

EVAPORATION TECHNOLOGY

DRASTICALLY REDUCE YOUR DISPOSAL COSTS

Economical Separation Solutions for Industrial Wastewater Treatment

Evaporation, or distillation, is a separation process that takes advantage of the changing physical states of water, or other solvents, from liquid to vapor. It is unique from other separation processes, in that the water is removed from the contaminants rather than the pollutants being filtered from the water. Before recent technological developments, the capital and energy requirements for evaporation processes had been too intensive for wastewater treatment or recycling applications. The economical use of evaporation was limited to product recovery applications or when all other treatment methods had failed. For over 35 years, however, EVALED™ evaporators and crystallizers throughout the world have been implemented as wastewater treatment and recycling solutions – economically and reliably. EVALED™ heat pump vacuum evaporators, hot/cold water evaporators, and mechanical vapor recompression (MVR) systems offer clean, simple, and

compact separation technology options for a wide range of difficult-to-treat industrial applications.

For concentrated waste such as produced water, which can contain 150,000 ppm TDS (total dissolved solids) or more, evaporation is the only practical and proven economical method for water recovery and reuse. Although other desalination technologies exist, such as reverse osmosis, the typical concentrations of bicarbonates, chlorides, sulfates, and hardness render processes that are common for pure water applications unreliable and maintenance cost-prohibitive for produced water treatment. Additionally, no other technology can attain such high water-recovery and concentration rates, capable of achieving residual total solids concentrations of over 85%, drastically reducing disposal costs.

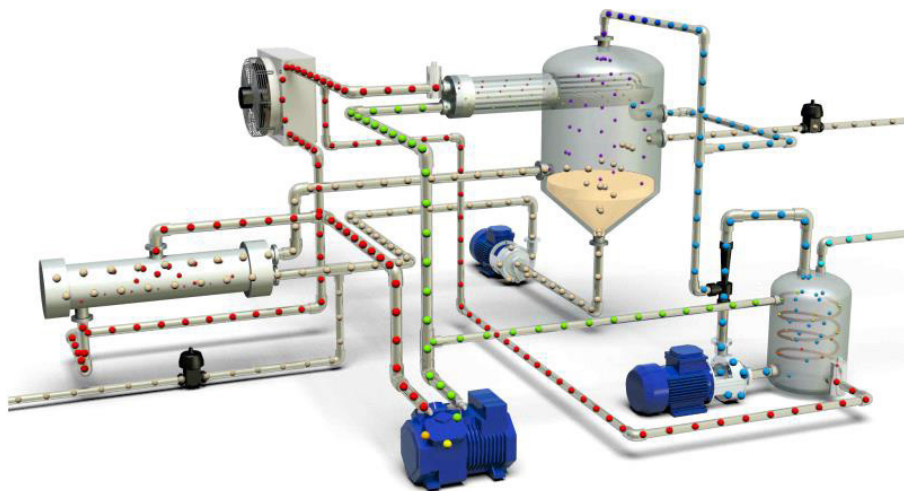


Figure 1: Forced circulation, heat pump vacuum evaporator process flow

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Evaporator Technologies

Evaporators are categorized by heating source, circulation method, and heat exchanger devices. The heating source for evaporation can be supplied by hot water, steam, thermal fluids, flue gases, and electrical energy – either directly through resistance, or indirectly with a heat pump or mechanical vapor recompression. Circulation methods include natural circulation, forced recirculation, scraped, and thin film. Direct heat exchange techniques include immersion heaters, submerged combustion, or submerged steam. Indirect heat exchange techniques include internal or external shell and tube heat exchangers, plate heat exchangers, or heating jackets.

Atmospheric Evaporation

The most basic design of an evaporator is a kettle-type system. Direct heat is applied at atmospheric pressure to boil the water, typically using combustion or steam. This is the simplest, but most energy-intensive, evaporation method. Under normal atmospheric pressure conditions (101.3 kPa), increasing the temperature of 1 kilogram of water from room temperature to boiling (100°C) and changing the phase from liquid to vapor, the system requires the addition of approximately 2500 kilojoules (kJ) of energy, corresponding to ~0.7 kWh/L. This energy is lost to the atmosphere because latent heat from condensation is not recovered.

Multiple heating methods exist to recover the energy of condensation and water for reuse within the process cycle. This reduces the total energy consumption for water evaporation by as much as 25 times, including heat pump vacuum evaporation, single or multiple effect distillation (MED), or mechanical vapor recompression (MVR) evaporator technologies.

Heat Pump Vacuum Evaporation

The heat pump vacuum evaporator offers reduced electrical energy consumption and superior reliability for low to medium flow produced water treatment applications (40-12,680 gal/day). Evaporation occurs under high vacuum conditions, of 4 kPa absolute pressure, lowering the boiling point of water to a temperature of approximately 30°C.

Figure 1 shows the main components of a typical vacuum heat pump evaporator. An intermediate thermal fluid, R-134a, or other refrigerant is compressed in order to raise its temperature and transfer the heat necessary for the wastewater to evaporate in the boiling chamber. The same thermal fluid is then air-cooled and expanded to absorb the latent heat from the wastewater vapor, condensing the vapor into a liquid for reuse.

Energy consumption is reduced to approximately 0.15 kWh/L of distillate (a 5x reduction compared to atmospheric evaporation) as most of the energy in the form of latent heat is reused for new vapor production. Electrical energy consumption primarily depends on the work required to compress the intermediate fluid, and to a small extent, fans to aid the air-cooling process.

In addition to the reduced energy consumption, the high-vacuum, low-temperature conditions significantly reduce the foaming, scaling, and corrosion phenomena typical when highly concentrating produced water.

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Hot/Cold Water – Single or Multiple Effect Distillation (MED)

MED exploits the same physical property of reduced temperature boiling under vacuum, while also utilizing the vapor produced within the first boiling stage (effect) to produce new vapor in a next stage at an even lower temperature and pressure. This vapor recycle can be cascaded several times in a (multiple effect) sequence. External heat energy is added only in the first chamber, typically provided by excess or waste hot water or steam. The vapor evaporated in the first stage continues to a condenser in the next effect where the latent heat is utilized to evaporate the liquid in the next stage. The latent heat of condensation remaining after the final stage is then absorbed by cooling tower water, an air-cooled exchanger, or a feed preheater, to condense the vapor for reuse.

The efficiency of the system is increased by each addition of an effect, however, this energy efficiency must be balanced with the increased capital cost of duplicating the core equipment. Energy consumption ranges from 0.018 kWh/L of distillate for a single-effect, to a low of 0.008 kWh/L for a typical four-effect evaporator. Capacities range from 790-15,800 gal/day of distillate production in package units, up to several MGD in large design-build systems.

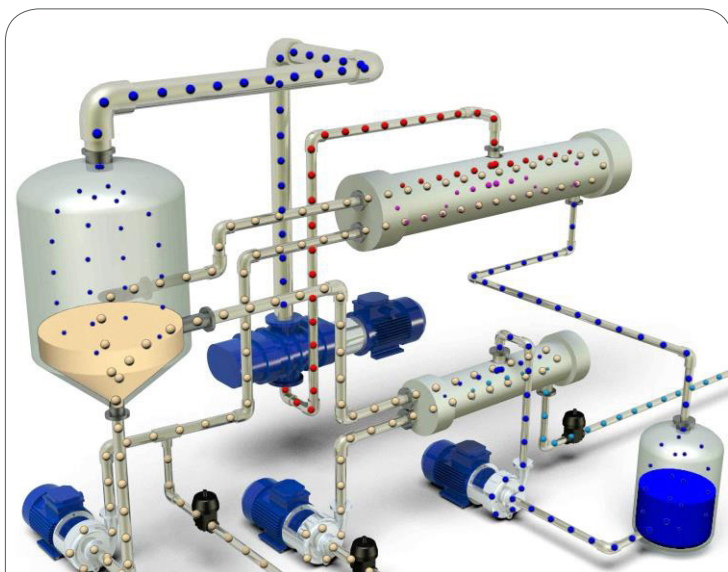


Figure 2: Forced circulation, mechanical vapor recompression (MVR) evaporator process flow

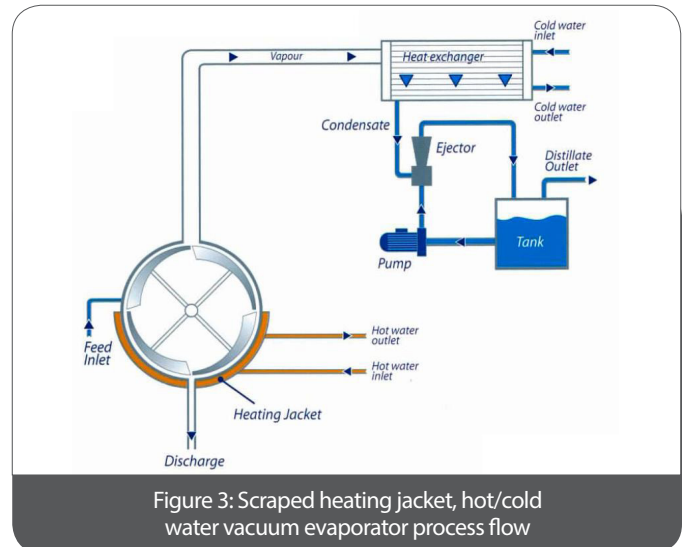


Figure 3: Scraped heating jacket, hot/cold water vacuum evaporator process flow

Mechanical Vapor Recompression (MVR)

The low electrical energy consumption of MVR evaporators allow treatment on medium- to high-flow wastewater treatment applications (2,600-53,000 gal/day) where excess or waste hot water/steam and cooling water is not available. Figure 2 shows the main components of a typical MVR evaporator. As opposed to a heat pump system, there is no intermediate thermal fluid needed in the MVR system. An electric resistance heater supplies the heat needed for initial evaporation. The vapor generated within the boiling chamber is then exploited for steady-state operation. A positive displacement compressor adiabatically compresses the vapor, increasing the pressure and temperature of the product vapor. The heated vapor transfers its latent energy in a primary heat exchanger, simultaneously providing the heat of evaporation for the waste liquid and condensation of the vapor to product distillate for reuse. A secondary heat exchanger recovers additional sensible heat from the distillate to preheat the incoming feed water, allowing a significant low energy consumption (approximately 0.03 kWh/L water, 25x lower than atmospheric evaporation). Although the boiling temperature is somewhat higher than in a heat pump system (90°C), the high velocity of liquid flow in the heat exchangers due to forced circulation reduces scaling, deposits, and fouling on the heat exchange surfaces.

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Choosing the Right Technology

A careful analysis of the chemical and physical properties of the waste fluid to be treated guides which type of evaporation should be applied. In addition to the utilities available and OPEX vs. CAPEX considerations for each evaporation technology, the equipment and devices specified for use in any evaporation system is application specific to the properties of the waste, fouling/scaling/corrosion potential, requirements for recycled water quality, and available final destination options for the residual slurry.



Figure 4: EVALED™ MVR evaporator system – part of PRAB's product line of produced water treatment solutions

ABOUT THE AUTHOR

Tim Hanna is the Vice President of Business Development for PRAB, a leading designer and manufacturer of wastewater recycling systems as well as engineered conveyors and equipment for processing turnings, chips, and metalworking fluids. Since graduating from Northwood University with a Marketing degree in 1970, Hanna has worked closely with companies and communities around the world who take advantage of the latest fluid filtration and chip handling technologies to both lower cost and increase environmental stewardship.

ABOUT PRAB

PRAB is a leading engineer and manufacturer of conveyors and chip and fluid management systems. Its customized solutions automate metal handling, reduce labor costs, reclaim and recycle expensive cutting fluids/coolants, and maximize return on recycling metals. With its expertise honed by more than 4,500 installations for the world's leading OEMs and suppliers, PRAB continuously improves material handling, housekeeping, and compliance to environmental rules and regulations within the automotive, aerospace, medical, electronics, defense, off-road, and energy markets. For more information about PRAB, visit prab.com.