

Innovative Technologies Advance Vacuum Equipment Application

Don't limit the use of vacuum equipment to conventional applications

Steam ejectors, vacuum process condensers and liquid ring vacuum pumps are mature products and each has supported the chemical industry for decades. Manufacturers of vacuum equipment continue to research and develop new ways these products can improve the operation of various processes through lower capital cost, environmental impact reduction or improved operating efficiency. Innovative technologies continue to increase the applicability of vacuum equipment in the chemical industry. In this issue, specialized vacuum equipment applications are reviewed.

Ejector Systems

Alternate motive fluids: Chemical process industries (CPIs) continue to rely on ejector systems to produce and maintain vacuum for numerous vital processes. Most often an ejector system is used in its classic form, with high-pressure motive steam used as the motive fluid. This mainstay of the CPI has its place, however, there are factors that preclude steam as a motive fluid. A particular process may contain components that solidify within an ejector, requiring frequent system shutdowns for product removal. Perhaps steam contacting the process will destroy a product being manufactured. Or, your plant is trying to reduce waste treatment costs. The use of alternate motive fluids extends the application of ejector systems when these issues apply. It is commonly believed that steam can be the only motive fluid, however, that is not the case.

Ejector system operation using motive fluids other than steam should be considered when any of the following conditions exist:

- When it is desirable to recover product for use or disposal without water contamination and the associated expense of water removal.
- When solids present in the process



deposit in ejectors, but dissolve in an organic fluid.

- When backstreaming of steam into the process cannot be tolerated.
- When the presence of water may introduce a serious corrosion problem.
- When contaminant scrubbing is eas-

ier in the absence of water.

- When it is desirable to reduce or eliminate air and water volatile organic compound (VOC) contamination.

Alternate motive fluids that have been successfully used include monochlorobenzene, methyl alcohol, ethylene glycol,

cyclohexane, refrigerants and phenol. The main advantages of using an organic fluid for an ejector are the motivating fluid acts as a solvent for the process vapors, the process fluid is not contaminated with water/steam, chemical treatment problems are minimized, and the total energy requirements are considerably less than if steam were used as a motivating fluid.

Vital processes where alternate motive fluids are used include, but are not limited to, toluene diisocyanate, methylene diphenyl diisocyanate, polyethylene terephthalate, styrene, butadiene and resins.

An organic motivated ejector system most often is a packaged, self-contained system that includes ejectors, condensers, a vaporizer, coolers, pumps, controls, piping, all auxiliaries and packaging. When specifying or evaluating this type of ejector system, be certain to assess a manufacturer's experience with the selected motive fluid or the capability the manufacturer has to pilot test prototype ejectors. Proof testing is an important step if successful installation experience is not available.

Liquid Ring Vacuum Pumps

Alternate seal fluids: Liquid ring pumps can operate with a myriad of service liquids. By far, the most common service liquid is water. Another very capable service liquid and often over-looked material is synthetic oil. Oil sealed systems are totally recirculated service liquid systems. In a total recirculation system, the service liquid is separated from the process gas in an air/oil separator and recirculated to the vacuum pump. The system would be supplied with a heat exchanger to cool the oil (remove the heat of compression) before it enters the vacuum pump.

Oil as a service liquid has several advantages over other liquids. Oil has a much lower vapor pressure than water. The ultimate vacuum achievable by a liquid ring vacuum pump is determined by the vapor pressure of the service liquid.



Therefore, an oil sealed liquid ring system can pull to a deeper vacuum than that of a system using water when operating at lower pressures. This also means less of the service liquid will flash, increasing the effective capacity of the vacuum pump.

Oil systems can operate at elevated seal temperatures. It is not uncommon to operate liquid ring pumps with oil at temperatures in the 160°F to 185°F range. This elevated temperature offers several advantages. The first is the ability to use an air-cooled heat exchanger. Air-cooled heat exchangers require a large difference between seal fluid temperature and ambient air temperature to operate efficiently. The high vapor pressures and low operating temperatures of most service liquids eliminate the possibility of using an air-cooled exchanger. With an oil temperature of 160°F and an ambient air temperature of 85°F, an air-cooled exchanger is easily used. Using an

air-cooled exchanger eliminates the need for cooling liquid and allows the liquid ring package to operate in a remote location where cooling media is unavailable. The air-cooled unit could be designed to be mobile.

The elevated temperature of the oil seal also allows the pumping of water-soluble gases, such as ammonia. Ammonia is highly soluble in water, which makes it difficult for liquid ring vacuum pumps to handle. The ammonia gas is in direct contact with the service fluid at the suction (vacuum) side of a water sealed liquid ring pump. This sealant water will absorb as much ammonia gas as it can due to high solubility. The sealant water then becomes an ammonia-water solution inside the pump. Ammonia gas will flash out when this solution is exposed to the vacuum side of the pump. The ammonia gas that flashes out will internally overload the pump, reducing the pump's vacuum

capability. To prevent water vapor from condensing and allowing ammonia gas to go into solution, a hot oil sealed liquid ring vacuum pump can be used. The oil is hot enough to keep water vapor from condensing, eliminating the absorption of ammonia gas. The hot oil has a low vapor pressure, allowing the liquid ring pump to operate down to 10 torr, if required.

Oil sealed liquid ring vacuum pump packages consists of a liquid ring pump, a vapor/liquid discharge separator, an oil mist coalescing filter, an air or water cooled heat exchanger, associated piping, and necessary accessories for remote operation.

Dry Vacuum Pumps

A technology emerging in the chemical and pharmaceutical industries is the dry vacuum pump. Unlike steam jet ejectors and liquid ring vacuum pumps, dry vacuum pumps do not require working fluids to create a vacuum. They operate by gas compression, or a combination of gas compression and mechanical compression (volume reduction).

This type of equipment has only become available in the CPI over the last several years due to advancements in the manufacturing/machining process. Because these pumps produce vacuum without working fluids, they are machined with extremely close clearances between the rotating elements and the pump walls. These clearances required a manufacturing process that can guarantee extremely tight tolerances. The tolerances must be maintained to stop the rotating elements from contacting each other, which would result in a catastrophic failure of the vacuum pump.

Close clearances between rotating elements are required to reduce internal back-slippage and allow the units to compress the process gas. In a liquid ring vacuum pump this would be accomplished by the service liquid and in a rotary vane this would be accomplished by the oil lubrication system. Back-slippage also is reduced by the turbulence inside the pump created

when the rotating elements turn. Some pumps will operate at speeds up to 6,000 rpm to maximize this phenomenon.

When compared to liquid ring vacuum pumps, which operate nearly isothermally, dry vacuum pumps run hot. In a liquid ring pump, the service liquid absorbs most of the temperature rise associated with the heat of compression. Because dry units lack this service liquid, this heat is added to the process gas. The low specific heats of gases coupled with the low mass flowrates associated with vacuum service result in pump discharge and internal temperatures ranging from 250°F to 600°F (115°C to 315°C).

The effects of these high temperatures vary. The effect is desirable in a process that contains a corrosive gas. Due to the high internal temperatures, a dry pump can easily handle corrosive vapors with standard iron construction, as corrosion normally occurs in the presence of moisture, which will not form on the hot internal surfaces. Utilizing a dry pump in this application could result in significant capital and operating cost savings. For instance, if a pump was installed in a process to handle wet HCL, a dry vacuum pump manufactured in cast iron could be used. This is much less expensive than a liquid ring pump manufactured in an exotic material such as the titanium required to handle wet HCL. There also is an environmental impact as the need for a service liquid requiring treatment is eliminated.



The temperature rise could be undesirable if the process gas has a low auto-ignition point. Here, special operating procedures as well as equipment such as detonation and flame arrestors would be required. It is also undesirable if the product polymerizes inside the vacuum pump. This could lead to frequent downtime for cleaning and vacuum pump repair. If cooler temperatures are required, configurations that permit the recycling of cooled gases are available.

Dry pumps are a new and emerging technology. It is likely the call for this type of equipment will grow as this technology is further refined. It is important to remember that while dry pumps offer advantages in some applications, they are not the answer for all applications. Care should be taken when applying this new technology.



Process Vacuum Condensers

Freeze condensing: Freeze condensation is gaining use in the edible industry to improve the efficiency of oil deodorization. Freeze condensation is a bit of a misnomer in this instance because steam goes directly from a vapor to a solid, without passing through a liquid state. That is due to the operating pressure of the process, approximately 1.25 torr. Freeze condensation also is successfully applied in plastics and resins processes.

Freeze condensation offers advantages. First, the use of freeze condensation will dramatically reduce the size and cost of the vacuum system. Second, process vapor removal by solidifying it on the heat transfer surface reduces the environmental impact because liquid and air wastes are appreciably reduced.

A typical freeze condensation installation will include two freeze condensers. One condenser is on-line building ice. The other is off line undergoing defrosting. The operating unit remains on line

building ice until operating begins to rise above a desirable level, then it is switched to defrost mode. The operating pressure of the process will increase over time. As ice builds on the heat transfer surface it will impede heat transfer because the ice acts as an insulator.

The critical aspect of freeze condenser design is the tube bundle design. It is important to balance run time and heat transfer. To maximize heat transfer it is desirable to maintain a tight spacing between the tubes for the greatest velocity. Higher velocity translates into improved heat transfer. However, as ice builds, it grows radially from the tube surface, restricting flow between the tubes and consequently causing an increase in pressure drop. A well-designed tube bundle will have widely spaced tubing to permit ice growth throughout the cycle while still performing effectively. Run times of eight hours are common between ice building and defrosting. If the tube bundle is not properly configured, the run time will be substantially less.

As a freeze condenser is a process vacuum condenser it is important to evaluate the condenser and vacuum equipment as one unit. They work together, and if properly optimized, a combining of the two will reduce capital and operating costs.

Summary

Leading vacuum equipment manufacturers develop and research new technologies that offer advantages for the CPI. Conventional uses for vacuum equipment remain the mainstay. However, significant operating efficiencies and economic/environmental gains may be realized by extending the applicability of mature products like steam ejectors, liquid rings pumps, dry vacuum pumps, and process condensers. Alternate motive or seal liquids extend the use of steam ejectors and liquid ring vacuum pumps. Dry vacuum pumps meet the growing concern of reducing waste streams and environmental impact. Freeze condensation is an innovative technology to improve operational reliability and reduce environmental impact.

When you are confronted with an application where it may not appear that conventional vacuum equipment will suffice, turn to your vacuum equipment manufacturers. They may have proven solutions available or they can engineer an answer that meets the objectives.

This is the final issue in a series of six educational newsletters on vacuum equipment.



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