



PRODUCT BROCHURE:
EVAPORATION



Evaporation systems have been around for more than a hundred years. They are used to concentrate a fluid by evaporating one or more volatile components present. Evaporation systems are found in many different types of industries including chemical, food and environmental, among others.

HRS is a heat transfer solution provider with more than forty years' experience and evaporation systems are an integral part of the range of process solutions we provide. Evaporation systems come in different types and the final configuration is application dependant. Meaning the same type of evaporator is not always valid. With many different types of heat exchangers within the HRS product range most of which can be used for evaporation, giving us the solutions for many different applications.

What makes HRS unique compared to other evaporation technology suppliers is the use of its Unicus scraped surface evaporator. The Unicus allows the concentration to higher levels compared with traditional evaporation techniques. Combining Unicus evaporators with other types within the same evaporation process puts HRS in a strong position to treat a wide variety of products and concentrations. Energy optimisation is always applied in our evaporation systems.

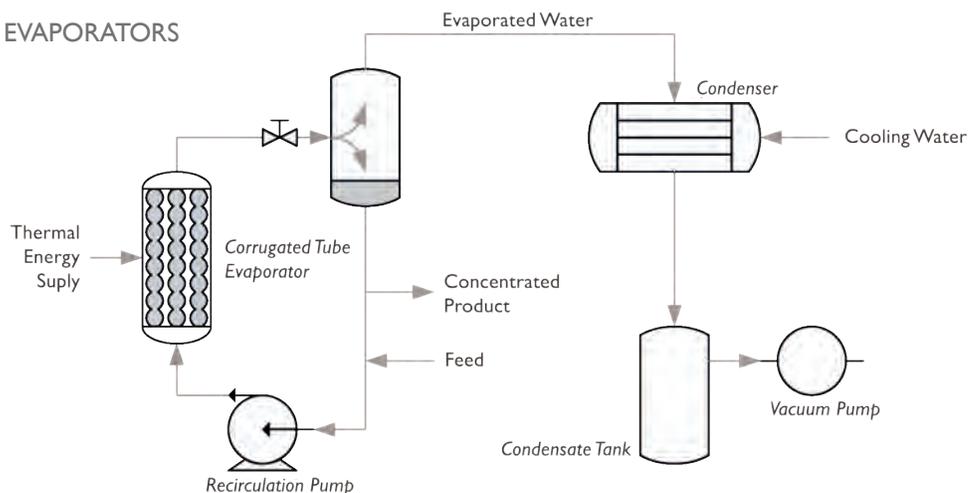
In our R&D centre we can study the evaporation of new products. In both lab scale and pilot plant scale studying all physical parameters that must be understood for designing full scale industrial evaporators. This document explains in detail HRS's Evaporation Technology offering.

FORCED RECIRCULATION EVAPORATION

The Forced Recirculation Evaporator (FRE) was one of the first systems to be built by HRS. 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. The flashed steam is then recovered by condensing it back to water using a heat exchanger.

FRE WITH CORRUGATED TUBE EVAPORATORS

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



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The product is recirculated at high flow velocity through the corrugated tube evaporator using a centrifugal pump. The combination of high velocity and corrugation creates high levels of turbulence. Meaning a high level of heat transfer is achieved and good resistance against fouling. Due to the improved performance using corrugated tubes, HRS prefers this evaporator type over smooth tube evaporators in a FRE system.

HRS FRE installation with corrugated tubes evaporators

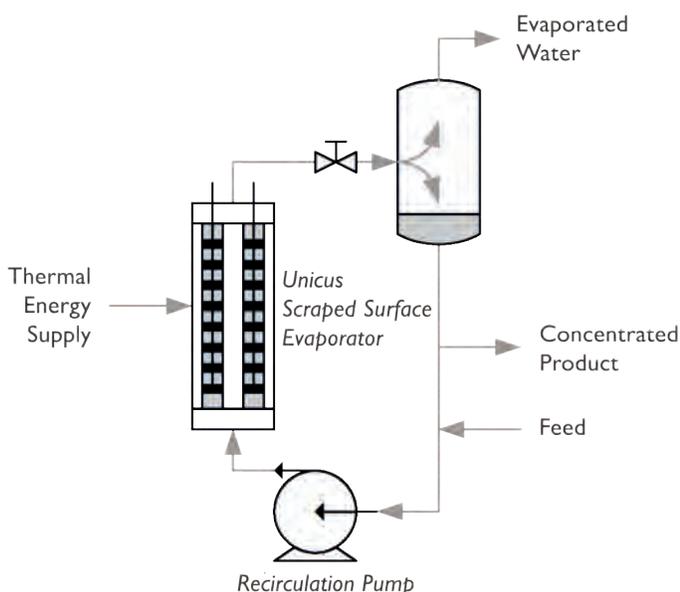
For low to medium viscosity products that have a risk of scaling the corrugated tube evaporator is the recommended technology. The evaporated steam is condensed and collected in a condensate tank.

A vacuum pump can be connected to this 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.



FRE WITH UNICUS SCRAPED SURFACE EVAPORATORS

The Unicus scraped surface heat exchanger was developed to offer efficient heat transfer for viscous fluids with high risk of fouling. The same risks appear in evaporation plants: as the products thicken its viscosity and fouling potential can increase. For this reason, traditional tube, plate or falling film evaporators have a limit to how far they can concentrate. With the Unicus technology, concentration levels can be taken much further. The scraping action keeps the evaporation tubes constantly clean and the scraping elements act as static mixing devices, keeping the heat transfer high despite increasing viscosities.



As the Unicus evaporator is a multitube heat exchanger, by adding more tubes a much higher heat transfer area can be obtained than with any other scraped surface technology. Unicus evaporators are ideal as final finisher-concentrators placed at the end of conventional evaporation plants. Placing a Unicus evaporator before a dryer can improve the overall plants performance in two ways:

- The Unicus can concentrate to higher 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 less than eliminating water in a dryer process.

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FRE WITH R SERIES EVAPORATORS

Where the Unicus evaporator is ideal for larger applications (due to its large surface area) for smaller applications HRS offers the R Series evaporation technology. The R Series heat exchanger is a rotary scraped surface heat exchanger. Running at speeds of up to 300 rpm makes it possible to introduce a lot of mixing in the product and therefore reaches higher rates of heat transfer than the Unicus technology.

Because of these characteristics, the R Series evaporator is the ideal choice obtaining efficient evaporation levels in arduous applications, where extreme viscosities and high solid loads are present. The R Series can be used in food grade applications for the concentration of products such as sauces and purees. The R Series technology can also be used as coolers in crystallization applications. One example is combining both the Unicus and the R Series in ZLD (Zero Liquid Discharge) applications.

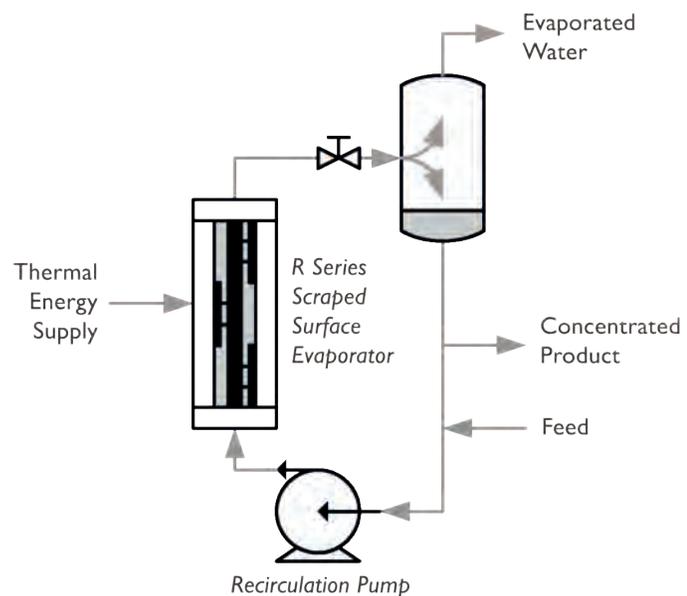
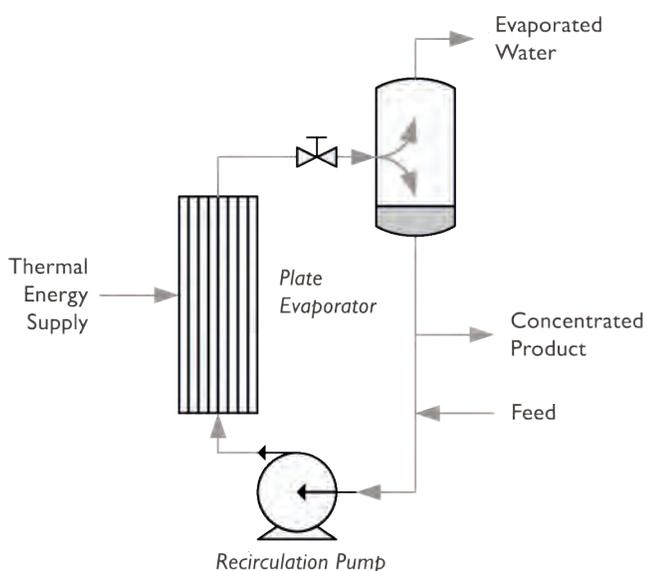


PLATE EVAPORATION



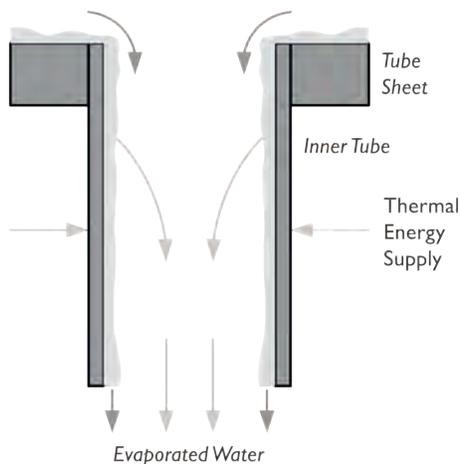
For products with very low viscosity and risk of fouling a plate evaporator is a good solution. HRS applies plate evaporators in an FRE setup.

Plate evaporators offer the advantage of compact design: a lot of heat transfer area possible 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.

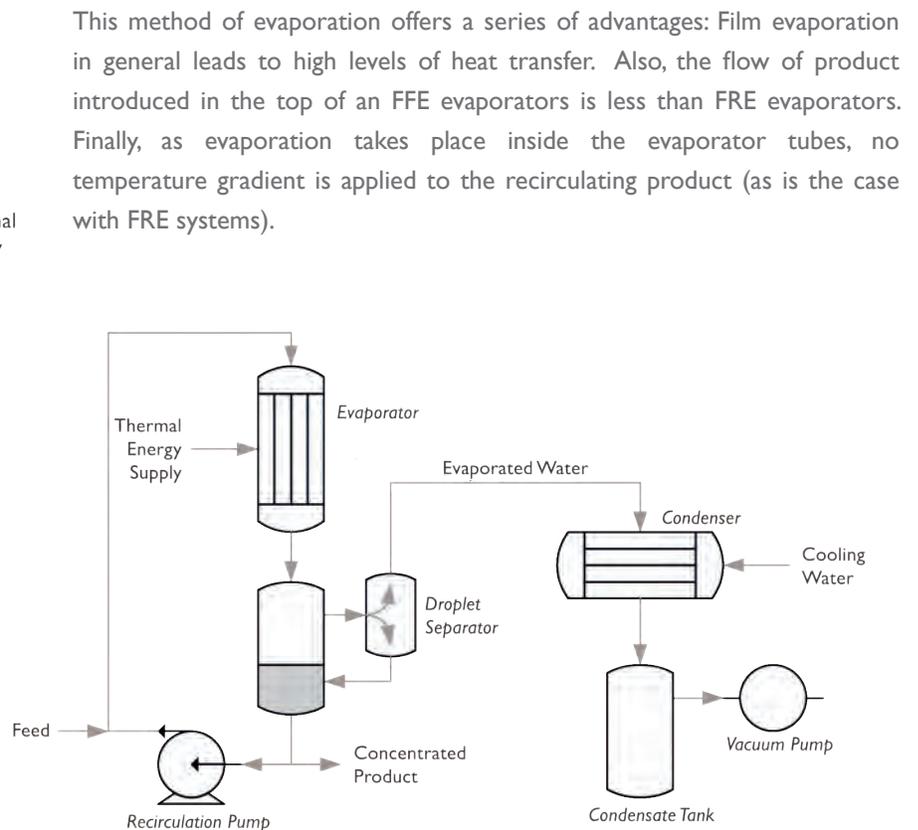
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FALLING FILM EVAPORATION

In falling film evaporators (FFE) the product is introduced at the top of a vertical installed tube bundle and product flows downwards as a thin film. On the other side of the tube wall the product is heated with a heating medium, normally steam. Evaporation takes place at the liquid film surface. The generated steam and liquid film travel in the same direction and the steam velocity helps to move the film surface.



This makes falling film evaporators especially suitable for applications with limited temperature differences between product and service fluid, such as TVR or MVR evaporators (explained later in this brochure). A typical FFE setup looks like this:



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 all the tubes. Product and steam flow downwards. The concentrated liquid is collected in a tank at the bottom and steam exits to the left entering a droplet separator tank. In this tank 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 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.

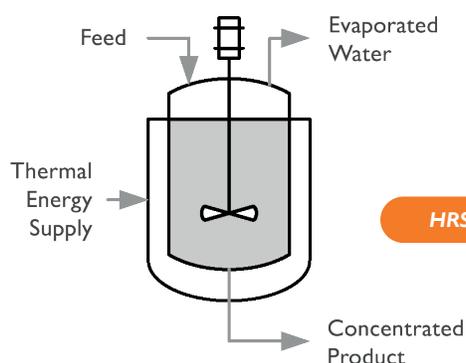


HRS 3 effect FFE plant for mango concentrate

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JACKETED TANK EVAPORATION

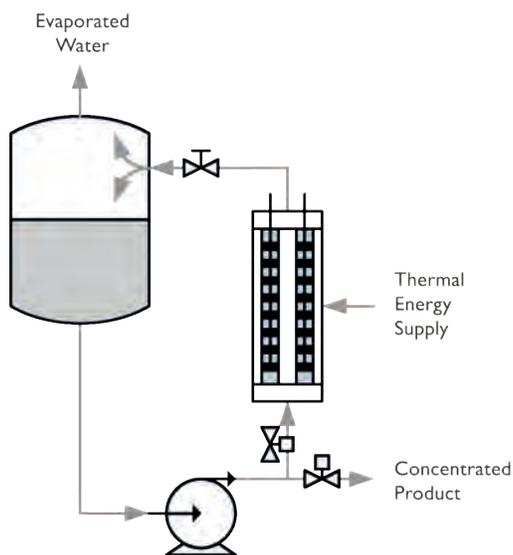
A jacketed tank evaporator (JTE) works with a very simple setup. Product is introduced into a tank that is jacketed which the heating media flows through. Product is brought to boiling point and steam evaporates and exits from the top. For good heat transfer an agitator is installed to create the necessary product turbulence. 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. There is no need for recirculation pumps and the jacketed tank evaporation process is simple and easy to install.



HRS Jacketed Tank Evaporator with MVR compressor



BATCH TANK EVAPORATION



FRE of FFE plants are normally used in continuous mode. Meaning feed is always coming in and concentrated product coming out. The recirculated product is always at the final concentration level. In a batch evaporator (BE) process a batch tank is filled and while the product concentrates no feed is added.

Evaporation is achieved by recirculating the batch fluid over an evaporator and superheating the fluid as in an FRE evaporator.

As the fluid enters the batch, water is flashed and escapes as steam from the top.

As the evaporation process progresses, the liquid level drops and the end of the process is reached when a specific low level is reached. BE plants are especially useful for products with a large change in viscosity and heat transfer as it concentrates.

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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. BE processing helps to reduce the overall time for concentrating the product.

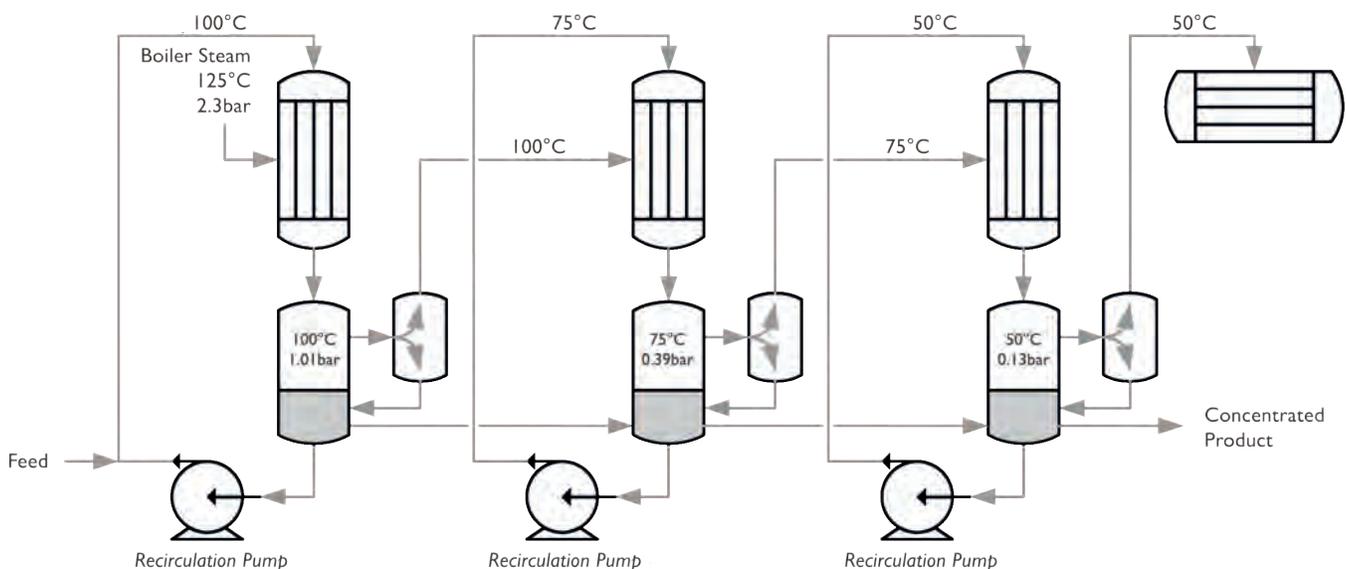
HRS Batch Evaporator with Unicus Evaporation Modules for Liquid Cheese Processing

ENERGY OPTIMISATION

It takes much more energy to evaporate water than to heat it up to its boiling point. That is why evaporation plants in general consume large amounts of energy. This has called for ways of optimizing the plants energy balance. Below we explain three such ways of optimisation:

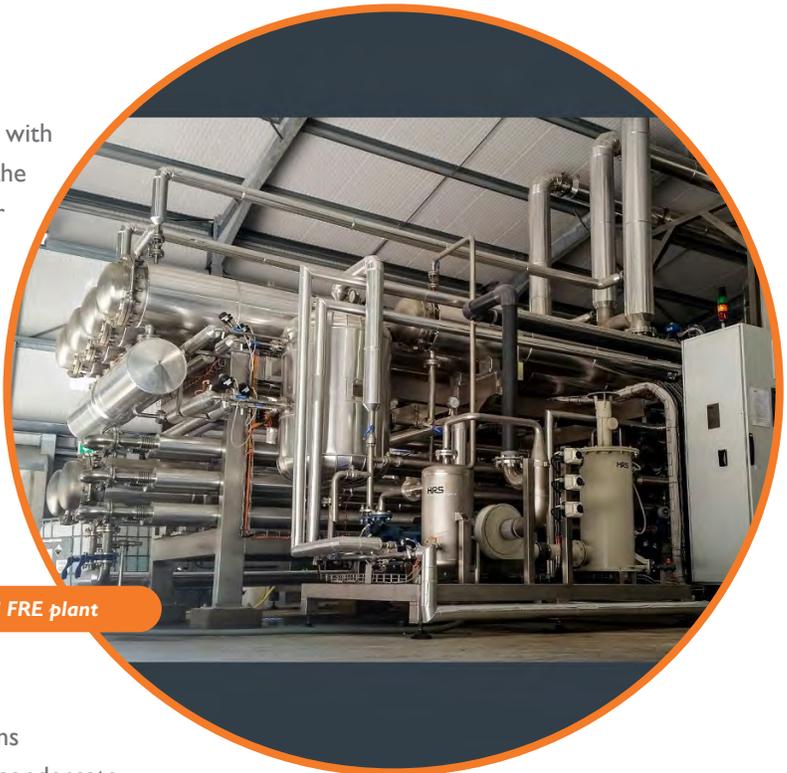
MULTI EFFECT STAGE EVAPORATION

Multi effect evaporation is the process in which the evaporated steam generated is used as thermal energy supply for a next evaporation step. This can be repeated several times. To reuse evaporated steam, the boiling temperatures and pressures in the next stage are lower than in the previous stage. This way there is a driving force (temperature difference) between the service fluid (evaporated steam) and product (product to evaporate) in the next stage. The following image explains the principle:



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The previous page shows an FFE evaporation plant with three stages. In the first stage (left hand side) the product is evaporated at 100°C/1.01bar using boiler steam at 125°C. The generated steam at 100°C serves as thermal energy for second evaporation stage (middle) where the product boils at 75°C/0.39bar. The 75°C steam generated here is the thermal energy for the third stage (right) where evaporation takes place at 50°C/0.13bar. The 50°C steam generated here is goes to the final condenser.



Three effect HRS FRE plant

Each evaporation stage takes care of a third of the total evaporation duty. The three condensate streams (50°C /75°C/100°C) can be combined as one total condensate flow out, and can be used to preheat the incoming product into stage I.

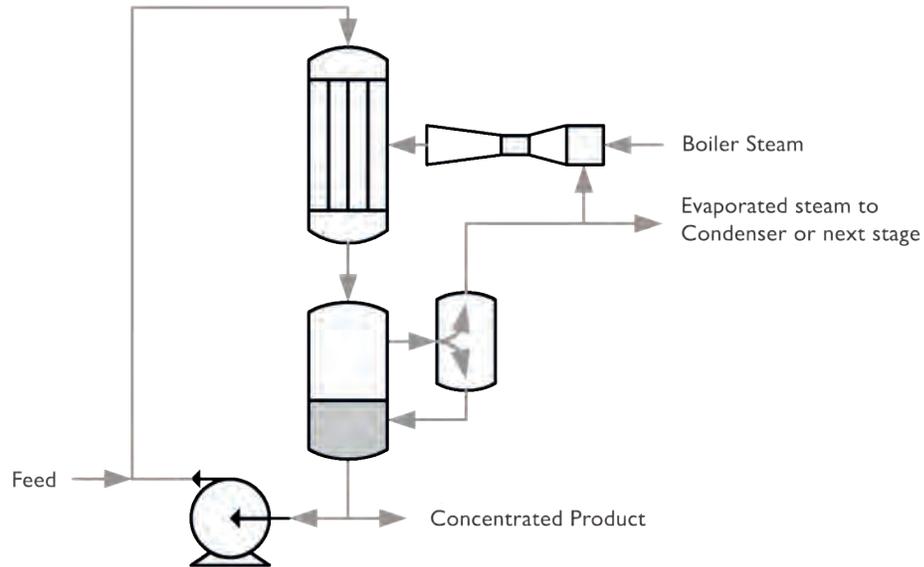
A vacuum system is required for precisely controlling the evaporation pressure in each stage, making sure there is an optimal driving force (temperature difference) between each stage. Multi effect evaporation can be regarded as a multiplier strategy: in the case presented here, 1 kilo of steam invested will evaporate 3kg of water from the product.

BATCH TANK EVAPORATION

Another way of reusing steam is by using thermal vapor recompression (TVR). In a TVR compressor, a part of the evaporated steam in an evaporator stage is mixed with boiler steam. The combined steam flow is then used as thermal energy for the same evaporation stage.

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

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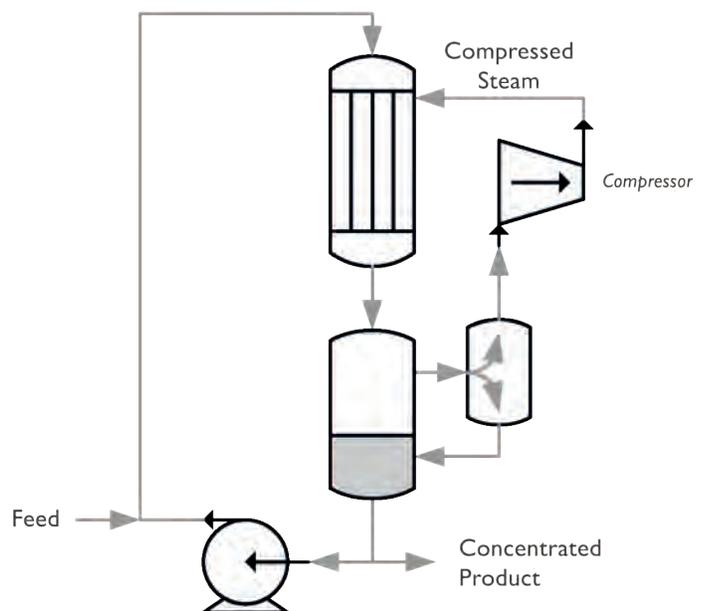
For that reason, FFE is an evaporator type often used in this type of process. Boiling point elevation is limited in order not to suffer any further reduction of temperature difference between service and product. If operation parameters are chosen correctly, a TVR setup can multiply the efficiency by two. A single stage evaporation plant with TVR will have a similar cost to a two-stage evaporation plant without TVR: 1 kg of boiler steam is needed to evaporate 2 kg of water.

MECHANICAL VAPOUR RECOMPRESSION

If no thermal energy is available and you can only work with electrical power Mechanical Vapor Recompression (MVR) is the solution. In an MVR evaporation plant, the steam generated is compressed using a lobe or turbine or fan compressor. By compressing the steam, the temperature and pressure is increased.

This way the same steam that is evaporated from the product can be used as thermal energy source for the same evaporation stage.

The temperature increase obtained is normally limited, in the order of 6-9°C for a single stage compressor.



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Like with TVR, MVR compressors are usually combined with FFE evaporation plants as the temperature difference between service and product is reduced. And as for TVR, boiling point elevation should be limited.

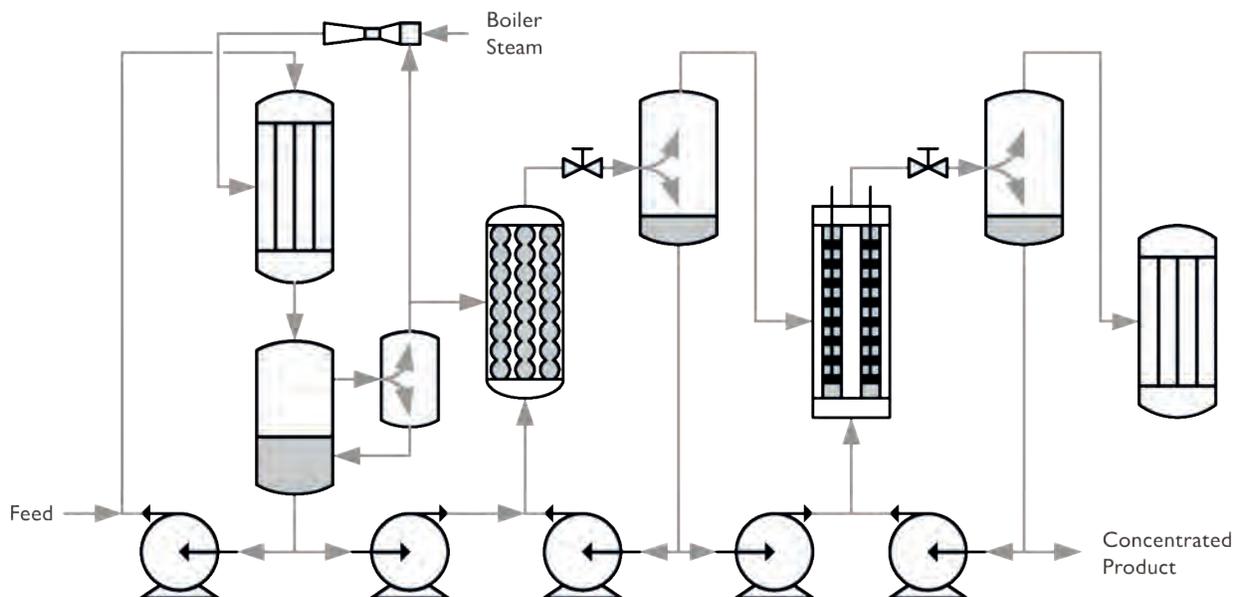
MVR plants offer interesting advantages:

The use of MVR compressors is one of the most economical ways of evaporation. The operational cost per ton of water evaporated is one of the lowest. A final condenser is not needed as the steam is condensed on the service side of the evaporator itself, and this can eliminate the cost water in cooling towers that are required for the final condensers cold water supply. The downside is that capital cost increases (for the MVR compressor a larger evaporator is required).



EVAPORATOR COMBINATIONS

The aforementioned evaporator solutions can be combined with the three methods of energy optimization in various combinations. The best solution is tailored to every individual application. Below is an example of a multistage evaporator solution combining three types of evaporators and a TVR setup:



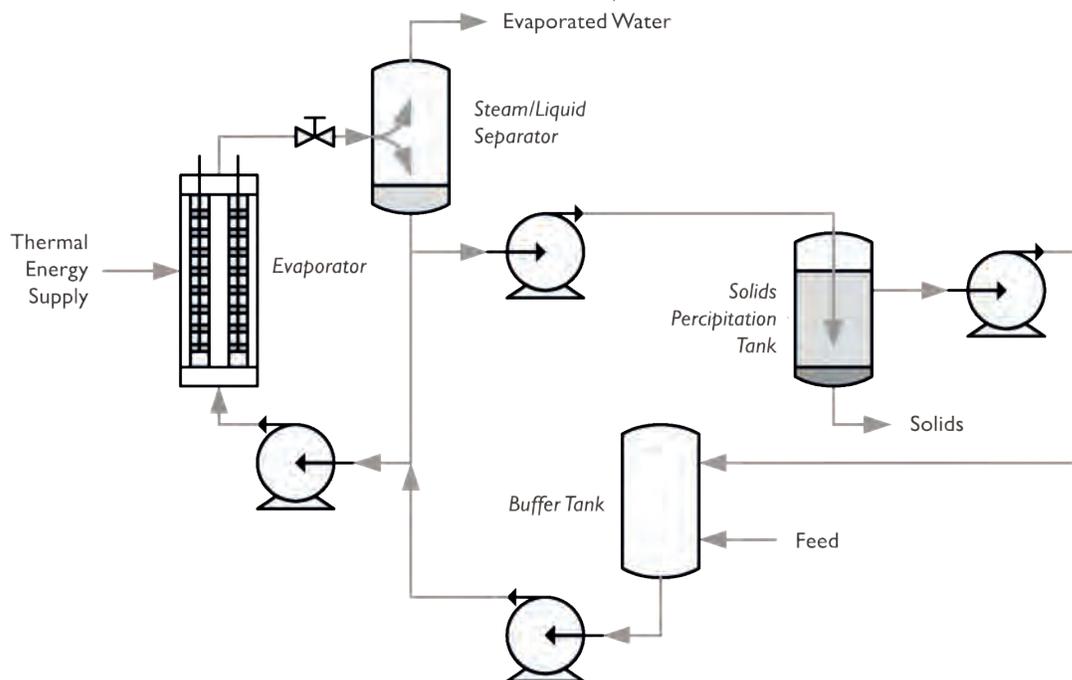
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The first stage evaporator is an FFE unit with mechanical vapor recompression. In this stage the dry matter concentration of the product is low, and viscosity is also limited. The steam generated in the first stage goes to the second stage where an FRE unit is used with a corrugated tube evaporator. Corrugated tubes with high fluid velocity are chosen as the fouling risk is increased with the increase in concentration.

In the final stage a Unicus scraped surface evaporator is used to deal with the high viscosity and fouling nature of the final concentrated product. The three stages combined with a TVR unit makes this plant as efficient as a four stage multi effect evaporation plant. This is just one example of combining different kinds of evaporation technologies in one plant.

FALLING FILM EVAPORATION

In a zero-liquid-discharge (or ZLD) process an evaporation system is combined with a solids precipitation or crystallization system. In the evaporator the product is concentrated as much as possible. It is then sent to a crystallization section where the suspended solids are separated from the saturated solution. This saturated solution is then recycled back into the evaporator. The flow sheet below explains the principle:



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HRS ZLD evaporation plant with Unicus evaporator

In this setup the evaporator concentrates the product to just above its saturation point. At the exit of the evaporator is 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 exit at the bottom. The supernatant liquid is returned to the buffer tank where it is mixed with fresh feed.

For products with a 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 settle. ZLD systems are tailored to the application. In most cases product trials are needed to establish the right process parameters.

RESEARCH AND DEVELOPMENT

It isn't always possible to design an evaporator based on a detailed product and application description. Often, the product to be concentrated is a mix of many different organic and/or inorganic compounds dissolved in water. The more complex the mix, the more difficult is to predict how the physical properties develop as the product concentrates and how fouling and crystallization develop when increasing concentration levels. In our R&D facility we study the application in different ways.

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?
- What is the quality of the evaporated water?
- What is the boiling point elevation?
- How do physical properties like density and viscosity change with concentration?
- What is the fouling behaviour?
- Is foaming a problem?
- What is 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's evaporation pilot plants will determine under the process parameters required for the full-scale evaporator:

- What is the right evaporator type: FRE vs FFE, Corrugated tubes, scraped surface or plate evaporators?
- What is the heat transfer coefficient for evaporation?
- What is the pressure drop of the product flowing through the evaporator?
- Is foaming under control, should anti foam be used



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.

FALLING FILM EVAPORATION

HRS designs, builds, and delivers turnkey evaporation plants solutions for a large range of applications. Below is a summary:

Environmental :

- Brine
- 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 wastes
- Fruit juice
- Fruit concentrate
- Sugar solutions
- Liquid cheese and proteins
- Sauces
- Purees



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