



PRODUCT BROCHURE:
EVAPORATION



Evaporation is the physical separation of a liquid from a dissolved or suspended solid by applying energy to make the liquid volatile. Evaporation systems have been around for more than a hundred years and are used widely in the chemical & process industry, and for a variety of purposes.

HRS is a heat transfer specialist with forty years' experience in thermal processing, with evaporation systems being an integral part of our range of process solutions. As evaporation systems are available in different technologies and configurations, care must be taken to ensure the final design and configuration is selected correctly for the product and application. HRS has a wide range of unique heat exchangers well suited for evaporation processes, giving us the ability to provide reliable solutions for applications that others cannot.

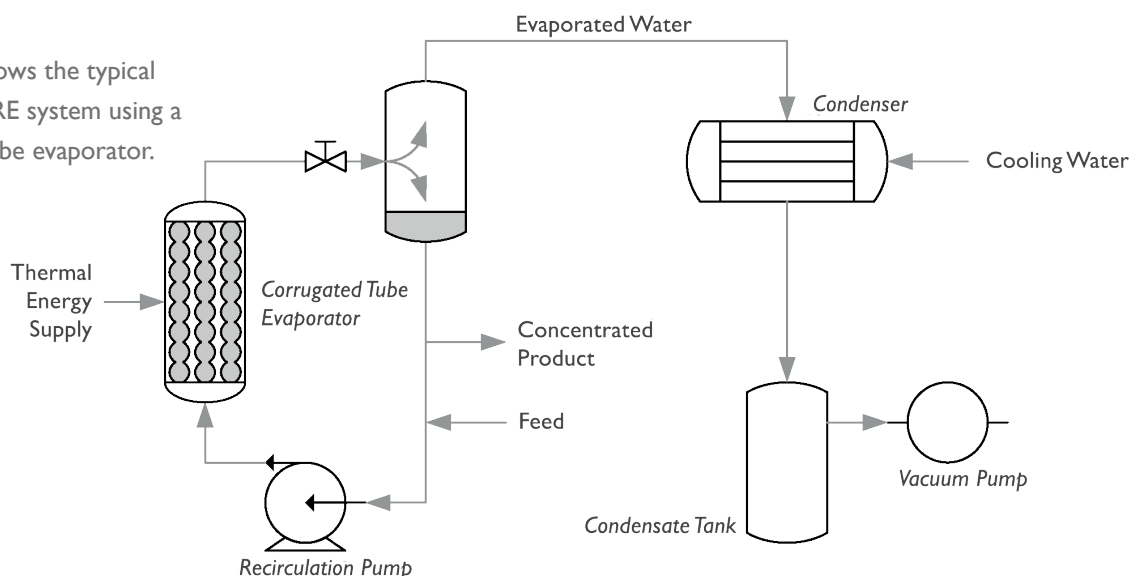
One range of technologies unique to HRS is our range of Scraped Surface Heat Exchangers. Applying this technology in an evaporation process allows HRS to achieve product concentrations levels much higher than traditional evaporation techniques. Combining scraped surface with our high-performance corrugated tube heat exchanger technology allows HRS to offer a system capable of treating a wide variety of products and solids concentrations, with a high degree of energy optimisation.

In our R&D centre we study evaporation of new products in both lab and pilot plant scale, evaluating all physical parameters that must be understood for designing full scale industrial evaporators. This document explains in detail the various configurations of Evaporation Technology we offer, and how we do things differently.

FORCED RECIRCULATION EVAPORATION

The Forced Recirculation Evaporator (FRE) was one of the first systems HRS developed and refined, beginning with the integration of our proven corrugated tube heat exchanger technology. In an FRE plant the product is heated under pressure to a temperature above its boiling point. Upon exiting the evaporator, the product is introduced in a flash separation vessel where the pressure is lowered. Due to the reduction in pressure part of the product will flash off, and the concentration of the fluid in recirculation is increased. The flashed steam is then recovered by condensing it back to water in a condenser.

The image shows the typical setup of an FRE system using a corrugated tube evaporator.



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FORCED RECIRCULATION WITH CORRUGATED TUBE EVAPORATORS

The product is recirculated at high flow velocity through the corrugated tube evaporator using a centrifugal pump. The combination of high fluid velocity and HRS' performance enhancing tube corrugations creates increased levels of turbulence within the evaporator. This turbulence results in a high level of heat transfer achieved and good resistance against fouling due to the improved performance offered with our corrugated tubes.

HRS FRE installation with corrugated tubes evaporators

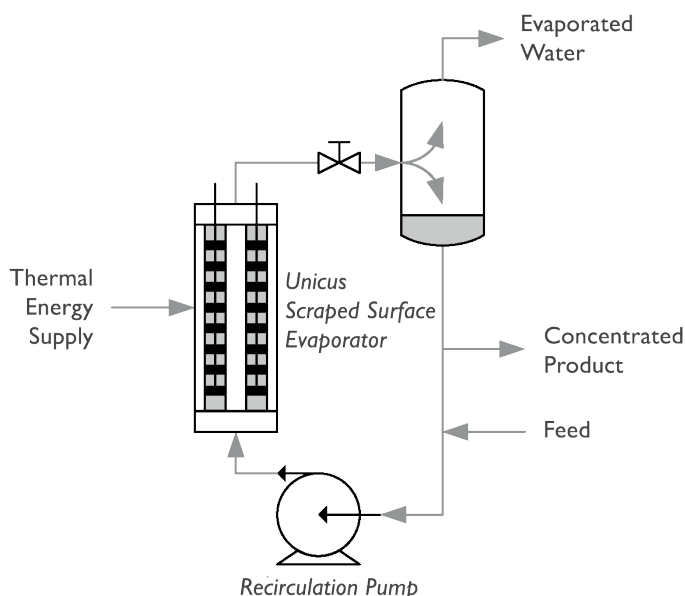
For low to medium viscosity products that have a risk of scaling the corrugated tube evaporator is the recommended technology offering significant benefits over smooth tube variants.

In the FRE process the evaporated steam is condensed and collected in a condensate tank. A vacuum pump can be connected to the condensate tank to control the evaporation pressure in the steam/liquid separation tank. Often the evaporated-condensed steam can be used to preheat the incoming product prior to entering the FRE system, allowing for significantly increased levels of thermal efficiency.



FORCED RECIRCULATION WITH HRS UNICUS SCRAPED SURFACE EVAPORATORS

The Unicus scraped surface heat exchanger was developed by HRS to offer efficient heat transfer for viscous fluids with high risk of fouling. The same risks are a concern in evaporation plants, as the product thickens its viscosity and fouling potential can increase significantly. For this reason traditional tube, plate or falling film evaporators are limited to how far they can concentrate. With the Unicus SSHE evaporator, concentration levels can be taken much further without fear of fouling or blocking. The scraping action continuously cleans the evaporation tubes, and the scraping elements act as dynamic mixing devices, keeping the heat transfer high despite increasing viscosities.



As the Unicus evaporator is a multitube heat exchanger, scalability for larger evaporation duties becomes easy and economical. By adding more tubes a much higher heat transfer area can be obtained than with any other scraped surface technology. Unicus evaporators are also ideal as final finisher/concentrator placed at the end of conventional evaporation plants. Placing a Unicus evaporator before a dryer can improve the plant's overall performance in two ways:

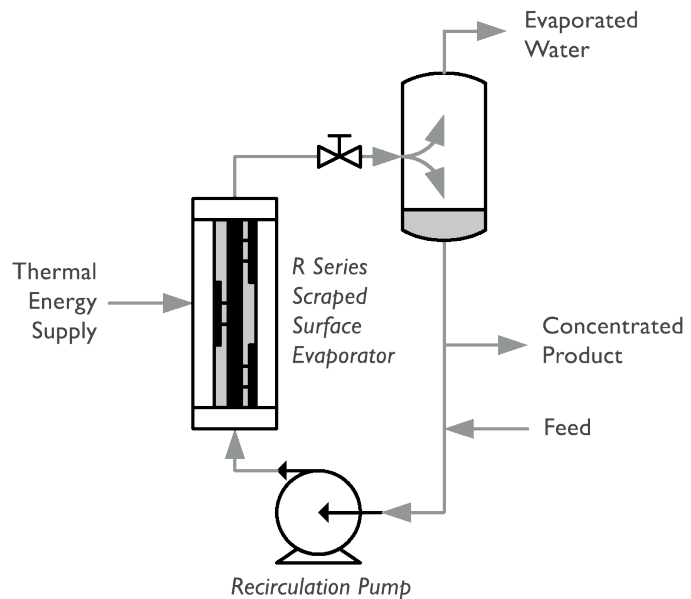
- The Unicus can concentrate to high solids concentrations. This reduces load of the dryer installation which becomes more compact (reduced CAPEX).
- The operational cost of eliminating water with a Unicus evaporator is much less than eliminating water in a dryer process.

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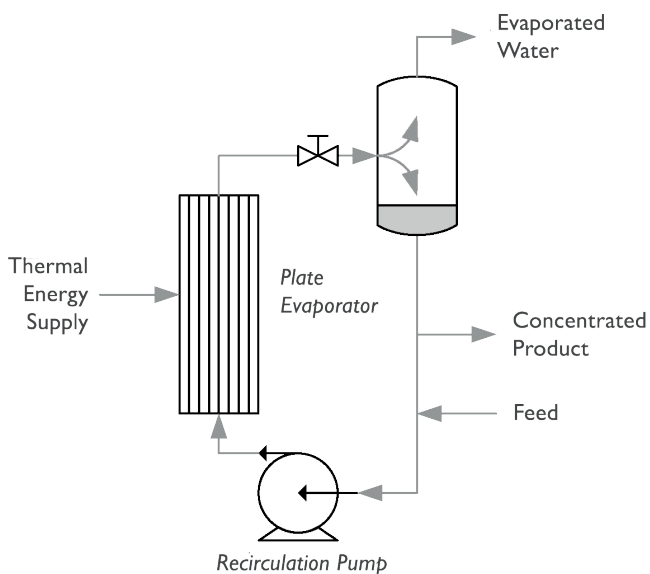
FORCED RECIRCULATION WITH HRS R SERIES EVAPORATORS

Where the Unicus SSHE evaporator is ideal for large duties (due to large surface areas available), the HRS R Series is perfectly suited to smaller evaporation applications where scraped surface is also required. The R Series is a rotary scraped surface heat exchanger, rotating at speeds around 300 rpm, making it possible to introduce a lot of mixing and turbulence in the product therefore reaching even higher rates of heat transfer. The higher heat transfer performance achievable in the R Series allows for solutions to be delivered in a small package.

Due to these characteristics, the R Series evaporator is the ideal choice for obtaining efficient evaporation performance in arduous food and beverage applications where extreme viscosities and high solid loads are present. The R series can be used for the concentration of viscous products such as sauces, purées, and proteins. The R Series technology can also be used in crystallization applications and is successfully integrated in systems alongside the Unicus to achieve Zero Liquid Discharge (ZLD).



FORCED RECIRCULATION WITH PLATE HEAT EXCHANGERS



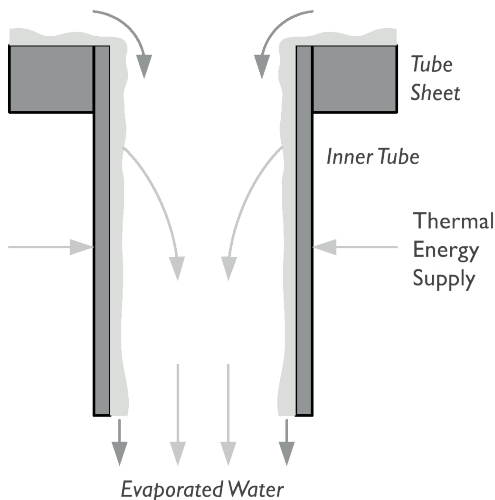
For products with very low viscosities and no risk of fouling, plate evaporators provide a good solution.

Plate evaporators offer the advantage of compact design, where a lot of heat transfer area can be offered within a small footprint. When there is a low level of suspended solids with small particle size present, wide gap or free flow plate evaporators are used.

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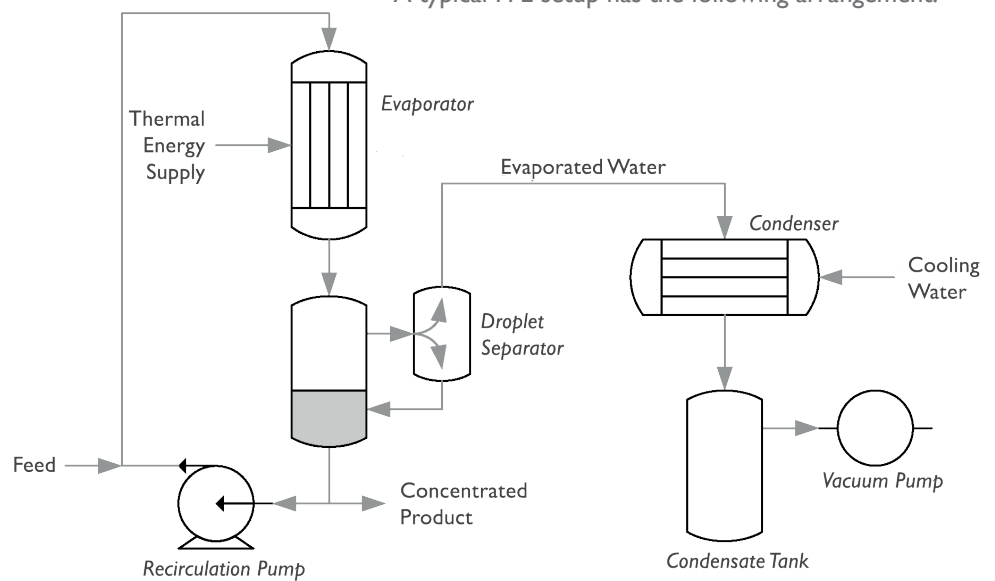
FALLING FILM EVAPORATION

In Falling Film Evaporators (FFE) the product is introduced at the top of a vertical tube bundle, where it is evenly distributed and falls downwards as a thin film against the tube wall. On the outside of the tube a heating medium, normally steam, is applied to raise the temperature of the product and evaporation takes place at the liquid film surface. The vapour generated as the product is evaporated, travels down with the liquid film and the steam velocity helps to move the film along the surface of the tube wall.



This method of evaporation offers several advantages: Film evaporation in general leads to very high levels of heat transfer. In addition, the product recirculation flow rate required in an FFE evaporator is far less than FRE evaporators, therefore resulting in lower power consumption. Finally, as evaporation takes place inside the evaporator tubes themselves, no temperature gradient is applied to the recirculating product (as is the case with FRE systems).

A typical FFE setup has the following arrangement:



The characteristics of falling film evaporators make them particularly well suited for applications where the service fluid temperature is close to the evaporation temperature, such as with TVR or MVR evaporators for example (further detail below).

A recirculation pump delivers product to the top of the falling film evaporator module (a smooth tube evaporator installed in a vertical position) where a special liquid distribution plate evenly distributes the product over the tubes. Product and steam flow downwards and the concentrated liquid is collected in a tank at the bottom. Steam exits to the side in a droplet separator where any remaining liquid particles are separated, and clean steam exits from the top. This steam is condensed in a heat exchanger and the condensed water is collected in a condensate tank. A vacuum pump can be connected to this tank if evaporation below atmospheric pressure is required. The condensed water can be used to preheat the incoming feed to the FFE unit for energy efficiency.

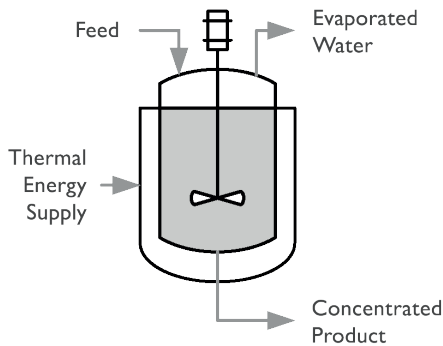


HRS 3 effect FFE plant for mango concentrate

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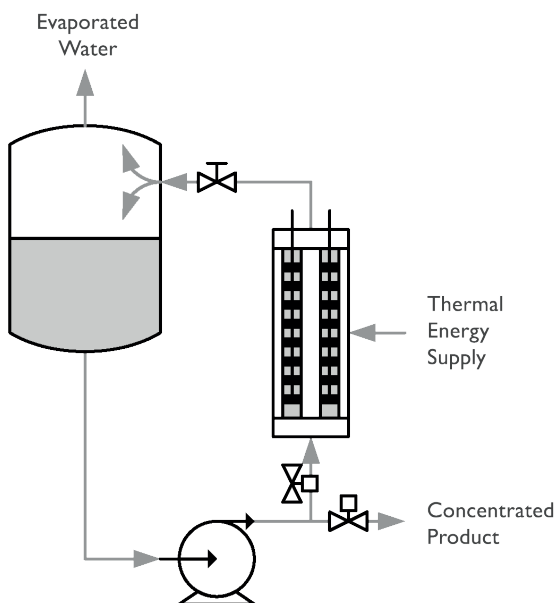
JACKETED TANK EVAPORATION

A Jacketed Tank Evaporator (JTE) is a very simple method of evaporation ideally suited to applications where CAPEX is strictly limited. Product is introduced into a tank with an external heating jacket in which the heating media flows. Product is raised to boiling point and steam evaporates and exits from the top. For good heat transfer, or if scraping is required due to product fouling, an agitator or scraper is installed to increase product turbulence and heat transfer rates. Jacketed tanks have less heat transfer area per unit of product volume compared to tubular or plate evaporators making jacketed tank evaporators suitable for only small evaporation duties. However there is no need for a recirculation pump, making the jacketed tank evaporation process simple and easy to install.



HRS Jacketed Tank Evaporator with MVR compressor

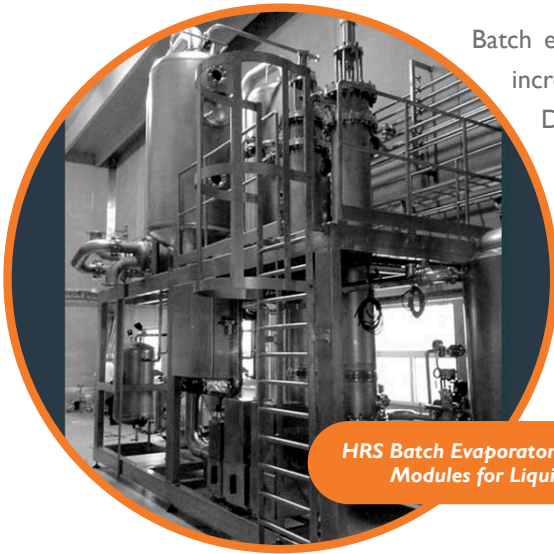
BATCH EVAPORATION



FRE and FFE plants are normally used in continuous operations, meaning concentrated product is always flowing to the evaporator, while concentrated product and evaporated water is continuously removed. This way the recirculated product within the evaporator is always at the final target concentration. In a batch evaporation process however, the system is filled and while the product concentrates no feed is added, and concentration increases over the course of the batch cycle.

Evaporation is achieved in a similar way to the FRE evaporator, whereby recirculating the fluid through a heat exchanger (either plate, corrugated tube or scraped surface) and super-heating the fluid above its flash point. As the fluid enters the tank, water is flashed and removed as steam from the top of the vessel. As the process progresses the liquid level is reduced, and the cycle ends when final concentration and low working level is reached.

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HRS Batch Evaporator with Unicus Evaporation Modules for Liquid Cheese Processing

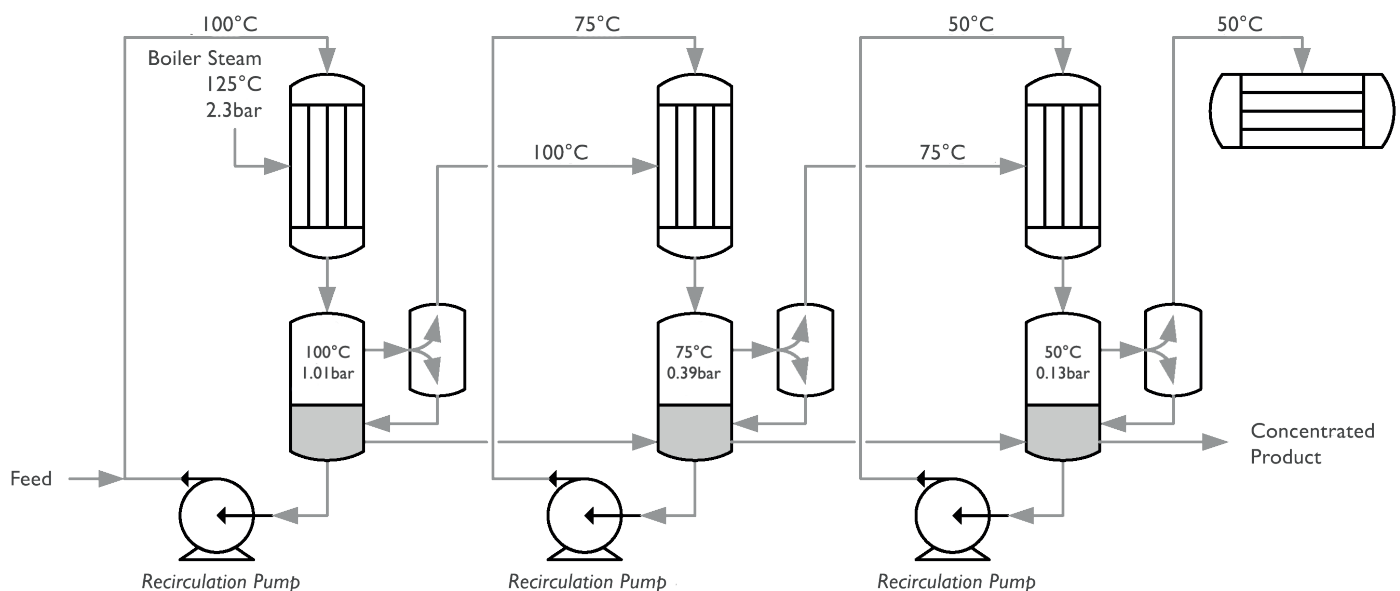
Batch evaporators are especially useful for products which exhibit a large increase in viscosity and reduction heat transfer as it is concentrated. During the initial phase (lower concentrations), heat transfer is still high as viscosities are low. Towards the end of the process heat transfer rates drop as viscosities increase. The average heat transfer over the whole cycle is higher than when compared to treating the same product in an FRE or FFE process, therefore helping to reduce the overall time required for concentrating the product.

ENERGY OPTIMISATION

The amount of energy required to evaporate water is far greater than required to raise its temperature to boiling point. Therefore evaporation plants in general consume large amounts of energy, and why different ways of optimising the plant's energy consumption have been developed. HRS integrates a variety of energy optimisation techniques to reduce the overall heat demand and help our clients maintain low operating costs:

MULTI-EFFECT STAGE EVAPORATION

Multi-effect evaporation is the process in which the evaporated steam generated in the first stage of evaporation is used as the thermal energy source for the next. This can be repeated several times over where the same kg of steam is reused to evaporate multiple kgs of water. In a multi-effect system the boiling temperatures and pressures in the next stage are lower than in the previous. This way there is a driving force (temperature difference) between the service fluid (evaporated steam) and product undergoing concentration in the next stage. The following image explains the principle:



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The previous image shows an FFE evaporation plant with three stages or 'effects'. In the first effect, boiler steam is applied at 125°C to the shell side as the service fluid to evaporate product at 100°C/1.01 bar on the tube side. The steam generated at 100°C is then sent to the shell side of the second effect as the thermal energy source where the pressure is lower, and the product evaporates at 75°C/0.39 bar. From here the steam generated at 75°C is used once again as the thermal energy source for the final effect, where evaporation takes place at 50°C/0.13 bar. The steam generated in the final effect at 50°C is sent to the condenser to be converted to water.



Three effect HRS FRE plant

Each evaporation stage takes care of one third of the total evaporation duty, and the three condensate streams (50°C /75°C/100°C) can be combined into one and used to preheat the raw incoming product prior to evaporation in the first effect.

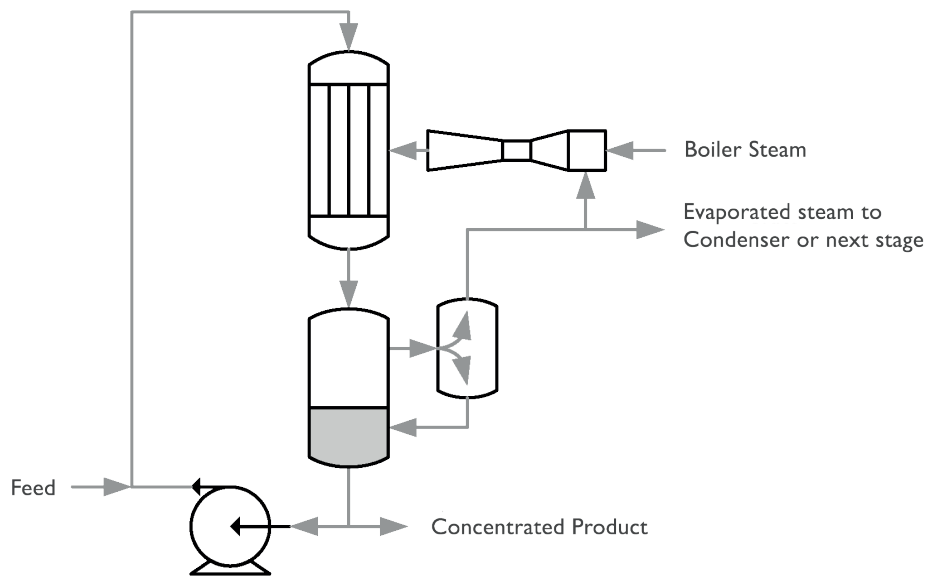
A vacuum control system is required for precisely adjusting the evaporation pressure in each stage, making sure there is an optimal driving force between each effect. Multi effect evaporation is used to significantly increase the thermal efficiency of the process as in the case presented here; where 1 kilo of steam invested will evaporate 3kg of water from the product, resulting in 300% thermal efficiency.

THERMAL VAPOUR RECOMPRESSION

Another technique HRS applies for energy optimisation and the reuse of evaporated steam is Thermal Vapour Recompression (TVR). In a TVR compressor, part of the evaporated steam is mixed with boiler steam and the combined steam flow is then used as thermal energy for the same evaporation stage.

The net pressure of the steam exiting the TVR is much closer to the evaporation pressure which results in a relatively low temperature difference between service and product temperatures.

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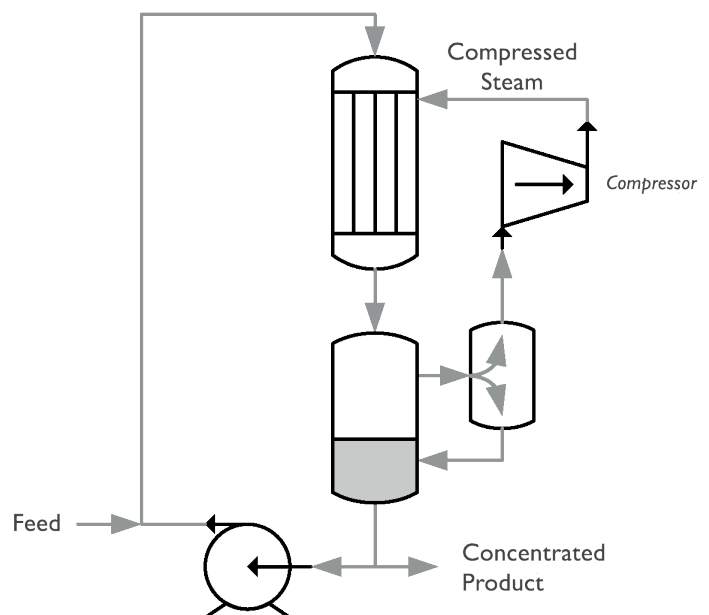


For this reason TVR is typically applied to FFE evaporators due to the ability to work with a close temperature approach as mentioned earlier. In a TVR evaporator boiling point elevation is limited in order not to suffer any further reduction of temperature difference between service and product. If operation parameters are chosen correctly, a TVR setup can double the thermal efficiency of the process. A single stage evaporation plant with TVR will have a similar capital cost to a two-stage evaporation plant without TVR where 1 kg of boiler steam is invested to evaporate 2 kg of water.

MECHANICAL VAPOUR RECOMPRESSION

For projects where no thermal energy is available (steam/hot water) and the client only has access to electrical power, Mechanical Vapour Recompression (MVR) is the solution. In an MVR evaporation plant the steam generated is re-compressed using a lobe, turbine, or fan compressor. By compressing the steam, the temperature and pressure is increased to a point where it can provide useful energy for evaporation.

This way, the same kg of steam which is evaporated from the product is reused as the thermal energy source for the same evaporation stage.



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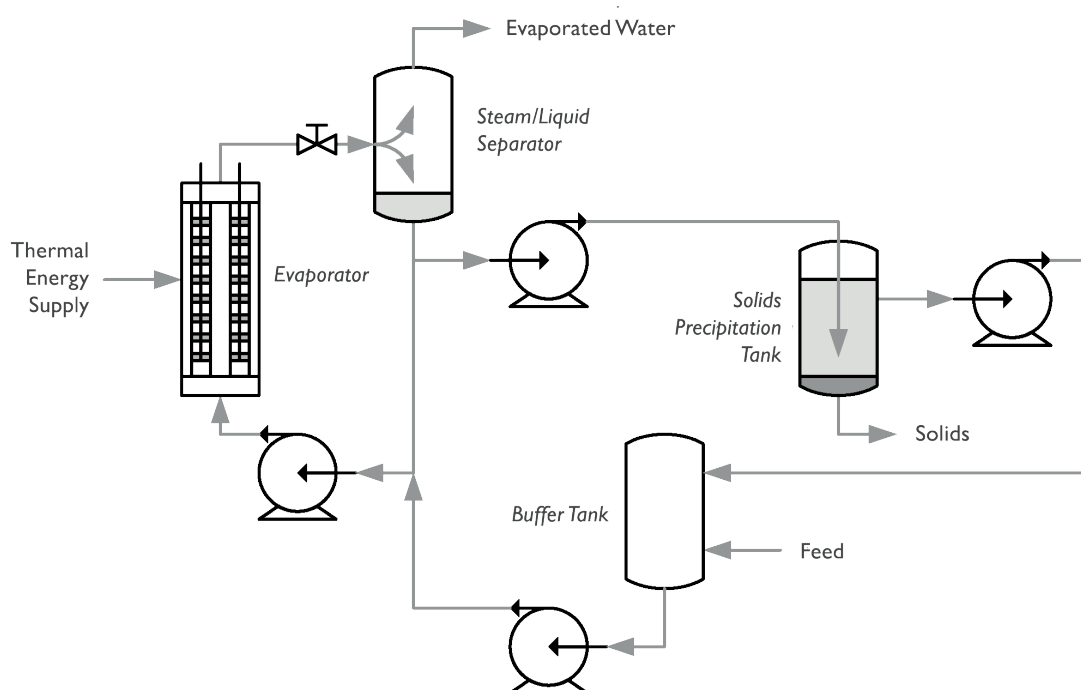
In this example the first stage evaporator is Falling Film combined with TVR. In this stage the dry matter concentration of the product is lowest, and viscosity is also restricted. As described earlier, the steam generated in the first stage passes to the second stage where an FRE is installed utilising HRS' corrugated tube technology. In the second stage the dry matter concentration is higher, and risk of fouling has increased, hence the high fluid velocities applied in forced recirculation along with HRS performance enhancing tube corrugations is needed.

In the final stage a Unicus scraped surface evaporator is installed to concentrate the product to the final target concentration, where product viscosities and risk of fouling is highest. The three stages applied in combination with a TVR makes this plant as efficient as a four stage multi-effect evaporation system at a lower capital investment.

This is just one example of how HRS combines different kinds of evaporation technologies for greater energy efficiency and cost optimisation.

ZERO LIQUID DISCHARGE

In a zero-liquid-discharge process an evaporation system is combined with a solids precipitation or crystallisation system to achieve a net-zero liquid output from the process. In the evaporator section the product is concentrated as much as possible, typically to the point of saturation, when it is then sent to a crystallisation section where the suspended solids are separated from the saturated solution. This saturated solution (or supernatant) is then recycled back into the evaporator and the process continues. The flow sheet below explains the principle:



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HRS ZLD evaporation plant with Unicus evaporator

In this example the evaporator concentrates the product to just above its saturation point. The evaporator outputs a stream with a large liquid content and small fraction of suspended solids. This stream enters the solids precipitation tank where the solids settle and are extracted at the bottom. The supernatant liquid is returned to the buffer tank where it is mixed with fresh feed.

For products with a steep solubility curve (high concentration at high temperature and low at low temperature) additional cooling to the solid's precipitation tank will help the solids to precipitate and settle out. ZLD systems are complex processes which are specifically designed to each application. In most cases product trials are required to establish the correct process parameters.

RESEARCH AND DEVELOPMENT

Designing an evaporator requires a great deal of knowledge and experience, yet the most seasoned professional cannot always establish a solution based on even the most detailed product and application descriptions. Often, the product to be concentrated is a complex matrix of many different organic and/or inorganic compounds dissolved in water. The more complex the mix, the more difficult it is to predict how the physical properties develop as the product concentrates and how fouling and crystallisation develop when increasing the levels of concentration. In our R&D facility we study evaporation in many ways to ensure the best commercial solution is achieved, guaranteed.

LAB TESTING

Using a lab scale evaporator and other lab equipment, the following can be learned:

- How much water can be eliminated from the product
- The quality of the evaporated water
- The boiling point elevation
- How physical properties like density and viscosity change with concentration
- The nature and rate of fouling
- If foaming is a problem
- The solubility curve (maximum concentration vs temperature, important for ZLD applications)

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PILOT PLANT TESTING

If the lab scale test shows potential for an industrial evaporation application, a test in one of HRS' evaporation pilot plants will determine this for certain under the same process parameters required for the full-scale evaporator:

- The correct evaporation process: FRE vs FFE, corrugated tubes, scraped surface or plate evaporators
- The heat transfer coefficient achievable for evaporation
- The pressure drop of the product flowing through the evaporator
- If foaming is a controllable phenomenon, or if anti-foam must be



HRS Evaporation Pilot Plant

Evaporators and ZLD plants for the environmental industry are especially difficult to design due to the large variation of product mixes. For these cases HRS always recommends lab trials and/or pilot plant trials before designing a suitable solution.

APPLICATIONS

HRS designs, manufactures, installs, commissions, and supports turnkey evaporation plants worldwide, providing unique and reliable solutions for a large range of industry applications:

Environmental :

- Brines
- Wastewater
- Manure
- Sludge
- Palm Oil Mill Effluent (POME)
- Leachate
- Industrial Effluents

Bioenergy:

- Digestate from biogas production
- By-products from bioethanol production

Food & Agricultural:

- Food and Agricultural Effluents
- Fruit Juice
- Fruit Concentrate
- Sugar Solutions
- Liquid Cheese and Proteins
- Dairy
- Sauces
- Purées
- Vinasse

And many more...



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