



FOOD TECHNOLOGY FACT SHEET

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Sanitary pump selection

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Introduction

Sanitary pumps are used to transport and meter solutions, slurries, and colloids of food and agricultural materials in operations where cleanliness is desired or mandated. For example, many food processing plants use sanitary pumps. Identification and selection of a suitable sanitary pump can be difficult or confusing because many varieties and versions are available. This fact sheet is a guide for sanitary pump selection.

Mandatory sanitation standards vary for different products and depend on the regulatory agency governing processing activities, as well as the local or on-site inspector(s). There are also voluntary standards published by various organizations. The Food and Drug Administration (FDA) enforces the Food, Drug, and Cosmetic Act, as well as other standards. Good Manufacturing Practices (GMPs) were developed to establish criteria in determining compliance with the FDA standards, particularly in regard to the terms "sanitary" and "unsanitary." GMPs lack specificity when it comes to describing acceptable equipment, including sanitary pumps. This window permits interpretation and allows inspectors to account for the variables of time and conditions. Current GMPs for manufacturing, packing, or holding human food can be found in the Code of Federal Regulations (CFR), Title 21, Part 110.

The United States Department of Agriculture (USDA) has exclusive jurisdiction in the areas of meat, poultry and egg products. Regulations can be found under Title 9, CFR. In the past, the USDA has published a list of accepted processing equipment, but this service has ceased. Firms are expected to comply with GMPs and to work with the on-site inspector to determine suitability of fluid handling equipment.

The International Association of Food Industry Suppliers (IAFIS), McLean, Virginia, maintains 3A Sanitary Standards. This widely accepted voluntary standard provides criteria for the sanitary construction and installation of dairy processing equipment. The 3A Sanitary Standards can often be applied to processes other than dairy.

Classification of Sanitary Pumps

Sanitary pumps are classified as follows:

- Centrifugal
- Positive displacement
- Jet
- Airlift

These pump classifications are explained in detail below. Figure 1 is a decision tree for selecting the correct sanitary pump classification for a particular application. The decision tree includes only centrifugal and positive displacement pumps. The units for viscosity, given in Figure 1, are centipoise.

Centrifugal

The two main components of a centrifugal pump (Figure 2) are the rotating impeller and the stationary casing. The high-speed impeller produces liquid velocity, while the casing forces the liquid to discharge from the pump, converting velocity to pressure. The relatively simple design of these pumps makes them ideal for many sanitary applications. A list of products typically handled by centrifugal pumps is given in Table 1. Centrifugal pumps are well suited to applications involving variable flow rates. Their flow capacity can be regulated by throttling and by varying impeller speed. Throttling requires an adjustable valve in the discharge piping and provides one of the most inexpensive means of flow control. Drawbacks of throttling are an increase in system pressure and wasted energy.

Positive Displacement

Positive displacement pumps have an expanding cavity on the suction side of the pump and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands and is forced out of the discharge side as the cavity collapses. Figure 3 shows some of the variations of positive displacement pumps, including: (a) hose, (b) rotary piston, (c) rotary lobe, (d) internal gear, (e) diaphragm and (f) piston. The same principle of operation applies for each variation. A positive displacement pump, unlike a centrifugal pump, will produce the same flow at a given speed, independent of discharge pressure. A positive displacement pump cannot be completely throttled because it is operated against a closed valve on the discharge side. If complete throttling is attempted, it will continue to produce flow, increasing the pressure in the discharge line until either the line bursts, the pump is severely damaged, or both. The most practical means to control flow rate is to adjust component speed with a variable-speed drive. Table 2 lists products typically handled by positive displacement pumps.

Table 1. Products typically handled by sanitary centrifugal pumps.

<i>Industry</i>	<i>Product</i>
Bakery	Batter, liquid sponge systems, fats and oils, flavorings, sweeteners, yeast slurry
Beverage	Alcohol and wine, beer, wort, yeast, fruit drinks, soft drinks
Confectionery	Syrups
Dairy	Whey, cream, milk, sweetened condensed milk
Meat packing	Smokehouse spray, liquid fat, blood processing, frying oil
Other	Cleaning solutions

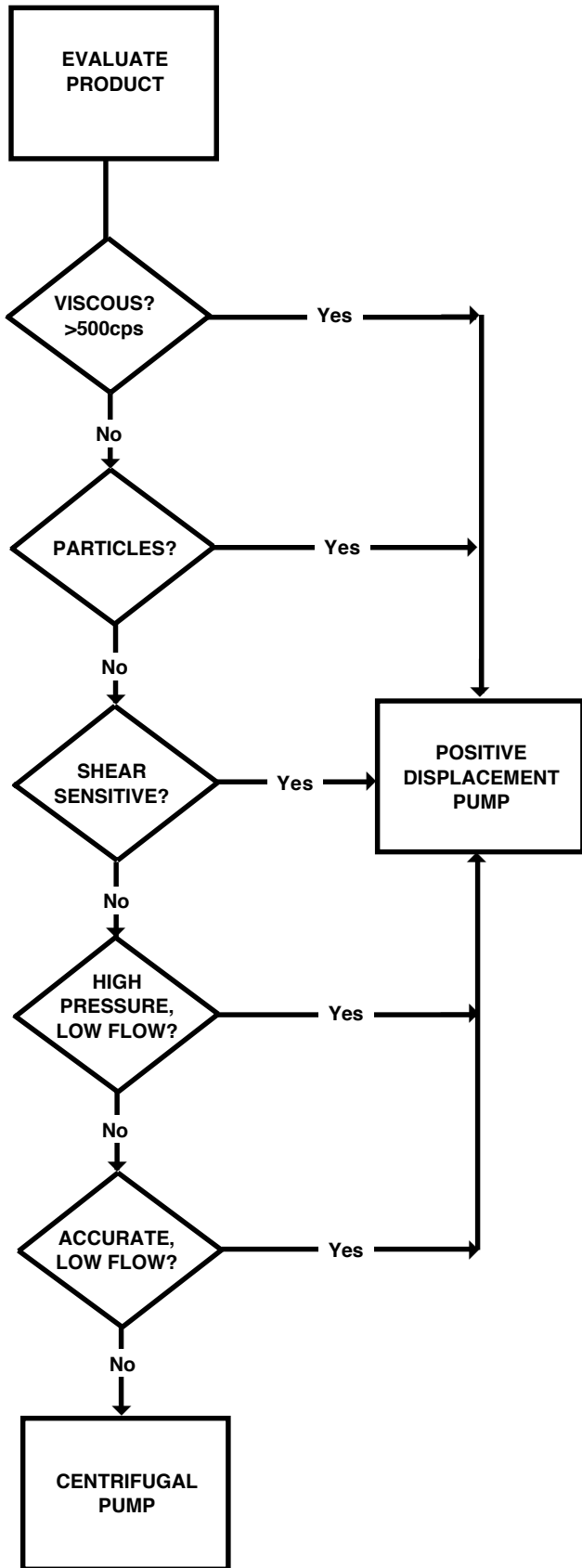


Figure 1. Decision tree for selecting sanitary pump classification.



Figure 2. Centrifugal pump. Lower inset shows impeller (Waukesha Cherry-Burrell).

Jet and airlift

Jet and airlift pumps are not as common in sanitary applications as centrifugal and positive displacement pumps. The jet pump (Figure 4) operates on the velocity energy of a fluid jet. The fluid is forced through a jet or nozzle so that all or nearly all of its energy is converted to velocity energy. The energy is directional and applied to the fluid to be moved. Jet pumps are frequently used for pumping sumps or process residues that contain solid matter or chemically active materials. When the jet is produced by a recirculated stream (as shown in Figure 4), the centrifugal pump must be protected from damage by solid particles in the fluid stream (Henderson, et. al. 1997).

An airlift pump is shown in Figure 5. It is not a pump in the strictest sense because it does not significantly alter the pressure or velocity head of the fluid in any practical degree. Air or other gas is delivered at the bottom of the lift pipe and mixes with the liquid. The air-liquid mixture, with lower specific weight than the liquid, rises in the pipe and is discharged at the point above the level of the liquid. This device can be used for elevating liquids that contain foreign materials or are corrosive. Twenty to 40 percent of the energy used to compress the gas is effective in elevating the liquid.

Sanitary Pump Selection Criteria

Application requirements in four areas must be identified to properly select a sanitary pump:

1. Process requirements
2. Product properties
3. Operational requirements
4. Cost

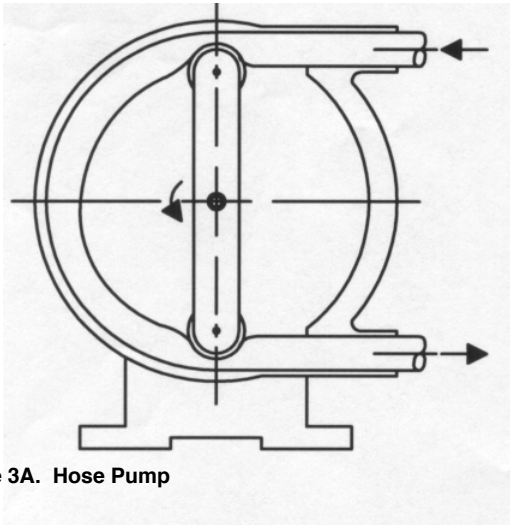


Figure 3A. Hose Pump



Figure 3D. Internal gear pump (Viking Pump).

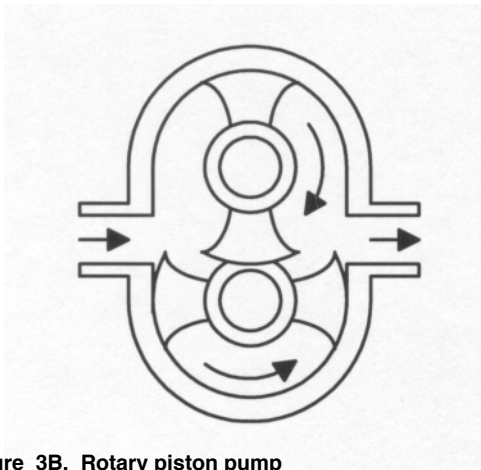


Figure 3B. Rotary piston pump



Figure 3E. Diaphragm pump (Graco, Inc.).



Figure 3C. Rotary lobe pump (Waukesha Cherry-Burrell).



Figure 3F. Air-operated piston, drum unloading pump (Graco, Inc.).

Table 2. Products typically handled by positive displacement pumps

Industry	Product
Bakery	Batters, flavorings, frostings, yeast slurry, liquid sponge systems, dough, fruit fillings, frying oil, cleaning solutions, sweeteners
Beverage	Flavor syrups, sweeteners, water, fruit drinks, alcohol, wine, fruit concentrates
Brewing	Beer, wine, crushed fruit, liquor
Canning	Baby foods, soups, tomato paste, fruit puree, puddings, jellies, salad dressings, mayonnaise
Confectionery	Chocolate, chocolate liquor, milk chocolate, cocoa butter, syrups, flavorings, fondant, cream fillings
Dairy	Fluid milk, cream, ice cream, cheese, yogurt, butter, juice, cleaning solutions
Food Processing	Fruit fillings, fats and oils, sweeteners, tomato base (paste, sauce and ketchup), cream-style vegetables, diced vegetables, slurries, puddings, salad dressings, gravy, mayonnaise, potato salad, baby foods, soups and stews, fruits and berries, citrus processing, syrups, cleaning solutions
Meat Packing	Emulsions, deboned meat, rendering operations, offal, blood, frying oil, prepared meat products, ground meat, fat
Other	Cleaning solutions

Process requirements

Process requirements define the information necessary to select a pump that meets the needs of production. Process factors that should be considered when selecting a sanitary pump are shown in Table 3.

A flow rate or range must be defined based on the present and future needs of the process. Conclude how many gallons per minute are required to empty the tank in the desired time or to provide enough product to satisfy the fill rate. A design flow rate fulfills the need of the process. The maximum flow rate is the most the pump can deliver as installed and under expected conditions. Maximum flow rate is considered for future expansion requirements or certain processing needs such as rapid product transfers.

Pressure rating of the pump is important. Factors to consider are rated pressure of the pump and piping, product sensitivity, and energy requirement. The pump manufacturer will specify the upper pressure limit for the pump. Sanitary piping systems are usually constructed of “schedule 5” tubing that is either welded together or employs clamp-type connections for disassembly, cleaning, and

connection to the pump. The upper pressure limit for the tubing and connectors ranges from 75 to 3,000 psi, depending on the connector style, product temperature, and installation and service conditions. In many systems, the pressure must be calculated for the given product, process conditions and piping arrangement. Assistance with this task can be obtained from the equipment supplier or vendor. Steffe and Singh (1997) provide an excellent resource for pipeline design for food products. Line size can be increased or decreased to control line pressure. It is customary to limit product flow rate to five feet per second

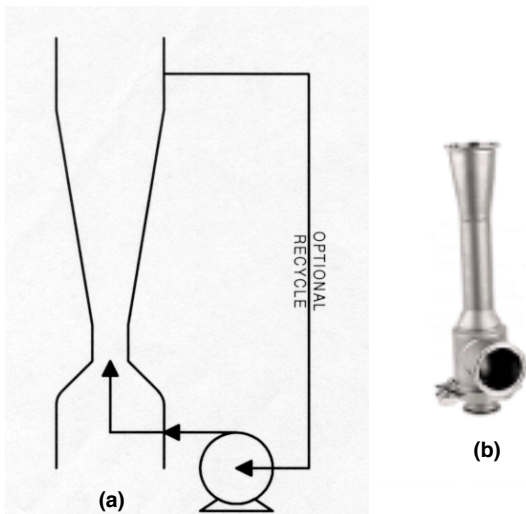


Figure 4. Jet pump (a) simplified schematic, (b) sanitary version (Tri-Clover, Inc.).

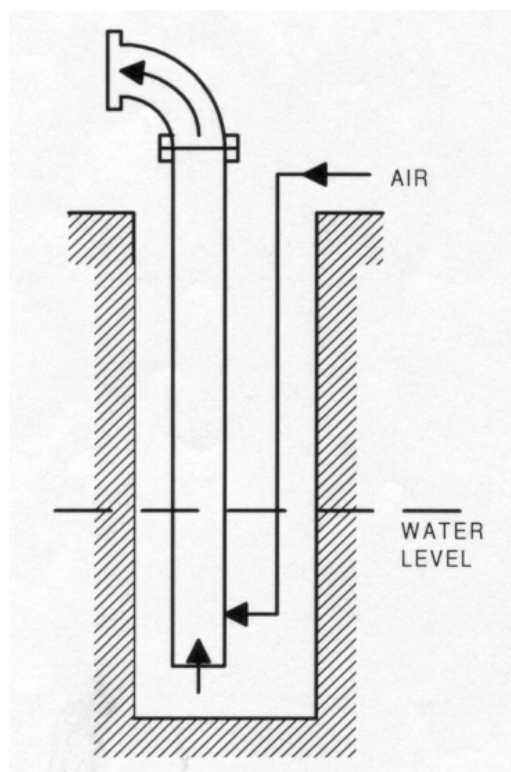


Figure 5. Airlift pump.

Table 3. Process requirements to consider when selecting a sanitary pump.

<i>Item #</i>	<i>Process Requirement</i>	<i>Value or Range (This column to be filled in by the reader)</i>
1	Maximum flow rate	_____
2	Minimum flow rate	_____
3	Design flow rate	_____
4	Pressure rating	_____
5	Sensitivity of product to shear	_____
6	Piping diameter	_____
7	Maximum temperature	_____
8	Minimum temperature	_____
9	Insulation required?	_____
10	Heated or cooled jacket required?	_____

or less. A minimum product flow rate may be specified to control product settling, temperature loss, or other physical phenomena.

Product Properties

Product properties provide the information needed to select the pump based on the characteristics of the pumped product. Table 4 lists product properties that may need to be considered.

The ingredient or product name is often the only item required to specify product properties because the behavioral properties of many foods are well known. In other cases, physical properties of the product may not be documented. If estimation is not possible or acceptable, laboratory measurements are needed.

Temperature of the product is important, since physical properties vary with product temperature. Further, many positive displacement pumps require extremely close tolerance between the impeller and casing. These close-fitting parts are designed to operate within a specified temperature range. If the range is exceeded, component expansion could damage the pump.

Viscosity is a measurement of resistance to flow and therefore is an important consideration in pumping applications. Product particle size information is required if particle integrity must be maintained or if the particles could interfere with the operation of the pump. Examples of particles are whole fruits, fruit pieces, meat chunks, noodles, nuts, and spices.

Information on chemical activity of the product is needed for specifying construction materials for the wetted pump parts. Handling highly acidic or caustic products and wash solutions may require stainless steel with low-carbon content (e.g., 316L) or other special material to prevent corrosion.

Shear sensitivity refers to the effect of the pump’s impeller on the product, caused by the “cutting” action of the impeller. Physical characteristics of some products will change after exposure to high shear. The product change may or may not be desirable.

Vapor pressure is the pressure in an enclosed area above the liquid product at equilibrium conditions. If the pressure in the pumping system is below the vapor pressure of the liquid, “flashing” will occur. Flashing is the vaporization of the liquid product into gas. The gas bubbles may eventually collapse when the system pressure increases. The phenomenon of bubble collapse is called cavitation.

Cavitation occurs most frequently near the pump impeller and can severely damage the pump. Melting and freezing points must be considered for products that could solidify during processing or processing downtimes.

Operational requirements

Operational requirements determine how the pump will be installed and operated in the plant. These requirements are summarized in Table 5.

Questions including the following list must be answered regarding the operation of the pump:

- What are the environmental conditions in the plant?
- How long (hours) will the pump be operated each year?
- Will the pump be cleaned by hand or automatically?
- What is the frequency of cleaning?
- Should the pump be controlled automatically or by hand?
- What is the desired range of speed for the pump?

Plant environmental conditions and available utilities are identified to ensure a safe and reliable installation. Environmental conditions are voltage level, hydraulic fluid or compressed air availability at the point of installation, ambient temperature range, wash-down or cleanup procedures, physical accessibility, and the presence of explosive vapors. Pumps are normally powered by electricity, pressurized hydraulic fluid, or compressed air. Pumps powered by compressed air and hydraulic fluids are normally less expensive to purchase, but require more energy to operate than electrically powered pumps. It is important to understand equipment cleanup procedures and to determine if hot, high-pressure water and strong chemicals will be used. If these two elements are present, the installation must be designed to withstand them.

A variable speed electric drive will provide pump speed control over a specified range. Speed adjustment for air and hydraulically powered pumps is accomplished via piping and valves. Fixed-speed, AC variable-frequency, and mechanically adjustable drives are available. When multiple fixed pump speeds are required for a particular pump installation, a fixed belt drive system may be the least costly approach. Mechanical, adjustable-speed drives are available, but initial cost and maintenance requirements are often higher than for

Table 4. Product properties to consider when selecting a sanitary pump.

<i>Item #</i>	<i>Product Property</i>	<i>Value</i> <i>(This column to be filled in by the reader)</i>
1	Ingredient or product name	NA
2	Minimum temperature	_____
3	Maximum temperature	_____
4	Design temperature	_____
5	Viscosity	_____
6	Particle size	_____
7	Specific gravity	_____
8	Chemical activity	_____
9	Abrasiveness	_____
10	Shear sensitivity	_____
11	Vapor pressure	_____
12	Melting point	_____
13	Freezing point	_____

Table 5. Operational requirements to consider when selecting a sanitary pump.

<i>Item #</i>	<i>Operational requirement</i>	<i>Value or Response</i> <i>(This column to be filled in by the reader)</i>
1	Voltage, hydraulic fluid, or compressed air available	_____
2	Ambient temperature range	_____
3	Wash-down procedures	_____
4	Physical accessibility	_____
5	Explosive vapors present?	_____
6	Annual hours of operation	_____
7	Manual or automatic cleaning	_____
8	Automatic or manual control (speed, on/off, flow rate)	_____
9	Speed (capacity) range	_____
10	Type of drive (fixed, mechanically variable, or variable frequency)	_____
11	Protection scheme (strainer, magnet, metal detector, pressure, current, or vibration sensor with control)	_____
12	Fixed or portable base	_____

variable-frequency drives. Because they are continuously variable, automatically controlled systems work best with variable-frequency, hydraulic and air-driven drives.

Protection of pumps is imperative, since sanitary pumps are expensive and pump failure results in costly downtime. Protection schemes include over-pressure, over-current, bearing-wear, run-dry, and contaminant protection. Run-dry conditions occur when the pump is operated without product. Over-pressure protection can be as simple as a spring-operated pressure-relief valve. A downstream pressure sensor (or current sensor on electric pump drives) combined with a controller can protect the pump from over-pressure and run-dry conditions. Current sensors may also be used to predict the failure of mechanical components such as bearings, seals, and drive parts. Vibration sensors are used to predict failure of mechanical components. Some pump designs are less susceptible to mechanical failure than others. Check with the pump supplier to determine protection requirements.

Protection of pumps from contaminants in the product stream is accomplished by using strainers, metal detectors, or line magnets. These devices are installed in the pipeline ahead of the pump. Strainers and line magnets can be installed in a duplex arrangement to facilitate operations. Duplex installations allow periodic cleaning and inspection of one protective device while the other, identical device, remains on-line. Figure 6 gives a schematic of a duplex strainer arrangement. Some pumps, by the nature of their design or type of contaminant expected, are immune to many types of contaminants in the product stream and may not require protection. For example, diaphragm pumps may not be damaged by metal particles.

Sanitary pumps can be mounted with drives on fixed or portable bases. Portable pumps optimize process flexibility and are ideal for situations where a pump or pumps are used on multiple lines that are not operated simultaneously. Portable pumps facilitate maintenance and cleanup. Whether fixed or portable, the pump base should be rugged and sanitary. Sanitary designation indicates that the pump base is easily cleaned and is free from ledges, cracks, and crevices that collect debris.

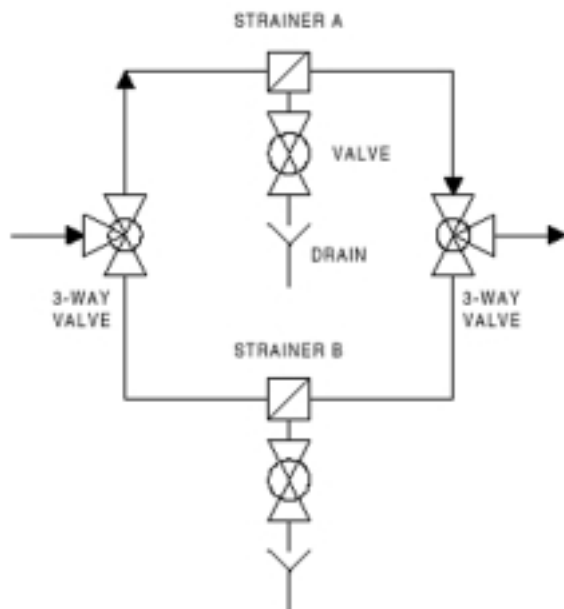


Figure 6. Duplex strainer arrangement with strainer "A" shown active.

Cost

Expense is a major criterion in the selection of sanitary pumps. Sanitary pumps are inherently expensive due in part to special construction materials and stringent cleaning requirements. Costly, corrosion-resistant materials (such as stainless steel) are specified for product contact areas. Product contact surfaces must be cleanable and smoothly polished. Quick-change fasteners, flanges, and gaskets are incorporated to facilitate disassembly for cleanup. Components are usually simple and designed to be extremely rugged to withstand constant disassembly for the cleanup procedure. Finally, sanitary pumps must be reliable because pump downtime translates to costly production downtime. Exotic construction materials, special surface finishes, quick-change parts, ruggedness, and reliability all contribute to increased cost.

Maintenance and operation costs of a pump should be considered when comparing pump alternatives. Lower initial pump costs do not always result in increased savings. An air-driven pump, for example, is more expensive to operate than a pump driven directly by an electric motor. Compressed air is expensive to provide both in terms of maintenance and energy requirements.

Conclusion

Selecting pumps for sanitary systems can be a complicated task. Physical characteristics of products to be pumped are often unavailable and difficult to estimate. The problem is further compounded when portable pumps are used for a variety of products with diverse characteristics and pumping requirements. In addition, the number of choices can be overwhelming. Food Engineering's Food Master 2000 database (Cahners, Radnor, PA) lists more than 75 manufacturers under the heading "Pumps, Sanitary." Table 6 provides a listing of some pump manufacturers. The listing is informational and is not an endorsement of any particular equipment or supplier. For additional information on selecting and purchasing food processing equipment, see the OSU Extension Fact Sheet FAPC-102, *Selecting and Purchasing Food Processing Equipment* (1999).

A goal of process design is to reduce expense and maintenance – including pumping requirements. Designing a system that makes use of gravity for product transfer can reduce pumping requirements. Combining operations in a single vessel can also be used to reduce pumping requirements. For instance, a single vessel may be used to cook and cool product. Another method used to reduce the need for mechanical pumping is pressure pumping. Pressure pumping uses the vessel as a pump cavity. The headspace of the vessel is pressurized with a clean, product-compatible gas, such as filtered air or nitrogen. The gas pressure forces the product to its required destination. A drawback of the pressure method is the higher cost of pressure-capable vessels.

In summary, the production process should be designed to minimize the use of pumps. Sanitary pumps should be selected carefully with regard to regulatory standards and the requirements given in the four application areas previously listed. Where possible, visit similar processing establishments to learn what works for others. Talk to suppliers and investigate the used equipment market and the cost of replacement and spare parts. Consider long-term, as well as short-term, costs of pumping systems when making a purchase decision. A properly selected, installed, and maintained pump will provide many years of service and one less distraction for busy operators and managers.

Table 6. Selected sanitary pump suppliers.

APV Fluid Handling Americas

100 South CP Ave.
Lake Mills, WI 53551
Phone: (920) 648-8311
Fax: (920) 648-1441
Comment: Centrifugal, positive displacement and specialty pumps
www.apv.com

Bran & Luebbe, Inc.

1025 Busch Pkwy.
Buffalo Grove, IL 60089-4516
Phone: (847) 520-0700
Fax: (847) 520-0855
Comment: Positive displacement and piston pumps

Fristam Pumps, Inc.

2410 Parview Rd.
Middleton, WI 53562-2524
Phone: (608) 831-5001
Fax: (608) 831-8467
Comment: Centrifugal, positive displacement and specialty pump
www.fristampumps.com

G & H Products Corp.

8201 104th St.
Pleasant Prairie, WI 53158
Phone: (414) 947-4700
Fax: (414) 947-4724
Comment: Centrifugal, positive displacement, and specialty pumps

Graco Inc.

PO Box 1441
Minneapolis, MN 55440-1441
Phone: (612) 623-6743
Fax: (612) 623-6580
Comment: Specialty piston pumps (drum and bulk unloading)
www.graco.com

Marlen Research Corp.

9202 Barton St.
Overland Park, KS 66214-1721
Phone: (913) 888-3333
Fax: (913) 888-6440
Comment: Two-piston, hydraulically operated pumps
www.marlen.com

Moyno Industrial Products, a unit of Robbins & Myers, Inc.

PO Box 960
Springfield, OH 45501
Phone: (937) 327-3182
Fax: (937) 327-3177
Comment: Progressive cavity pump
www.moyno.com

Seepex, Inc.

511 Speedway Dr.
Enon, OH 45323
Phone: (937) 864-7150
Fax: (937) 864-7157
Comment: Progressive cavity pump
www.seepex.com

Sine Pump Sundstrand Fluid Handling

14845 West 64th Ave.
Arvada, CO 80007
Phone: (303) 425-0800
Fax: (303) 425-0896
Comment: Positive displacement pumps

Tri-Clover Inc.

9201 Wilmot Rd.
Kenosha, WI 53141-1413
Phone: (414) 694-5511
Fax: (414) 694-7104
Comment: Centrifugal, positive displacement and specialty pumps
www.triclover.com

Viking Pump, Inc., a unit of IDEX Corp.

PO Box 8
4th & Geber
Cedar Falls, IA 50613-0008
Phone: (319) 266-1741
Fax: (319) 273-8157
Comment: Positive displacement pumps
www.vikingpump.com

Warren Rupp, Inc., a unit of IDEX Corp.

PO Box 1568
Mansfield, OH 44901-1568
Phone: (419) 524-8388
Fax: (419) 522-7867
Comment: Air-operated diaphragm pumps
www.warrenrupp.com

Watson-Marlow Bredel

220 Ballardvale St.
Wilmington, MA 01887
Phone: (978) 658-6168
Fax: (978) 658-0041
Comment: Peristaltic pumps
www.watson-marlow.com

Waukesha Cherry-Burrell

2300 One First Union Center
301 South College St.
Charlotte, NC 28202
Phone: (800) 252-5200
Fax: (800) 252-5012
www.gowcb.com

Wilden Pump & Engineering Co.

22069 Van Buren St.
Grand Terrace, CA 92313-5651
Phone: (909) 422-1730
Fax: (909) 783-3440
Comment: Air-operated diaphragm pumps
www.wildenpump.com

References

Bowser, Tim. 1999. Selecting and Purchasing Food Processing Equipment. OSU Food Technology Facts, FAPC-102. Oklahoma State University Cooperative Extension Service, Stillwater, OK.
Henderson, S.M., R.L. Perry and J.H. Young. 1997. Principles of Process Engineering. American Society of Agricultural Engineers, St Joseph, MI.

Steffe, J.F. and R.P. Singh. 1997. Pipeline Design Calculations for Newtonian and Non-Newtonian Fluids. In Handbook of Food Engineering Practice, K.J. Valentas, E. Rotstein, and R. Singh, editors. CRC Press, NY.