Self-cleaning heat exchanger technology and practical experiences in wastewater treatment

Klaren International, based in The Netherlands, is the inventor and developer of the proprietary self-cleaning shell and tube heat exchanger technology for operation up to zero-fouling. The technology applies continuous circulation of solid particles through the tubes of the heat exchangers to remove fouling deposits from the tube wall. Any type of fouling can be effectively handled. Any combination of hard or soft, biological, or chemical, fibrous or protein, or any organic type, or a combination of these can be removed. Klaren International employs a team of specialists that designs and commissions new heat exchanger systems or the retrofit of existing systems into this self-cleaning configuration.

Marco Van Beek, CTO of Klaren International

Self-cleaning fluidized bed heat exchanger technology

The operating principle of the self-cleaning fluidized bed heat exchangers is based on the circulation of cleaning particles made of ceramic or stainless steel and with a size between 1 and 3 mm through the vertical tubes as illustrated in Figure 1. A fouling liquid flows upwards through the tube bundle of the heat exchanger that incorporates specially designed inlet and outlet channels. In the inlet channel the solid particles are fed to the fluid using a proprietary distribution system to ensure a uniform division of particles over all the tubes. The particles are fluidized by the upward flow of liquid where they create a mild scouring effect on the wall of the heat exchanger tubes, thereby removing any deposit at an early stage of fouling formation. Since the fluid velocity is higher than the falling velocity of the particles, they are lifted to the top of the heat exchanger where they are collected in the outlet channel and brought into a separator where they disengage from the liquid and are returned to the inlet channel through a downcomer pipe. To control the amount of particles fed to the inlet, a part of the inlet flow to the heat exchanger is used to push the particles from the downcomer into the inlet channel. Then the cycle is repeated.

Fluidized bed evaporator

Fluidized bed heat exchangers can be used as forced circulation evaporators by combining the heat exchanger with a flash vessel downstream the liquid outlet. The principle of such a system is shown in Figure 2. In this configuration, it is important to suppress boiling in the heat exchanger by having enough back pressure, since the effect of vapor bubbles in the heat exchanger tubes can negatively influence the stability of the fluidized bed. The outlet liquid flashes when pressure is reduced in the flash vessel where liquid and vapor are separated. The vast majority of the liquid is recirculated back to the inlet of the heat exchanger while a small fraction is discharged as the product flow. The amount of discharge allows to control the solids concentration inside the evaporator which is the same as the product flow. Both the release from evaporated water as well as the product flow are compensated by an inflow of fresh feed.

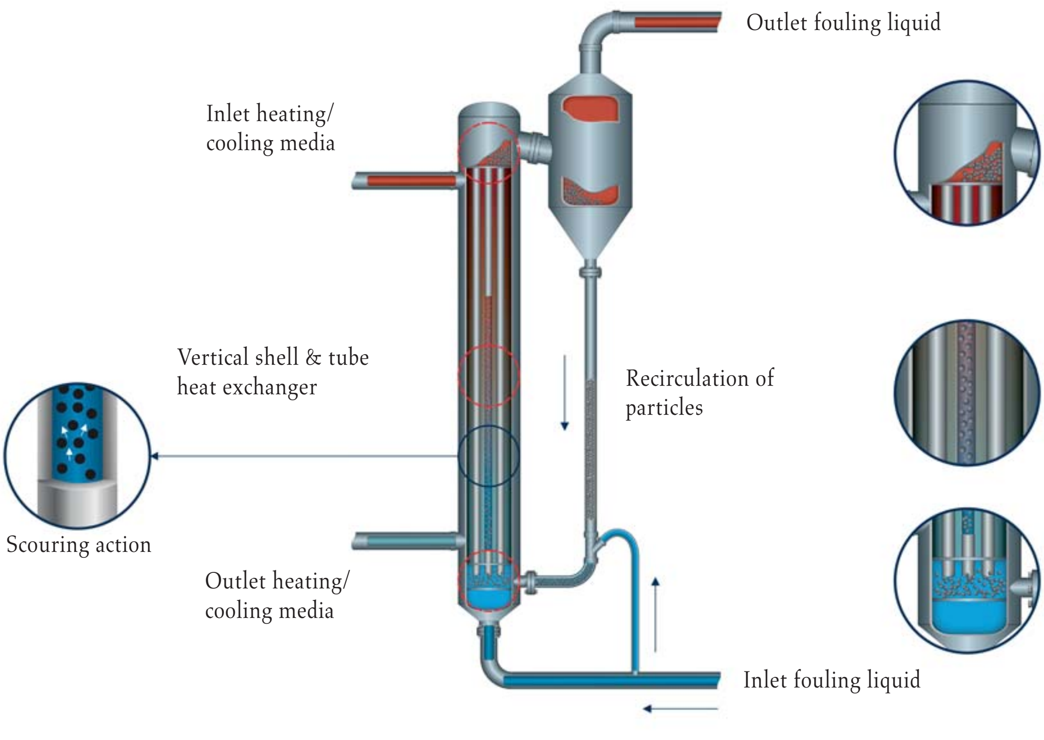


Figure 1: Principle of Self-cleaning Fluidized bed Heat Exchanger.

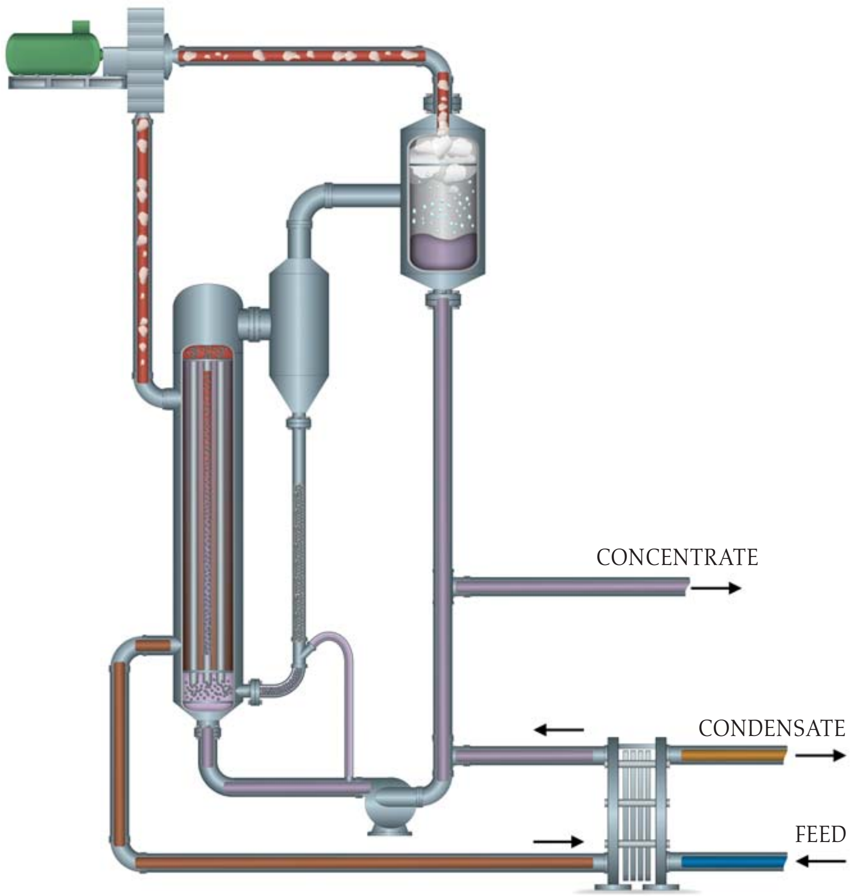


Figure 2: Fluidized bed heat exchanger with flash vessel (in single stage MVR).

The forced circulation evaporator with fluidized bed heat exchanger can be implemented in almost any type of evaporation configuration such as a multi-effect evaporator plant (with or without TVR) as well as in a single stage MVR.

Case study:

Fouling is a severe problem for evaporators treating wastewater streams. To tackle the problem of fouling, companies apply various solutions such as chemical cleaning, high pressure water jet cleaning and redundancy in equipment. A dyestuff manufacturer in India was looking for a solution for their severe fouling problem in their evaporator plants for wastewater treatment and decided to retrofit one of their existing evaporator plants with the self-cleaning technology.

- Before retrofit

The 4-effect evaporator plant with TVR has an evaporation capacity of around 4.8 m^3/h and was normally operated for a period of 12 to 15 days and shut down for 5 to 7 days for cleaning with a high pressure water jet. Post-cleaning the plant runs at 80% of the capacity on day 0 and the capacity drops to 50% before the next cleaning. From the operational experience of this multi effect evaporator plant the 1^{st} effect with a steam temperature of 115°C is the heat exchanger which encounters the most fouling and is the limiting factor for operation of the entire plant. The subsequent effects of the MEE plant also encounter fouling but lesser as compared to the first effect of the plant.

- Nature of fouling

The fouling layer developed at the inside of the tube is dark greyish in colour. The layer is hard and strongly adhered to the surface of the tubes with a thickness between 1 and 3 mm on average. The fouling layer developed was insoluble in water as well as in a hydrochloric acid solution. Upon inspection of the tube bundle some of the tubes were found to be completely blocked with this type of fouling layer.

- Retrofit

Considering the high fouling tendency of the fluid especially in the 1^{st} effect, it was chosen to retrofit the 1^{st} effect of the evaporator plant. This effect was retrofitted into the self-cleaning configuration by changing the 3-pass tube bundle into a single pass by modifying the inlet and outlet headers, adding an inlet channel for the distribution of particles underneath the tube bundle and installing a particle separator in between the outlet of the heat exchanger and the flash vessel for which the flash vessel was lifted in height to give a natural suppression of boiling by the available static head.

Recent installation example with Klaren's self-cleaning technology.

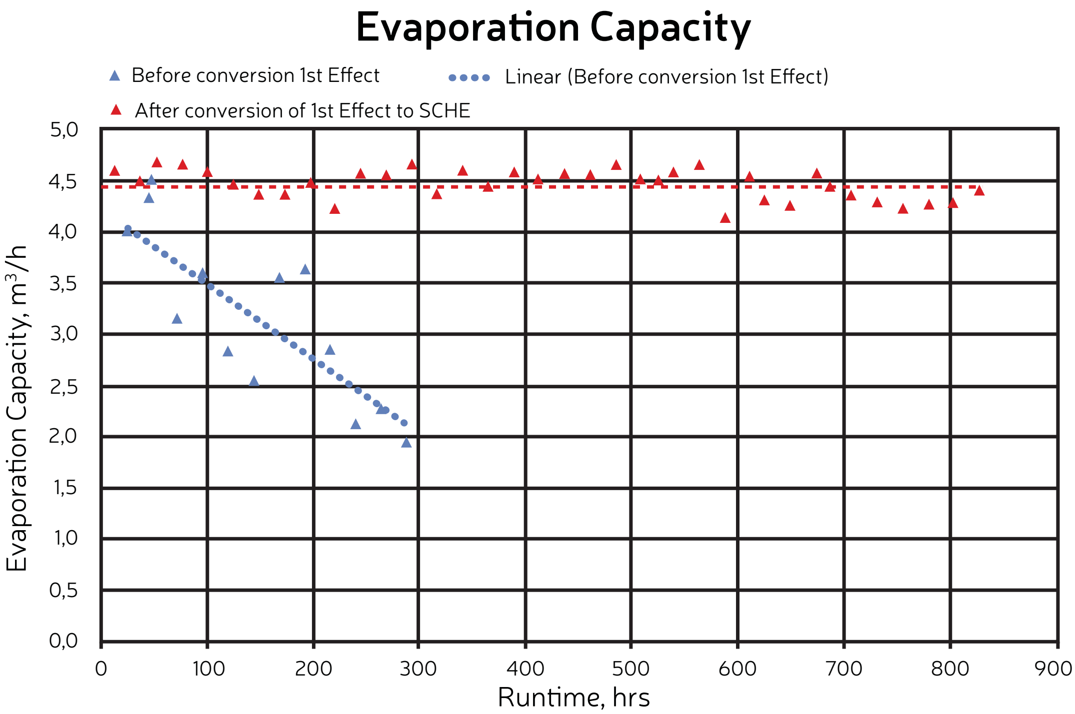
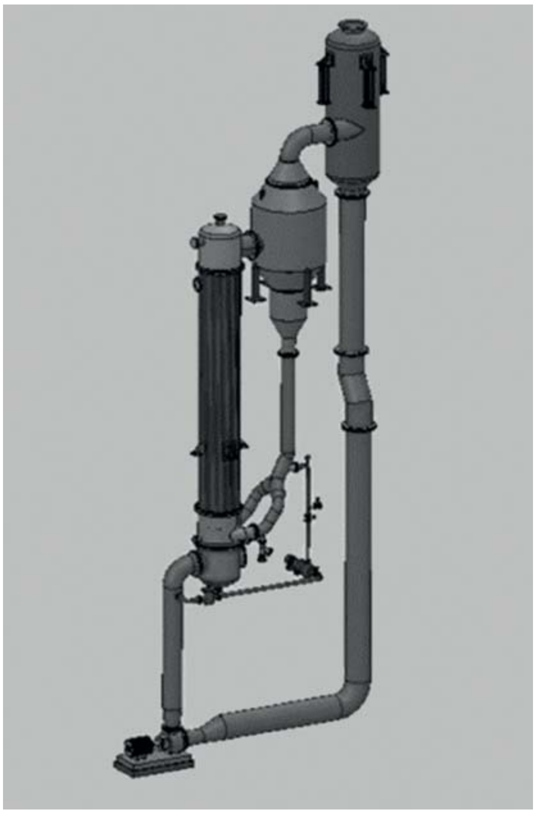


Figure 3: Variation of evaporation capacity before and after the retrofit over the first 800 hours of operation.

- Result

The plant performance is monitored by a daily balance of the feed entered, the condensate as collected and the product taken from the MEE. The daily average evaporation rate in m^3/h is calculated from the balance.
Figure 3 shows the evaporation capacity as function of the hours of operation of the plant with the original configuration and after the retrofit of the 1st effect to the self-cleaning fluidized bed heat exchanger. The data shown below is as received from the operations team of the plant.



Layout of revamped forced circulation evaporator with self-cleaning technology.

After retrofit, the plant data showed that the evaporation capacity remained constant for a period of more than 800 hours. The difference between the decreasing capacity before and the continuous capacity after the revamp is impressive. After this initial period the plant has continued operation and has reached 8000 hours without cleaning the 1st effect.

Conclusion

The plant performance after the retrofit of the 1st effect has proven the performance of a fluidized bed as an on-line and in-line cleaning mechanism. While before the retrofit the evaporation capacity reduced with 50% within 300 hrs, after the retrofit the evaporation capacity remained constant. The increased evaporation capacity reduces the necessity of investments in new MEE plants making the business case for the retrofit positive.
The retrofit of the 1st effect not only effected the fouling behaviour of this effect but also reduced the fouling in subsequent effects. Although there is no hard proof for this, it is expected that a reduction in size of the solids in the system is the cause for this.
Thanks to experiences gathered with respect to several retrofits and new installations in the wastewater treatment area in the last years, the self-cleaning technology is the proven solution to achieve up to zero fouling operation.

About the Author

Marco Van Beek is the CTO of Klaren international. With a mechanical engineering background, immense experience in plant operations and PhD in the subject of fouling, Marco enjoys solving challenging customer problems together with his team.
You can reach him on vanbeek@klarenbv.com for any questions.