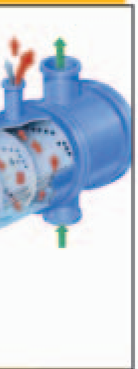


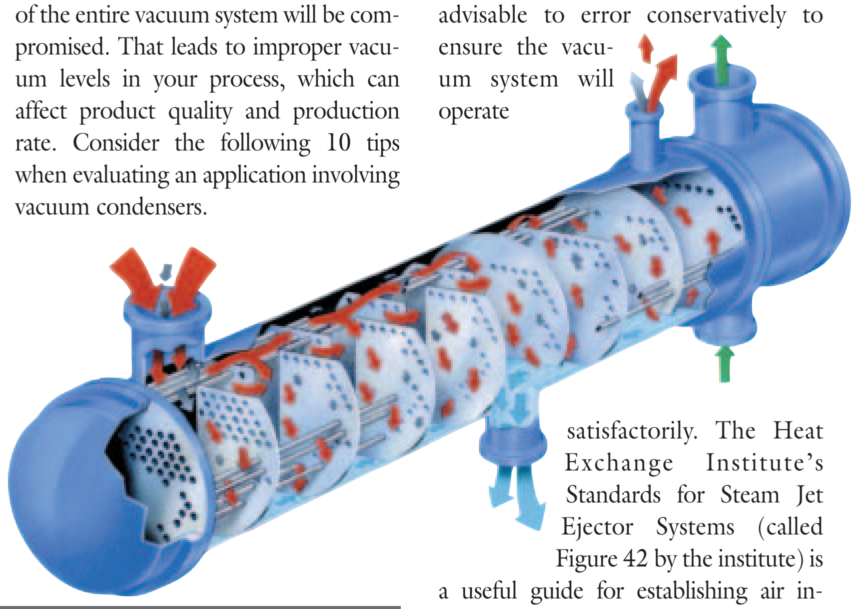
10 TIPS TO ENSURE Reliable Vacuum Condenser Performance

Carefully evaluating your process and its operating parameters will help you specify a vacuum condenser that maintains a satisfactory vacuum level. Failing to take these 10 tips into account may result in improper vacuum levels, compromising product quality and production rate.

BY JAMES LINES, GRAHAM CORP.

Vacuum condensers are unlike conventional heat exchangers. There are several important factors you must bear in mind as a specifier or user of vacuum condensers.

A vacuum condenser, whether a precondenser ahead of a vacuum system or an intercondenser within the vacuum system, is an integral part of the vacuum system. If the vacuum condenser is not performing properly, then performance of the entire vacuum system will be compromised. That leads to improper vacuum levels in your process, which can affect product quality and production rate. Consider the following 10 tips when evaluating an application involving vacuum condensers.



HOT SHEET

KEY BENEFIT
If your vacuum condenser is not performing properly, the performance of the entire vacuum system can be compromised. Follow these tips to select the right system in the right way.

EQUIPMENT COVERED
Vacuum condensers

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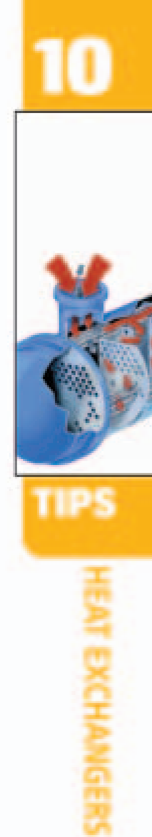
TIP 1: Conservatively Estimate Noncondensible Loading

This is probably one of the most important design considerations. It is advisable to error conservatively to ensure the vacuum system will operate satisfactorily. The Heat Exchange Institute's Standards for Steam Jet Ejector Systems (called Figure 42 by the institute) is a useful guide for establishing air in-leakage of commercially tight systems operating under vacuum. Even though your process model may not indicate the presence of air or other noncondensibles, your process will operate under vacuum and will have air in-leakage. The amount of noncondensible gases, whether they are air, nitrogen or some other noncondensible, will affect the performance of and the amount of con-



densation in your vacuum condenser. The greater the amount of noncondensibles, the less efficient a vacuum condenser is and greater is the amount of vapors that are carried out of the vacuum condenser with the noncondensible gases.

TIP 2: Understand Vapor-Liquid Equilibrium of the Vapor Components in Your Process

Not all combinations of vapor components behave ideally. As a mixture of vapor is condensed and the condensates commingle vapor-liquid equilibrium calculations depend upon the condensate behavior. Most often, shell-side condensation is employed because that permits effective management of high volumetric vapor flow associated with vacuum operation. Shell-side condensation is satisfactory when vapor-liquid equilibrium is ideal and the condensates are immiscible. By contrast, if the condensates are miscible, then it may be necessary to specify tube-side condensation. Tube-side condensation also is necessary if solubility of gases in the condensate should be considered. Normal applications where tube-side condensing might be the best choice could be an alcohol, like methanol, and steam, or if the process vapors are ammonia and steam. Tube-side condensation keeps the vapors and condensate in close contact and at the same temperature, which is necessary for accurate estimation of vapor-liquid equilibrium at a given pressure and temperature.

TIP 3: Properly Elevate a Vapor Condenser

A typical installation will have condensate from a vacuum condenser draining by gravity to a receiver. The condenser is under vacuum and condensate receiver is normally at some pressure above local atmospheric pressure, for example 2 psig. The condensate drain leg from the condenser to the receiver will have a liquid level that varies depending upon the operating pressure of the condenser. If the elevation between the receiver and vacuum condenser is insufficient, then liquid in the drain leg is drawn into the condenser. That will reduce the operating efficiency of the condenser.

The required height is a function of the pressure differential between the operating pressure of the vacuum condenser and the condensate receiver, along with the density of the condensate. The operating pressure of the condenser will vary for a number of reasons. Safe practice is to assume the worst case, which is complete vacuum in the vacuum condenser. Figure 1 may be used to determine minimum elevation above the condensate receiver.

TIP 4: Define the Range of Cooling Water Temperature and Flow Rate

Be certain to specify the most extreme cooling water condition for design considerations. Also, accurately define the cooling water flow rate available to the condenser. If the cooling water temperature or flow rate is more extreme in actual practice than the design basis, then that will negatively affect the operation of the vacuum condenser.

What is extreme? It depends on the parameters of your application. It could mean that the actual temperature of the cooling water to the vacuum condenser is above design. For example, the design could call for cooling water at 88°F (31°C), but the actual supply temperature to the condenser is 95°F (35°C). It also could be a flow rate below design. For instance, the design could call for a cooling water flow rate of 500 gal/min, but all that that is available is 350 gal/min.

In either instance, the condenser efficiency is negatively impacted, which could compromise the vacuum level of your process. If either or both of these extreme conditions occur, the operating pressure of the vacuum condenser will rise. That may not become a problem unless it causes one of the components in the vacuum system to become compromised because it cannot operate against pressure established in the condenser.

TIP 5: Properly Instrument the Process and Cooling Water Sides of a Vacuum Condenser

Include pressure and temperature gauges in the piping to and from a vacuum condenser. Do the same for the cooling water connections as well. If it is not possible or desirable to include instrumentation at the time of installation, be certain to include connections. If a vacuum condenser is performing poorly, it may become necessary to collect pressure and temperature data

FIGURE 1. CONDENSER ELEVATION

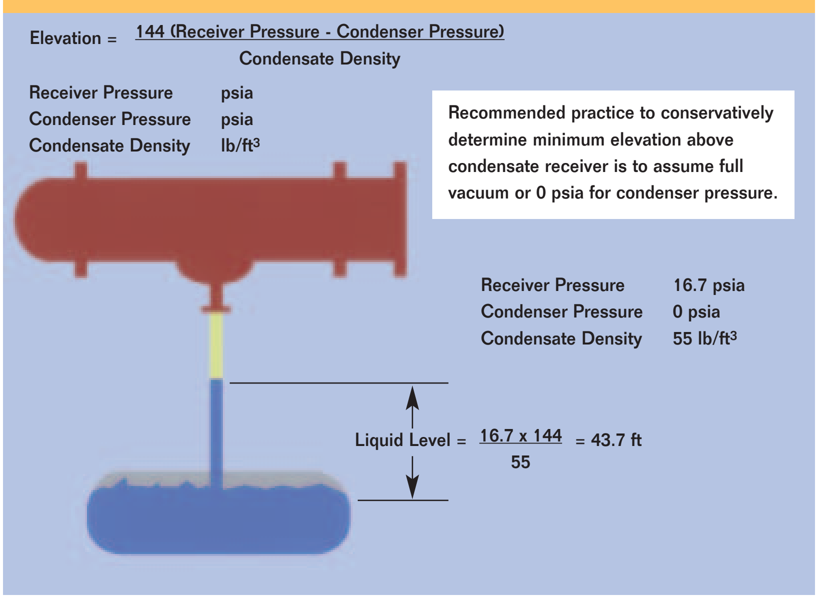


Figure 1. The required elevation of a vacuum condenser is a function of the pressure differential between the operating pressure of the vacuum condenser and the condensate receiver, along with the density of the condensate.

while the condenser is in operation to diagnose the cause of poor performance. Pressure gauges must be absolute pressure indicators; any standard temperature gauge will be satisfactory.

TIP 6: Remember That Vacuum Condensers are Part of the Vacuum System

Vacuum condensers are integral to the vacuum system and should be included as part of the vacuum system (figure 2). This tip applies for a precondenser that may be between your process vessel and a typical vacuum system. By including the vacuum condensers as part of a vacuum system, you are assured of a single source of supply and guarantee. If the condensers are broken apart from the vacuum system, there is a possibility that the condensers will not be compatible with the other vacuum-producing equipment. Include the vacuum condensers in the vacuum equipment suppliers' scope of supply.

FIGURE 2. VACUUM CONDENSERS PART OF A SYSTEM

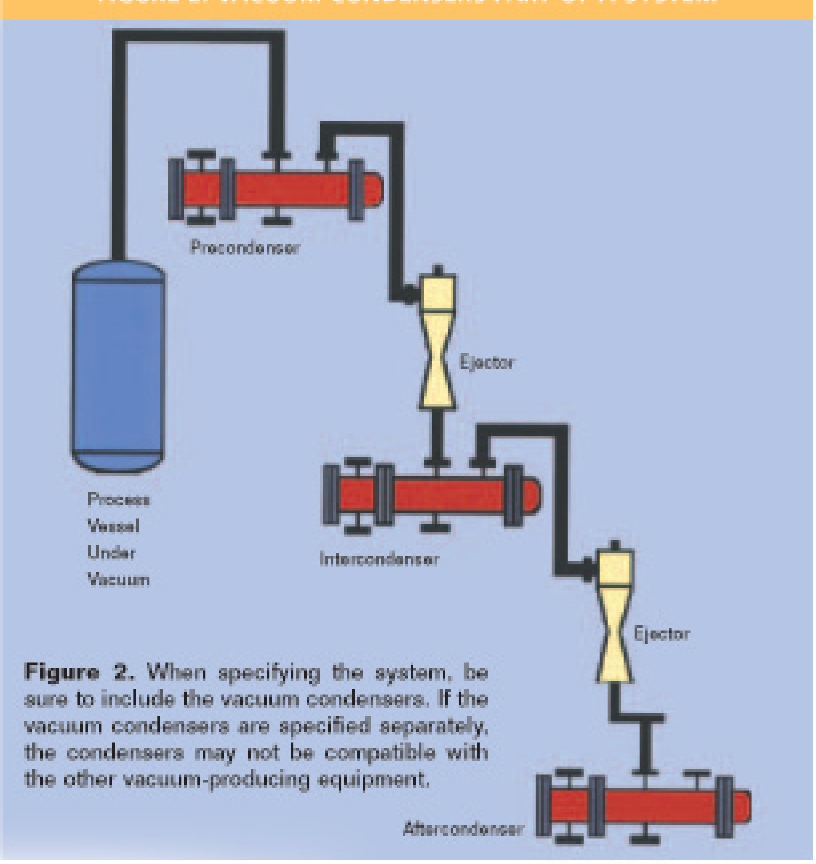


Figure 2. When specifying the system, be sure to include the vacuum condensers. If the vacuum condensers are specified separately, the condensers may not be compatible with the other vacuum-producing equipment.

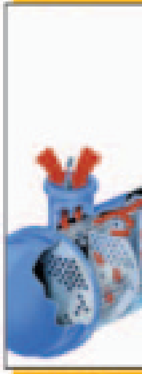


FIGURE 3. EFFECT OF PRESSURE DROP ON CONDENSER PERFORMANCE

A vacuum condenser handling 1,000 pph water vapor and 100 pph air at 1 psia is designed for 85°F (29°C) outlet temperature. How does pressure drop change the amount of water vapor condensed?

Pressure Drop	Outlet Pressure	Water Vapor Exiting Condenser	Percent Condensed
5 Percent	0.95 psia	104 pph	89.6
10 Percent	0.90 psia	122 pph	87.8
15 Percent	0.85 psia	146 pph	85.4
20 Percent	0.80 psia	181 pph	81.9

Figure 3. Pressure drop affects the amount of condensation that occurs in a vacuum condenser.

TIP 7: Beware of Commercially Available Heat Transfer Software

As the operating pressure for a vacuum condenser becomes lower, for example below 50 torr, commercially available software may not accurately model vacuum condenser performance. Reliable designs are not always generated by software you might use for typical heat exchange applications. Commercial software may underestimate pressure drop across the condenser and, therefore, predict more condensation than actually occurs. Also, the commercial software may specify surface area that is in excess of what actually is required. Should you use commercially available software to design a vacuum condenser, it may be a much larger and more costly vacuum condenser than you actually need. Worse yet, it may not work properly.

TIP 8: Understand the Degree of Fouling

You must make a decision about the fouling tendency of the process and cooling water. Knowing the fouling behavior of the process or cooling water will guide you to specify appropriate geometry for the vacuum condenser. If, for example, process vapors are on the shell side and the vapors have a high fouling tendency, then it is advisable to specify a removable-bundle-type heat exchanger. Removable-bundle designs are more costly than fixed tubesheet designs, but if periodic cleaning of the shell side is a possibility, then a removable-bundle design is preferable.

If the cooling water is dirty or has a high degree of fouling, then a straight-tube design is preferred, and you should avoid the use of a U-tube condenser. The type of condenser design, whether it is a removable bundle or U-tube, also will depend upon the type of cleaning required to remove fouling deposits. Is it possible to clean in place either the tube side or shell side? Is it required to water lance the outer surfaces of the tubing to remove shell-side deposits? Is it

necessary to rod out the tubes to remove fouling deposits inside the tubes?

TIP 9: Understand How Vacuum Side Pressure Drop Affects Performance

Pressure drop is important when operating under vacuum (figure 3). The vacuum condenser that operates at 50 torr is impacted significantly by a 5 torr pressure drop; 5 torr is only 0.1 psia. By contrast, a 5 torr pressure drop will have a minimal impact for a vacuum condenser that is operating at 300 torr. Pressure drop affects the amount of condensation that occurs in a vacuum condenser. The greater the pressure drop, the less condensation that occurs and the greater the vapor load is that exits the condenser. Vacuum condensers often have specialized designs to minimize pressure drop. High pressure drop across a vacuum condenser is an efficiency drain on the overall vacuum system.

> REMOVABLE-BUNDLE DESIGNS ARE MORE COSTLY THAN FIXED TUBESHEET DESIGNS, BUT IF PERIODIC CLEANING OF THE SHELL SIDE IS A POSSIBILITY, THEN A REMOVABLE-BUNDLE DESIGN IS PREFERABLE.

TIP 10: Consult With a Vacuum Equipment Supplier

If you are designing a vacuum condenser or having one designed by a heat exchanger company that is not a vacuum system specialist, then involve the vacuum equipment supplier you intend to use to review the design of the vacuum condenser. The vacuum equipment supplier must integrate the vacuum condenser into its design to ensure the overall system operates satisfactorily. If you do not involve the vacuum equipment vendor, then there is a high probability that the vacuum condenser will not be properly integrated into the vacuum system and your process objectives will not be met.

Vacuum condensers are reliable, however, they must not be considered a general heat exchanger. Special requirements are associated with vacuum condensers that you must keep in mind when specifying, installing and operating them. If you factor these 10 tips into the design basis for your next vacuum condenser, you are off to a good start specifying and eventually installing a proper vacuum condenser. PH

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