Evaporation Technology

Applications, types, efficiency

engineering for
a better world

gea.com

Content

Evaporation plants are required whenever in a process water or any other solvent has to be removed, concentration has to be increased or volume reduced.

To meet the wide spectrum of process requirements, GEA designs plant solutions using different evaporator types, plant configurations and heating options. Each evaporator type offers its own benefits, and the most suitable type is selected with consideration of the main process parameters: scaling tendency, thermal product sensitivity, annual operating hours, and accessibility for maintenance.

An economical and energetically optimized evaporation plant is created by intelligent interconnection of the evaporator types and other components of the process plant as well as the utilization of waste heat by vapor recompression.

GEA'S ROLE IN EVAPORATION TECHNOLOGY

Since the beginning of the 20th century, GEA has been significantly involved in the development of evaporation technology through its brands Wiegand and Kestner.

Research and development

Due to ongoing research and development work spanning many decades, and the experience of several thousand installed references, GEA continues to provide the broadest technical expertise and the respected ability to offer the best solution for almost any product, evaporation rate, operating condition or application.

GEA has several own Research and Development Centers, where numerous laboratory and pilot plants are available for detailed analyses and testing in the field of evaporation, crystallization and distillation. At the R&D centers, important physical characteristics such as boiling point elevation, viscosity, solubility and maximum achievable concentration are determined. Certain pilot plants are available as mobile units and can therefore be installed at a customer's site. Data is captured and plant operating behavior modelled by state-of-the-art computer programs. Part of the pilot units are equipped in ATEX configuration and can be used to concentrate flammable mixtures. Scale-up and modelling is relying on decades of experience with exclusive focus on the singular technologies.

Analytical inhouse capabilities are critical to understanding project chemistry and its impact on process design. The analysis of customer samples is often the basis of evaluation and proposing a customized solution.

WHAT CAN GEA R&D OFFER YOU?

- from analytical & bench scale testing to pilot testing
- tailor-made design relying on experience in combination with experimental data
- development of new processes with qualitative and quantitative support
- inhouse or on-site support with pilot testing
- standard lab data (physical properties) and complex analytics (e.g. HPLC, GC, AAS)

More than **3500** tests since 1908

> 25 pilot plants (related to evaporation, crystallization, distillation)

7 mobile pilot plants (5 evaporators, 2 distillation systems)

Reference products

From acetone to zinc dichloride, from high-quality product to waste water, evaporation plants are used where a liquid has to be concentrated – be it in the chemical, food or other industries

With more than 4500 reference plants in various markets worldwide, about 3500 test reports and about 100 patents, GEA stands for innovative, tailor-made evaporation plants and solutions.

Flexible solutions

GEA has always understood that a successful business relies on the ability to adapt quickly to evolving market conditions. Our focus is the development of proprietary process designs and technology for our customers in a broad range of markets.

We are the right partner for you to find and implement the optimal process solution for your product – for any application.

Extracts and hydrolysates

POTASSIUM CALCIUM SULFATE
GELATIN MINERAL
LITHIUM SALT SOLUTIONS
BLOOD PLASMA
MEAT & BONE EXTRACT POTASSIUM CHLORIDE
WHEAT STARCH EFFLUENT
LYSINE TEA EXTRACT
WHOLE EGG PROTEINS AMMON
SPIN BATH SOLUTIONS CITRIC
BLACK LIQUOR ETHANOL
SOYA WHEY THREONINE MONOSODIUM
DEWATERING OF PROCESS STREAMS NICKEL CHLOR
CORN STEEP LIQUOR AMMON
MONOSODIUM GLUTAMATE OAT & RIC
SODIUM FORMALDEHYDE SULFOXYLATE (SFS) WASH AND
PHOSPHORIC ACID DRUG
URANYL NITRATE METHANOL Y
APPLE & CITRUS JUICES
TITANIUM SULFATE SUGAR
PROTEIN HYD

Inorganic chemicals and salts

Fertilizers

Organic chemicals

Starch and protein products

Beverages

Food and dairy products

POTATO STARCH EFFLUENT
PIGMENTS **OIL EMULSIONS** PECTIN
BIOBASED CHEMICALS
SOUP SEASONING **COFFEE EXTRACT**
CALCIUM CHLORIDE KAOLIN **SULFURIC ACID**
VITAMINS **GLYCERIN** MALTOSE SODIUM THIOCYANATE
IUM SULPHATE **CALCIUM CARBONATE** FISH STICK WATER
ACID **CAPROLACTAM** GLUCOSE
DEXTROSE **CARROT JUICE** **PROTEIN HYDROLYSATES**
GLUTAMATE **WHISKY STILLAGE** FRUCTOSE
INULIN
IDE **CAUSTIC SODA** **MALT EXTRACT**
IUM NITRATE SODIUM HYDROXIDE (LYE)
E MILK **SODIUM ALUMINATE**
RINSING WATER **METHYLENE CHLORIDE** **LACTIC ACID**
EXTRACTS SORBITOL **ISOPROPANOL** GLUTAMIC ACID
EAST EXTRACTS & HYDROLYSATES
FIBER BOARD PRESS WATER
SUBSTITUTES TANNING EXTRACTS **AMINO ACID**
ROLYSATE **ENZYMES**

Fermentation products

Stillage, steep and stick water

Industrial waste water

OVERVIEW OF REFERENCE MARKETS

With an extensive expert knowledge and the experience from thousands of delivered plants, GEA can develop customer-optimized process solutions and plant components for a wide range of markets.

Falling film evaporators

Vertical shell-and-tube heat exchanger, with integrated wrap-around, monobloc-type or laterally arranged separator

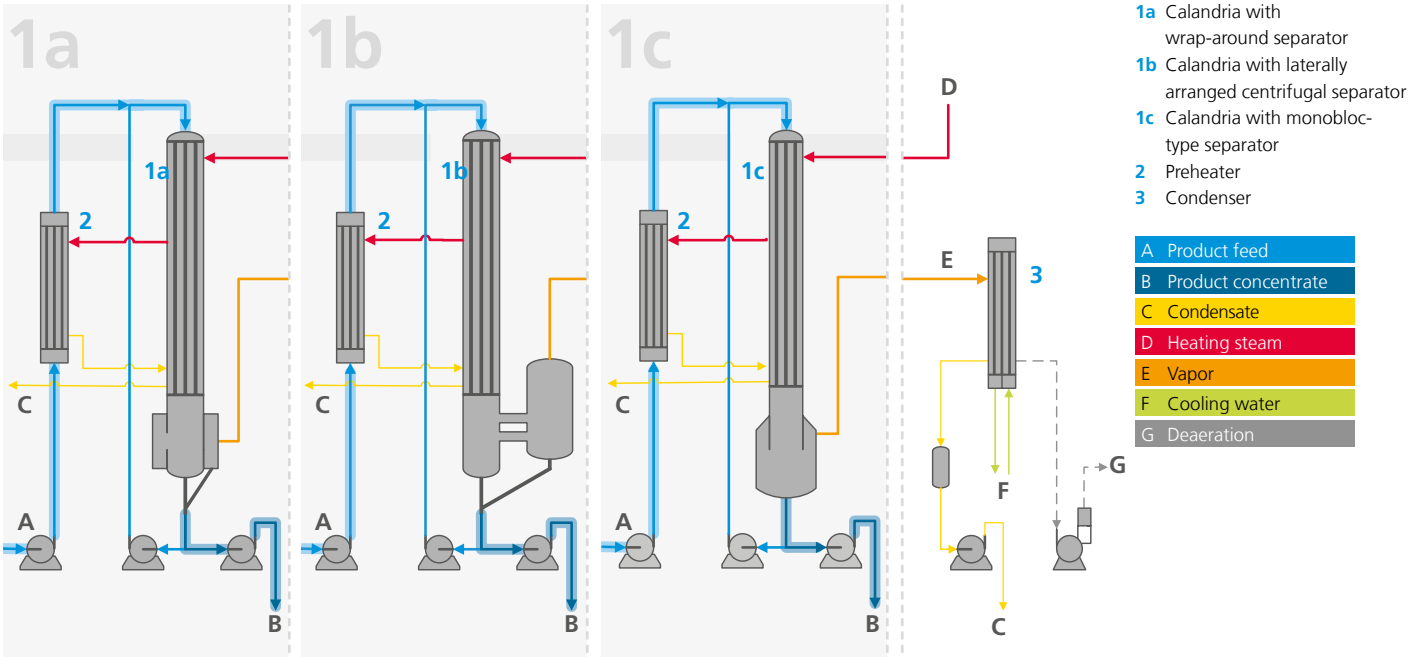
Functional principle

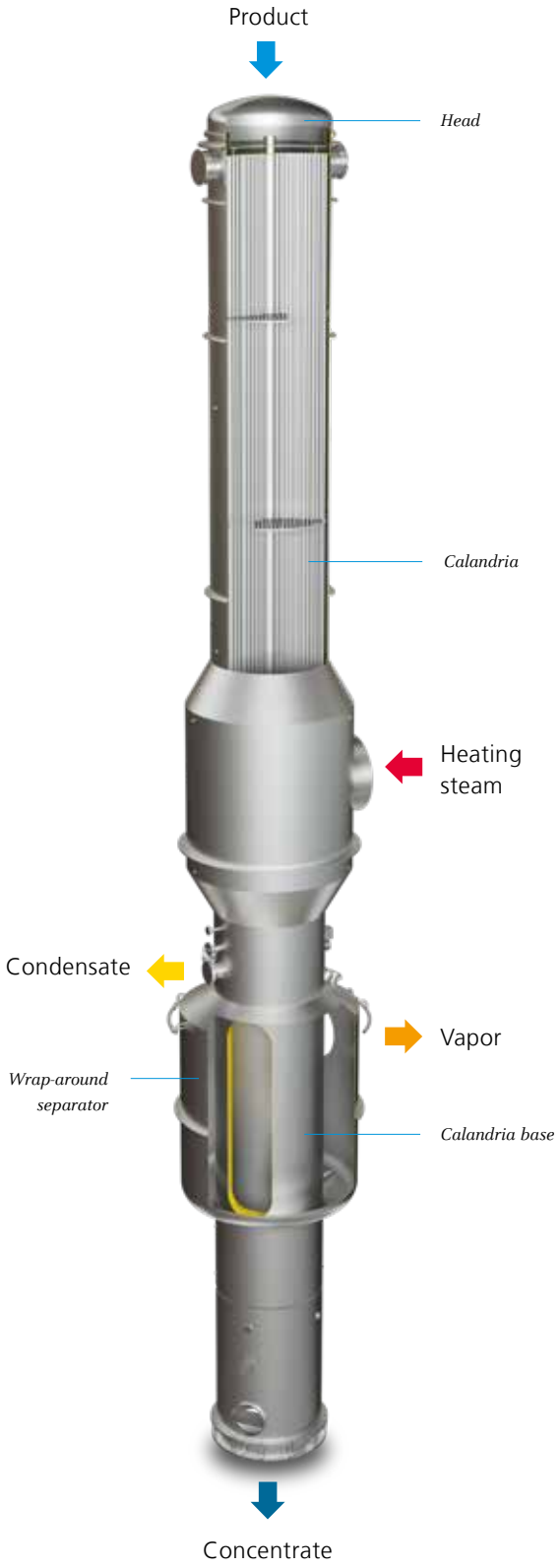
The liquid to be concentrated is fed to the top of the heating tubes and distributed so that it flows down as a thin film on the inside of the tube walls. The liquid film begins to boil due to the external heating of the tubes and is thus partially evaporated. The downward flow, initially caused by gravity, is enhanced by the parallel, downward flow of the vapor formed. Residual liquid film and vapor are separated in the lower part of the calandria and in a wrap-around, monobloc-type or laterally arranged centrifugal separator.

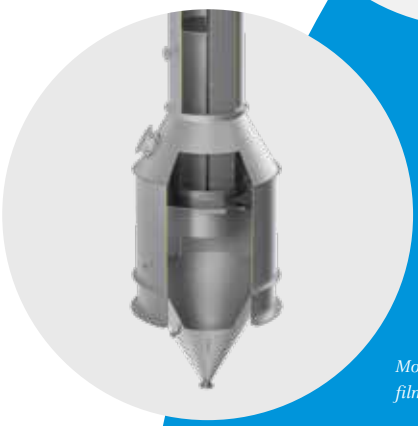
It is essential that the entire heating surface, especially in the lower regions, is evenly and sufficiently wet with liquid. Where this is not the case, dry spots will result that will lead to incrustation and the build-up of deposits. GEA plants provide for a complete wetting which is achieved by thoroughly selecting a suitable distribution for the head of the evaporator. Wetting rates are increased by using longer heating tubes, dividing the evaporator into several compartments or by recirculating the product.

Particular features

- **Best product quality** – due to gentle evaporation, mostly under vacuum, and extremely short residence times in the evaporator.
- **High energy efficiency** – due to multiple-effect arrangement or heating by thermal or mechanical vapor recompressor, based upon the lowest theoretical temperature difference.
- **Waste heat usage** – the evaporator can be heated by exhaust gas streams or hot water due to the flexible design of the heating side.
- **Simple process control and automation** – due to their small liquid content falling film evaporators react quickly to changes in energy supply, vacuum, feed quantities, concentrations, etc.
- **Flexible operation** – quick start-up and easy switchover from operation to cleaning, uncomplicated changes of product.







Two examples of suitable distribution systems, above: perforated bowl, below: tubelet

Monobloc-type falling film evaporator

Falling film evaporator with laterally arranged centrifugal separator

FIELDS OF APPLICATION

Capacity ranges of up to 150 t/h, relatively small floor space requirement.

Particularly suited for temperature-sensitive products.

Liquids which contain small quantities of solids and have a low to moderate tendency to form incrustations.

Forced circulation evaporators

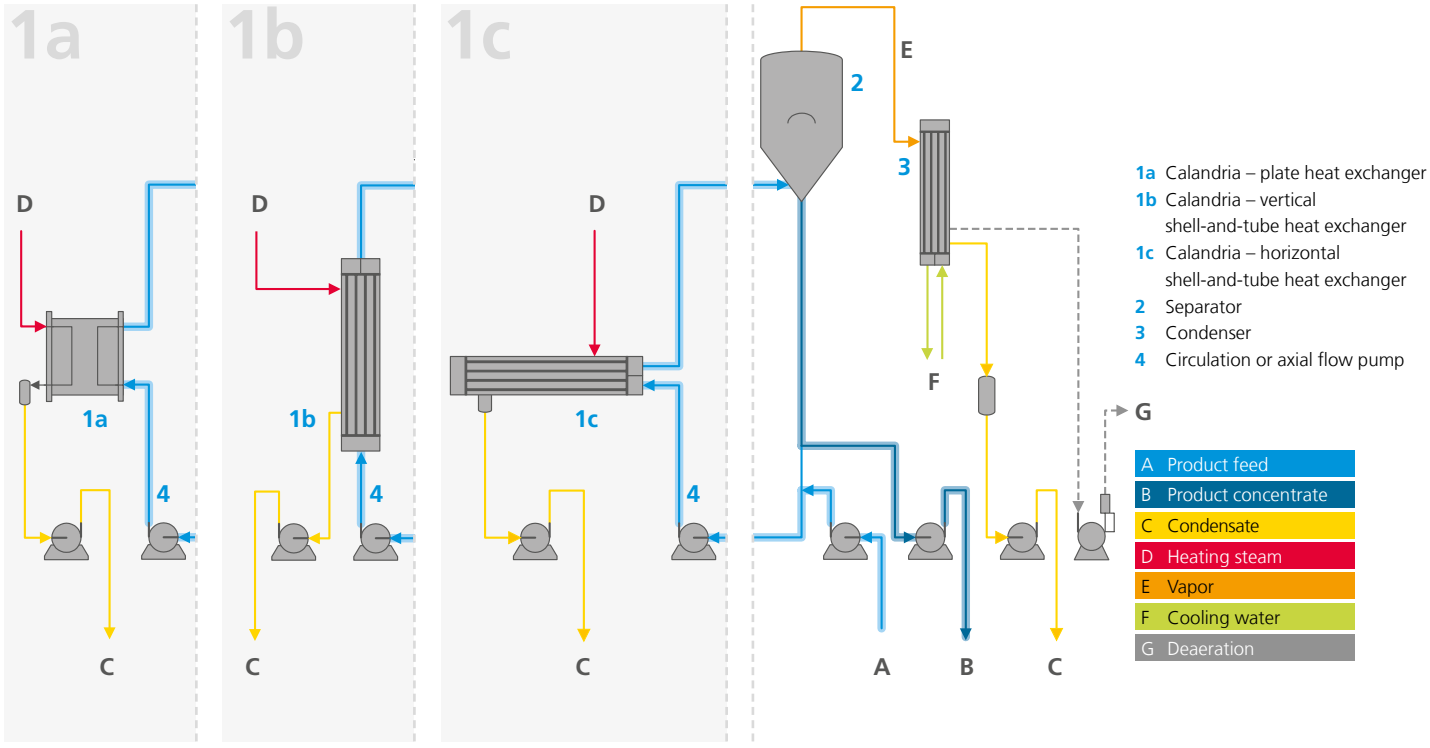
Shell-and-tube or plate heat exchanger as calandria with circulation pump and flash vessel/separator arranged above the calandria.

Functional principle

The liquid is circulated through the calandria by means of a centrifugal or axial flow pump, where it is superheated at an elevated pressure, higher than its normal boiling pressure. Upon entering the separator, the pressure in the liquid is rapidly reduced resulting in some of the liquid being flashed, or rapidly boiled off. Since liquid circulation is maintained, the flow velocity in the tubes and the liquid temperature can be controlled to suit the product requirements independently of the pre-selected temperature difference.

Particular features

- **Long operating period**s – boiling/evaporation does not take place on the heating surfaces, but in the separator. Fouling due to incrustation and precipitation in the calandria is therefore minimized.
- **Optimized heat exchange surface** – flow velocity in the tubes determined by the circulation pump.



2-effect falling film, forced circulation evaporation plant in counterflow arrangement with downstream system for the purification of vapor condensate by distillation of waste water containing salts and organic compounds. Evaporation rate: 9000 kg/h concentrated to 65 % DS

FIELDS OF APPLICATION

Liquids with a high tendency for fouling, highly viscous liquids, as high concentration step in multiple-effect evaporation plants.

Forced circulation evaporators are optimally suited as crystallization evaporators for saline solutions.

Axial flow pump

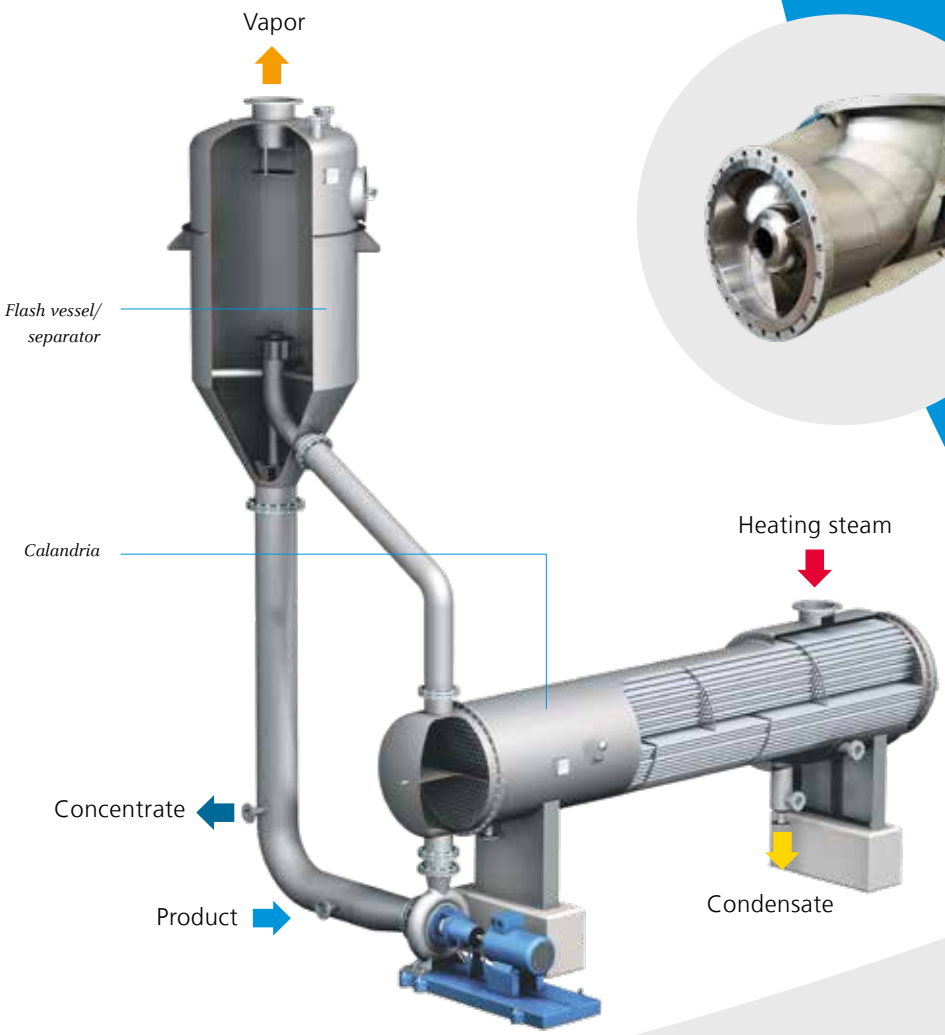


Plate evaporators

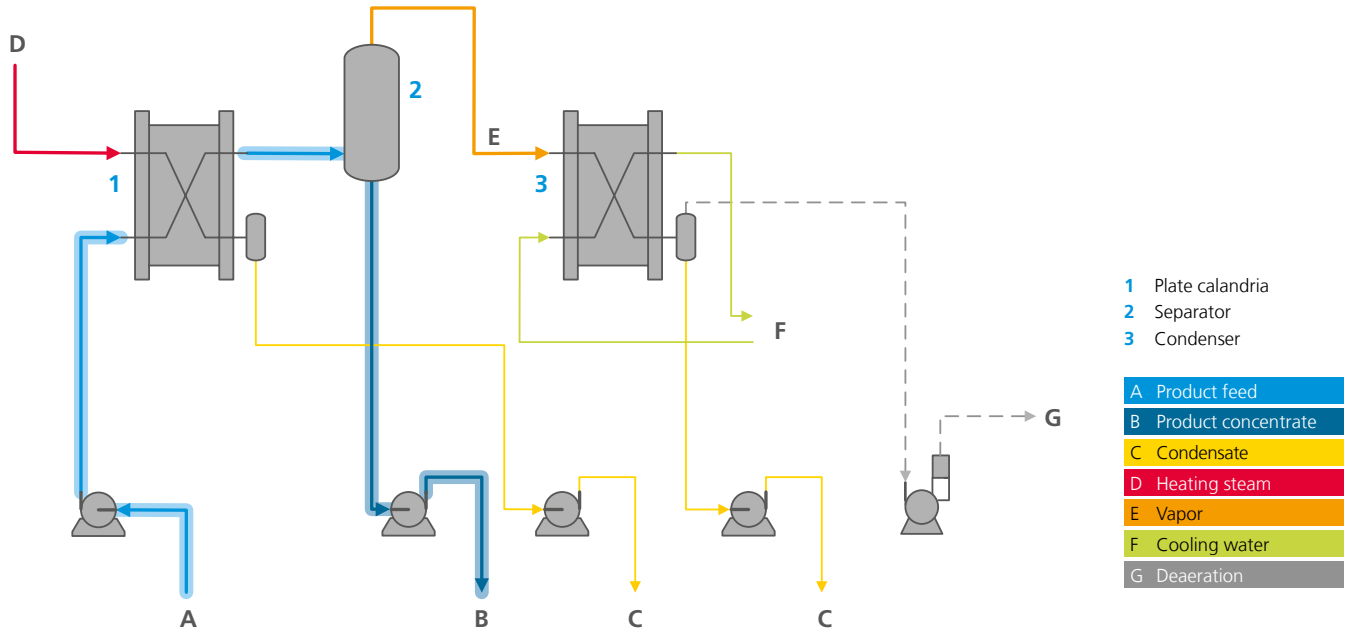
A plate-and-frame configuration employs special plates, with alternate product and heating channels, downstream centrifugal separator

Functional principle

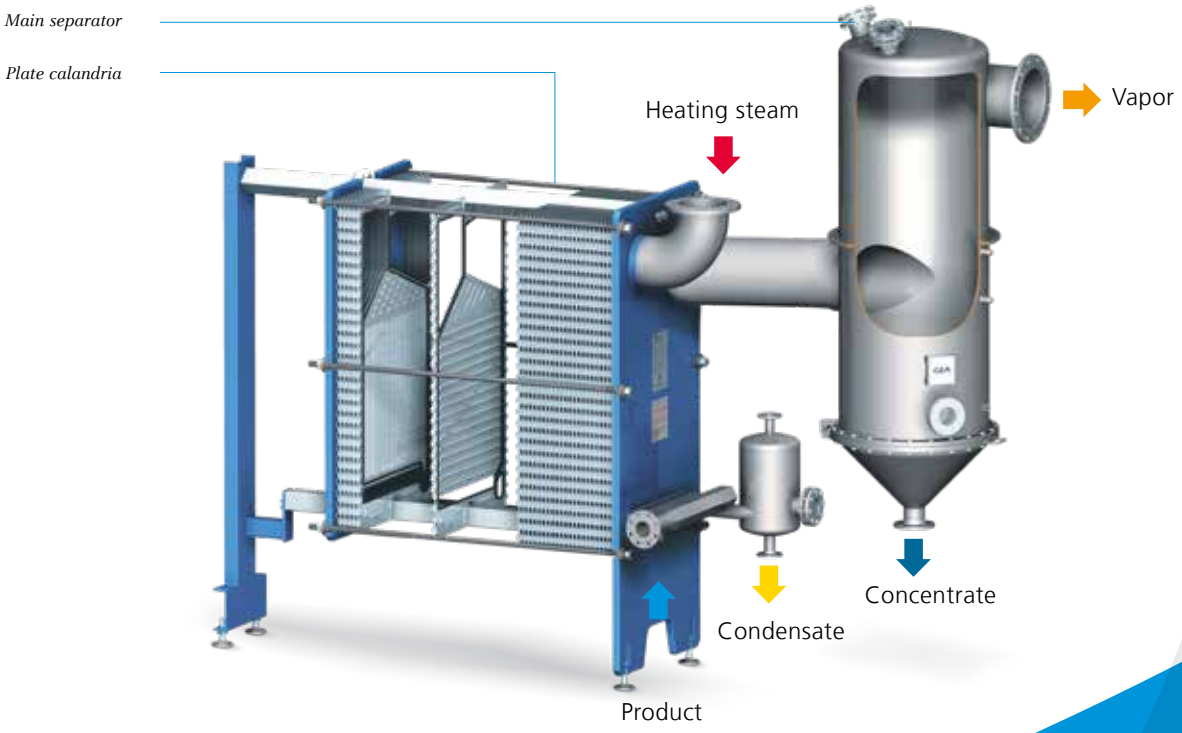
Product and heating media are transferred in counterflow through their relevant passages. Defined plate distances in conjunction with special plate shapes generate strong turbulence, resulting in optimum heat transfer. Intensive heat transfer causes the product to boil while the vapor formed drives the residual liquid, as a rising film, into the vapor duct of the plate package. Residual liquid and vapors are separated in the downstream centrifugal separator. The wide inlet duct and the upward movement ensure optimum distribution over the total cross-section of the heat exchanger.

Particular features

- **Use of different heating media** – due to plate geometries, the system can be heated with both hot water as well as with steam.
- **High product quality** – achieved by especially gentle and uniform evaporation during single-pass operation.
- **Little space required** – as a result of the compact design, short connecting lines and small overall height of max. 3 – 4 m.
- **Easy installation requiring little time** – due to pre-assembled, transportable construction units.
- **Flexible evaporation rates** – by adding or removing plates.
- **Ease of maintenance and cleaning** – as plate packages can be easily opened without special tools. The plates are sealed by gaskets located within specially designed slots that do not require adhesives.



Multiple-effect plate evaporation plant for fructose.
Evaporation rate: 16 t/h



FIELDS OF APPLICATION

Low to medium evaporation rates.

Liquids containing only small amounts of undissolved solids and with no tendency to foul.

Temperature-sensitive products, for highly viscous products or extreme evaporation conditions, a product circulation design is chosen.

Natural circulation evaporators

Vertical shell-and-tube heat exchanger of short tube length, with a separator arranged laterally at the top

Functional principle

The liquid is fed to the bottom of the heating tubes. Due to the external heating of the tubes the liquid film on the inside walls of the tubes starts to boil and partially evaporates. As a result of the upward movement of the vapors produced, the liquid is also transported upwards – according to the thermosiphon or rising film principle. After the separation from the vapors it flows back into the evaporator through a circulation pipe, ensuring stable and uniform circulation. The larger the temperature difference between the heating chamber and the boiling chamber, the greater the intensity of evaporation and, consequently, the liquid circulation and heat transfer rates.

Where the boiling chamber of the circulation evaporator is divided into several separate chambers, each one equipped with its own liquid circulation system, the heating surface required for high final concentrations can be considerably reduced compared to an undivided system.

The final concentration is only reached in the last chamber. In other chambers, the heat transfer is considerably higher due to the lower viscosities and boiling point elevations.

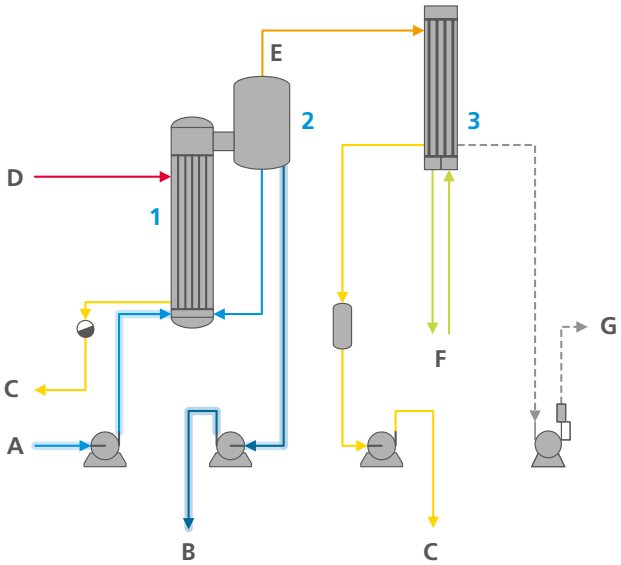
Particular features

- **Quick start-up and large specific capacity** – the liquid content of the evaporator is very low due to the relatively short length and small diameter of the heating tubes (1 – 3 m).

3-effect circulation evaporation plant for glycerine water. Evaporation rate: 3600 kg/h

1 Calandria
2 Separator
3 Condenser

A Product feed
B Product concentrate
C Condensate
D Heating steam
E Vapor
F Cooling water
G Deaeration



FIELDS OF APPLICATION

Products insensitive to high temperatures, where large evaporation ratios are required.

Products which have a high tendency to foul.

Non-Newtonian products, where the apparent viscosity may be reduced by the high velocities.

The circulation evaporator with divided boiling chamber and top-mounted separator can be used as a high concentrator.

Multi-flash evaporators

Multi-flash evaporators with shell-and-tube heat exchangers

Functional principle

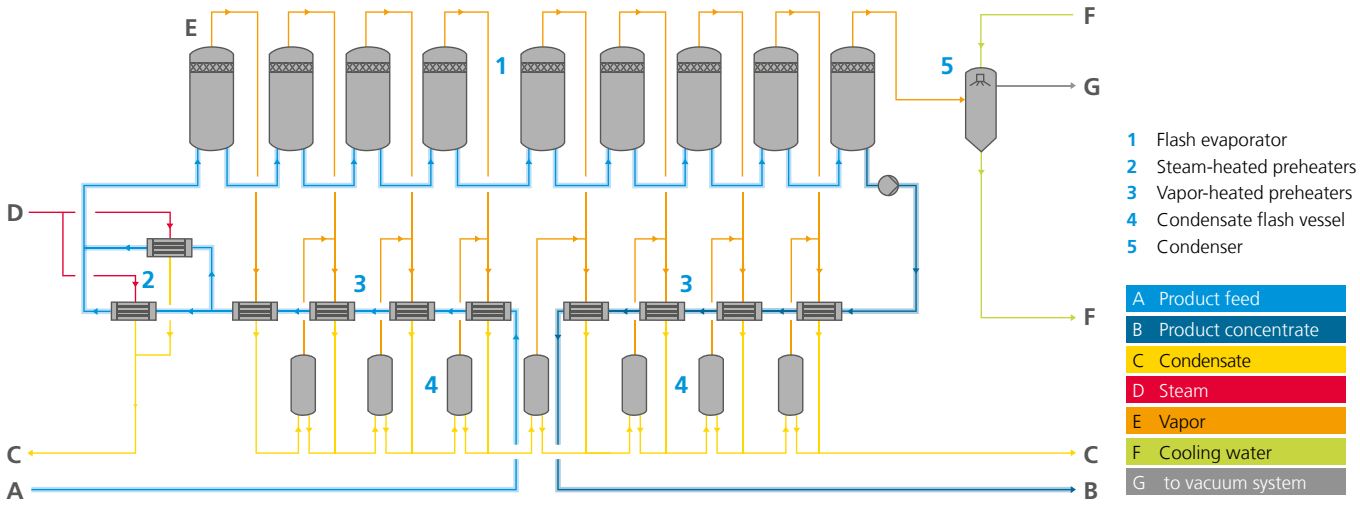
The liquid to be concentrated is heated in a series of heat exchangers and then routed into a cascade of flash vessels with a pressure gradient. Upon entering a vessel, part of the liquid flashes into vapor while the remaining liquid is cooled down. The produced vapor is used to heat the feed and/or discharge flow, depending on how the flash vessels and heat exchangers are arranged. The required heat input is provided by live steam of the first heat exchanger. The liquid is fed to the vessel at the highest pressure and then flows to the next flash vessel by gravity.

Particular features

- Robust and simple technology
- Minimal scaling (no evaporation in a heat exchanger)
- Easy bypass of a flash stage for cleaning
- Easy maintenance
- Few product pumps thanks to gravity transfer between stages
- Limited power consumption
- High number of stages possible to maximize heat recovery
- Medium heat transfer coefficient compared to falling film, a 13-stages multi-flash evaporator corresponds to a 6-effect falling film evaporator
- Short floor space
- Limited turn-down ratio (no recirculation)

Fields of application

For applications involving large throughputs with a relatively low concentration factor, the combination of multiple effect pre-heater systems for heat recovery followed by multi-stage flash evaporation is advantageous. Economic for solutions with low boiling point elevation both from an investment and operational point of view.



Installation options

Each of our plants is specially designed according to the customers' requirements.

Outdoor installation

Partly outdoor and indoor installation

Skid design

In addition to the process-related and energetic requirements for an evaporation plant, the spatial conditions at the customer's as well as the official requirements applicable at the respective location, e.g. in terms of noise and environmental protection play an important role in the design of the system. This can be decisive when choosing the type of evaporator and the arrangement of the components.

Outdoor installation

Due to their height of up to 25 m many evaporation plants are installed outdoors. Very noisy components like a mechanical vapor recompressor are housed in a sound-proof enclosure.

Partly outdoor and indoor installation

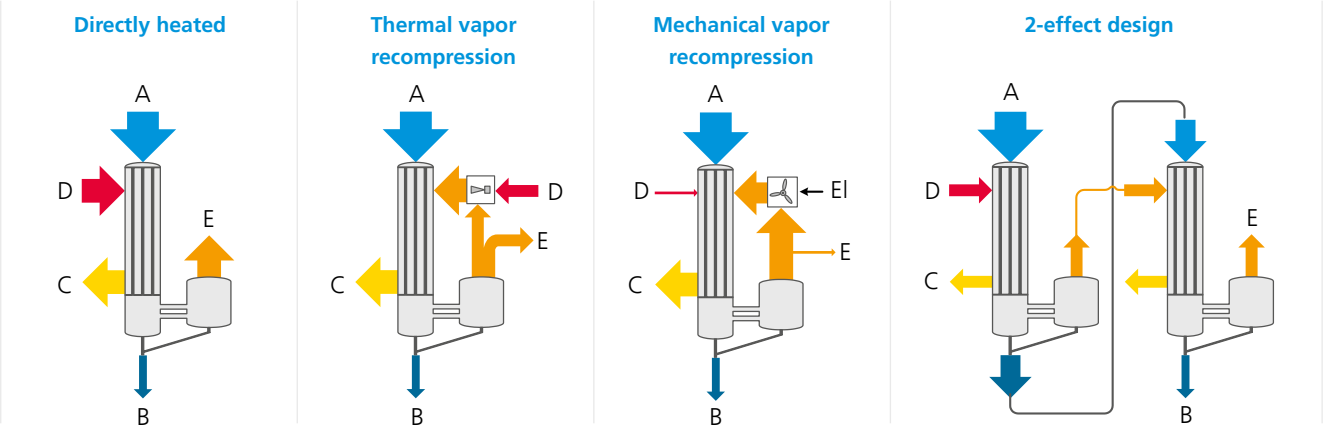
In most evaporation plants, the sensitive and noisy components are enclosed, while the calandria, which can have a height of up to 10 – 12 m, protrudes from the building. The most comfortable option is when the hall is built after the evaporation plant is installed. Otherwise the installation and assembly can be challenging.

Skid design

Skid designed evaporators are mainly used for evaporation capacities up to 4000 kg/h. GEA evaporators in skid design are completely preassembled. This specification requires a compact arrangement of the individual plant components and a well thought-out piping system. According to its size, the plant can consist of one or several units which do not exceed the transport dimensions of an ordinary semi-trailer. Transporters for extraordinary dimensions are not required. This design can reduce the transport costs and saves time and costs for on-site assembly and commissioning.

Energy efficiency of evaporation plants

Energy consumption can be tailored to customer requirements through intelligent thermal configurations of the evaporation plant.



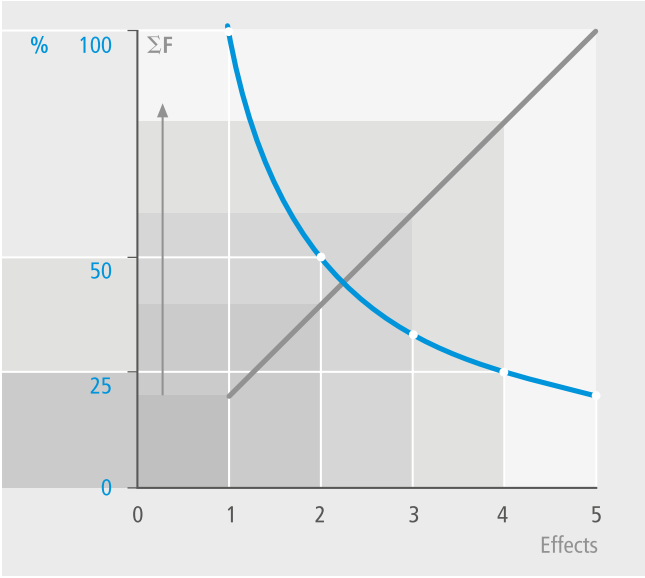
A Product / B Concentrate / C Condensate / D Heating steam / E Vapor / El Electrical energy

In a single-effect evaporator the heat content (enthalpy) of the evaporated vapor is approximately equal to the heat input on the heating side. In the case of water evaporation, about 1 kg/h of vapor will be produced by 1 kg/h of live steam, as the specific evaporation heat values on the heating and product sides are about the same.

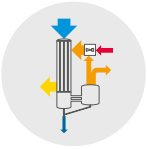
Multiple-effect evaporation

If the amount of vapor produced by primary energy is used as heating steam in a second effect, the energy consumption of the overall system is reduced by about 50 %. This principle can be continued over further effects to save even more energy. The highest permissible heating temperature of the first effect and the lowest boiling temperature of the final effect form an overall temperature difference which can be divided among the individual effects. As a result, the temperature difference per effect decreases with an increasing number of effects. The heating surface must be dimensioned correspondingly larger in order to achieve the specified evaporation capacity. The total heating surface of all effects increases proportionally to the number of effects.

	Live steam	Vapor	Specific steam consumption
1-effect-plant	1 kg/h	1 kg/h	100 %
3-effect-plant	1 kg/h	3 kg/h	33 %



Decrease of the specific steam consumption in % and increase of the approximate total heating surface ΣF in relation to the number of effects



Thermal vapor recompression

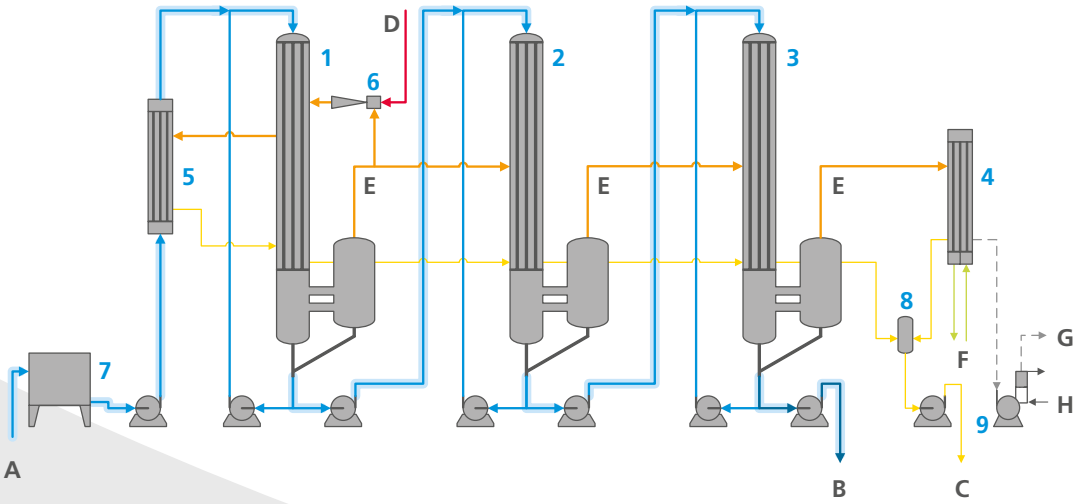
During vapor recompression, vapor from the separator is recompressed to the higher pressure of a heating side of the tube bundle.

For thermal vapor recompression (TVR) steam jet compressors are used. They operate according to the steam jet pump principle. They have no moving parts and therefore no wearing parts. This ensures maximum operational reliability. Thermal vapor recompressors are designed in-house. GEA is looking back to a history of 100 years of designing and supplying steam jet pumps and compressors.

Approximately half of the vapors produced by the evaporation process can be reused for heating. The other half flows to the next effect to drive the evaporation process there. A certain steam quantity, the so-called motive steam, is required for the operation of a thermal vapor recompressor.

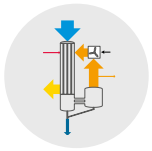
The use of a thermal vapor recompressor gives the same steam/energy saving as an additional evaporation effect.

4-effect falling film evaporation plant heated by thermal vapor recompressor for lysine solution Evaporation rate: 47 t/h



1,2,3 Falling film evaporators
4 Condenser
5 Preheater
6 Thermal vapor recompressor
7 Feed tank
8 Condensate collection tank
9 Vacuum pump

A Product feed
B Product concentrate
C Condensate
D Heating steam
E Vapor
F Cooling water
G Deaeration
H Service water



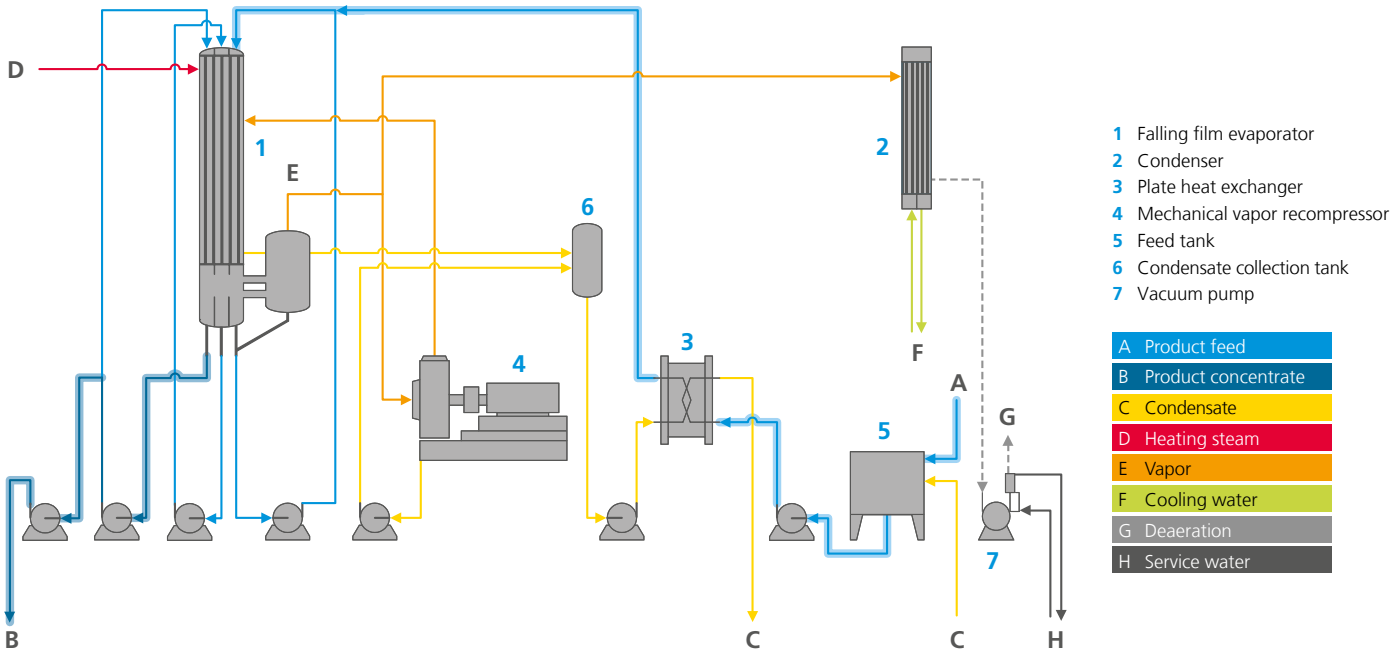
Mechanical vapor recompression

Evaporation plant with two fans for mechanical vapor recompression and forced circulation as finisher. Evaporation rate: 67 t/h

Evaporation plants heated by mechanical vapor recompressors (MVR) require particularly low amounts of energy.

While a steam jet compressor can only compress part of the vapors, a mechanical compressor compresses all vapors of an evaporator to the pressure of the corresponding heating steam temperature, using a small amount of electrical energy compared to the enthalpy recovered in the vapor. Only minimum quantities of live steam are required, generally just during start-up. The quantities of residual waste heat to be dissipated are considerably reduced. The energy of the vapor condensate is frequently utilized for the preheating of the product feed.

Due to their simplicity and maintenance friendly design, single stage centrifugal fans (high-pressure fans) are used in evaporation plants. They operate at high flow velocities and are therefore suited for large flow rates at vapor compression ratios of 1.2 to 1.5. Rotational speeds typically are 3000 up to 12000 rpm. For high pressure increases, multiple fans can be used.



Process automation, plant performance and service

The major goal of any production plant is to achieve the desired product at constant quality by continuous productivity

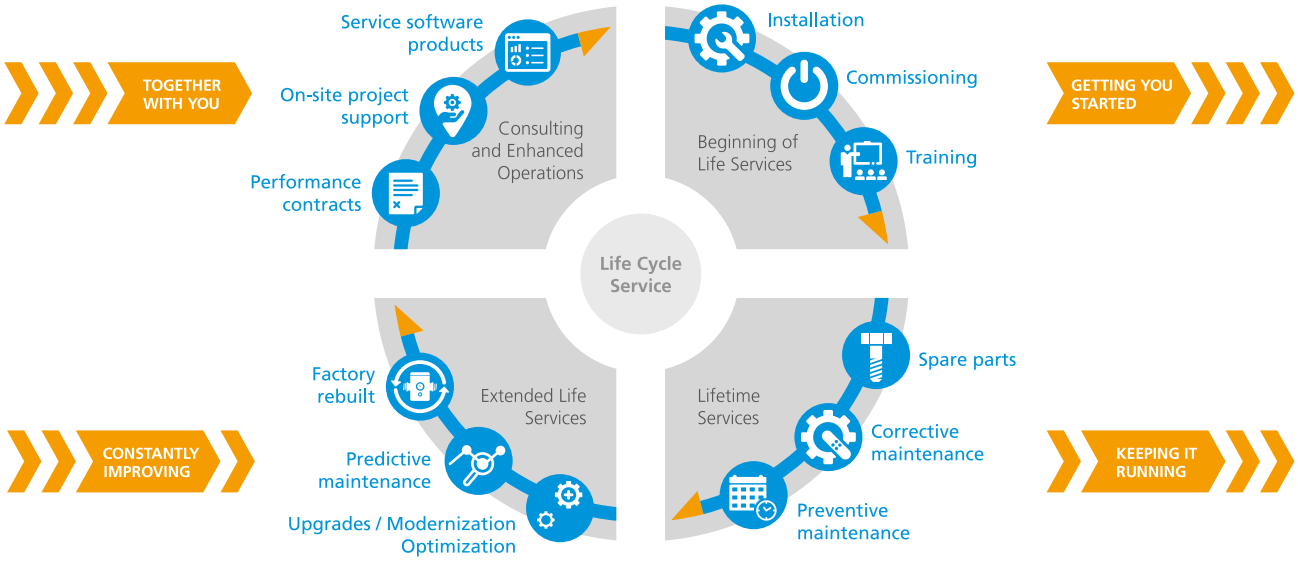
All parameters which might influence the evaporation plant or alter the mass and heat balances need to be monitored and controlled. In accordance with the technical and customer's requirements, GEA evaporation plants can be equipped with the relevant measuring and control systems up to fully-automatic process control systems. We use Siemens SIMATIC PCS7, GEA Codex® or any other suitable software requested by the customer. Instrument and system specifications are selected in cooperation with our customers to ensure the best hardware service during the lifetime of the plant.

Being a partner to our customers is our mission. GEA provides support throughout the entire life cycle of a delivered plant and equipment to ensure business success. To guarantee optimal performance and operational excellence, we provide a wide range of services to maintain and improve your plant and equipment.

Beginning of life cycle service

Getting you started with seamless support for instant productivity and performance. Installation, commissioning and staff training are carried out by our assembly supervisors, project engineers and process control experts. On request we create an enhanced **Digital Twin** (3D model plus dynamic process simulations) of your plant with variable automation levels. This has significant benefits:

- The process control can be programmed and tested before commissioning of the plant with the **Advanced Factory Acceptance Test (FAT)** using the dynamic process model.
- **Virtual commissioning** shortens the commissioning time and identifies errors in advance.
- **Operator training** at the virtual plant help familiarize the operators with the plant before its commissioning.



Lifetime services

Keeping your plant running with the most cost-efficient way of ensuring safety and reliability.

- Preventive maintenance including periodic inspections and audits, maintenance contracts, calibration services and spare parts planning for scheduled maintenance.
- Corrective maintenance real-time assistance anywhere in the world through our service engineers and technicians.
- On request video remote support via GEA Remote Eye Wear or other mobile devices to solve problems onsite more quickly.
- Fast delivery of the appropriate spare parts to ensure minimal downtime. Original spare parts maintain the performance of your GEA equipment and plant, ensuring safety and reliability, minimizing down time and maximizing productivity.

Extended services

Constantly improving by sharing our knowledge to safeguard your investment.

- Predictive maintenance from GEA monitors the operation and performance of defined equipment in your plant. Combining this information with the experience of the GEA technicians, allows you to optimize your maintenance activities and related costs.
- Upgrades and optimization – we work with you to make sure your equipment and plant keeps up with the demand and improved technology: improving safety and efficiency, reducing costs, providing longer lifetime and ensuring the flexibility you need.

We have developed software solutions that enable you to review and optimize the performance of your plant:

GEA Dashboard – enables the display and monitoring of all necessary KPIs (Key Performance Indicators) on a dashboard. Using digital technologies, such as advanced machine learning algorithms, GEA increases the efficiency and productivity with full visibility of the process.

Consulting and enhanced operations

Together with you by enduring commitment to you and your business.

Performance contracts from GEA avoid cost traps and offer service packages focused on availability and cost control.

Our sophisticated software solutions provide the tools you need to manage your plant effectively, including project information, service history reports, plant asset register and spare parts.

engineering for
a better world

We live our values.

Excellence • Passion • Integrity • Responsibility • GEA-versity

"Engineering for a better world" is the driving and energizing principle connecting GEA's workforce. As one of the largest systems suppliers, GEA makes an important contribution to a sustainable future with its solutions and services, particularly in the food, beverage and pharmaceutical sectors. Across the globe, GEA's plants, processes and components contribute significantly to the reduction of CO_2 emissions, plastic use as well as food waste in production.

GEA is listed on the German MDAX and the STOXX® Europe 600 Index and also included in the DAX 50 ESG and MSCI Global Sustainability indexes.

GEA Wiegand GmbH
Am Hardtwald 1
76275 Ettlingen,
Germany
Tel +49 7243 705-0
gea.com/contact

GEA Process Engineering SAS
4, rue Jean Pierre Timbaud
78185 Montigny-le-Bretonneux,
France
Tel +33 130 146 110
gea.com/contact