Optimizing vacuum systems for energy-efficient operation

Ejector, liquid-ring pump combination boosts energy savings

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The economic factor must be taken into consideration in the design and manufacture of equipment that utilizes utilities such as steam, cooling tower water and electricity.

Evaluating operating costs can make or break the profit of a commodity, and can dictate whether an expansion should take place.

Using a combination of liquid-ring pumps and steam jet ejectors in vacuum system design provides cost savings to a chemical plant by reducing energy requirements, maintenance and downtime.

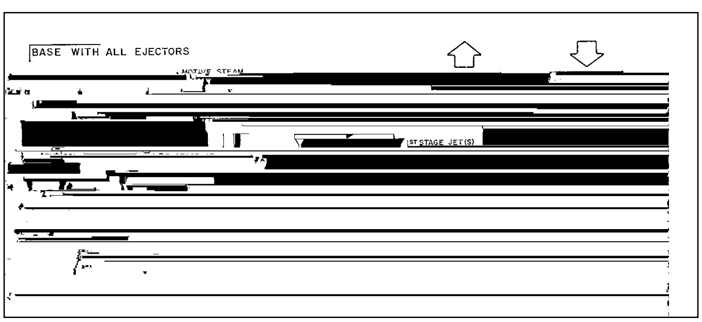
EJECTOR OPERATION

Steam jet ejectors have long been used as a means of transporting gases, liquids or solids from one pressure level to a higher pressure level, particularly in subatmospheric applications.

The ejector has no moving parts, making it easy to operate and durable.

In operation, atmospheric- to high-pressure fluid passes through a motive nozzle where its pressure is dissipated, accelerating the fluid to high velocity as it exits the mouth of the nozzle.

This high-velocity fluid stream (usually steam) issuing from the nozzle mouth entrains the suction fluid. These two streams mix as they pass into a diffuser. The velocity profile constantly changes and the pressure inside the venturi of the ejector continues to rise as the discharge of the venturi is reached.



Left: Fig. 1. Typical schematic of a chemical process ejector system.

Right: Fig. 2. Liquid-ring pump operating principle.

A single-stage ejector can compress gases, liquids or solids over a range of 12:1 or more, depending on the actual suction and discharge pressures.

To produce various vacuum levels, ejectors are staged together in two, three, four or more stages.

Ejectors can be designed as single-element or multielement systems, allowing for flexibility in the process load condition. Along with the steam jet ejectors, shell-and-tube vacuum condensers can be utilized in the system design to condense steam and organic vapors and cool the non-condensible gases to the optimum interstage pressures.

Ejector systems for applications in the chemical industry typically have a primary jet mounted at or near the top of the process evaporator pointing vertically down or located at the same elevation as the intercondensers, approximately 45 ft minimum above the condensate receiver liquid level (Fig. 1).

A variation of this configuration is to eliminate the primary jet, and the load from the process evaporator goes directly to the condenser.

The atmospheric-stage jets and the stage directly upstream of the next condenser handle all non-condensible gases. This results in relatively large ejector sizes and, thus, high steam consumption.

STEAM CONSUMPTION

While the use of steam jet ejectors is an economical method of transporting product between pressure levels, to obtain optimum energy efficiency a design that reduces steam consumption should be considered.

Energy costs for the operation of an ejector-condenser unit vary widely. With steam, the cost depends on the generation method (i.e., oil, gas, coal and electricity). For example, steam costs vary from $1.00 to $15.00 per 1,000 lb; while the cost of cooling water varies from $0.30 to $2.50 per 1,000 gal; and electricity costs vary from $0.02 to $0.10 per kw per hr.

The spiraling increase of fuel costs for generating steam forces designers to consider vacuum system configurations that use a combination of steam and electricity. The use of liquid-ring pumps reduces steam consumption while maintaining reliable operation.

PUMP OPERATION

A mechanical liquid-ring pump can operate singly, or can be paralleled with any combination of ejectors. The pump uses a seal liquid

Additionally, the liquid ring's scrubbing action reduces emissions as