BACKGROUND
After its “old” factory was well past its service life, our customer decided to renew it. The plan was not to make the new factory a copy/paste of the old factory but to incorporate new understanding into the process technology. Moreover, the integral energy management had to be optimised. In the old factory, extra heat was added to the “production process” and cooled off in a cooling tower together with the exothermal heat from the process. However, the temperature of the released heat was simply too low to still be useful.

In the new factory, it was decided to raise the temperature of the process so that the released heat could be usefully applied, that heat now being used to create “vacuum steam”. Steam compression then produces a higher pressure and temperature so that the steam can be incorporated in the process cycle. This reduces the process demand for external heat, and much less heat has to be removed by means of cooling towers.

THE SITUATION
The product of the exothermal process enters at a temperature of 110°C and must be cooled down to 90°C. On the one hand, the steam pressure in the steam generator is set as high as possible to achieve the steam condition that requires the least possible driving power from the compressor. On the other hand, excessive steam pressure would produce too small a temperature

Falling film evaporation: The most efficient energy optimisation for exothermal processes
difference between the heat source and the steam, which would result in a much larger required heat transfer surface so that the heat exchangers would become too expensive. Moreover, the process medium has a high viscosity, which results in the wall heat transfer of this medium to be low. That is why it is important to find an evaporation temperature as close as possible to 90°C, but with sufficient driving force to realise an efficient design in terms of size and price - the search for optimisation.

Three solutions were studied to establish how steam can be generated in the most efficient way.

1: THE THERMOSYPHON REBOILER
This is a vertical heat exchanger with the viscous process medium on the outside of the pipes, and the water/steam mixture inside; see drawing.

Alongside the vertical heat exchanger there is also a separation tank. In that tank a water level is maintained that is replenished by a supply of fresh water, resulting in the separation of steam and water. The water level is kept above the top of the pipe plate of the steam generator, and because the tank and the heat exchanger function as communicating vessels the pipes are filled with water. The water in the pipes evaporates due to the heat supplied by the hot medium, so that the weight of the water column in the pipes reduces, causing it to rise. The mixture of steam and water flows into the separation tank, the water flows downward and the steam flows out through a connection at the top of the tank.

The big problem with this principle in this situation is “boiling point suppression”. For example, take an evaporation temperature of 84°C with a corresponding evaporation pressure of 0.556 bar. The vertical pipe length is 6 metres. This 6 metres of extra water column produces a pressure at the bottom of the pipes of approx. 1.156 bar, with a corresponding evaporation temperature of 113°C! As a consequence, the water does not boil in a large part of the pipes, but takes place only though a low heat transfer coefficient. This adverse boiling suppression gives rise to a far from optimal heat transfer process and eliminates this solution.

2: THE KETTLE TYPE REBOILER
The advantage of this solution is that no individual separation tank is necessary; see drawing. The shell has a much larger diameter than the bundle (the diameter of this bundle is approximately 2 metres), creating an area of steam above the bundle with natural separation of steam and water. The horizontal body includes a water level that is maintained at a few centimetres above the pipe bundle.

Here, too, the consequence is boiling point suppression. Due to the level of liquid, the water pressure in the bottom pipes of the bundle is much higher than the 0.556 bar, with the result that the water here does not
evaporate, resulting in boiling suppression. The highly viscous medium now runs through the pipes and would lead to a very low heat transfer coefficient because of the low Reynolds number. The use of turbulence promoters in the pipes somewhat eases this problem. However, the adverse boiling suppression means that this solution must also be eliminated.

3 FALLING FILM EVAPORATION
This solution creates a situation in which no liquid level is maintained over the bundle and no boiling suppression can take place. This solution also involves a vertical heat exchanger with evaporating water in the pipes. This condensate flows downward from the top of the pipes as a thin film. On the way down, part of the water evaporates and is led upward as steam (against the current of the falling water). Due to the thin water film, the heat transfer coefficient to the water is very high! The non-evaporated water exits the pipes at the bottom and falls into the bottom tank. Replenishment condensate is also pumped into this tank. A fixed water level is maintained in the tank; this level controls the supply of fresh condensate. From this bottom tank, excess water is led to the top of the pipe plate, where a special header ensures that every pipe is supplied with sufficient water and that this water is evenly distributed over the pipe wall.

To compensate for the inferior heat transfer coefficient of the product, low-finned pipes are used on the outside of the pipes thus the heat-transfer surface is increased by roughly a factor of three by creating a threaded profile on the pipes.

The solution is a perfect example of simplicity and robustness. It is controlled by means of two quantities. One involves the level in the bottom tank: this level directly controls a valve for the supply of the fresh condensate, a simple and effective solution. In addition, it is important that enough water is sent to the top of the pipe plate but also that the water level is not too high. The pump is adjusted so that enough excess water is pumped upward. If the formation of steam reduces (for example, because the process is running on a lower capacity), an overflow pipe is installed in the top tank so that the level can never become too high.

CONCLUSION:
The decision to use steam generators based on the falling film principle results in equipment with the highest possible steam pressure and therefore a good investment. This is the best possible economic balance between CAPEX and OPEX.

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