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Rethinking reboilers

External reboilers can provide potential savings of up to $1 million

External reboilers can provide potential savings of up to $1 million (€631 million), compared with a direct seal heated mash column

Rethinking reboilers

The subject of bioethanol divides the world into believers and sceptics. The latter often claim that producing the biofuel requires more energy than it saves.

Whether that is true or not, it is certainly possible to save energy in the distillation process, which, together with the evaporator and dryer, is the biggest consumer of energy in an ethanol plant. Improving energy efficiency by achieving a lower steam-to-ethanol rate will increase profits for producers of bioethanol – and provide believers with the benefits of bioethanol through better arguments.

Direct steam injection versus external reboilers

There are many different setups of distillation systems. However, in all types, the ethanol is separated first from the fermented mash and later from water in different distillation columns. All these columns must be heated by a process vapour or steam. One way to heat them is with direct steam injection, which is the oldest and simplest principle. The steam is directly injected into the column and mixes with the product.

In an external reboiler, the product is heated and partly evaporated without being mixed with the heating media. The two streams flow in independent closed loops. Typical types of external reboilers are plate, shell and tube and kettle reboilers.

Advantages of direct steam injection

+ Simple operation
+ Low investment costs
+ Low maintenance costs

Disadvantages of direct steam injection

- High temperature impact on the product, which can decrease by-product quality
- Loss of steam condensate for the boiler system
- Dilution of vinasses/ stillage, which increases the energy consumption substantially

The last two disadvantages in particular have made the use of external reboilers more and more attractive. In many countries disposing of un-concentrated vinasses (stillage) by using it as fertiliser in agriculture is either already forbidden or soon will be. Consequently, ethanol producers are faced with the need to treat the bottom product of the first distillation column.

Currently, the standard solution is to concentrate the vinasses through evaporation. In a grain-based distillery, a mechanical separation step is usually used before the evaporation step.

For the sake of clarity the following section refers mainly to sugar- or molasses-based plants. However the results apply to grain-based plants as well since the mechanical separation step does not affect the underlying principles of the following calculation example.

The example shows potential savings in operation costs achieved by replacing a direct steam injection system with an external reboiler system. It is based on the following assumptions:

- The vinasses must be evaporated before leaving the plant
- The model plant produces 240 m^3 of ethanol/d in 8,000 h/year
- 24 t/h of steam is required to heat the mash column
- The steam condensate mixes entirely with the vinasses and is discharged with them
- The vinasses evaporation system consists of three effects and is heated by live steam
- Live steam is used to preheat the boiler feed water
- Steam costs: $10 /tonne
- Fresh water costs: $0.4 /tonne

Steam savings

Using direct steam injection will result in dilution of the vinasses in the mash column. An additional 24 t/h of water must be removed in the subsequent evaporation system. If a surface reboiler was used, this dilution would not occur. Therefore valuable energy can be saved. Assuming use of the simple three effect evaporation system mentioned above, 8 t/h of steam could be saved, which would give a yearly cost reduction of $640,000.

Steam savings:
8t/h x 8000h x $10/t
= $640,000 / year

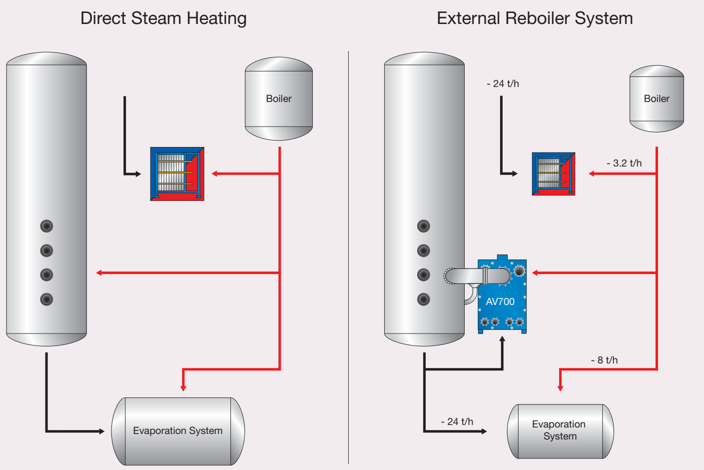
Moreover the lower evaporation load in the evaporation system would require less area in the evaporators. Therefore, a smaller, more compact system could be built and investment costs would be lower as well.

Boiler feed water savings

By avoiding mixing the heating steam and the vinasses, use of an external reboiler makes it possible to recycle the steam condensate. If using direct steam injection, the lost steam condensate must be replaced at the boiler. Consequently use of a surface reboiler saves water and water-treatment costs of up to $76,800 yearly.

Fresh water savings:
24t/h x 8000h x $0.4/t
= $76,800 / year

Because the recycled steam condensate is hot while fresh water is normally cold, using a closed loop in the steam



A comparison of a direct steam heating and an external reboiler system

system means there is less need to preheat the boiler feed water. Assuming a fresh-water temperature of 30°C and a returned-steam condensate temperature of 100°C, this gives a ΔT of 70 K. Therefore, in addition to savings on water replacement, there would be even more substantial savings of $256,000 on preheating.

Heat load for preheating: 70k x 4.18kJ / (kg x K) x 24,000kg/h = 1950kW
Steam demand: 1950kW ÷ 2200kJ / kg = 3.2t/h
Steam savings: 3.2t/h x 8000h x $10/t = $256,000 / year

In this case investment costs will be lower because, the water treatment plant needs less capacity and the boiler feed preheater can be smaller.

The AlfaVap700 would be an appropriate external reboiler system for this service, if using a plate reboiler in thermosyphone mode. The complete installation with controls and piping would cost approximately $390,000.

The total savings in operation costs per year are $972,800, which would give a payback time of less than six months. This can be achieved by using an AlfaVap700 as an external reboiler system. This is a substantial amount and serves as a strong motivation for questioning the traditional approach of using direct steam injection in the ethanol distillation process.

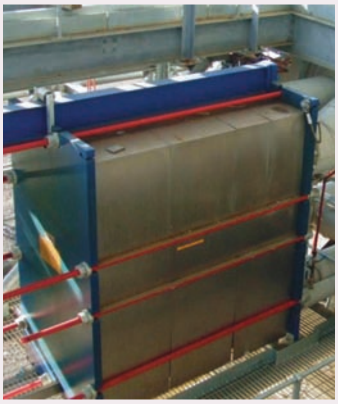
In addition, less energy is consumed to produce bioethanol when an external reboiler system is used. This adds weight to the arguments of specialists who believe in the benefits of using bioethanol as a means of saving energy – even when all aspects of producing it are taken into account.

Successful installations of thermosyphone plate reboilers

The AlfaVap plate reboiler, a rising film reboiler, consists of a plate pack of corrugated plates with a special design for evaporation. The plate pattern causes high turbulence in the channels, which leads to exceptional alpha values and heat-transfer efficiency. High heat-transfer efficiency combined with the low static head of the AlfaVap enable the unit to reach ΔT's of as low as 5 K between the hot and the cold side. Traditional shell-and-tube rising film reboilers reach only 10-15 K in similar applications.

BFB, Munich – an example of heat recovery

The BFB distillery in Munich produces 120,000 l/d of ethanol. During an



110% capacity and a small footprint

optimisation project in 2004, BFB purchased two AlfaVap350 plate reboilers to heat one of their columns. The units were designed to run in parallel as thermosyphone reboilers. For improving the energy balance, the technical manager, Georg Scheuermeyer, decided to use a 96.4% ethanol-water vapour from one of the other columns to run the reboiler. The bottom product in the column is a 96.0% ethanol-water mixture. The units were designed to run on a ΔT between the hot side and the cold side of 5.5 K at an evaporation rate of 8 t/h.

The units run at an evaporation rate of nearly 9 t/h with a ΔT of 6 K. The absolute pressure in the unit is 709 mbar(a).

British Sugar, Wissington – outperforming the design

British Sugar built its first distillery in Wissington and decided to use an AlfaVap500 unit as the rectification column reboiler. The unit has been in operation without any problems since September 2007. The reboiler is heated with slightly superheated steam of 2.7- 3.0 bar(a). The boiling temperature of the bottom product in the reboiler is around 123°C, which results in a calculated ΔT of around 9 K between the hot and the cold side. The unit currently runs with roughly 17 t/h of steam and gives 110% of the designed capacity.

The plate reboiler concept works with very low ΔT, which provides new possibilities for heat recovery in the distillation system as lower pressure steam and process vapours can be considered as heating sources.

In addition, the data shows that the plate reboiler concept can live up to expectations for higher heat transfer efficiency, which is the basis for their compact and light design. These benefits result in easier installation of the reboiler and faster start-up due to a lower hold-up volume in the units. ●

Compact installation of the reboilers on one floor

For more information
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