TECHNICAL ARTICLE SERIES

Critical selection factors for thermoplastic pumps

ARTICLE # TL-132

INDUSTRY: General

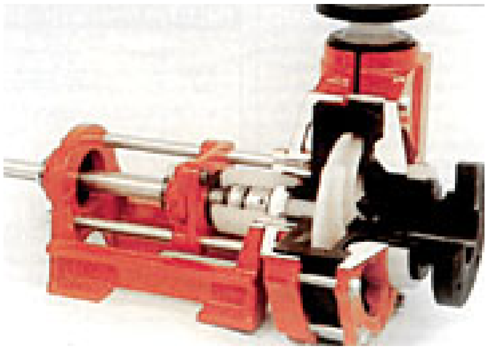
ENTITY: Various

SOLUTION(S) PUMPED: Various

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

Vanton Pump & Equipment Corp.
201 Sweetland Avenue
Hillside, NJ 07205 USA
Telephone: 908-688-4216
Fax: 908-686-9314
E-Mail: mkt@vanton.com
www.vanton.com

Vanton Pumps (Europe) Ltd
Unit 4, Royle Park
Royle Street
Congleton, Cheshire, UK CW12 1JJ
Telephone: 01260 277040
Fax: 01260 280605
www.vantonpump.com



A PVDF impeller in combination with a lower cost polypropylene casing provided a cost-effective, durable pump for handling a corrosive/abrasive hydrofluoric acid glass etchant.

Sanitary-design peristaltic pump handles liquid protein and water at a pharmaceutical company. The casing is made of ultra-high molecular weight (UHMW) polyethylene, and flexible liner of neoprene.

Critical selection factors for thermoplastic pumps

Reprinted from Chemical Processing
Dan Besic, Chief Engineer, Vanton Pump & Equipment Corp.

Non-metallics offer broad abrasion and superior corrosion resistance

Although the use of thermoplastic pumps has become so common that some designs are now being carried on the shelves in distribution stocks, for those applications involving highly corrosive or abrasive fluids, selection of the right pump and the materials of construction should be made with care.

A recent article by a group of engineers at Bechtel, San Francisco, CA, states, "Plastic has yet to realize its potential as a material of construction for the chemical process industries. The reason for this under-utilization is a lack of confidence in plastic, usually resulting from its misapplication."

Despite the fact that individual thermoplastics can tolerate a broader range of corrosive and abrasive conditions than metals, misapplication is certainly the major reason for pump failure.

The primary limitation on the use of thermoplastics is temperature.

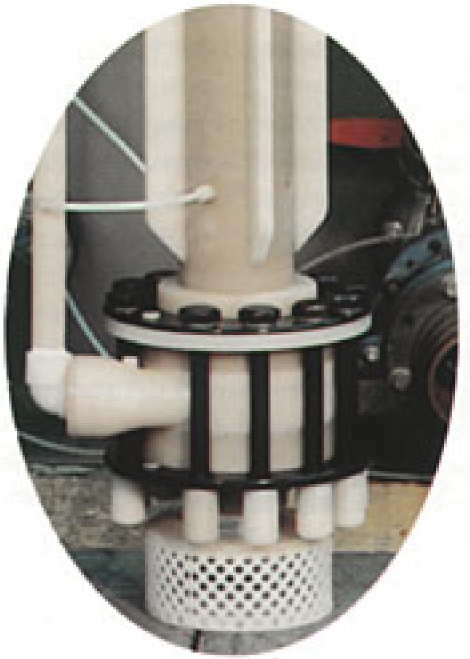
A good guide to upper temperature limits for those materials most frequently specified in thermoplastic pump construction is given in Table 1. For use at higher temperatures, complete data on the service conditions should be discussed with the pump manufacturer.

Because pumps are purchased for specified flow requirements and heads, these parameters present no problems. Pump manufacturers provide performance curves for their designs, and these can be readily checked against a user's requirements.

The most critical criterion is suitability of the material selected for the fluid to be pumped. This is particularly significant as corrosion and erosion directly affect maintenance, repair and downtime costs. In specifying or purchasing a plastic pump, it is important to make sure that all wetted components are made of the proper material.

Metals have a fixed rate of corrosion in any given fluid. These rates are listed in available handbooks. For many applications, the rate is so low that it is insignificant. However, where metallic corrosion is a factor resulting in excessive maintenance, expensive repair, pump failure, or product contamination, engineers ten to look closely at the selected materials. For many of these applications, stainless steel types 304 and 316 are standard.

Engineered thermoplastics compete favorably in price with stainless steel, and thus, their chemical inertness has become a major reason to consider them. With installations requiring high alloys or exotic metals, thermoplastics offer significant savings in both initial equipment costs and upkeep. With the precaution noted previously about temperature limitations, existing suitability tables for thermoplastics are a good place to start the evaluation.


The metal clamping plates holding the casing and cover were also coated with ECTFE. The threads were then protected with specially engineered PVDF sealing nuts.

There are many applications for which thermoplastic pumps are the only reasonable choice. These include handling such corrosives as bromine and strong oxidizing acids. Installations that cannot tolerate metallic contamination (e.g., ultrapure water, reagent-grade chemicals and pharmaceutical and electronics industry fluids) are also ideal candidates for thermoplastic pumps.

Another area where thermoplastic pumps are mandatory is the handling of waste streams with unknown chemical compositions or where the composition fluctuates across the full pH spectrum.

Table. 1. Recommended maximum temperatures for thermoplastics

Material	Max temp., °F
PVC (polyvinyl chloride)	140
PP (polypropylene)	185
PE (polyethylene)	200
CPVC (chlorinated polyvinyl chloride)	210
PVDF (polyvinylidene fluoride)	275
ECTFE (ethylene chlorotrifluorethylene)	275
PTFE (polytetrafluoroethylene)	275

The significant seven

Thermoplastics are so named because they are composed of linear molecular chains that flow over each other and separate when heated, then solidify into predetermined shapes upon cooling. They can be reformed without significant property change upon reheating.

Because of their homogeneous structure, thermoplastics offer high resistance or complete inertness to many aggressive fluids. They physical properties of the seven thermoplastics most frequently used for aggressive fluids are show in Table 2.

Common misconceptions

Manufacturers of plastics often attempt to convince the user that one brand or formulation is better than another, but the common perception that plastics are plastics still prevails. Just as there is a variation in the characteristics of individual metals, there are significant differences between one plastic and another, and between filled homogeneous and virgin materials. The pump manufacturer's selection of the material for each component is another important performance factor.

Although many people harbor the idea that all plastics are alike or very similar, or have had a bad experience with an off-the-shelf plastic pump in a difficult application and have ruled out the choice of a plastic pump, it is important to keep in mind the statement made by the Bechtel engineers about misapplication as the prime reason for plastic pump failure.

Table 2 clearly illustrates the differences among the seven most commonly used thermoplastics. Taken in conjunction with the temperature ratings for each material, they are a good guide to selection —but nothing is as significant as direct experience —the user and the pump manufacturer's.

A second misconception is that the use of plastic pumps can cut initial capital outlay. The "plastics are cheap" concept is a carry over from the Japanese toy syndrome of yesteryear. Consider the use of thermoplastic pumps for a given application because they may prove to be better in terms of eliminating corrosion, resisting abrasion, lowering maintenance and reducing spare parts inventory.

The perception that one might replace trouble-free metal pumps with "cheap" thermoplastic ones is not valid. Engineered thermoplastic pumps made of virgin, homogeneous molded and extruded shapes are quality products competitively priced with stainless-steel pumps.

Another misconception is that plastic pumps are simply metal pumps made out of plastics. This was true to some extent a number of years ago when pumps made of various thermoset materials were introduced. These fiberglass-reinforced polyester/glass-reinforced plastic (FRP/GRP) pumps are very similar to metal pumps in design and performance.

They can successfully handle many corrosive materials at temperatures to 250°F. Because of their composite fiber/resin construction, however, they are subject to absorption, wicking and bleeding out of the absorbed chemicals. This can cause contamination of the pumped fluid, as well as deterioration of pump components. They are severely limited for use with abrasive fluids.

Thermoplastic pumps, on the other hand, are not metal pump clones. They are engineered to take advantage of the unique characteristic of plastics. The use of molded shapes provides for smooth interior contours and surfaces, minimizing friction and turbulence.

Identifying plastic pumps, on the other hand, with metal pump characteristics can lead to troublesome and costly conclusions. A good example is the simplified L3/D4 ratio for shaft deflection. This abbreviated version of the full formula (Fig. 1) for shaft deflection used by mechanical engineers works well when comparing two metal pumps of similar materials.

When used to compare a metal pump with a plastic one, however, the lighter weight of the plastic impeller is not taken into consideration in determining the downward vertical force. Because a maximum ratio of 50 is preferred, the plastic pump is often not even considered for the application. Thermoplastic pumps, with the lightweight impeller and smaller diameter shaft, are frequently designated "not suitable" when the L3/D4 ratio is used, despite the many advantages they offer.

Thermoplastic pumps are engineered to take advantage of the unique characteristic of plastics. They use of molded shapes provides for smooth interior contours and surfaces, minimizing friction and turbulence.

Another common misconception is that plastics are for small pumps. It is true that many small pumps are specified in plastics, but thee is nothing small or lightweight about polypropylene thermoplastic sump pumps that stand 25 ft. tall and weigh more than 2,000 lb. that have been built for handling corrosive waste and stormwater runoffs, or the large 6 X 4 centrifugals that handle scrubbing liquids for hydrochloric acid fumes at large galvanizing and plating facilities.

Table. 2. Physical properties of pump thermoplastics

Material	Specific Gravity	Tensile Strength	Hardness R-Rockwell D-Shore	Impact Strength (IZOD)
PVC	1.30-1.58	6,000-7,500	R113	0.4-2.0
CPVC	1.49-1.58	7,500-11,000	R121	0.6
PP	0.902-0.910	4,000-5,500	R80-110	0.5-2.2
PE	0.925-0.940	3,500-4,500	R35-40	1.5-12.0
PVDF	1.75-1.78	5,560-8,250	D-80	3.6-4.0
ECTFE	1.68-1.8	6,500-7,500	D-75, R93	No break at 73°F
PTFE	2.14-2.20	2,000-5,000	D-50-55	3.0

Satisfied users

The fact is that hundreds of thousands of engineered thermoplastic pumps are now handling corrosive, abrasive, hazardous and ultrapure fluids in process lines, laboratories, transfer operations and an endless list of chemical, industrial, electronic and municipal waste applications.

Selected case histories below highlight some of the unusual applications associated with the unique characteristics of thermoplastic materials. They should make it clear that whenever there is a danger of corrosion or abrasion in the pumping of acidic, caustic, hazardous, toxic or noxious fluids, or those that cannot tolerate metallic contamination, thermoplastics should be considered.

Mobile unit for liquid protein

A large pharmaceutical manufacturer required a metering pump of sanitary design that could readily be taken to a variety of plant locations. Mobility was significant, so was the necessity of avoiding any metallic components in contact with the liquid protein. The engineers insisted on a thermoplastic material and a design that eliminated internal crevices, dead areas and threads where bacteria might hang up and multiply.

The answer was found with a skid-mounted lightweight peristaltic-type rotary pump with its casing made of ultra-high molecular weight (UHMW) polyethylene and its flexible liner made of neoprene. The interior surfaces of the pump casing were flame polished, and the suction and discharge quick-disconnect fittings were spin-welded into position to eliminate threads. Fluid traps and threaded connections were thus avoided.

Pumping is accomplished by means of a precision-molded phenolic rotor mounted on an eccentric shaft. The oscillating motion of the rotor against the inner surface of the flexible liner creates a progressive squeegee action on the liquid trapped between the outer surface of the flexible liner and the inner surface of the casing or pump body. Only the liner and casing contact the fluid. The pump is self-priming and sealless, with metering controlled by a variable speed drive motor.

Ultrapurity for hydrogen peroxide production

To assure maximum purity for the production of hydrogen peroxide, and international producer of this universal chemical decided to specify centrifugal pumps constructed of ECTFE.

Specifications for the centrifugal pumps called for this virgin, unpigmented, homogeneous fluoropolymer to be used for the casing, impeller and shaft sleeve. The seal rings were specified in VitonM fluoroelastomer, and the casing gasket in TeflonM PTFE. The rotating face of the mechanical seal was furnished in Teflon and the fixed face in ultrapure ceramic. External metal parts were to be epoxy coated. The pumps were required to handle 70% $H_2 0_2$ at 50 gpm against a total dynamic head of 80 ft at a temperature of 85OF.

Glass etching with HF

When metal horizontal centrifugal pumps failed repeatedly, causing high replacement costs and extensive downtime, a major manufacturer of decorative glass objects switched to thermoset pumps to handle the etching solution. This highly corrosive/erosive hydrofluoric acid (HF) and abrasive grit mixture proved destructive to the fiberglass-reinforced composite material, and severe production losses resulted. A decision was made to test an all-PVDF pump in this service because this fluoropolymer has superior abrasion resistance in addition to its resistance to HF.

The test installation was successful —but the high cost of the PVDF pump was a cause for concern. At a meeting between the pump manufacturer and the maintenance chief, it was decided to test a second pump, utilizing PP for the casing and flanges, and limiting the use of PVDF to the impeller, the part subject to the most erosion from the abrasive mixture. The compromise worked. As the other pumps in the system failed, they were all replaced by the customized thermoplastic design.

Fluoropolymers for bromine

Handling bromine, which rapidly attacks most metals, can be a major headache. In a case of sump pumps handing the corrosive halogen, the problem was solved by using polyvinylidene fluoride (PVDF) for all structural components in the pumps. The stainless-steel shaft was completely isolated from the liquid by a heavy sectioned PVDF sleeve, welded to a PVDF impeller.

To retain the hazardous bromine vapors, a specially designed PVDF stuffing box was packed with woven polytetrafluoroethylene (PTFE).

Because of the heavy weight of bromine (specific gravity = 3.11), solid PVDF casing and flange bolts would not be able to withstand the high pressures, so metal bolts had to be used. The exposed metal created a problem, which was solved by coating each of the metal bots with 50 mils of ethylene chlorotrifluoroethylene (ECTFE).

An overview

Engineered thermoplastic pumps are playing an increasingly significant role in the handling of fluids which aggressively attack most metals.

Because the choice of materials is relatively large, as it is with metals, it is important to understand how variations in composition and manufacture can affect performance. Additives are often incorporated to simplify molding or increase strength, and various pigments may be added to identify a particular type of material or the manufacturer.

For most applications, these additives prove helpful or harmless. Where ultrapure fluids are being pumped, however, or in applications which cannot tolerate any contamination, virgin, homogeneous, unpigmented thermoplastics are required.

Fig. 1. Full formula for shaft deflection.

$$Y = \frac{FL^3}{3EI} = \frac{FL^3}{3xEx0.049D^4}$$

Y = Maximum deflection
Y_1=Primary seal
Y_2=Secondary seal
F = Total downward force (W+Rt)
W=Impeller weight plus weight of shaft overhang
Rt=Radial thrust due to hydraulic force
L = Shaft overhang from front bearing to impeller
L_1=Shaft overhang to primary seal force
L_2=Shaft overhang to secondary seal force
E = Modulus of elasticity
I = Moment of inertia ($0.049D^4$)
D = Diameter of shaft at the seal face