Choose the Right Vacuum Pump

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The need to operate under vacuum is widespread throughout the chemical process industries (CPI). Distillation, drying, flash cooling, stripping, and evaporation are among the unit operations that frequently take place at less than atmospheric pressure.

In many process applications, the overriding consideration is the amount of vacuum (or degree of evacuation) required. Of the five major types of vacuum producing devices discussed here, the ejector can achieve the greatest degree of evacuation: down to 5 micrometers of Hg absolute. Dry pumps and rotary piston pumps can each evacuate to 10 micrometers Hg; once-through oil pumps can reach 500 micrometers Hg; and liquid ring pumps can go down to 10 mm Hg.

Aside from its vacuum producing ability, each of the five types has its own set of attractions and drawbacks. Many of these depend on the particular application.

Ejectors are workhorses

The simplest and probably most widely used vacuum producer is the ejector (Figure 1). Sometimes called a jet pump, an ejector works by converting pressure energy of a motive fluid (which may be the same as or different from the process fluid) into velocity energy (kinetic energy) as it flows through a relatively small converging-diverging nozzle. This lowered pressure of the motive fluid creates suction in a mixing chamber, into which the process fluid is drawn from the vessel being evacuated. The process fluid mixes with and becomes entrained in the motive fluid stream. This mixed fluid then passes on through a converging-diverging diffuser, where the velocity is converted back to pressure energy. The resultant pressure is higher than the suction pressure of the ejector.

Ejectors use many types of motive fluid. Steam is the most common. Other popular choices include ethylene glycol, air, nitrogen, and vaporized organic solvents. To avoid contamination and other problems, it is important to choose a motive fluid compatible with the process fluid.

Ejectors offer a range of attractions:

- Simple design, with no moving parts and practically no wear
- Can be mounted in any orientation
- Can be fabricated of virtually any metal, as well as various types of plastics. The latter are usually fiber reinforced grades
- Lowest capital cost among vacuum producing devices
- Offers the largest throughput capacity of any vacuum producing device - can handle more than 1,000,000 ft^3/min of process fluid
- No special startup or shutdown procedures required
- Can handle condensable loads
- Simple repair and maintenance.

On the other hand, there are also disadvantages to ejectors:

- The requirement of a pressurized motive fluid
- The inevitable contamination of the motive fluid by the process gas, and vice versa
- Can be noisy; may require discharge silencers or sound insulation
- In most cases, the need for a cooling liquid source to condense the mixture of motive and process-fluid vapors

Ejectors are especially attractive when the process load contains condensable or corrosive vapors, very low absolute pressures are needed, or the vacuum producing capacity required is very large. However, these devices are not confined to such applications; they should also be evaluated, along with other options discussed below, in other process situations.

Ejectors also work well as boosters upstream of liquid ring pumps (below). This combination can minimize capital and utility costs with no sacrifice in performance.

As in any nozzle, the phenomenon known as critical flow can arise with an ejector. Roughly speaking, critical flow prevails when the discharge pressure is at least twice the suction pressure. Under these circumstances, a standing shock wave is set up.

A common misconception arises with regard to critical flow: that if the discharge pressure is reduced, the suction pressure of the ejector will decrease and thus a higher vacuum will be created. This is not possible, because the shock wave isolates the inlet conditions from the discharge conditions. An alternative way for and chemical, plastics, pharmaceuticals and synthetic fibers plants; refrigeration at pulp and paper mills; drying in chemical and pharmaceutical plants; drying, flash cooling and refrigeration at food plants; and product degassing in steel mills. A related widespread use is condenser air venting at power plants.

Liquid ring pumps are cool

Another vacuum producing device that can evacuate vessels containing condensable or otherwise "wet" loads is the liquid ring vacuum pump (Figure 2). In its approximately cylindrical body, a sealant fluid under centrifugal force forms a ring against the inside of the concentric casing.

The source of that force is a multi-bladed impeller whose shaft is mounted so as to be eccentric to the ring of liquid. Because of this eccentricity, the pockets bounded by adjacent impeller blades (also called buckets) and the ring increases in size on the inlet side of the pump, and the resulting suction continually draws gas out of the vessel being evacuated As the blades rotate toward the discharge side of the pump, the pockets decrease in size and the evacuated gas is compressed, enabling its discharge.

The ring of liquid not only acts as a seal; it also absorbs the heat of compression, friction and condensation. In principle virtually any type of liquid can be used, so long as it is not prone to vaporization (and thus to cavitation) at the process conditions. Popular choices include water, ethylene glycol, mineral oil and organic solvents. Assuming that the evacuated process vapor does not react with or dissolve in the sealant liquid, contamination is minimized and the condensed process fluid is available for reuse in the plant.

The advantages of liquid ring vacuum pumps are as follows:

Simpler design than most other vacuum pumps; employs only one rotating assembly

Can be fabricated from any castable metal

Minimal noise and vibration

Very little increase in the temperature of the discharged gas

Can handle condensable loads

No damage from liquid or small particulates entrained in the process fluid   Maintenance and rebuilding are simple compared to most other vacuum pumps

Inherently slow rotational speed (1,800 rev/min or less), which maximizes operating life

Can be started and stopped over and over

Can use any type of liquid for the sealant fluid, in situations where mingling with the process vapor is permissible

The drawbacks of liquid-ring vacuum pumps are as follows:

Inevitable mixing of the evacuated gas with the sealing fluid

Risk of cavitation, which requires that a portion of the process load be noncondensable under the pump operating conditions

High power requirement to form and maintain the liquid ring, resulting in larger motors than for other types of pumps

Achievable vacuum is limited by the vapor pressure of sealant fluid at the operating temperature The liquid-ring pump is especially attractive when the process load contains condensable vapors, or if liquid carryover is present (due either to normal operation or process upsets), or if cool running operation is required due to flammable or temperature sensitive process fluids. However, these devices may also prove to be the best choice for other process situations.

For condensable process fluids, the choice between a liquid-ring pump and an ejector usually depends on the nature of the customer's business. Ejectors offer the lower capital cost, but the liquid-ring models are ordinarily less expensive to operate. Accordingly, for example, a customer with a ready source of inexpensive steam for use as motive fluid might favor the ejector.

One-stage (medium vacuum) versions of the liquid-ring pump can evacuate up to 20,000 ft^3/min. Two-stage (high-vacuum) versions evacuate up to 7,000 ft^3/min.

Like ejectors, liquid-ring vacuum pumps are widely employed in the CPI. They are found at petroleum refineries and petrochemical plants for vacuum distillation and vapor recovery, and as an adjunct to vent gas compressors. Chemical and pharmaceutical

These pumps work by either of two mechanisms, volumetric reduction or the

Solvent recovery not possible, due to oil contamination

Costly to repair or rebuild

Cannot readily accommodate condensable vapors

Requires constant monitoring of the oil system

OTO pumps are usually found in pharmaceutical plants and fine-and-specialty-chemical plants, for drying, evaporation, distillation or other vessel evacuation tasks. Typical capacities are about *450* ft^3min.

In practice, the OTO pumps have often been misused, the aforementioned limitations being ignored. Today, this type of pump is being replaced by dry pumps, which incur lower lifecycle costs.

Rotary-piston models

A rugged type of vacuum-producing device is the rotary-piston vacuum pump. Its piston is attached to a cam that is mounted eccentrically to the main bore of the pump cylinder.

At the start of the cycle, the volume between the piston and cylinder increases as the shaft rotates the piston cam assembly. Gas is drawn in through a channel in the piston, until this volume is at its maximum. At that point, the pocket