Concentrate Plants

for the Fruit and Vegetable Industry

GEA Process Engineering
GEA Wiegand

Evaporation technology is a process of separating substances by means of thermal energy. The concentrated liquid which is still pumpable usually is the desired final product. Evaporation might also aim at recovering the volatile constituent as in the case of the recovery of solvents and aroma.

In the beverage industry, a frequently used process is evaporation under vacuum. Freshly pressed fruit juice from stone, pomaceous and soft fruit as well as juice from citrus and tropical fruit is concentrated and is in this way preserved. Before or during the evaporation process, volatile flavours are extracted from the thin juice, are recovered and are re-added to the fruit juice later on for intensifying the typical fruit taste.

The advantages of evaporation of juice and storage of concentrate are obvious:

- Six to seven times the quantity can be stored in a storage tank under simplified storage conditions.
- Concentrate can be preserved without being cooled due to its high sugar content.
- Fluctuations in quantity and quality of different vintage can be balanced and adapted to the market situation.
- Concentrate as commodity is easier to market.
- The transport of concentrate is simpler and cheaper.

Another important application of evaporation technology in the fruit juice industry is the concentration of extract based on different starting materials.
For example, juice residues and oil can be extracted from the pulp of the fruit or from the peels of citrus fruit. The recovered extract can be concentrated by evaporation and can be reused, and different types of oil can be separated.
Pectin can be extracted from the pomace of apples and pears and from the peels of beet and citrus fruit. The extract is concentrated in an evaporation plant, and the pectin is then precipitated from the concentrate by means of, for example, alcohol. The alcohol can be efficiently recovered in a combined evaporation and distillation process.
Evaporation plants are also used in other fields of the beverage industry, e. g. in the brewing industry for the concentration of malt extract, brewer's yeast, yeast extract, hop extract, grain press water and wort. The dealcoholization of beer in a falling film evaporation plant is a particularly gentle process which guarantees the characteristic taste of beer with a residual alcohol content of less than 0.05 %. Extract from coffee, tea and other plants can also be optimally concentrated in evaporation plants.

Selection of evaporator types and plant designs

The concentration of fruit juice in evaporators occupies a central position in the juice industry. Among the different types of evaporators, **falling film evaporators** are particularly suitable for the production of fruit juice concentrate due to their safe and efficient operation. The necessary high final concentrations which depend on type of fruit, degree of ripeness, juice production method, pretreatment and fiber and pulp proportion, can be reached in this way.

In GEA Wiegand falling film evaporators, the juice to be evaporated is distributed onto the upper tube sheet and onto the heating tubes by an especially developed distribution system. From this system, the product flows downwards in the heating tubes to the lower tube sheet as a thin film. The evaporated vapour (steam) flows downwards in the same direction and consequently accelerates the flowing of the film. This limits the period of residence, during which the juice to be evaporated is retained in the heating tube, to a few seconds.

The product flows through one evaporation effect after another until it is discharged. For quality reasons, the product is not recirculated.
The short residence times and the small temperature differences in falling film evaporators allow high boiling temperatures in the first effects of the plant (usually ranging from 95 °C to 100 °C in the first effect). With increasing concentration, the boiling temperatures decrease to approx. 45 °C in the last evaporation effect.

4-effect falling film evaporation plant with aroma recovery system for apple juice, in compact design; evaporation rate: 8,000 kg/h

A larger total temperature range and smaller temperature differences in the falling film effects ensure efficient multiple-effect operation with a low heating steam and cooling water consumption and a high standard of product quality. The relatively large cross-sections in the heat exchanger tubes of the preheaters and in the heating tubes of the evaporation effects make it possible to also evaporate products that contain fibres and pulp.

Falling film evaporators also show a stable operating behaviour at reduced load and with different products. As the time of product flowing through the plant is very short, the plant can be quickly cleaned with small amounts of cleaning agent (as a rule with caustic soda and nitric acid).

Plant arrangements

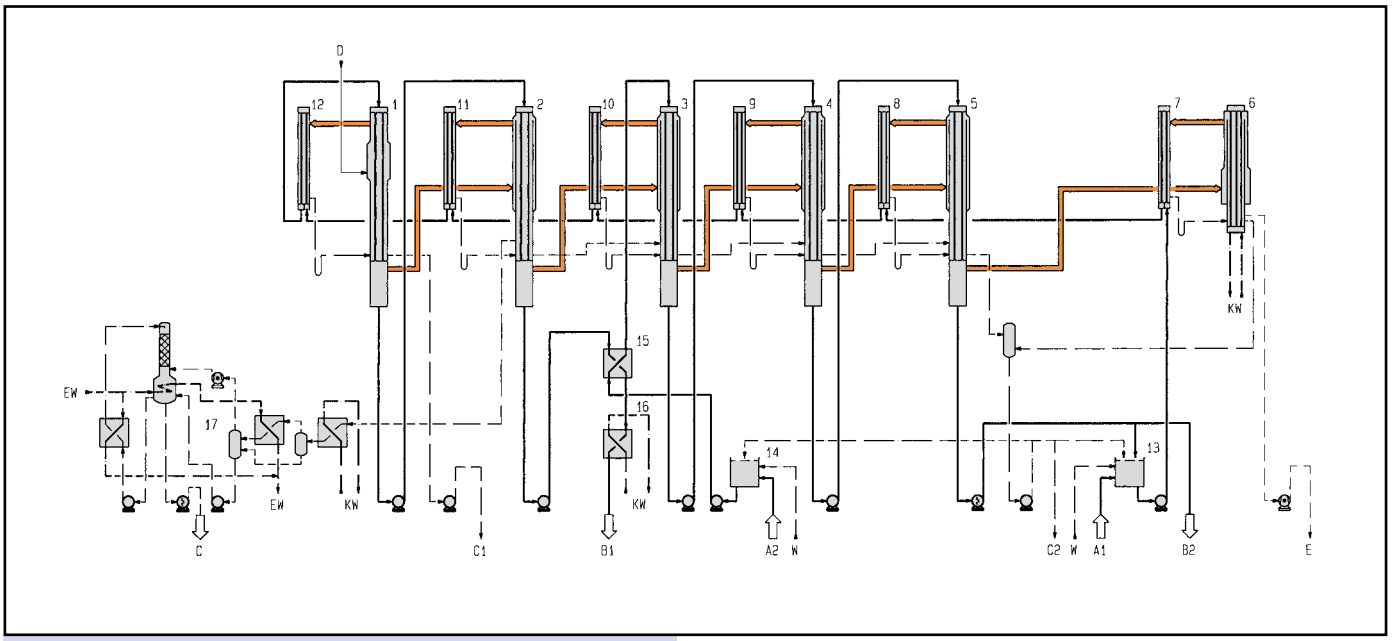
For an optimum plant design different factors of influence are of importance. Apart from the above-mentioned evaporator features and product requirements, the efficiency study and specific customer requests are also significant aspects.

For efficiently designing a plant, the investment cost and the regular operating costs, i. e. mainly the utility costs, must be taken into account. In this context, the energy situation of the entire factory should be examined.
By means of **multiple-effect evaporation and thermal or mechanical vapour recompression** specifically low consumption figures can be reached.

Due to the seasonally short operating period, mainly evaporation plants equipped with thermal heating system are used in the juice industry. With increasing evaporation rate, the plants have up to 6 effects.

left:
1-effect pre-evaporator with mechanical vapour recompressor and 5-effect directly heated finisher for fruit juice;
evaporation rate: more than 100 t/h

right:
5-effect falling film evaporation plant for apple juice (ill. page 5);
evaporation rate: 12,000 kg/h



5-effect falling film evaporation plant, directly heated, with aroma recovery system (DIFFAR), concentrate cooling system and fining outlet, for apple juice

1-5	*calandrias*	*B2*	*clear juice concentrate*
6	*condenser*	*C*	*aroma*
7-12	*preheaters*	*C1*	*live steam condensate*
13,14	*feed tanks*	*C2*	*vapour condensate*
15,16	*plate condensers*	*D*	*live steam*
17	*aroma recovery system*	*E*	*deaeration*
A1	*cloudy juice feed*	*EW*	*chilled water*
A2	*clear juice feed*	*KW*	*cooling water*
B1	*cloudy juice for intermediate treatment*	*W*	*water*

In smaller and medium-size plants of up to 20 - 30 t/h evaporation rate, the product is preconcentrated and the aroma is recovered in effect 1 and, if necessary, 2. Then the cloudy juice is fined (clarified). The clarified juice is then time-delayed conveyed back into the next effects of the plant and is evaporated to final concentration.
The advantage of combined operation consists in the low investment cost, and, at the same time, high efficiency of a multiple-effect plant.

3-effect plate evaporation plant, directly heated; evaporation rate: 3,500 kg/h

For higher evaporation rates, the cloudy juice is preconcentrated in an independent pre-evaporator, and the clarified juice is evaporated in a high concentrator. For energy reasons, both plants usually have 5 to 6 effects. The advantage consists in the more flexible operation with simultaneous high efficiency. The investment costs, however, are higher than for a combined plant. Alternatively, the pre-evaporator can also be designed as 1-effect system heated by mechanical vapour recompressor. A high-pressure fan driven by an adjustable-speed motor is used as compressor in this case.

Thermal vapour recompressors are also used for the heating of evaporation plants. This further reduces the steam consumption. The amount of steam which usually can be saved corresponds to an additional effect.

Plate evaporators

The main feature of this plant concept is the compact design. The constructional height ranges from 3 to 5 metres depending on the design. Plate evaporators normally are designed for rising flow in single-pass operation. This keeps the thermal strain on the product as low as possible. The concentration of clear juice or juice containing little pulp are the preferred fields of application in the fruit juice industry.

Aroma recovery systems

Rediluted fruit juice must stand comparison with the taste of freshly pressed juice. Even the most gentle concentration process cannot prevent the fact that the fruit juice concentrate lacks the specific flavours. If the volatile flavours are extracted from the juice before or

during concentration and, if these flavours are stored at cool temperatures, separate from the de-aromatized fruit juice concentrate, undesired conversion with juice constituents is practically not possible. In this way, the concentrated flavours (aroma concentrate) can be preserved for a long period of time.

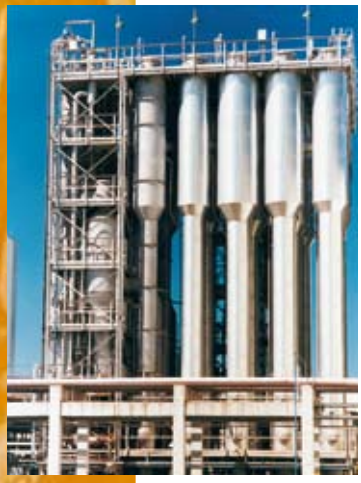
If the aroma concentrate is re-added when the juice is being rediluted, the typical flavour of the fresh juice can be restored almost completely.
Each flavour consists of a number of constituents that more or less differ in quantity, solubility and boiling points. The vapour quantity to be evaporated in the evaporator depends on the type of juice and the desired aroma yield. It usually ranges from 10 to 45 % of the initial quantity.

The aroma quantities depend on the type of juice and range from 0.5 to 2 % of the fresh juice quantity. The aroma concentrate is discharged from the plant as cooled clear liquid.

There are different processes of aroma recovery:

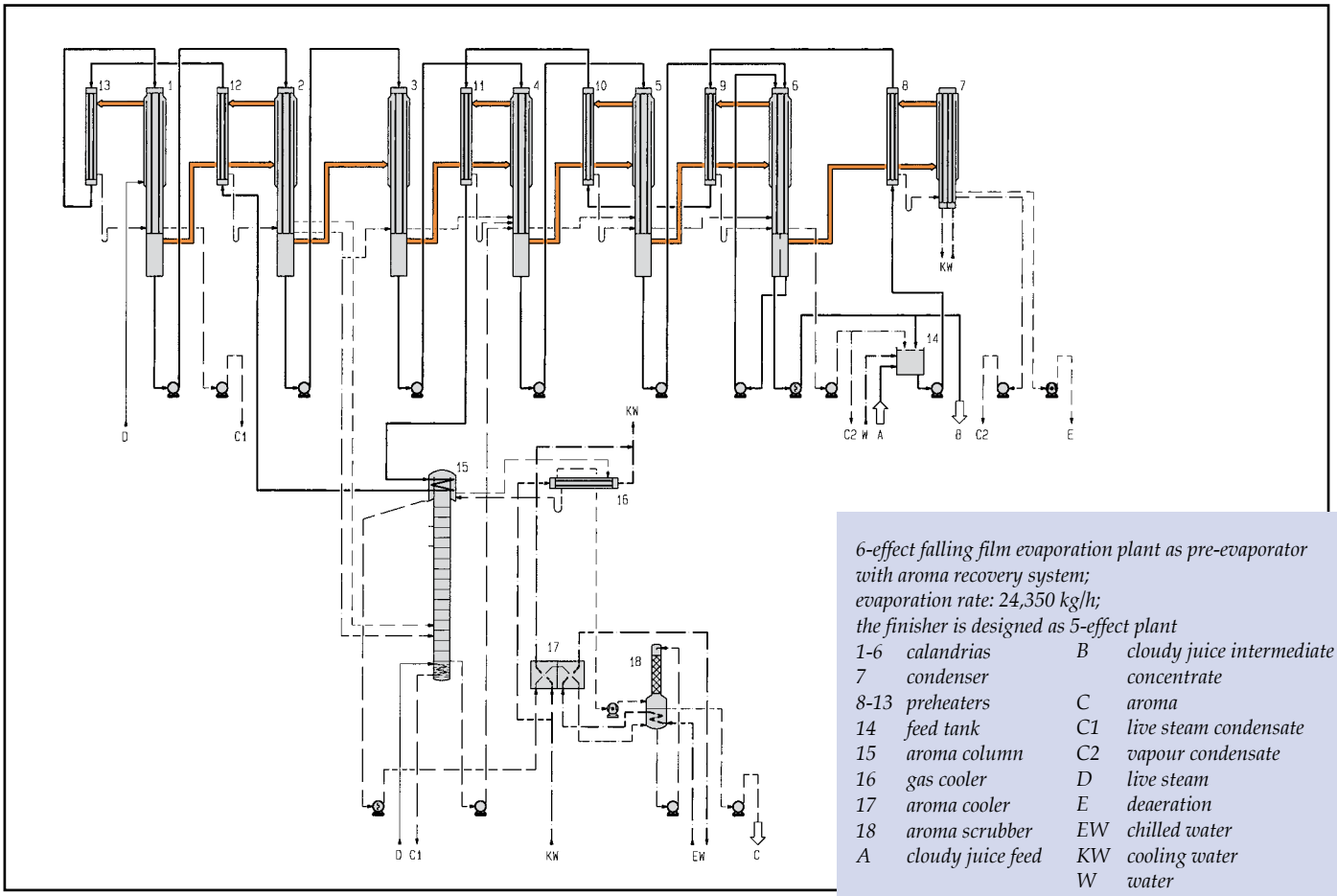
Distillation/rectification
The vapours containing aroma are conveyed from the pre-evaporator to the next effect for heating. The steam is almost completely condensed in this effect. The residual vapours which contain higher quantities of aroma and inert gases, are then separated into aroma concentrate and water residue in a fractionation column. In the upper part of the column the volatile flavours accumulate. The water residue flows off from the bottom.

Fractionation columns are mainly equipped with bubble-cup trays which make it possible to draw off different quantities at different trays of the columns if different types of fruit are being processed.



left:
5-effect falling film evaporation plant with thermal vapour recompressor, desulphurization system and flash cooling system, for grape juice; evaporation rate: 45,000 kg/h

right:
two 5-effect falling film evaporation plants with thermal vapour recompressor, with pasteurization system, concentrate cooling system, aroma recovery and d-limonene separation systems, for orange juice; evaporation rate: 24,000 kg/h



6-effect falling film evaporation plant as pre-evaporator with aroma recovery system;
evaporation rate: 24,350 kg/h;
the finisher is designed as 5-effect plant

1-6	*calandrias*	*B*	*cloudy juice intermediate concentrate*
7	*condenser*	*C*	*aroma*
8-13	*preheaters*	*C1*	*live steam condensate*
14	*feed tank*	*C2*	*vapour condensate*
15	*aroma column*	*D*	*live steam*
16	*gas cooler*	*E*	*deaeration*
17	*aroma cooler*	*EW*	*chilled water*
18	*aroma scrubber*	*KW*	*cooling water*
A	*cloudy juice feed*	*W*	*water*

Diffusion-assisted aroma rectification (DIFFAR)
This process is based on aroma concentration by means of partial condensation of the vapours containing aroma. As described above the vapours from the pre-evaporator are condensed in the downstream calandria. The remaining vapours containing aroma and inert gases are then cooled and liquefied in special heat exchangers by means of cooling water and chilled water. The inert gases containing aroma are scrubbed with aroma concentrate in a downstream arranged scrubbing column.
DIFFAR is the more inexpensive alternative of aroma recovery and can easily be connected to most existing falling film evaporators.

Desulphurization system

The sulphurization of freshly pressed grape juice is a simple and safe preserving process. The necessary quantity of sulphur dioxide or its aqueous solution usually is 600 - 2,500 mg SO_2 per litre of juice. According to most food standards fruit juice beverages must not contain more than 60 to 80 mg SO_2 per litre.

The desulphurization process which is accordingly required can be combined with the evaporation process.

The easiest method of desulphurization is to heat the juice to a sufficiently high temperature and to flash it subsequently. The vapours produced during this process entrain the free sulphur. For problematic juice, for instance red grape juice of a certain pH value, tannin content etc., GEA Wiegand installs a desulphurization column upstream of the first evaporation effect. Heating to approx. 100 °C and longer periods of residence in the desulphurization column achieve a good degree of desulphurization even with juice of very low acid value and of low concentration. The quality of the juice will not be impaired if it is immediately cooled after evaporation.

Concentration of citrus juice

Citrus juice occupies a special position among fruit juice. When concentrate is produced, particular requirements must be taken into consideration. This shall be explained by the example of orange juice.
Freshly extracted orange juice of 10 – 11 % DS, from which pulp has been removed to a large extent by means of screw presses and centrifuges, flows to the evaporator. A degasser is connected upstream of the evaporator for removing air and other types of gas and for preventing the formation of disagreeable odours and flavourings.

Prior to the actual concentration process, the juice is pre-heated and is heated to pasteurization temperature. It is essential that the residence times of the product are as short as possible in order to maintain the quality of the juice to a large extent.

The temperature profile is chosen in such a way that the enzymes splitting pectin are inactivated and that micro-organisms are extinguished to a large extent in order to reach stability of the cloudy juice and to prevent the formation of alcohol caused by the fermentation of sugar.

After heating, the juice is evaporated to 62 – 63 % DS in a multiple-effect falling film evaporator. It is important that the product is evenly distributed onto the heating tubes throughout the entire operating period of the evaporation plant, as juice tends to precipitate (hesperidin). It is also significant that the correct velocities of vapours in the heating tubes are chosen so that possible hesperidin deposits on the tube walls are not removed and that the evaporation plant does not need to be switched into cleaning mode prematurely.

Depending on the evaporation rate, GEA Wiegand orange juice evaporation plants have 4 to 6 effects and operate in connection with thermal vapour recompressors. In this way, the steam consumption can be improved once again compared to a directly heated evaporation plant without increasing the residence time of the product in the plant.

The flash cooling system connected downstream of the evaporation plant flashes the product down to a temperature of 12 – 13 °C. At the same time, the final concentration of 65 % DS is reached by evaporation.

Together with the water the volatile flavours of the orange juice are also evaporated. This impairs the taste of the concentrate. The recovery of the flavours from the vapours is therefore of major importance so that they can be re-added to the concentrate during redilution. For this process, a rectification column with downstream arranged aroma scrubber is used. The aroma scrubber operates at temperatures nearing the dew point. After separation of the oily phase from the aqueous phase almost the entire aroma will in this way be available again.

GEA Wiegand falling film evaporators operate at lower maximum temperatures and substantially lower residence times than conventional systems, thus producing orange concentrate of higher quality which comes nearest to the original flavour of the fruit.

4-effect falling film evaporation plant for orange juice; evaporation rate: 12,000 kg/h

Pectin

For the production of pectin, the dried peels of e. g. apples and citrus fruit are ground and conveyed to an extraction system. The raw extract is separated from the pomace by means of belt press filters or in decanters and separators and is clarified. After concentration and cooling, pure pectin is recovered by the precipitation of alcohol.

The alcohol is recovered and the remaining vinasses is treated in a combined distillation/evaporation plant.

GEA Wiegand uses falling film evaporation plants equipped with mechanical vapour recompressors for the concentration of pectin. The falling film evaporation plant for the treatment of vinasses is directly heated by steam or by vapour from the distillation system. For alcohol distillation, columns with sieve trays and structured packings are used.

The GEA Group can provide nearly all of plants and components required for a complete process line for the production of pectin.

left:
1-effect falling film evaporator with mechanical vapour recompressor for citrus pectin;
evaporation rate: 35,000 kg/h

right:
combined 2-effect falling film evaporation plant with rectification column for the treatment of precipitation alcohol;
feed rate: 37,000 kg/h

Control concepts

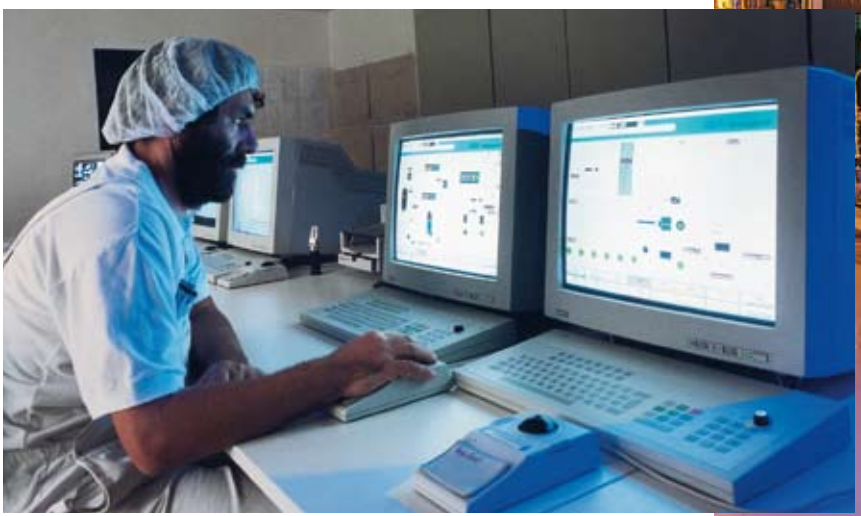
Depending on the technical requirements and the customers' specific requests GEA Wiegand evaporation plants are equipped with the relevant measuring and control equipment – from the simple conventional control system to the PLC* system.

Manual operation
The plant is operated and monitored by means of local measuring instruments and manually actuated valves and fittings.

Semi-automatic process control
The most important process parameters such as steam pressure, vacuum, product supply and final concentration are maintained by means of compact controllers or by a PLC system (programmable logic controller) with software controllers. The passes for product and condensate are switched and the cleaning procedures are controlled by means of hand valves or remote controlled fittings.

Automatic process control
The functions are controlled in the same way as for semi-automatic operation. In addition, individual or all process sequences including start-up with water or product, shut-down and cleaning are automated by application-specific software in connection with a PLC system.

Each control concept offers the possibility of operating and monitoring the plant by means of various types of visualization system.



*PLC - Programmable Logic Controller

Research and development

In many cases, tests are necessary for determining the data on which to base the plant design and for studying the behaviour of the product during evaporation. The objective of the tests is to define the best operating con-ditions, to determine the most suitable type of evaporator and to produce concentrate and distillate samples.

The GEA Wiegand R & D Centre is equipped with modern laboratory equipment and test plants and is therefore optimally suited for analyses in the fields of evaporation technology and distillation technology.

GEA Wiegand has several test plants of different design which can also be transported to our customers‘ when required. GEA Wiegand is therefore in a position to make practice-oriented analyses and to develop new processes.

GEA Wiegand’s intensive research and development work has resulted in numerous patents in Germany and abroad, long years of experience and knowledge of a vast range of products from **A**pple to **Z**ymase.

Overview on our Range of Products

Evaporation plants
to concentrate any type of fluid food, process water, organic and inorganic solutions and industrial waste water; with additional equipment for heating, cooling, degassing, crystallization and rectification.

Membrane filtration – GEA Filtration
to concentrate and process fluid food, process water, industrial waste water, to separate contaminations in order to improve quality and recover valuable substances.

Distillation and rectification plants
to separate multi-component mixtures, to recover organic solvents; to recover, clean and dehydrate bio-alcohol of different qualities.

Alcohol production lines
for potable alcohol and dehydrated alcohol of absolute purity; integrated stillage processing systems.

Condensation plants
with surface or mixing condensers, to condense vapour and steam/gas mixtures under vacuum.

Vacuum / steam jet cooling plants
to produce cold water, to cool liquids and product solutions, even of aggressive and abrasive nature.

Jet pumps
to convey and mix gases, liquids, and granular solids; for direct heating of liquids; as heat pumps; and in special design for the most diverse fields of application.

Steam jet vacuum pumps
also product vapour driven; also in combination with mechanical vacuum pumps (hybrid systems); extensive applications in the chemical, pharmaceutical and food industries, in oil refineries and for steel degassing.

Heat recovery plants
to utilize residual heat from exhaust gases, steam/air mixtures, exhaust steam, condensate and product.

Vacuum degassing plants
to remove dissolved gases from water and other liquids.

Heating and cooling plants
mobile and stationary plants for the operation of hot-water heated reactors and contact driers.

Gas scrubbers
to clean and remove dust from exhaust air, to separate aerosols, cool and condition gases, condensate vapours and absorb gaseous pollutants.

Project studies, engineering for our plants.

GEA Process Engineering

GEA Wiegand GmbH

P. O. Box 100949, 76263 Ettlingen, Germany
Tel. +49 7243 705-0, Fax: +49 7243 705-330
info.gewi.de@geagroup.com, www.gea-wiegand.com

P05E 032010 HINKEL380