Figure 1. Ejector System for soybean oil deodorizer

Ejector systems for fats, oils, oleochemicals

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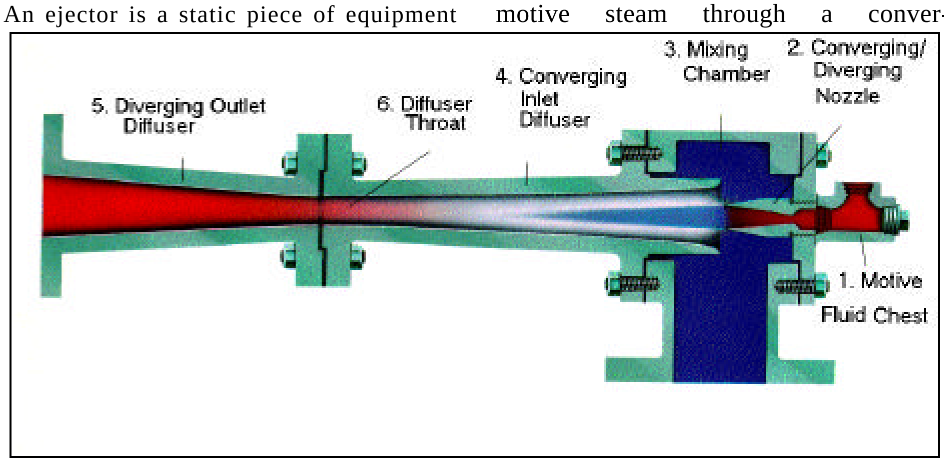
Essential processes in the production of natural fats and oils and derivative oleochemicals are performed under vacuum, i.e., at a pressure below atmospheric. Such processes, including solvent extraction, degumming, bleaching, interesterification, fractionation, winterization and deodorization, are supported by ejector systems (Figure 1.). Ejector systems are employed to produce and maintain proper vacuum. The complexity of the various processes necessitates an integrated ejector system for an optimized unit operation. An integrated system will ensure that a proper balance of operating and evaluated cost is maintained while satisfying demands of the process itself. Even though ejector systems are an integral part of the process, many users and operators of these systems do not understand their operational characteristics or what influences their performance.

Ejectors

An ejector is a static piece of equipment with no moving parts (Figure 2). The major components of an ejector are the motive nozzle, motive chest, suction chamber, and diffuser. An ejector converts pressure energy of motive steam into velocity. Thermodynamically, high velocity is achieved through adiabatic expansion of motive steam through a conver-



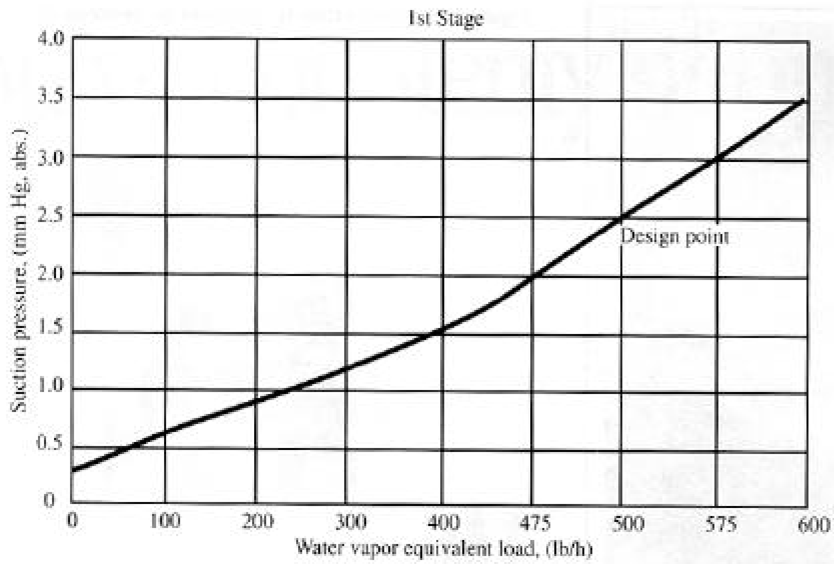


Figure 3. Ejector performance curve for first stage of deodorizer ejector system. (Water vapor equivalent load is on the abscissa and suction pressure maintained by the ejector is shown on the ordinal. Minimum motive steam pressure, 140 psig at 450°F; maximum pressure discharge, 13 mm Hg absolute).

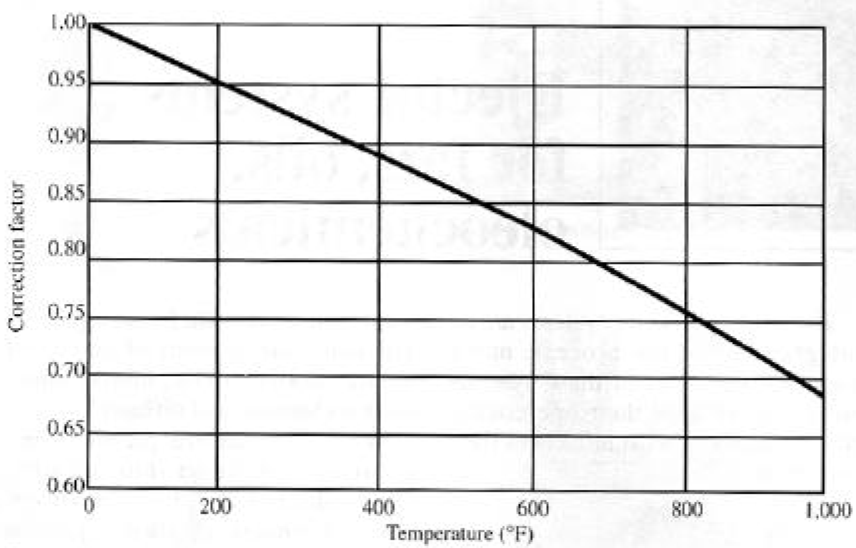


Figure 4. Temperature-correction factor curve for converting different temperatures to 70°F equivalent load.

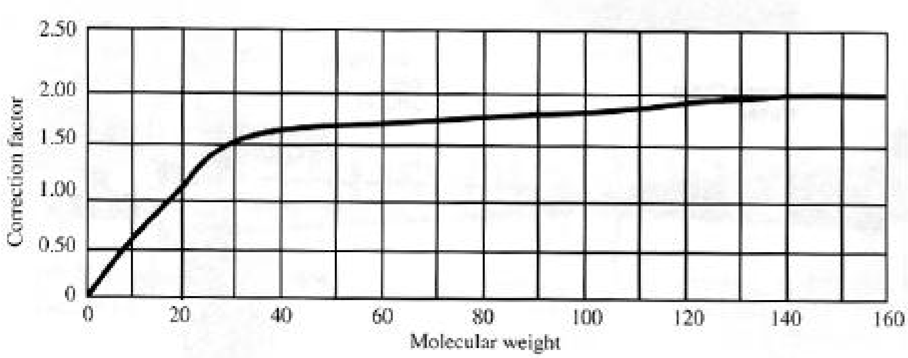


Figure 5. Molecular weight correction factor to convert different vapors to water vapor equivalent.

gent/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 steam nozzle. Actually. the motive steam expands to a pressure below the suction fluid pressure. This creates the driving force to bring suction fluid into an ejector. Typically, velocity exiting a motive steam nozzle is in the range of 3,0004,000 ft./s.

High-velocity motive steam entrains and mixes with the suction fluid. The resultant mixture is still supersonic. As the mixture passes through the convergent, throat, and divergent sections of a diffuser, high velocity is converted back to pressure. The convergent section of a diffuser reduces velocity of the supersonic flow as cross-sectional area is reduced. This statement may appear to contradict intuition but a thermodynamic characteristic of gases at supersonic conditions is that velocity is decreased as cross-sectional area is reduced. The diffuser throat is designed to create a shock wave. It is the shock wave that produces a dramatic increase in pressure as the flow goes from supersonic to subsonic across the shock wave. In the divergent section of the diffuser, cross-sectional flow area is increased and subsonic velocity further reduced and converted to pressure.

Ejector performance is summarized on a performance curve (Figure 3). A performance curve describes how a given ejector will perform as a function of water vapor equivalent loading. Other important information noted on an ejector performance curve is the minimum motive steam pressure, maximum permissible steam temperature, and maximum discharge pressure (MDP).

Equivalent load is used to represent a process stream, which may be made up of many different components, such as air, water vapor, free fatty acids (FFA) or various organics, in terms of an equivalent amount of water vapor (Figures 4,5). Heat Exchange Institute (Cleveland, Ohio) Standards for Steam Jet Ejectors describe the method used to convert to water vapor-equivalent

Table 1
Conversion of 421 pph of water vapor, 40 pph air, and 25 pph of glycerine at 125°F to water vapor equivalent load at 70°F

Component	Flow, pph	MW	MW_{CF}	$Temp_{CF}$	EQ load, pph
Air	40	29	1.25	0.983	32.6
Water vapor	421	18	1.00	0.983	428.3
Glycerin	25	92	1.84	0.983	13.8
Total equivalent load					475.0

$$\text{Equivalent load} = \frac{\text{Actual flow}}{MW_{CF} \times Temp_{CF}}$$

MW, molecular weight; CF, correction factor; EQ, equivalent; pph, pounds per hour

or an air equivalent load. Water vapor equivalent loading is often selected because most factory performance testing of an ejector is done with a water vapor load (Table 1).

The performance curve may be used in two ways. First, if suction pressure is known for an ejector, the equivalent water vapor load it handles is easily determined. Second, if the loading to an ejector is known, then it is possible to estimate the expected suction pressure for the ejector. If field measurements differ from a performance curve, then there may be a problem with either the process, utilities, or the ejector itself.

Condensers

Condensers may be categorized as direct contact or surface type. Here we will focus solely on surface-type condensers, otherwise known as shell-and-tube condensers. Direct-contact condensers are still in use but because of pollution concerns, they are not often currently specified.

Condensers are manufactured in three basic configurations: fixed tubesheet, “U” tube, or floating head bundle (Figure 6). The basic configurations differ only in ease of maintenance and capital cost, but thermodynamically will perform similarly.

The primary purpose of a condenser in an ejector system is to reduce the amount of vapor load that a downstream ejector must handle. This will greatly improve the efficiency of an ejector system. Although vacuum condensers are constructed like process shell-and-tube heat exchangers, their internal design differs significantly owing to the presence of two-phase flow, noncondensible gas, and vacuum operation.

Vacuum condensers for fats, oils, and oleochemical applications generally have the cooling water running through the tubes. Condensation of water vapor and organics takes place on the shell-side the outside surface area of the tubes. Generally, the inlet stream enters through the top of the condenser. Once the inlet stream enters the shell, it spreads out along the shell and penetrates the tube bundle. A major portion of the condensibles contained in the inlet stream will change phase from vapor to liquid. The liquid falls by gravity, runs out of the bottom of the condenser and down the tail leg. The remainder of the condensibles and the noncondensible gases are collected and removed from the condenser through a vapor outlet connection. An exception to the general rule is the first intercondenser of a deodorizer ejector system, where process vapors are on the tube-side the inside surface of the tubes.

There are two basic types of vacuum condensers typically offered. For larger units approximately 30” in diameter and larger a long air-baffle design is used. A long air-baffle runs virtually the full length of the shell and is sealed to the shell to prevent bypassing of the inlet stream directly to the vapor outlet. This forces vapors to go through the entire tube bundle before exiting at the vapor outlet. Similarly, smaller units use an up-and-over baffle arrangement to maximize vapor distribution in the bundle. In this configuration, the exiting vapor leaves the condenser at one end only. The vapors are forced through a series of baffles in order to reach the vapor outlet.

As mentioned previously, a condenser is designed to limit the load to a downstream ejector. In many cases, the inlet load to a condenser is many times greater than the load to a downstream ejector. Consequently, any loss in condenser performance will have a dramatic effect on a downstream ejector. This makes

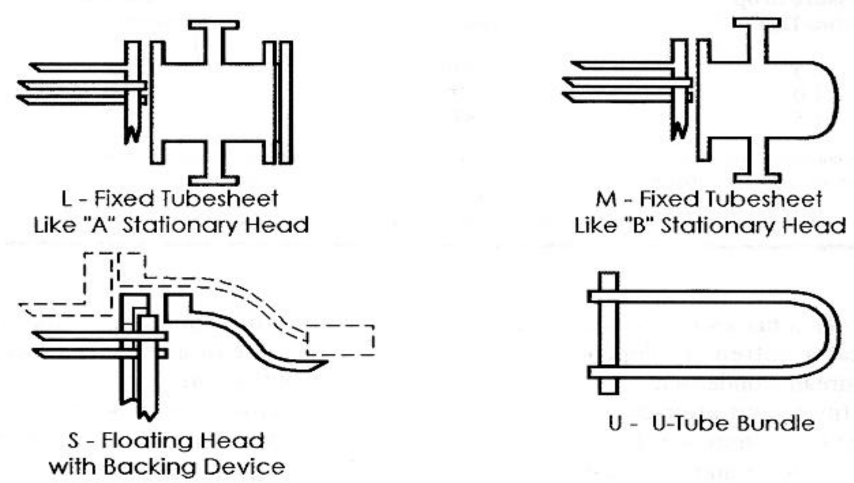


Figure 6. Basic condenser configurations

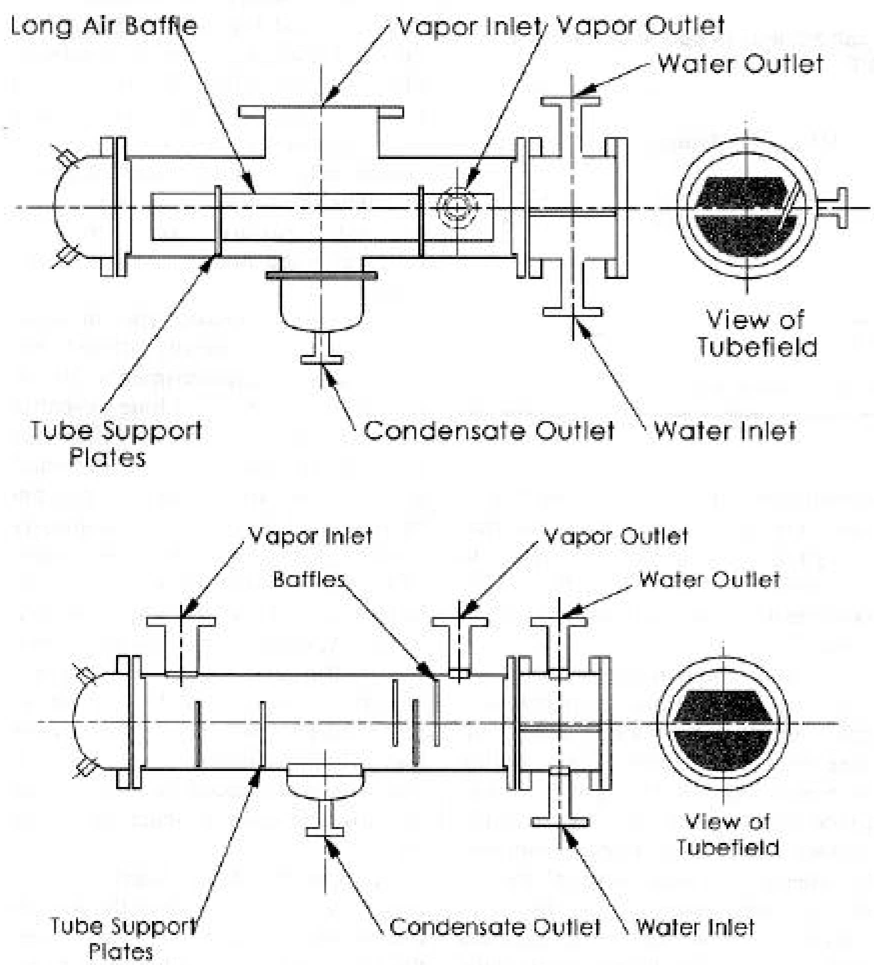


Figure 7. Vacuum condensers typically used as condensers or precondensers: Tema "X" and "E" shells

Table 2
Determination of the amount of glycerin vapor carryover from a precondenser[a]

Pressure drop (mm Hg)	Glycerin carryover (pph)	Glycerin condensed (%)
0.5	2,846	52.5
1.0	3,595	40.0
1.5	4,878	18.7

[a] Precondenser operating at 6 mm Hg absolute inlet pressure with inlet load at 50 pph of air, 400 pph of water vapor, and 6,000 pph; glycerin discharge temperature of 280°F; glycerin vapor pressure of 3.1 mm Hg

MW, molecular weight; CF, correction factor; EQ, equivalent; pph, pounds per hour.

the performance of an ejector extremely dependent on the upstream condenser.

Inter and aftercondensers of an ejector system are designed to condense steam and condensible organics and coal noncondensible gases (Figure 7). This condensation will occur at a pressure corresponding to the discharge pressure of a preceding ejector and the suction pressure of a downstream ejector. Intercondensers are positioned between two ejector stages and must operate satisfactorily in order for the entire system to perform correctly.

Precondensers

A precondenser, which is positioned ahead of an ejector system, is a highly specialized condenser and should be considered part of the ejector system. The operating pressure of a precondenser in fats and oils processing is typically 10 mm Hg absolute (abs) or less.

Process load from a distillation column or still consists of large quantities of condensible vapors, such as glycerin, methyl esters or fatty alcohols, plus noncondensible gases. The low pressure condition will result in extremely high volumetric flow rates. It becomes a challenge to effectively manage a large volumetric flow rate at low pressure drop while still accomplishing necessary heat transfer. The tube field layout and shellside baffling are quite special and often unique to each application.

The tube pitch may be variable, with an open pitch at the inlet and tighter pitches at the outlet where volumetric flow is considerably less than at the inlet conditions. Location of a precondenser is important for an optimized system. It is key to locate a precondenser as close as possible to the process vessel. Attachment of a precondenser directly to the vacuum vessel is preferred. This will minimize pressure loss so as to reduce utility consumption and maximize condensation. Note that a precondenser is part of an ejector system. Often specifiers and purchasers separate a precondenser from the ejector system. This will result in more costly systems, with increased operating costs. When properly designed and integrated in an ejector system, precondenser performance is optimized to match the performance characteristics of the ejector systems. The following example highlights the importance of maintaining lower pressure drop across a precondenser (Table 2). As pressure drop increases, condensation decreases.

Utilities

Motive steam pressure, quality, and temperature are critical variables. Cooling water flow rate and inlet temperature are important as well. Often, actual utility supply conditions differ from those used

Table 3
Calculation to determine the amount of steam that will pass through a motive nozzle (applicable only when pressure upstream of nozzle is at least twice the downstream pressure)

pph steam $= 892.4 \times D_n 2 \times C_d \times (psia/vg)^{0.5}$

pph steam	= mass flow rate of steam in pounds per hour
D_n	= diameter of steam nozzle in inches
C_d	= nozzle discharge coefficient
psia	= motive steam upstream pressure, in pounds per square inch, absolute
v_g	= specific volume of motive steam at upstream pressure in cubic feet per pound

Example:
Determine the amount of steam that will pass through a steam nozzle having a 0.5" throat diameter and 95% discharge coefficient. Calculate mass flow rate based on 150 psig dry and saturated (D&S) conditions, 150 psig at 500°F, and 140 psig at 365°F.

150 psig D&S	892.4 x (0.5)2 x 0.95 x (164.7/2.7593)0.5 = 1,637 pph (100%)
150 psig @ 500°F	892.4 x (0.5)2 x 0.95 x (164.7/3.3403)0.5 = 1,488 pph (91%)
140 psig @ 365°F	892.4 x (0.5)2 x 0.95 x (154.7/2.9480)0.5 = 1,535 pph (94%)

to design an ejector system. When this occurs, system performance may or may not be affected.

Steam

Motive steam supply condition is one of the most important variables affecting ejector operation. If motive supply pressure falls below design pressure, then the motive nozzle will pass less steam. If this occurs, an ejector is not provided with sufficient energy to entrain and compress a suction load to the design discharge pressure of the ejector. Similarly, if' motive steam supply temperature is appreciably above the design value. then again, insufficient steam passes through the motive nozzle. With either lower than design steam pressure or higher than design steam temperature. the specific volume of the motive steam is increased and less steam will pass through a motive nozzle. Less steam passing through a motive nozzle results in less energy available to do the necessary work (Table 3).

Any ejector may operate unstably if it is not supplied with sufficient energy to entrain and compress a suction load to the design discharge pressure. In certain cases, it is possible to rebore an ejector motive nozzle to a larger diameter if actual supply steam pressure is below design or its temperature above design. This larger steam nozzle will 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 greater than 20% above design steam pressure, then too much steam expands across the nozzle. This has a tendency to choke the diffuser throat of an ejector. When this occurs, less suction load is handled by an ejector and vacuum vessel pressure will rise. If an increase in vessel pressure is undesirable, then new ejector nozzles with smaller throat diameters are required.

Steam quality is important. Any ejector is designed to operate with dry steam conditions. Wet steam is damaging to an ejector system. Moisture droplets in motive steam lines are rapidly accelerated as steam expands across a motive nozzle. High-velocity moisture droplets are erosive. Moisture in motive steam lines is noticeable when inspecting ejector nozzles. The rapidly accelerated moisture droplets erode nozzle internals. There is an etched striated pattern on the diverging section of a motive nozzle, and the nozzle mouth may actually have signs of wear. Also, the inlet diffuser section of an ejector will show signs of erosion due to direct impingement of moisture droplets. It is also possible to measure the exhaust temperature from the ejector to determine if wet steam conditions are present. Typical ejector exhaust temperatures are in the range of 250-300°F. If moisture is present, a substantially lower ejector 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.

It is possible to have performance problems due to wet steam. When moisture droplets pass through an ejector nozzle, they decrease the energy available for compression. This will reduce the suction load-handling capability of an ejector. Also, the moisture droplets may vaporize within the diffuser section of the ejector. Upon vaporization, the volumetric flow rate within the ejector will increase. Here again, this reduces the suction load-handling capability of an ejector. It is recommended that supply steam be dry or above 99% quality. With extremely wet steam, any ejector will perform poorly.

Water

When cooling water supply temperature rises above the design, ejector system performance is penalized. A rise in cooling water temperature lowers the available log mean temperature difference (LMTD) of a condenser. Should this occur, that condenser will not condense enough steam or condensible organics, and therefore there will be an increased vapor load to a downstream ejector. Because of inadequate condensation there also will be an increase in pressure drop across that condenser. The operating pressure of the condenser will rise. If an ejector preceding this condenser cannot discharge to the higher pressure, then the system will break performance. Broken ejector system performance is characterized by a higher than design vacuum vessel pressure, and actually, the pressure may be unstable, characterized by fluctuations.

This may also occur if the cooling water flow rate is below design. At lower-than-design cooling water flow rate, there is a greater water temperature rise across a condenser. Here again, this will lower the available LMTD and a similar situation to what was described previously will occur. Furthermore, lower cooling water flow rate translates into lower velocities through the condenser. Reduced velocities result in a reduction in the heat transfer coefficient, which reduces condensation capability of a condenser.

Problems with cooling water normally occur during summer months. This is when the water is at its warmest and demands on heat exchange equipment are highest.

If cooling water flow rate or temperature is off design, then new ejectors or condensers may be required to provide satisfactory operation.

Corrosion and erosion

Corrosion is the result of improperly selected metallurgy. Corrosion may occur in ejectors, condensers, or vacuum piping. Extreme corrosion may cause holes and subsequently result in air leakage into the vacuum system. Air leakage into a vacuum system will deteriorate performance and may result in broken ejector operation. The presence of air also adds to the noncondensible load a system must handle. The amount of vapor carryover from a condenser is proportional to the amount of noncondensible gas. As noncondensible gas increases, so does condensible carryover from a condenser.

Poor steam quality and high velocities may cause erosion of the diffuser and motive nozzle internals. Ejector manufacturers will provide certified information that defines the motive nozzle and diffuser thrust diameters. If a routine inspection of these parts indicates an increase in cross-sectional area over 7%, then performance may be compromised and replacement parts are necessary.

Fouling

Pre-, inter-, and aftercondensers are subject to fouling as are all other heat exchangers. Such fouling may occur on the tubeside, shellside or both. Fouling deters heat transfer and, at some point, may negatively affect system performance. Cooling tower water is most often used as the cooling fluid for vacuum condensers. This water is normally on the tubeside. Fouling deposits on tubing internals cause a resistance to heat transfer.

Over a prolonged period, actual fouling may exceed the design value and condenser performance becomes inadequate. Vacuum vessel overhead gases, vapors, and motive steam are normally on the shellside of a condenser. Depending on the type of process, an organic film may develop on the outside surface of the tubing. This film is a resistance to heat transfer, and over time will exceed design. If fatty acids are present, they may solidify on cold tube surfaces. The solidified fatty acids deter heat transfer. In deodorizer systems, the tubes are continually washed with alkali-dosed (NaOH) condensate. This removes fatty acid buildup.

When actual unit fouling exceeds design values used, then a condenser performs inadequately. Once fouled, a condenser is unable to condense sufficient quantities of organic vapors and motive steam. This results in a discontinuity in the what a preceding ejector is able to discharge to and the suction pressure maintained by a downstream ejector at higher vapor load.

Routine maintenance procedures should include periodic cleaning of condenser bundles. Cleaning procedures must be for both tubeside and shellside of a condenser.

Process conditions

Process conditions used in the design stage are rarely experienced during operation but are very important for reliable vacuum system performance. Vacuum system performance may be affected by the following process variables that may act independently or concurrently:

- Noncondensible gas loading
- Condensible organics
- Vacuum system backpressure

Ejector systems are susceptible to poor performance when noncondensible loading increases above design. Noncondensible loading to an ejector system consists of air that has leaked into the system, nitrogen, and/or light organics. The impact of higher-than-design noncondensible loading is severe. As noncondensible loading increases, the amounts of saturated vapors discharging from a condenser increase proportionately. The ejector following a condenser may not be able to handle increased loading at the operating pressure of that condenser. The ejector before that condenser is unable to compress to a higher discharge pressure. This discontinuity in pressure causes the preceding ejector to break operation, When this occurs, the system will operate unstably, and vessel pressure rises above design. Noncondensible loading must be accurately stated. If not, any ejector system is subject to performance shortcomings. If noncondensible loading is consistently above design, then new ejectors are required. Depending on the severity of noncondensible overloading, new condensers may be required as well.

Condensible organic loading is important, particularly for a precondenser. Organic load below design is rarely a problem. A problem arises when the load is above design or the compositional makeup of the load varies significantly.

If condensable organic load is above design, then the precondenser will be short on surface area for the increased thermal duty. Therefore, less organics will condense and the pressure drop across the condenser will rise. Ultimately, this will translate into an increase in vessel pressure, which may be stable or unstable.

Vacuum system back pressure may have an overwhelming influence on satisfactory performance. Ejectors are designed to compress to a design discharge pressure. If the actual dis-

Table 4
Ejector evaluation

Problem	Effect	Corrective action
1. Lower-than-design motive steam pressure	1. Poor ejector performance nozzles	1. Raise steam pressure or re-bore steam
2. Higher-than-design motive steam pressure	2. Reduced ejector capacity and steam waste	2. Reduce motive pressure or replace steam nozzles with new nozzles designed for a higher steam pressure
3. Higher-than-design steam temperature (by 50°F or more)	3. Poor ejector performance steam nozzles	3. Raise steam pressure or re-bore
4. Higher-than-design discharge pressure	4. Poor ejector performance	4. Look downstream for problems that could include: (a) condenser problem (b) downstream ejector problem (c) discharge piping restrictions
5. Low ejector discharge temperature. Ejector discharge temperature should be superheated at least 50°F above saturation. If not, the cause is wet motive steam.	5. Reduced ejector capacity or poor performance steam line.	5. (a) Insulate steam lines (b) Add moisture separator in motive
6. Greater than design load or mechanical problems with ejector. Either worn-out internals or possible internal steam leak around steam nozzle threads.	6. Higher-than-design suction pressure (assuming motive steam pressure and quality are normal and discharge pressure is equal to or less than design)	6. Inspect internal dimensions and replace, if necessary. Tighten steam nozzle to steam chest if necessary, or weld nozzle to steam chest.

Condenser evaluation

Problem	Effect	Corrective action
1. High DP across shellside (as a rule of thumb, normally DP should be 5% of absolute design operating pressure or less)	1. Poor condenser performance: (a) Shellside or tubeside fouling (b) Cooling water temperature higher-than-design (c) Low cooling water flow rate (d) Higher-than-design condensible organic (approximatley 20–30% above design)	1. (a) Clean tubes (b) Reduce cooling water temperature, increase flow (c) Increase cooling water flow (d) Reduce organic load or install larger condenser and downstream ejector
2. Higher-than-design tubeside DP	2. Poor condenser performance: (a) Tubeside fouling (b) Higher-than-design cooling water flow	2. (a) Clean tubes (b) Not a problem
3. Higher-than-design tubeside DT (temperature change in cooling water)	3. Poor condenser performance: (a) Tubeside fouling (b) Higher-than-design flow	3. (a) Increase flow rate (b) Increase cooling water flow rate or replace condenser
4. High vapor outlet temperature	4. Poor condenser performance	4. (a) Tube fouling (b) Cooling water flow rate low or inlet temperature high (c) Possible internal bypassing. Check with manufacturer. (d) Check whether downstream ejector not functioning and backstreaming.

charge pressure rises above design, an ejector will not have enough energy to reach that higher pressure. When this occurs the ejector breaks operation and there is an increase in vacuum vessel pressure. When back pressure is above design, possible corrective actions are to lower the system back pressure, rebore the steam nozzle to permit the use of more motive steam that enables the ejector to discharge to a higher pressure, or install completely new ejectors. System back pressure is the most common cause of inadequate vacuum. Failing to make adequate allowance for the back pressure due to the pressure drop in the vent line or tail leg, for the submergence of the tail leg in a condensate receiver, or for site barometric pressure will negatively affect system performance.

Some ejector and condenser problems, their effects, and possible corrective actions are shown in Table 4.

Glycerin plants

Glycerin production is done at an extremely high vacuum, very low absolute pressure. Typically the operating pressure of a glycerin vacuum flash still is below 10 mm Hg abs. Overhead load from the flash still consists of glycerin, water vapor, and air at temperatures approaching 400°F. In one glycerin process, different glycerin product qualities are produced via fractional condensation. Overhead glycerin vapors from the vacuum flash still are fractionally condensed by three vacuum precondensers ahead of a four-stage ejector system (Figure 8). The three glycerin condensates produced by fractional condensation have varied commercial value.

The primary vacuum precondenser fractionally condenses overhead load so as to produce “commercially pure” glycerin. Tight control of the condensation profile is necessary to maintain high purity levels. To maintain control of product quality, vaporizable water on the condenser tubeside is used. By controlling tubeside operating pressure, the boiling temperature is varied to maintain the outlet vapor temperature of the condensing glycerin above the point where impurities began to condense, thereby ensuring contaminant free condensate.

The secondary precondenser uses water vaporization as the cooling medium as well; however, the operating pressure of the tubeside is lower. This condenser produces glycerin condensate marketed as “high gravity.” Again, the outlet vapor temperature of the glycerin is maintained so as to limit impurities in the condensate.

The final precondenser makes use of tower water to condense and recover remaining glycerin vapors exiting the secondary condenser. The condensate is recycled back to the process.

With three precondensers in series operating at such low absolute

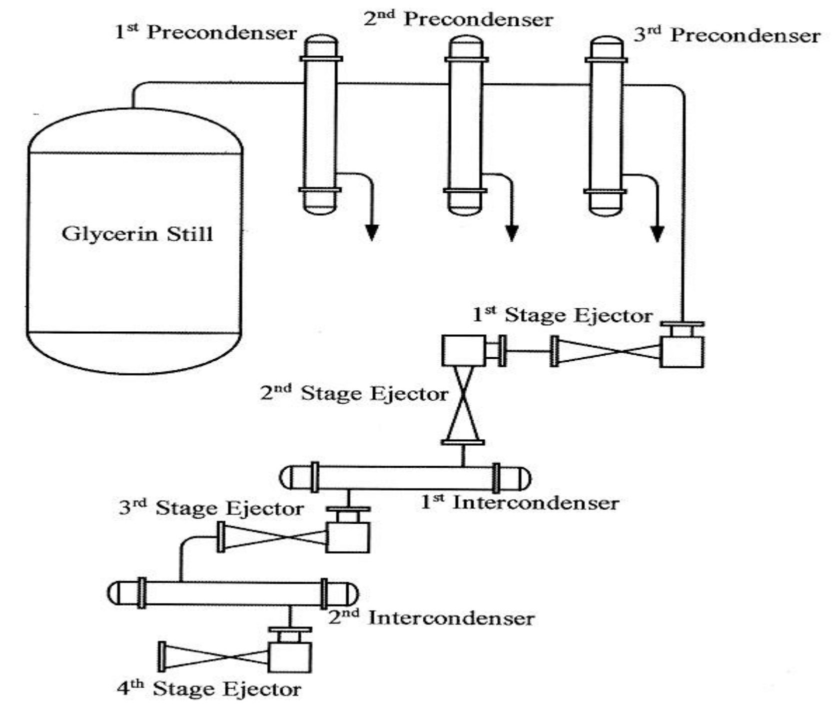


Figure 8. Glycerine plant flow chart

pressure, pressure drop across each precondenser is extremely important. High differential pressure drop not only results in added utilities necessary for the ejector system which backs up the condensers but also reduces the amount of glycerin recovered. The highest value "commercially pure" glycerin production is reduced when pressure drop is high, Furthermore, high pressure drop increases glycerin carryover to the ejector system and as a consequence, increases product loss.

Glycerin plant condensers often have open tube pitches and large distribution areas above and through the tube field. Typical spacing between tubes in a general heat exchanger would be 1.25 times the tube diameter. In vacuum condensers operating at the low pressures necessary to support glycerin production, spacing between tubes increases to 1.5 to 2.0 times tube diameter. This is necessary to enable vapors to distribute above the tube field and flow through the tube bundle at velocities suitable for low pressure drop, Target pressure drop is 1O - l5% of the operating pressure.

Boiling water vacuum condensers are rather sophisticated. The thermal and hydraulic design warrants careful consideration. To enable an optimized design to be achieved, the precondenser requirements should be discussed with the ejector system manufacturer, Often manufacturers with experience have proprietary designs for this type of service.

The foregoing is typical of one glycerin process. Another process utilizes a packed column with direct condensation inside the column and a water-cooled precondenser after the column for reclamation of remaining glycerin.

Edible oil plants

Edible oil deodorization is done under vacuum at very low absolute pressures. Early systems operated at 5 to 6 mm Hg abs and had direct-contact condensers. Today's plants operate at 1.5 to 3 mm Hg abs and have surface-type intercondensers. This lower operating pressure reduces stripping steam consumption within the deodorizer, and energy consumption is lower. Stripping steam is used within the deodorizer to lower fatty acid partial pressure, thereby allowing the fatty acid to vaporize from the oil. Therefore, the deodorizer overhead load to the vacuum system is steam, free fatty acid, fatty matter, volatile organic compounds, and air. Normally, two ejectors in series compress deodorizer overhead load to the first intercondenser.

Fatty acids solidify upon contact with cold surfaces. The first intercondenser is designed to handle fatty acid loading without special provisions, the fatty acid would rapidly solidify in the condenser. This first intercondenser is designed for tubeside vacuum condensation, with cooling water on the shellside. The fatty acid solidified as it contacts the cold surface of the tubesheet and tubes. If provisions for removing solidified fatty acid are not included, tube holes in the tubesheet will plug. This reduces performance and ultimately results in a rise in deodorizer operating pressure. An increase in deodorizer operating pressure reduces the amount of fatty acid removal from the oil; less will vaporize due to a higher operating pressure. This degrades product quality and marketability of the oil.

The top head of the first intercondenser has a nozzle that sprays caustic flush solution on the inlet tubesheet to remove fatty acid deposits (Figure 9). This is a continuous washing operation, as fatty acid buildup is rapid. Must of the fatty acid is removed in the first intercondenser, and secondary condensers do not require this feature.

An interesting concept that offered appreciable savings in operating costs was employed at an edible oil refinery in Canada. In regions where cooling water temperature varies significantly between summer and winter months, it is possible to control motive steam consumption to optimize operating costs. In any deodorizer ejector system,

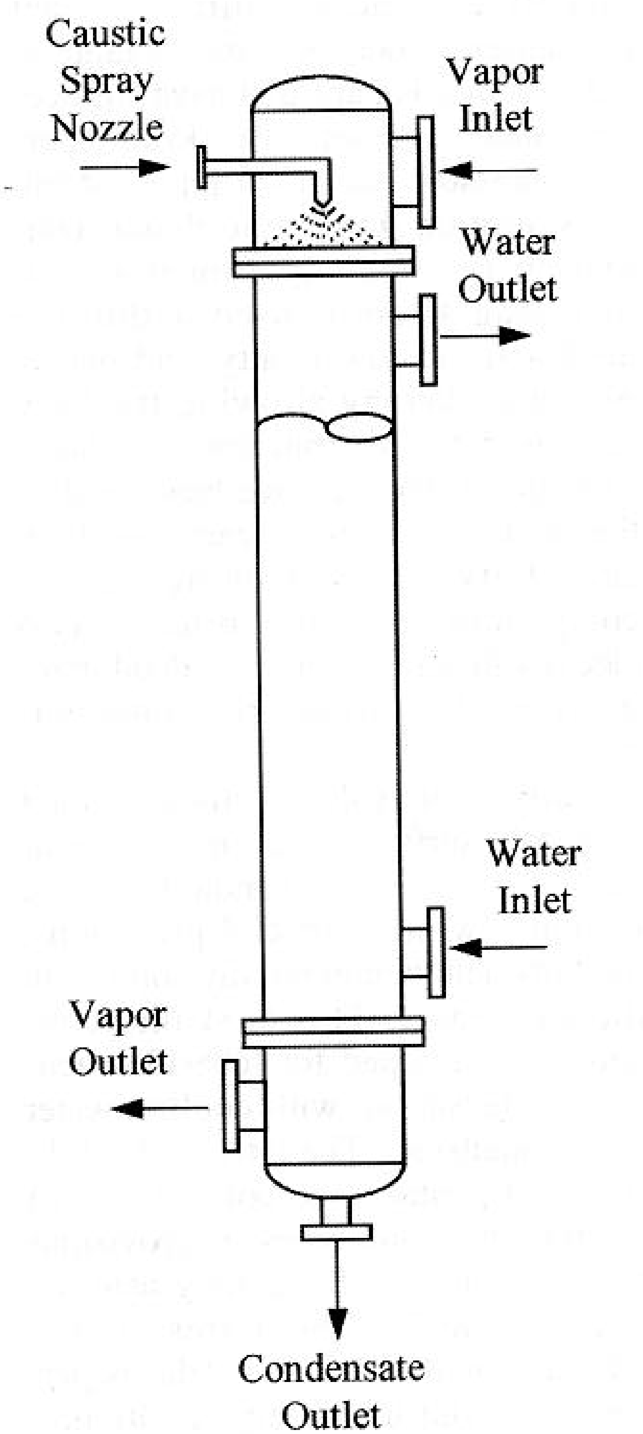


Figure 9. First intercondenser for fatty alcohol/methyl ester facility

the second stage ejector uses most of the motive steam required by the ejector system. Steam consumption for this ejector may be controlled as a function of cooling water temperature.

The principle at work in this arrangement is that as cooling water supply temperature decreases, the operating pressure of the first intercondenser decreases as well. This occurs because colder cooling water will increase the available LMTD, thus enabling that condenser to operate at a lower pressure. As operating pressure of the first intercondenser is reduced, less energy is required to entrain and compress the second stage ejector load to the operating pressure of the condenser. A savings in motive steam usage is possible due to a reduction in actual discharge pressure for the second stage ejector (Figure 10).

An exacting test procedure must be followed by the ejector manufacturer to assess operating characteristics of the second-stage ejector as a function of motive steam supply pressure. Motive steam supply pressure to the second ejector is reduced as cooling water inlet temperature is below design, Actually if water temperature is cold enough, the second-stage ejector may be bypassed entirely, thus tremendous savings in steam consumption may be realized during winter months. It is also important to design the secondary equipment those items downstream of the first intercondenser to follow the performance of the first intercondenser. A caveat to bear in mind is that processing of certain oils may result in increased fatty acid fouling in the first intercondenser when cooling water is permitted to drop below 75-80°F. Common operating practice is to control cooling tower fan speed so as not to permit water temperature falling below 75°F.

Fatty alcohols/methyl esters

Fatty alcohol and methyl ester distillation plants will use precondensers and three and four-stage ejector systems. Once again, the precondenser should be married to the ejector system. Operating pressure of the distillation column is less than 10 mm Hg and will have 10,000 to 30,000 pounds per hour (pph) C_{12} load or greater. A precondenser should be mounted directly atop the vacuum column, as shown in Figure 11. This keeps pressure drop to a minimum but will require a special layout for optimal performance.

Either tempered water or boiling water is used on the tubeside to effect organic condensation on the shellside of the condenser. Here the temperature of the tubeside fluid is important so as to maintain the metal temperature above the point where methyl esters will solidify. An added benefit from boiling water is that the large enthalpy change associated with boiling water permits less water to be used as opposed to the amount required if tempered water is used. The figure depicts a horizontal condenser mounted directly on the distillation column, which is typical of tempered water-cooled precondensers.

Summary

Complexity of ejector systems in fats, oils, and oleochemical production requires that careful consideration be given to their design, installation, and performance troubleshooting. An ejector system is truly an integral part of the process. If properly designed, an ejector system will provide problem free performance. When precondensers are involved, it is important to integrate the precondenser into the ejector system design. This will ensure a unitized design that minimizes capital cost and operating expenses.

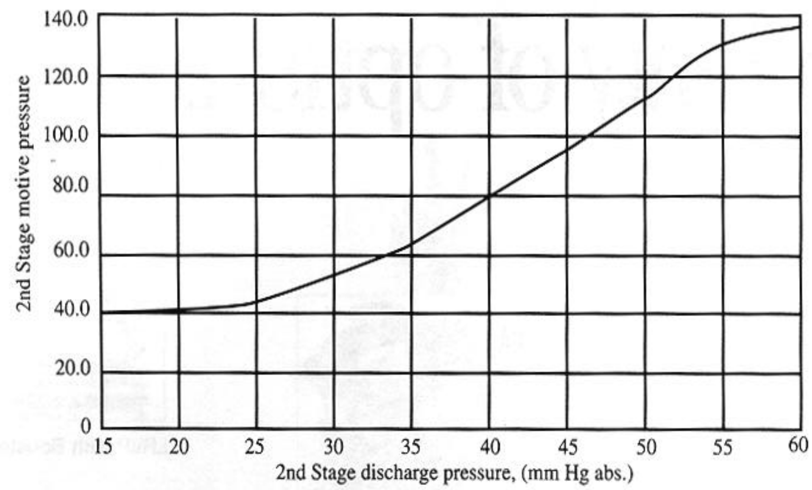


Figure 10. Second-stage motive pressure vs. discharge pressure

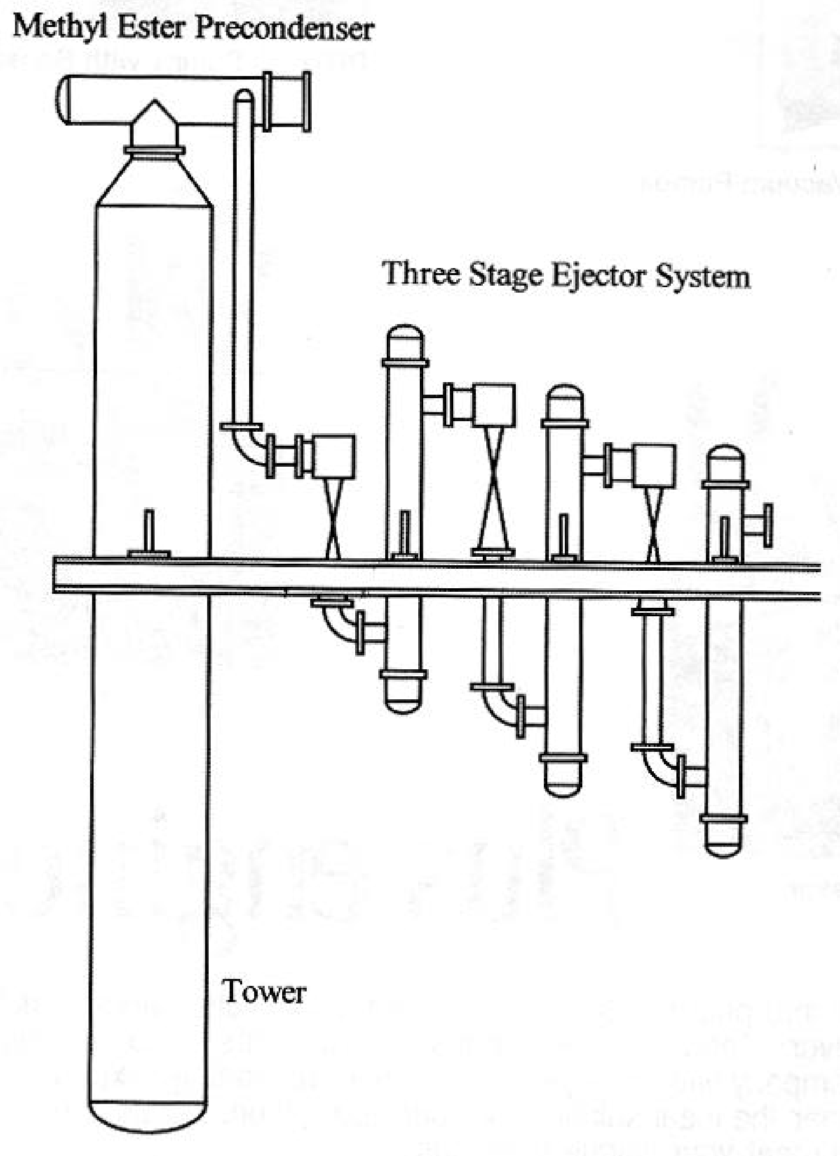


Figure 11. Precondenser mounted atop vacuum column