INDUSTRIAL PLATE EVAPORATORS

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Abstract

For many years plate evaporators have been used for a wide range of applications such as fruit juice evaporation, desalination aboard ships, refrigerants and smaller industrial applications. None of these types of plate evaporators is suitable for larger industrial evaporation duties. The background for the development of and experience with such a large industrial evaporator is given.

Introduction

Over 20 years ago Alfa Laval developed the Nirex compact desalination unit for marine application. This unit uses a modified plate heat exchanger as an evaporator and condenser for producing fresh water. Evaporation takes place at 40°C with minimal pressure drop and is still being widely used today. Other compact evaporators that have been in use for the same length of time or longer and are still being manufactured are the agitated-film evaporator for viscous and heat-sensitive products, the thin film evaporator with the extremely short residence time of about 1-10 seconds for heat sensitive products, and plate evaporators for the fruit juice industry. In the early 1980s the new generation of cassette evaporators, the ACE, was developed. These were designed to meet the highest requirements of fruit juice concentrate producers regarding product quality, energy consumption and flexibility.

The largest number of plate evaporators can be found in the refrigerant market. Small brazed plate heat exchangers are commonly used in small freon evaporators and condensers. The welded alfa laval twin plate heat exchanger construction is used for larger refrigerant systems with freon or ammonia in the welded channel.

All the above mentioned plate evaporators are excellent for the specific duties for which they have been developed. For larger industrial duties like sugar, glucose, solvents, chemicals, black liquor, waste water etc. these do not efficiently and competitively meet the specific requirements in these industries. Alfa Laval therefore started to develop an industrial plate evaporator. Sugar was selected as the first priority.

The plate heat exchanger has today more or less completely replaced the shell and tube heat exchanger within the beet sugar industry. The industry was looking for the possibility to make improvements in efficiency for the evaporation units. In the early 1980s the West European sugar industry was using 40 kg steam/100 kg beet processed. Today 25 kg/100 kg is common with around 20 kg steam/100 kg beet in Germany. In Eastern Europe it is 50-60 kg steam/100 kg beet. In cane sugar producing countries the steam consumption is about the same as in Eastern Europe but fuel is provided in the form of bagasse and so energy efficiency has not received as detailed attention. The main uses of steam are in evaporation and crystallisation.

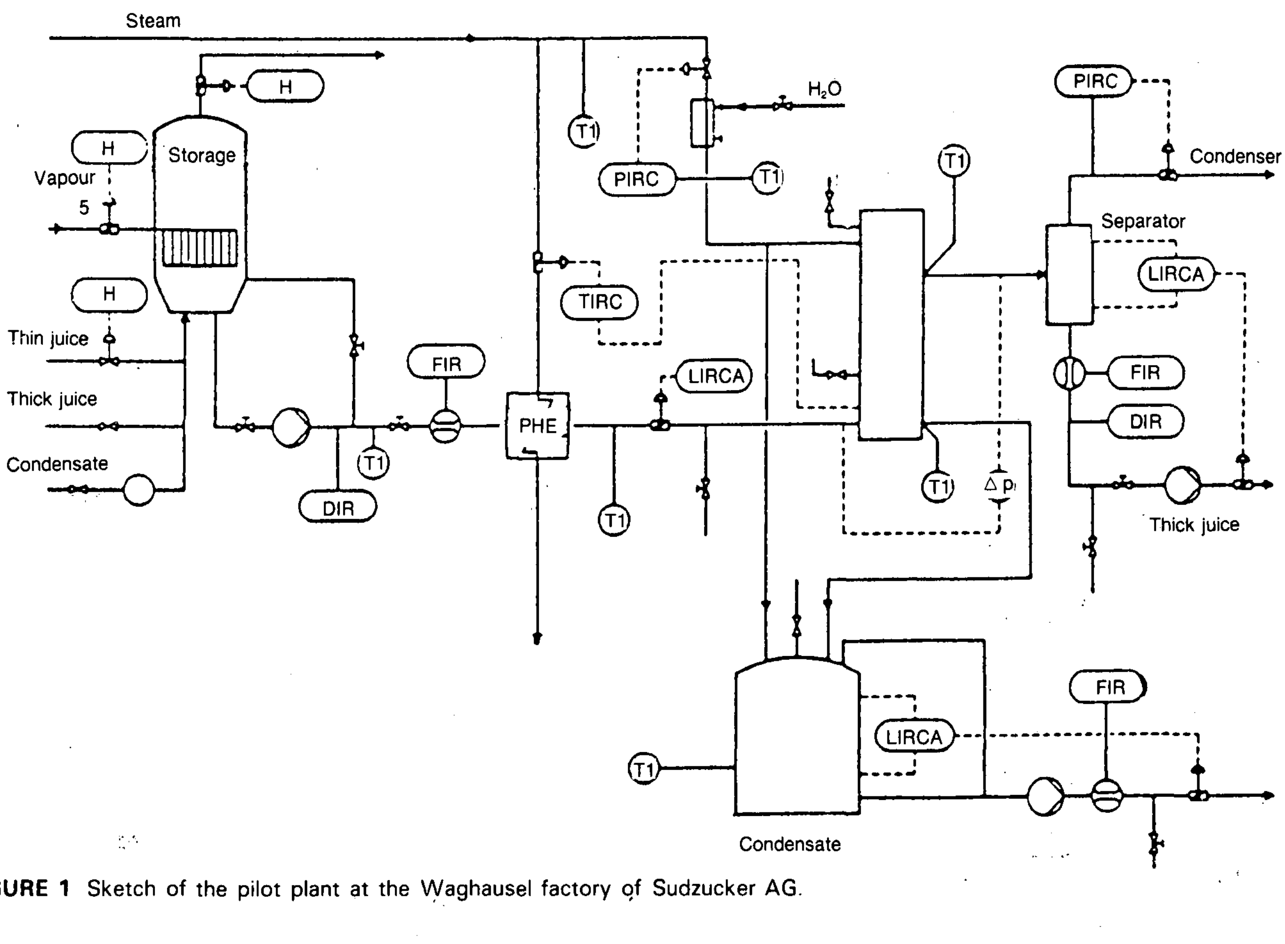

FIGURE 1 Sketch of the pilot plant at the Waghausel factory of Sudzucker AG.

Development of the new EC500 plate evaporator

In 1986 contact was established between Sudzucker AG in Germany and Alfa Laval who determined the following requirements:

- Higher efficiency evaporators for better heat transfer.
- Smaller temperature differences over each effect. Possibility to go to seven effects within the same overall temperature difference of 40°K to reduce further the steam consumption.
- Shorter residence time to reduce colour and invert sugar formation. If possible improve the total quality.
- The industry is changing over from carbon steel to stainless steel material to prolong life and to reduce fouling tendencies.
- Cost advantages.

The first study showed that it was possible to achieve the above. The newly developed fruit juice cassette evaporator, the ACE, was using the falling film principle. Further study showed however that a rising film plate evaporator would be preferable due to:

- There were no distribution problems.
- Recirculation could be omitted thus reducing energy costs and retention time.
- Larger fluctuations in flow rates were allowed as there were no wetting problems.
- It was possible to achieve higher heat transfer values.
- It was more competitive in price.

In 1987 Sudzucker AG installed a pilot plant in parallel with the actual evaporation line (Licha *et al.*, 1989) at their Waghausel factory (Figure 1). In this line the entire pressure and concentration range could be studied, viz. heat transfer value (k) at various pressures and concentrations, and pressure drops; as well as different plate configurations such as channel spacing and height and various plate patterns (tubular and different herring bone patterns).

One of the reasons for installing a pilot plant and not a full scale unit was that British Sugar installed four larger Alfa Laval units at their Wissington factory the same year in order to boost their third and fourth effects in both trains (Anon, 1991). The results from these installations showed that:

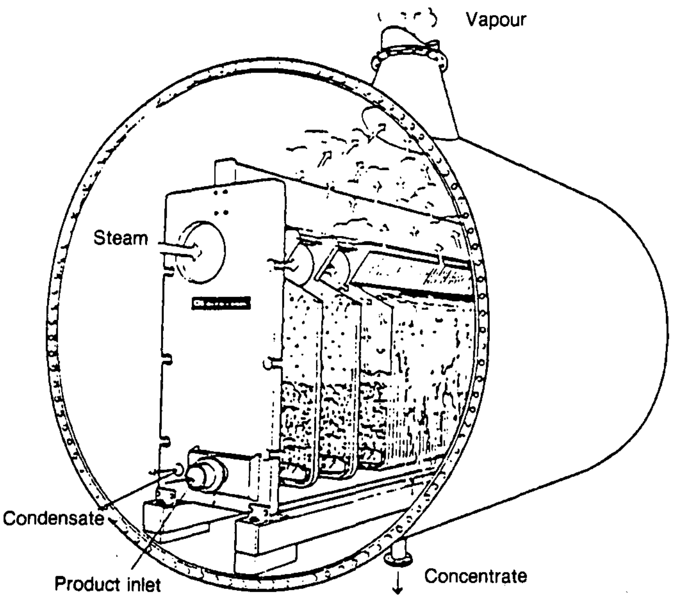

FIGURE 2 Principle of the plate evaporator installed at the Waghausel factory of Sudzucker AG.

- The heat transfer value of the plate evaporator was much higher particularly at higher concentrations. On average the required area for a total plant was indicated to be only half that of a tubular (Roberts) type evaporator.
- The plate evaporator could work at temperature differences, defined as heating steam temperature - product outlet temperature, of 3-4°K maintaining a high k-value.

In 1988 at Waghausel the first effect was boosted using the first plate evaporator prototype having no outlet ports and installed inside a separation vessel (Figure 2).

A falling film plate evaporator was installed in parallel in the same vessel to compare the two principles. Each of the plate evaporators was designed for 50 m^3/h product inlet. The Alfa Laval plate evaporator was operating down to a temperature difference of 3,4°K still maintaining a k-value of 4,250 $W/m^2,K$ (Figure 3).

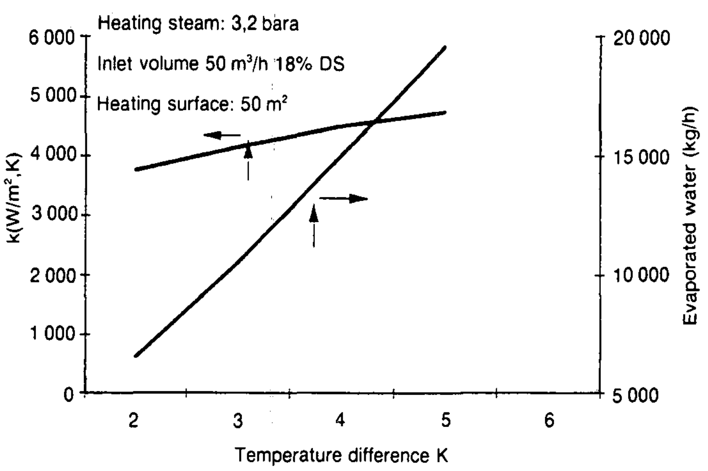

FIGURE 3 Thermal performance of the AL prototype at Waghausel factory of Sudzucker AG (Licha *et al.*, 1989).

After the campaign the falling film unit was taken out of operation because of low k-values and distribution problems and has been replaced by the first of the Alfa Laval industrial rising film evaporators. Alfa Laval's first prototype is still in operation.

The new Alfa Laval plate evaporator, EC500

The EC500 (Figure 4) was developed in 1989 based on the experience of two campaigns in Wissington and on the pilot plant and prototype installation in Waghausel. The new unit was introduced in 1990 (Punter and Christopherson, 1992).

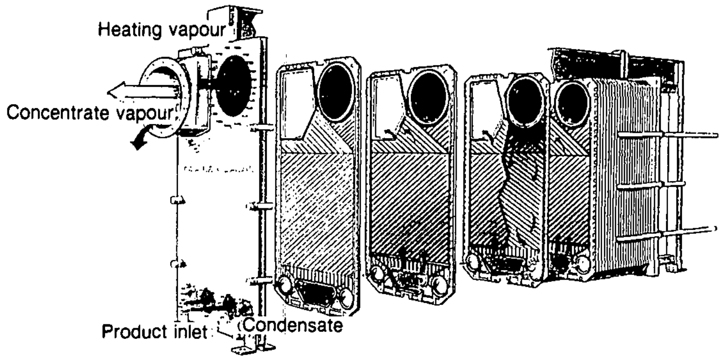

FIGURE 4 The Alfa Laval EC500 plate evaporator.

Features of the EC500 plate evaportor

- The climbing film has been found to be a more efficient principle.
- The channel is designed for small pressure drops.
- Herringbone pattern showed the optimal performance.
- Low channel height of only about 1,3 m gives a small static head.
- Laser welded steam chambers.
- Clip-on glue free gaskets on product side.
- Two juice/vapour outlet port designs.
- Small volume on juice side gives a short residence time.
- Different channel geometry for low pressure and higher pressure operations.
- Compact and low installed weight (only 3 m high).
- Available in two designs:
  - Standard design as described below for normal installation.
  - Open outlet design for mounting inside a vessel giving a reduced overall pressure drop and thus higher efficiency.

Todate nearly 80 units have been sold of which over 50 have been taken into operation. The units are operating as boosters, single complete effects in series with Roberts or falling film evaporators, or as effects in series.

Operating results

All the requirements defined in 1986 have been fulfilled. A comparison of k-values at the Sudzucker factories (Figure 5) confirms that above 40°Bx the EC500 requires approximately half the suface area of that in conventional evaporators. The difference is not as big at lower brix values.

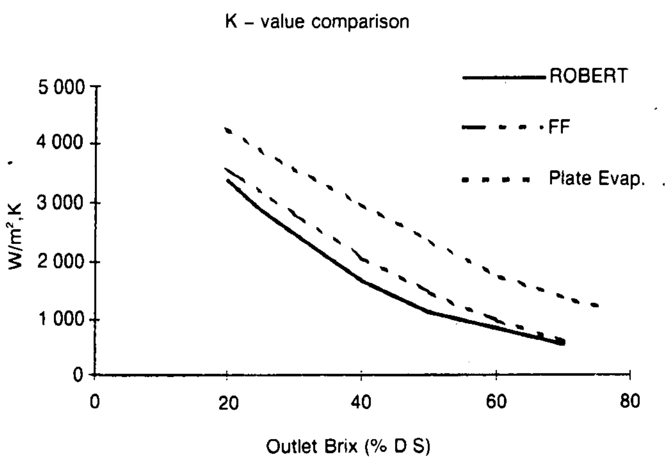

FIGURE 5 Comparison of heat transfer coefficients (k values) (Licha *et al*,. 1989).

The formation of colour and invert sugar is also reduced as shown in Figure 6.

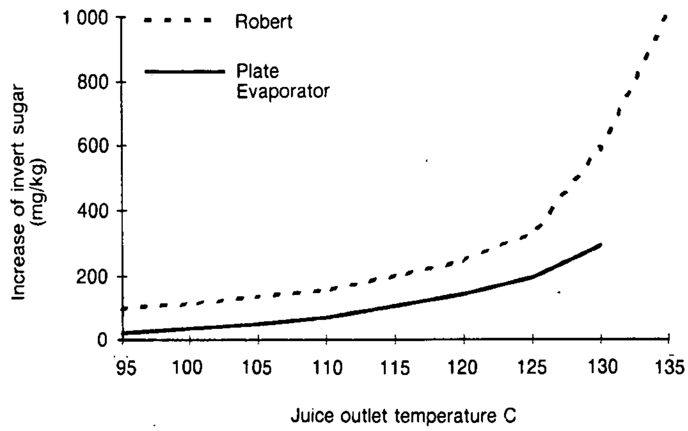

FIGURE 6 Comparison of inversion in different evaporators at different temperatures (Licha *et al*, 1989).

Several units are operating continuously at low temperature differences confirming that it is possible to increase the total number of effects within the same overall temperature difference.

Other industrial applications

A distillery is another interesting application for the EC500. Today the EC500 operates as a column reboiler and for evaporating stillage to eliminate a waste stream problem.

It has also been operating for other waste waters like waste water concentration from yeast production. Waste water management is an extremely important new area for evaporation as new and stricter emission laws will soon go into effect. Evaporation is one potential way to meet the more stringent regulations.

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