially useful in contact with oils at elevated temperatures and is recommended for use in a wide range of corrosive applications.

VITON®

This DuPont fluoroelastomer is unsurpassed for service in oils, fuels, solvents, and most mineral acids. It also resists most aliphatic and aromatic hydrocarbons such as carbon tetrachloride, toluene, benzene, and tylene. Viton is not recommended for low-molecular-weight esters and ethers, ketones, certain amines, hot anhydrous hydrofluoric, or chlorosulfonic acids.

KALREZ®

This is another DuPont fluorocarbon that plays a significant role in plastic pumps. It has the chemical and heat resistance of Teflon and the properties of an elastomer. Kalrez resists all classes of chemicals except the fluorinated solvents.

APPLICATIONS

As stated previously, sound material selection should be based on published data as tempered by actual experience. For example, a study of relatively high impeller maintenance by manufacturers handling liquids and slurries considered compatible with PVC and polypropylene revealed that substituting impellers made of fluoropolymers such as PVDF increased service life appreciably. In the erosive/corrosive slurries studied, it was found that where metal pump life was measured in weeks, PVC impellers showed double the life, impellers of poly-propylene extended it four to five times, and upgrading to PVDF impellers provided years of troublefree service.

Sometimes experience will demonstrate that economic advantages may be attained without affecting performance by downgrading the specified material. A glass product manufacturer pumping a corrosive/abrasive solution of hydrofluoric acid and a proprietary powder compound experienced repeated failures and high maintenance cost with horizontal centrifugal pumps of metal, and then with pumps of fiberglass reinforced polyester. A review of these early pump failures indicated that the major cause of these failures was impeller erosion. The company solved its problem by specifying pumps with all wetted parts of PVDF. Because the lower cost polypropylene material could also resist the corrosion, it was decided to specify future pumps with casings and casing covers of polypropylene. Only the impeller was specified in the higher-cost fluoropolymer. Initial costs for new pumps were lowered by downgrading from PVDF to polypropylene for the casing and casing cover only. Performance remained at the same high level.

Here's another case where the original material specification proved right for part of the system, but not all of it. Polypropylene vertical centrifugal pumps with cantilevered shafts were specified for a hot brine application. The material was indicated to be satisfactory for the nominal brine concentrations anticipated. In actual service, however, the brine concentration and the operating temperatures and pressures increased significantly towards the end of the processing cycle. The mechanical properties of polypropylene were stretched beyond their limits, deforming the bolts and clamping flanges of the pumps. In addition, the impellers were severely eroded by the concentrated brine. Thought was given to specifying titanium pumps to replace the plastic ones, but the cost was prohibitive. An economical solution to the erosion problem was found by substituting PVDF material for those polypropylene components in the hydraulic head. The pressure- and heat-related problems were solved by using PVDF for the bolts, clamping flanges, discharge pipe, and elbow. The vertical columns remained in polypropylene. The material upgrade to PVDF was made only in those pumps positioned near the end of the processing cycle, where the excess pressure and heat required greater strength and temperature resistance.

Bromine is an extremely corrosive chemical that attacks most metals, including the high nickel alloys. Even the nickel pumps that are sometimes used rarely last more than a couple of months. Maintenance problems are constant, and as the pumps age, repairs and related downtime become unbearable. Laboratory tests and field experience indicated that solid, virgin-grade PVDF was totally resistant to the bromine, so the vertical pumps designed for this service had to limit fluid contact to PVDF material. This included the casing, casing cover, impeller, column, bolts, nuts, and washers. The stainless steel shaft had to be sleeved in PVDF and welded to the PVDF impeller. Components exposed to the escaping fumes also had to be protected. This required a special shaft-sealing arrangement to retain the vapors within the sump or tank. It consisted of a PVDF stuffing box packed with woven PTFE. The underside of the CPVC cover plate was protected by a coating of PVDF material. In the longer pumps required for bromine service, the heavy weight of the chemical presented a mechanical problem. The pressure was too great even for the high strength of PVDF material used for the bolts and clamping flange. The bolts had to be specified in cast iron, and the clamping plates were made of steel. This solved the pressure problem, but it took some creative engineering to isolate the metal components from the bromine. Each cast iron bolt was encapsulated in ECTFE. Because the Acme threads of the bolts could not be protected in this manner, special PVDF sealing nuts were designed and used in conjunction with fluoropolymer internal O-rings, completely isolating and sealing the bolts and threads. The steel clamping plates holding the casing and casing cover were coated with 50 mils of ECTFE.

Plastics technology continues to extend the use of nonmetallic materials into many applications previously considered the exclusive domain of metals. We see it in automobiles, airplanes, home appliances, and just about every phase of daily life. It should not be surprising, therefore, to see the inroads plastics have made in connection with pumps, valves, and all aspects of fluid handling equipment. The high cost of maintenance and repair caused by corrosion and abrasion will continue to spur the use of plastic pumps.