SECTION 9.9

FOOD AND BEVERAGE PUMPING

JAMES L. COSTIGAN
JOHN DRANE

INDUSTRY STANDARDS

Pumps for use in food, beverage, and pharmaceutical industries must meet various hygiene standards. These standards define the materials of construction and the "cleanability" of the pump. Unlike other industrial applications, pumps for the food and beverage industries must meet rigid sanitation codes, know in the industry as the "3-A" Standards*. These standards were originally established for the dairy industry by the following organizations:

1. The International Association of Milk, Food, and Environment Sanitarians.
2. The U.S. Public Health Service.
3. The Dairy Industry Committee, composed of representatives from the following:
   - American Butter Institute
   - American Dry Milk Institute
   - Dairy and Food Industries Supply Association
   - Evaporated Milk Association
   - International Association of Ice Cream Manufacturers
   - Milk Industry Foundation
   - National Cheese Institute
   - National Creameries Association

*Available from the International Association of Milk, Food and Environmental Sanitariums, Box 437, Shelbyville, IN 45176.

In the U.S., the 3A standards are widely enforced. They are recognized internationally, but are not enforced to the same degree. The 3A standards are a self-certifying standard, and they consider design and construction features only. They do not require microbiological testing for cleanability.

In Europe, the "Supply of Machinery (Safety) Regulations" (1992) defines the safety and hygienic requirements for equipment to be used on agri-foodstuffs. This is legislative and is not a voluntary standard. Compliance with these regulations enables the CE Mark to be attached to the machine. Non-compliance means machines cannot be sold within the European community (EC). The European Committee for Standardization (CEN) will produce a standard (TC 197) for pumps for food use, in support of the "Machinery Regulations" that will eventually form the controlling standard for all pumps designed for food use in the EC.

An independent group, formed mainly from users of sanitary equipment (European Hygienic Equipment Design Group—EHEDG), has produced guidelines for all types of equipment, including pumps. This group acts in an advisory capacity to CEN and other standardization bodies. These guidelines are generally very onerous, but they are often specified by end users of hygienic equipment.

The principle requirements of hygienic pumps are that the wetted parts should be compatible with the products being pumped, and that the pump can be easily cleaned, either by dismantling or by clean-in-place (C.I.P.) processes. Externally, the pumps should be smooth and free from crevices where dirt could lodge and bacteria or insects could flourish.

Emerging standards issued by the American Food and Drug Authority (AFDA) and European Directives based on these standards specify suitable materials for contact with foodstuffs. They also define any restrictions that may apply to them and test methods to prove compliance. These standards are recognized internationally and are widely used.

PUMP DUTIES

Pumps are used for filling, emptying, transferring, dosing and mixing. They are also used to convey the process fluid through plant items with a high resistance to flow, such as membrane filters and heat exchangers. In general, pumping should not harm any solids in the liquid, and delicate shear-sensitive products must be handled gently. The choice of a particular pump depends on consideration of a number of factors. These include capacity, delivery pressure, and suction conditions. The calculation of system pressure losses is discussed in Section 8.1.

It is important to consider the viscosity of the liquid at the actual shear rate and temperature appropriate for the system. Newtonian liquids have a constant viscosity with shear rate (for example, glucose). Nonnewtonian liquids such as tomato ketchup have a viscosity that is dependent on shear rate. Some liquids become less viscous with increasing shear rate; these liquids are called *thixotropic.* Examples of a thixotropic liquid are starch and molasses. Others, less commonly, become more viscous with increasing shear rate; these liquids are called *dilatant.* An example of a dilatant liquid might be some candy compounds. Most liquids also become less viscous with increasing temperatures.

The fact that viscosity changes with shear rate and temperature means that a careful assessment must be made of all fluids that we intend to pump. This assessment would normally produce three values of viscosity that must be considered in the pump and system design.

1. Viscosity in the storage tank (low shear)
2. Viscosity in the pipe work (medium shear)
3. Viscosity in the pump (high shear)

A shear-sensitive material, which will degrade with work, would normally need a positive displacement pump with low shear characteristics, pump speed being selected accordingly. If solids in the product are not to be damaged, a pump with suitable-sized spaces and cavities must be selected. In some cases, high shear rates will be advantageous to the process (for example, mixing of emulsions) and the pump and system can be selected accordingly.

The chemistry of the liquid will determine the compatibility of the pump materials. The viscosity of the process fluid and its rheological properties affects both the speed at which the pump can run and also the friction losses to be expected within the system. The friction losses will affect the power required to run the pump. Generally, the more viscous a product, the slower the pump will need to run. If the product is very viscous, larger suction piping may be required, or in some cases, special enlarged inlets are used with auger assistance.

If the product is abrasive or carries hard solids in suspension, again pump speed will often need to be reduced to give economic life to pump components. Often, pumps with resilient components or those that do not have fixed clearances are better suited for this service. If, however, the solids in suspension are liable to settle at low speeds, speed must be increased to keep the solids in suspension to protect component life.

The product temperature may affect the suction performance capability of the pump. Also, for high fluid pumping temperatures, the pump and pumping elements must be selected to take account of differential expansion or contraction resulting from temperature variations. In some cases, pump performance is limited because of liquid properties.

PUMP TYPES

Food and beverage pumps are divided into two generic types: rotodynamic and positive displacement. Both types are widely used in the food and beverage industries.

Rotodynamic Pumps Rotodynamic (centrifugal) pumps are widely used in hygienic applications (Figure 1) because they are simple and inexpensive, they give a smooth delivery, and they are relatively easy to clean. They are, however, limited by viscosity that will greatly reduce pump efficiency above about 500 centipoise, generally regarded as the limiting viscosity. As the pumps rely on speed of rotation to generate head, there are fairly high shear rates within the pumping elements that affect shear-sensitive products. Also, because it is not self-priming, it has a limited ability to handle entrained gases and vapors. A positive feature of centrifugal pump designs is that the performance varies according to the system operating conditions to which it is subjected. Unlike a positive displacement pump, the discharge of a centrifugal pump can be partially or fully closed without over-pressurizing the pump.

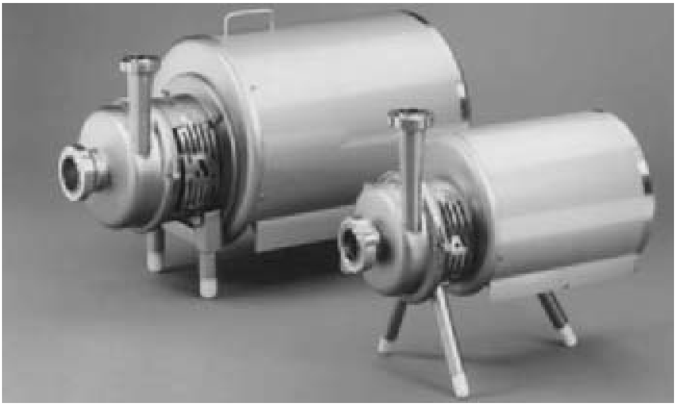


FIGURE 1 Hygienic centrifugal pump (APV Fluid Handling)

ADVANTAGES These pumps are simple; they are of generally robust construction; pumps are easy to clean in place; pumps cannot be over-pressurized against a closed valve; they can be connected in series for increased pressure; and they can be connected in parallel for increased flow.

DISADVANTAGES These pumps typically are not self-priming; they are generally limited to about 500 centipoise viscosity; they are limited ability to handle fluids that are shear-sensitive; and they have a limited ability to handle high percentages of entrained gases.

Positive Displacement Pumps Positive displacement pumps are used in processes where viscosity limits the capabilities of a centrifugal pump or where the process needs to be versatile and the batches vary. They are normally self-priming and can handle gaseous products. However, all positive displacement pumps require pressure relief systems to prevent damage to the pump or system if a valve is closed or the outlet blocked.

Many types of positive displacement pumps are available and they are normally split into two groups—rotary and reciprocating, the reciprocating type needing a valving system to be able to operate. Valves increase shear rates and are susceptible to wear and blockage.

Gear Pumps

ADVANTAGES These pumps are self-priming; there is uniform discharge with little pulsing; the pumps are reversible; due to small clearances, little flow variation with change of viscosity or pressure.

DISADVANTAGES They can only pump clean fluids due to fine clearances and rubbing gear teeth; they cannot run dry; they need close tolerances to operate, so fits and alignment are critical.

Lobe Rotor Pumps (Figure 2)

ADVANTAGES These pumps can run dry for short periods as rotors have clearance, but run-dry time is limited by the seals; pumps can self-prime on low lifts; pumps can handle solids in suspension; there is little change of product velocity as it passes through the pump, so the pump has good net positive suction head (*NPSH*) performance, once primed; pumps can generally handle viscous materials; pumps are usually reversible.

DISADVANTAGES Fixed clearances can mean rapid performance degradation because of abrasive wear; pump has two shafts and associated shaft seals; suction lift limited at low speed/viscosity due to clearance of rotors.

Flexible Impeller Pumps (Figure 3)

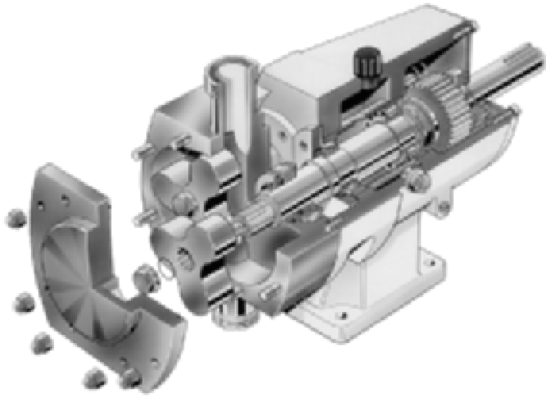
ADVANTAGES Pumps are generally self-priming; pumps create relatively low pressure pulsations while pumping; pumps are reversible; pumps can handle gaseous fluids and fluids with some solids in suspension; pumps are easily cleaned.

DISADVANTAGES Pumps cannot run dry; pumps are only suitable for low pressure applications; pumps are not suitable for abrasive services.

Progressive Cavity Pumps (Figures 4 and 7)

ADVANTAGES These pumps are self-priming; they exhibit uniform discharge with little pulsation; they are reversible and can handle gaseous fluids; they can handle solids in suspension and abrasives and can handle shear-sensitive fluids with little damage.

DISADVANTAGES The pumps cannot run dry.



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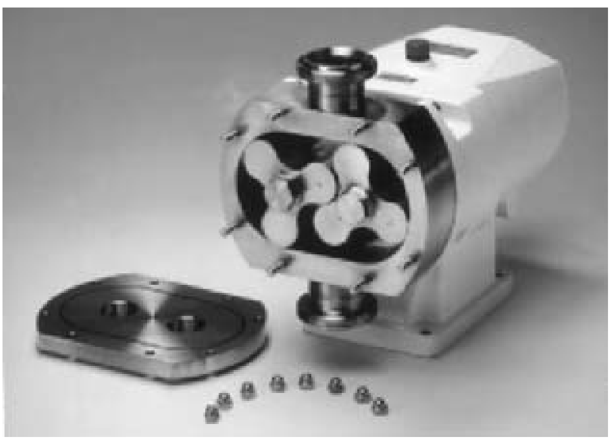

B

C

FIGURE 2A through C Rotary lobe pumps (Alfa Laval Pumps, Ltd.)

A

B

FIGURE 3A and B Flexible impeller pumps (ITT/Jabsco).

A

B

FIGURE 4A and B Hygienic progressive cavity pumps (Mono Pumps, Ltd.)

FIGURE 5 Hygienic peristaltic pump (Watson-Marlow, Ltd.)

Peristaltic Pumps (Figure 5)

ADVANTAGES Pumps are self-priming; they can run dry and are reversible; they can handle gaseous fluids and can pump abrasive material and solids in suspension; they have only one contact part with no seals.

DISADVANTAGES Tube failure means loss of product; at low rotational speeds, pulsation can be a problem.

Piston Pumps

ADVANTAGES Pumps may be used for very precise dosing; pumps can handle high pressures.

DISADVANTAGES Pumps are not reversible; they need valves to operate; and they generally have pulsing flow.

Diaphragm Pumps

ADVANTAGES Pumps can run dry for short periods; they are fairly easily cleaned; and they have no glands.

DISADVANTAGES Pumps are not reversible; they need valves to operate; and they have pulsing flow.

Mechanical Seals Pumps in the food and beverage industries are almost totally fitted with mechanical seals (see Figure 6). These seals must be simple in construction and designed in such a way as to facilitate cleaning. Cleaning in place (C.I.P.) is a frequent requirement, and mechanical seals for these pumps are specifically designed for this purpose.

FIGURE 6 A hygienic mechanical seal (Roplan, Ltd.)

A

FIGURE 7A through C Typical installations of a progressive cavity hygienic pumps (Mono Pumps, Ltd.)

Pump Drives Standard electric motors, usually totally enclosed and fan-cooled, are used throughout the industry. A stainless steel casing is sometimes used to enclose the motor and simplify external cleanability. Pump units must be either grouted to the floor or mounted at least 2 in (50mm) above the floor to enable cleaning and eliminate any build-up of debris.

Figures 7A, B and C show typical installations of progressive cavity hygienic pumps.

B

C