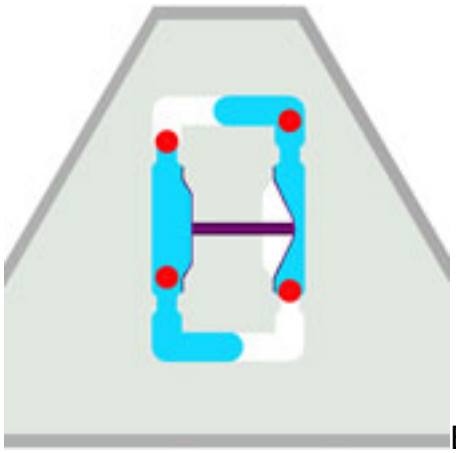
Take Control of Your Operations



By ANDREAS KNEER

Plastic pneumatic diaphragm pumps are used widely in chemical, semiconductor and pharmaceutical applications, as well as other industries that require sanitary operating atmospheres. These types of pumps are ideal for these applications because of their almost universal chemical resistance—since they utilize housing materials constructed of PTFE (polytetrafluoroethylene) and conductive PTFE—and high wear resistance—thanks to housing materials that use PE (polyethylene) and conductive PE.

With the increasing degree of automation found in plant construction and operation, functional reliability is playing an enhanced role with respect to the total cost of a plant. Therefore it is crucial that the right components contribute to a plant's operation (for example, comparatively low-cost pumps that are small, but effective) as unscheduled plant shutdowns that result in production downtime quickly accumulate into high costs that disturb the value-creating process and have a negative effect on the overall bottom line.

The Challenge

Finding the proper pump for a specific production process requires a lot of legwork. Different pump modes of operation must be considered—from positive displacement to centrifugal to peristaltic, for example—along with workload, flow rates, working pressures, and on and on and on.

One style of pump to be considered for chemical, pharmaceutical or semiconductor operations is pneumatic diaphragm pumps. These types of pumps are commonly used in static-fluid energy machines that are characterized by energy conversion in an enclosed working space with periodic energy transfer. Appropriate to their mode of operation, these pumps are classified as lift-displacement machines. Features of pneumatic diaphragm pumps are a gentle product displacement, dry-running and overload-proof operation, self-priming, insensitivity to solids, infinite variability and

easy-to-operate functions.

One key to pump efficiency is its ability to provide a uniform delivery flow. In order to achieve this uniform flow rate, along with design-related, low-residual pulsation, pneumatic diaphragm pumps are usually designed as externally circulated double-diaphragm pumps (Figure 1). This means that two identical diaphragms are arranged opposite of each other, with each separating the air chamber from the product chamber, while they are interconnected by means of a piston rod.

The pressurized “drive air” that is created by the pump’s operation flows into the chamber behind a diaphragm. To enable the pump to perform its working stroke, the introduced compressed air must overcome the internal friction of a pump (static/sliding friction on the sealing and bearing elements) and the diverting forces of the diaphragms, as well as the product-sided back pressure. The continuous flow of drive air causes the pressure behind the membrane to increase until the counteracting resistance forces are overcome. The diaphragm then displaces the medium from the decreasing product chamber and performs its working stroke. This forces the medium that is being transported to be pushed out of the pressure side. To ensure adequate operation, the diaphragm is pressure balanced during the delivery stroke.

Meanwhile, the opposite diaphragm, which is connected via the piston rod, moves in synchronism toward the stroke-performing diaphragm. The expanded air behind this diaphragm is allowed to escape. The medium then enters the enlarging product chamber on the suction side, allowing the diaphragm to perform its suction stroke.

The crux of this pneumatic double-diaphragm design dictates that maximum delivery volume and the maximum possible delivery head (i.e. back pressure) are the main parameters of the pump’s operation. The dimensioning of the necessary wall thickness, product passage cross-sections and valve lift grow out of these design parameters. Therefore, the delivery volume of pneumatic diaphragm pumps can be influenced via the form and dimensions of the displacement chamber, the volume-changing kinematics (or diaphragm stroke) and the number of working strokes per unit of time.

Additionally, the design of the product chamber and determination of the diaphragm stroke are aimed mainly at achieving a long diaphragm life. Ideal dimensions are large diaphragm diameters combined with small diaphragm strokes. The geometrically optimized design of the air or product chamber for the minimization of dead volume in the respective final diaphragm position positively influence the pump’s efficiency.

The number of maximum possible working strokes (in addition to drive and back pressure), depends on the air passage volume to be filled behind the diaphragms. The dimensioning of the air passages is an optimization task. On one hand, this volume should be kept to a minimum in order to avoid unnecessary dead volume. On the other hand, the air passage cross-sections within the pump and the air-control system must be dimensioned for the expanded, pressure-less air, as this takes up a larger volume than the pressurized drive air. The expanded air behind

the diaphragm performing the suction stroke must be able to escape quickly enough to prevent the entire system from being slowed down by an inefficient “air cushion.”

Because of the pump’s designed-in internal flow reversal, pneumatic diaphragm styles require a control that provides the diaphragms with an alternating supply of compressed air. In modern combustion engines, injection systems distribute the fuel/air mixture to the individual cylinders. Analogous to this example, air-control systems in pneumatic diaphragm pumps alternately introduce pressurized air into the air chambers behind the diaphragms, or discharge the expanded air to the silencer.

A distinction can generally be made between two types of air-control systems:

- Direct
- Indirect

Direct air-control systems are characterized by the fact that the distance of the control travel by the pilot piston corresponds to the diaphragm stroke. In other words, direct air-control systems are normally used in small sizes (piston rod=pilot piston) and are arranged centrally between the diaphragms.

With indirect air-control systems, by contrast, the travel distance of the pilot piston does not correspond to the diaphragm stroke. The pilot piston is controlled only during the last millimeters of the diaphragm stroke. The air-control system is also arranged between the diaphragms, and the piston rod and pilot piston are two entirely different components. (Figure 2).

The Solution

Air-control systems operate under extreme conditions. They switch up to 10 cycles per second, are subject to pressure differences of up to 7 bar, come into contact with chemically aggressive atmospheres, depending on the pump application, and must be absolutely reliable and maintenance-free for the above described reasons.

The requirements are met only by precision controls such as the pneumatically piloted PERSWING P® air-control system.

In order to achieve high-reversing frequencies, the pneumatically piloted PERSWING P® air-control system makes use of two compressed air properties:

- High flow rates
- Small mass

The PERSWING P® air-control system has only two moving components (the main and pilot pistons) and is a 5/2 way valve (Figure 3) and consists of only four different, completely metal-free components (Figure 4). The pilot piston controlled

by the diaphragm opens and closes via control edges. Air passages below the main piston alternately apply compressed air to the left or right side downstream of the main piston. This pneumatically switches in a horizontal direction, alternately supplying the diaphragms with compressed air or discharging the expanded air.

The position of the pilot piston control edges with respect to the piston rings in the main piston is geometrically designed, so that the air control is always clearly defined and independent of the position of the main piston and pilot piston with respect to each other (during pump operation or after shutdown of the unit). The PERSWING P® air-control system is without dead center and, therefore, fulfils the most important criterion relating to an air-control system for pneumatic diaphragm pumps.

In the case of internally circulated pneumatic diaphragm pumps (which have been specially developed for the semiconductor industry), the air-control system is not arranged between, but next to, the diaphragms. The result of this design is a minimal number of surfaces that can be contacted by. This eccentric arrangement of the air-control system was previously directly operated within older pumping units.

This is where the newly developed, pneumatically piloted PERSWING P® air-control system, with a built-in “drag system,” comes into use (Figure 5, page 4). The pilot piston is decoupled from the full diaphragm stroke and, like an indirect air-control system, is initially “carried along” toward the end of the diaphragm stroke. Analogous to this, the main piston control’s travel distance, which depends on the pilot piston travel, reduces. The advantage is an optimization of the air-sided dead volume, as less volume is filled with compressed air, and less expanded air must be discharged to the silencer.

In contrast to other air-control systems with vertically arranged main pistons, the position of the main piston of the PERSWING P® air-control system is always clearly defined after pump stoppage from any operating point, as the main piston does not need to fall back into an “initial position” by the force of gravity (which makes them susceptible to faults as the main piston can stick in this arrangement and not reach its necessary initial position).

The control-valve housing, the two caps, as well as the main and pilot pistons are made of PETP (polyethyleneterephthalate). PETP is a plastic with high strength, rigidity, form and dimensional stability. PETP is also characterized by favorable sliding and wear properties. On account of the very good machinability of PETP, the narrow tolerances necessary for sealing purposes can be adjusted with the associated surface quality.

Sealing of the air passages between the main and pilot pistons takes place with the aid of piston rings. Because sealing points at components that move relative to each other are always subject to friction, the main point in addition to minimizing the static and sliding friction coefficients, is to also positively influence the wear behavior. This is also an optimization process.

On the one hand, the piston rings must be capable of exerting sufficient sealing force in order to prevent leakages. On the other hand, the sealing force must not be excessive, as this would increase the internal friction, which expresses itself in unnecessary wear and heat development.

The PERSWING P® air-control system is provided with piston rings of a PTFE compound. PTFE is characterized, in addition to its almost universal chemical resistance, by excellent sliding properties (?=0.05...0.25) and temperature resistance up to 260°C (500°F). This admixture gives the PTFE parent material the necessary wear resistance for these applications.

Conclusion

High demands are placed on pneumatic diaphragm pumps, as pump failures in an age of automation in plant construction are often accompanied by undesired production downtimes that can incur enormous costs. These requirements apply in particular to air-control systems of pneumatic diaphragm pumps, as these are he heart of the pumps.

The pneumatically piloted PERSWING P® air-control system is a precision control system, which based on the geometric design of the pilot piston control edges and the associated piston ring seals on the main piston, is absolutely without dead center. Independent of the position of the main and pilot pistons with respect to each other, the air passage cross-sections for reversal of the main piston at all operating points of the pump are always clearly defined.

Material selection enables, in contrast to other air-control systems, maintenance-free operation, as the PERSWING P® air-control system operates completely without lubrication.

After more than 12 years of production, the PERSWING P® air-control system is used in more than 80,000 pneumatic diaphragm pumps and has proven itself on the market through high customer satisfaction. The PERSWING P® air-control system ensures efficient operation in Almatec's small submersible and laboratory pumps (AD 6), in the standard series (E-Series), in the semiconductor series (Futur-Plus SL), in high-pressure pumps (AH series, up to 15 bar) and in the metal pumps (CHEMICOR series).

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