RCM Thermal Kinetics

Evaporator Selection Guide

Evaporators, used to perform an energy-intensive vaporization process to concentrate a solution, can be found in a range of industries, from food and beverage to pharmaceutical, pulp and paper, and chemical processing. They are available in several styles to best suit your specific needs.

Evaporation is used for numerous applications, such as concentrating caustic soda solutions, eliminating moisture from pharmaceutical products, and ensuring optimal consistency of beverages. The recovered solvent — usually water — can then be recycled back through another part of the system to reduce waste.

In this guide, we'll explore the main design criteria for different evaporators and assist you in your search for the right evaporation system.

What to Consider When Choosing an Evaporator

Many individual evaporator systems and components can be customized to best suit your needs. Some of the most common types of evaporators supplied by TK include:

- Forced circulation
- Natural circulation
- Vertical rising film
- Falling film
- Rising and falling film tubular
- Rising or falling film plate

To narrow down your options, you must first choose one of these configurations:

Forced circulation evaporators are best for highly fouling service and higher viscosity applications. The circulation rates can be increased to above 8 ft/sec tube velocity, which minimizes fouling rates. Film evaporators are viscosity limited since the liquid film breaks down forming dry spots on the tubes. The forced circulation suppressed boiling operation assures better control and stability with reduced fouling.

Plate evaporators generally have higher heat transfer coefficients (HTCs) than tubular evaporators, particularly for viscous fluids, and offer relatively low headroom and installation costs, as well as quicker cycle times and easy addition of area if needed. Tubular evaporators, how-ever, are better suited for larger systems, fluids with high particulate loading (slurries), low viscosity fluids, and for many corrosive or hazardous fluids.

Vertical rising film units can be configured for natural recirculation relying on the buoyant effect of vapor and liquid in the tubes to promote recirculation, thus eliminating the need for large recirculation pumps. Generally useful for large systems with low viscosity and low boiling point elevation. Film evaporators provide the highest heat- transfer coefficients (HTCs) and are typically the most cost efficient of the tubular evaporators. However, they are not suitable for heavily fouling or highly viscous solutions. Circulation evaporators, though more expensive, will significantly reduce fouling and better manage highly viscous products.

Rising/falling film tubular systems are used to reduce the overall height of the evaporation plant without greatly increasing the recirculation pumping rate needed to maintain tube wetting. One special design employed by Thermal Kinetics, is a long tube version for applications having suspended solids and fouling proteins such as corn stillage or distillery slop. This can plug falling film liquid distributors and would require long vertical pipes for circulating the process liquid from the bottom back to the top of the unit. This special design uses a small portion of the tubes for upward flow generating a two phase mix of vapor and liquid which naturally distributes the liquid across an unobstructed tubesheet. This reduced fouling and plugging at the top tubesheet reduces the pumping head requirements for greater recirculation at lower power consumption.

Application-specific considerations should also be taken into account, including:

- Materials of construction
- Configurations for energy efficiency
- Operational and product characteristics

Materials of Construction

Manufacturers should consider two major factors when selecting materials for an evaporation system: corrosion and ease of cleaning. Since evaporation systems are typically subjected to harsh environments — often passing corrosive processing fluids containing chloride, acidic or caustic chemicals — they must be made of resilient materials. For example, a sulfuric acid evaporator can be made of graphite to prevent corrosion of the heat exchanger, as well as providing adequate heat transfer.

For applications where proper hygiene and sanitation are of the utmost importance, such as those in the food and beverage industry, it's imperative that evaporators are not only easy to clean, but also capable of enduring frequent cleaning and exposure to caustic soaps and chemicals. Popular material choices for hygienic evaporators include 304 and 316 stainless steel. Product contact surfaces are polished, welds ground smooth, and piping as well as auxiliary equipment constructed for sanitary use including specific codes for special applications (3A, NSF, plus requirements of the FDA and USDA, etc.).

Definitions, Concepts, Operational and Product Characteristics

Several operational and product characteristics can affect both energy consumption and production output; keeping these factors in mind when selecting an evaporator will help you determine the best method of heat transfer and energy source for your application.

Below are several operational and product characteristics that can affect the evaporation process:

- Heat sensitivity — If the chemicals or food ingredients passing through an evaporator are heat sensitive, temperature can be reduced by running the evaporator at low pressures or decreasing the amount of fluid and its time spent inside the evaporator.

- **Fouling** — This gradual buildup of solids on the heat transfer surfaces can ultimately cause system shutdowns for cleaning and maintenance. By selecting the proper evaporator, these system shutdowns can be reduced.

- **Foaming** — Although foaming is common and potentially harmless, too much foam in the system will cause carryover to other process equipment. Increasing the vapor velocity in the tubes to shear the foam, spraying the solution onto the foam to shear it, or adding an anti-foaming substance when possible can all help minimize negative affect of foam.

- **Solids content** — Changes in solid concentration can plug tubes, resulting in fouling and loss of heat transfer surface. This in turn can lead to reduced heat transfer rates and reduced evaporator capacity (evaporation rate per hour), which ultimately increases downtime as further cleaning may be required.

- **Boiling point elevation** — water boils at 212 °F at atmospheric pressure. Dissolved solids modify this normal boiling point and this phenomenon is called boiling point elevation. Low molecular weight dissolved solids such as salt (sodium chloride) and caustic soda (sodium hydroxide) can have very large impact on boiling point. For example 30% calcium chloride boils at about 230 °F at atmospheric pressure. This impact must be taken into account in the evaporator pressure and temperature profile.

- **Reactivity** — At certain temperatures or concentrations, a reaction make take place in the material being evaporated and if this is undesirable, those process conditions must be avoided so the reaction does not take place.

- **Viscosity** — Any increases in liquid viscosity will contribute to an overall reduction in HTC. This is a common case for most evaporation systems and the manner of configuring a multiple effect system and contracting methods can maximize performance and minimize the impact of high viscosity fluids.

- **Heat transfer medium** — Liquid/steam-evaporators tend to require less heat transfer area due to higher hot side HTCs, while hot-oil-heated evaporators have lower hot side HTCs, resulting in higher heat transfer area required. However, if the material being evaporated is not heat sensitive, hot oil can be the better choice because the oil temperature can be higher than steam temperatures, and that would lower the amount of heat transfer area required for the hot oil system.

- **Shell side vapor velocity** — In order to produce sufficient HTCs without exceeding the pressure drop, evaporator tubes and heating jackets (shell side of a tubular unit) must pass vapor at precise velocities, promoting removal of non-condensable gas (air), and develop good vapor shear.

• **Distillate-to-concentrate ratio** — There must be enough fluid — moving at high enough velocities — to lubricate the inside of the evaporator, thereby decreasing the risk of fouling and salting of solids on

Components of an evaporation system:

Vapor/Liquid separator: the outlet of an evaporator is a mixture of liquid concentrate and vapor. The vapor must have liquid droplets removed (de-entrained) before is it condensed in either the next evaporator shell to provide heating or in the final condenser so that a pure water stream can be recovered.

Vacuum System: this can be a liquid ring vacuum pump, steam jet ejector system or a number of other specialty systems. Most evaporators operate well below atmo-spheric pressure and result in some in-leakage of air or the feed will have dissolved gasses entrained. These non-condensable gasses must be removed from the system after the water vapor has been condensed and must be removed at the pressure of the last effect such that compression of the gas to atmospheric pressure is needed. The

Main evaporator heater: this is one of the major types listed above such as falling film.

Condenser: the vapor evaporated from the last effect (see energy configurations) of an evaporator is condensed using a shell and tube heat exchanger (or other type) which is cooled using cooling tower water, chilled water, or in some cases uses an air cooled fan driven heat exchanger.

Heat recovery exchangers: energy efficient systems all employ some means of reusing heat from product streams, final vapor and intermediate vapors to preheat the feed to the evaporator so that primary steam is used mainly for evaporation and not sensible heating.

Keeping these factors in mind will help you narrow down your options when selecting an evaporator.

Configurations for Energy Efficiency

All evaporation projects present the opportunity or obligation to conserve energy, as the nature of these processing systems is removal of a large proportion of solvent (water) requiring huge energy input. Putting a value to this, consider that it requires about 1000 Btu to evaporate one pound of water and only 100 Btu to heat water from 100 °F to 200 °F. Although the evaporation process itself is energy intensive, there are many ways to ensure green evaporator usage, resulting in both economic and environmental benefits.

Energy efficiency is particularly important for large evaporation systems with extensive capacities. The bigger the equipment and capacity, the more energy can be conserved by intelligent design. Because of this,making investments in green technology is not only ethically sound, but also cost effective.

• **Mechanical Vapor Recompression (MVR) System** — An MVR uses a mechanical driver, i.e. a compressor, to increase the pressure of the vapor boiled off in the evaporator to recycle and drive the evaporation process.

MVRs are very energy efficient when large evaporation duties and low electricity costs are present.
The compression ratio of an MVR is usually limited to between 1.4 and 2.0 depending on the compression equipment used, meaning that the MVR system cannot be used on solutions with a boiling point elevation greater than approximately 5 °F.
Since latent heat energy is always re-used, the process only requires enough energy to compress the vapor providing effective efficient preheating of the feed has been accomplished.
Typical energy efficiency: < 100 Btu per 1000 Btu of water removal.

- **Thermo Vapor Recompression (TVR) System** — A TVR uses thermal energy, i.e. steam jet ejector, to increase the pressure of the vapor boiled off in the evaporator to recycle and drive the evaporation process. evaporation process.

- TVRs are very energy efficient when small evaporation duties and low steam costs are present.
- The compression ratio of a TVR is directly dependent on the pressure of motive steam and ratio of flow of motive steam to compressed steam.
- Steam condensate is not recoverable – it is mixed with process condensate.
- Typical energy efficiency: < 500 Btu per 1000 Btu of water removal in a single effect.

- **Multi-Effect Evaporation System** — A series of evaporators that operate at different pressure so that the vapors from one can be used to drive another.
- A multi-effect evaporation system is very energy efficient when dealing with large evaporation duties and low steam costs.
- These systems can be used on a solution with almost any boiling point elevation. The boiling point elevation, the further apart the evaporators' operating pressures.
- Typical energy efficiency:
- 500 Btu per 1000 Btu of water removal for a double effect.
- 330 Btu per 1000 Btu of water removal for a triple effect.
- 200 Btu per 1000 Btu of water removal for a quintuple effect.

When designing an evaporation system, choosing the proper energy-efficiency system will help ensure value and reliability.

Thermal Kinetics' Evaporator Systems

With so many things to consider, selecting an evaporator may seem daunting at first. Thermal Kinetics can assist you every step of the way to ensure you find the right fit for your industry and application.

We proudly offer a wide selection of evaporators, all of which are available in multi-effect, TVR, MVR, and completely customizable variations to meet your unique needs. Our standard evaporator equipment includes:

- Falling Film Tubular Evaporators (FF)
- Rising/Falling Film Tubular Evaporators (RFC)
- Rising Film Tubular Evaporators (VRC)
- Forced Circulation Evaporators (FC)
- Internal Pump Forced Circulation (IPFC) Evaporators
- Plate Stripping and Evaporation Systems (PSE)

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TEAM UP WITH THERMAL KINETICS

For almost two decades, Thermal Kinetics has been developing high- quality custom process equipment. Our talented group of engineers, designers, and developers will work alongside your team to implement an innovative, technologically advanced, and energy-efficient solution to fully optimize your system's processes.

To learn more about how Thermal Kinetics can help you with your next evaporator system project, contact us today.

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