TECHNOLOGY

Understanding ejector systems necessary to troubleshoot vacuum distillation

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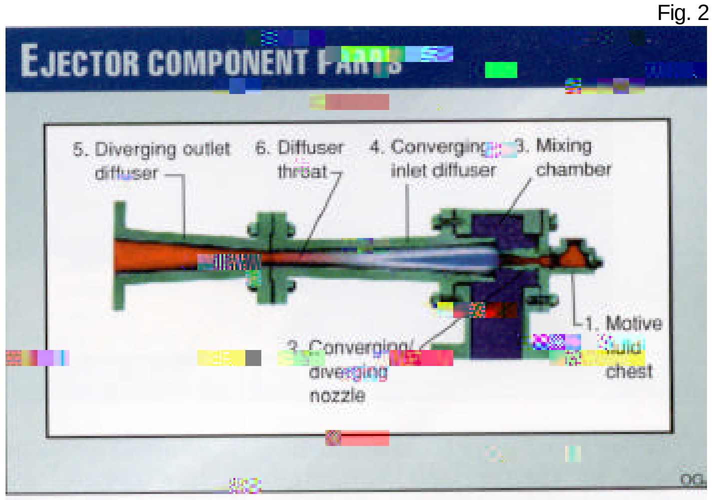
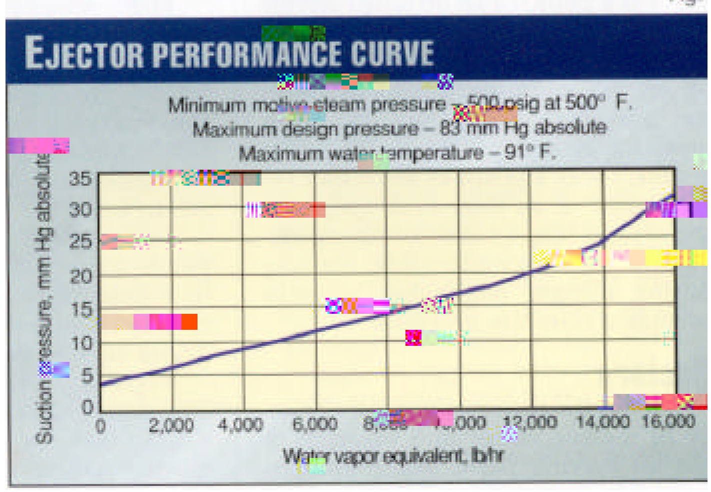
A complete understanding of ejector system performance characteristics can reduce the time and expense associated with troubleshooting poor crude vacuum distillation unit (CVDU) performance.

Variables that may negatively impact the ejector-system performance of vacuum-crude distillation units include utilities supply, corrosion and erosion, fouling, and process conditions.

Fig 1.

Fig. 2





Tables 1 and 2 are troubleshooting guides to ejector and condenser problems in vacuum ejector systems. Fig. 1 is a photo of an installed ejector at a CVDU.

Two actual case studies conducted by service engineers on CVDU-ejector systems show how to troubleshoot ejector problems. The first problem was a result of improper replacement of an intercondenser, and the second was a result of underestimation of noncondensible loading during design, which has recently become a common problem.

Ejectors

An ejector converts pressure energy of motive steam into velocity. It has no moving parts. Major components of an ejector consist of the

motive nozzle, motive chest, suction chamber, and diffuser (Fig. 2).

High velocity is achieved through adiabatic expansion of motive steam across a convergent/divergent steam nozzle. This expansion of steam from the motive pressure to the suction fluid operating pressure results in supersonic velocities at the exit of the

Table 1

EJECTOR TROUBLESHOOTING

	Problem	Effect	Corrective action
1	Lower than design motive-steam pressure.	Poor ejector performance.	Raise steam pressure or bore steam nozzles.
2	Higher than design motive-steam pressure.	Reduced ejector capacity and wasted steam.	Reduce motive pressure or replace steam nozzles with new nozzles designed for a higher steam pressure.
3	Higher than design steam temperature (50° F.+).	Poor ejector performance.	Raise steam pressure or bore steam nozzles.
4	Higher than design discharge pressure.	Poor ejector performance.	Look downstream for problems: a. Condenser problem b. Downstream ejector problem c. Discharge-piping restriction.
5	Low ejector-discharge temperature. Ejector-discharge temperature should be superheated at least 50° F. above saturation. [illegible] cause is wet motive steam.	Reduced ejector capacity or poor performance.	a. Insulate steam lines b. Add moisture separator in steam line.
6	Higher-than-design suction pressure (assuming [illegible] steam pressure and quality are normal and discharge pressure is equal to or less than design).	Greater than design load or mechanical problems with [illegible]. Either worn out internals or possible internal steam leak around steam-nozzle threads.	Inspect internal dimensions and replace [illegible] necessary. Tighten steam nozzle to steam chest if necessary [illegible] weld nozzle to steam chest.

Table 2

CONDENSER TROUBLESHOOTING

	Problem	Effect	Corrective action
1	High ΔP across shellside (As a rule of thumb, normally ΔP should be 5% of absolute design operating pressure or less).	Poor condenser performance: a. Shellside [illegible] fouling b. Cooling water temperature higher than design c. Low cooling water flowrate d. Higher-than-design condensible hydrocarbon (about 20-30% above design).	a. Clean tubes b. Reduce temperature, increase water flow c. Increase cooling water flow d. Reduce hydrocarbon load or larger condenser and downstream ejector required.
2	Higher than design tubeside ΔP.	Poor condenser performance: a. Tubeside fouling b. Higher-than-design cooling water flow.	a. Clean tubes b. Not a problem.
3	Higher than design tubeside ΔT.	Poor condenser performance: a. Low cooling water flow b. Higher than design [illegible]	a. Increase flowrate b. Increase cooling water flowrate or replace condenser.
4	High vapor-outlet temperature.	Poor condenser performance: a. Tube fouling b. Cooling water flowrate low or inlet temperature high c. Possible internal bypassing. d. Downstream ejector not functioning and backstreaming.	a. Clean tubes b. Increase water flowrate or reduce inlet temperature c. Check with manufacturer d. Check with manufacturer

temperature is appreciably above the design value, insufficient steam passes through the motive nozzle. Both lower-than-design steam pressure and higher-than-design steam temperature increase the specific volume of the motive steam and reduces the amount of steam through a motive nozzle.

In certain cases, it is possible to re-bore an ejector-motive nozzle to permit the passage of more steam through the nozzle, thereby increasing the energy available to entrain and compress the suction load.

If motive-steam pressure is more than 20% above design, too much steam expands across the nozzle. This often chokes the diffuser throat of an ejector. When this occurs, less suction load is handled by an ejector, and the CVD-column pressure rises. If an increase in column pressure is undesirable, then new ejector nozzles with smaller throat diameters are required.

Table 3

VACUUM-TOWER OVERHEAD COMPOSITION

	Design		Actual	
	Flow rate, lb/hr	Molecular wt	Flow rate, lb/hr	Molecular wt
Noncondensible gas	700	40	1,500	32
Water vapor	13,000	18	15,000	18
Condensible hydrocarbon	7,500	170	13,000	170

Steam quality

Wet steam is very damaging to an ejector system because high-velocity moisture droplets are erosive. These droplets are rapidly accelerated as steam expands across a motive nozzle.

Erosion of nozzle internals caused by wet motive-steam is noticeable when inspecting ejector nozzles or diffuser internals. There is an etched striated pattern on the diverging section of a motive nozzle, and the nozzle mouth may actually wear out. Also, the inlet diffuser section of an ejector will show signs of erosion as a result of direct impingement of moisture droplets (Fig. 4a).

Fig. 4b depicts an ejector cutaway showing severe damage caused by wet steam. The inlet diffuser shows substantial metal loss. Metal-scale buildup can be seen in the outlet diffuser section.

The exhaust temperature from the ejector can determine if the steam conditions are present. Typical ejector exhaust temperatures are in the range of 250 to 300° F. If moisture is present, a substantially lower exhaust temperature will exist.

To solve wet-steam problems, all lines up to an ejector should be well insulated. A steam separator and trap should be installed immediately before the motive-steam inlet connection of each ejector. In some instances, a steam superheater may be required.

Wet steam can also cause performance problems. Moisture droplets through an ejector nozzle decrease the energy available for compression. This reduces the suction-load handling capacity of an ejector.

Also

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[illegible]

The ejector following a condenser may not be able to handle increased loading at that operating pressure of the condenser. The ejector preceding that condenser is unable to compress to a higher discharge pressure. This discontinuity in pressure causes the preceding ejector to break operation.

When actual noncondensible loading is consistently above design, new ejectors