Energy efficiency at its best - Bioethanol plant of Lantmännen Agroetanol

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abstract

Energy efficiency is a proven, cost-effective way of cutting greenhouse gas emissions and contributing to sustainability. The new bioethanol plant of Lantmännen Agroetanol AB in Norrköping, Sweden, utilises process technology licensed by Vogelbusch for distillation and dehydration. The proprietary Multipressure system reduces the steam consumption by over 50% compared with traditional distillation systems. Further, optimum thermal integration of both the distillation and dehydration units significantly reduces energy use.

Keywords: **bioethanol plants, energy efficiency, Sweden**

Höchste Energieeffizienz - die Bioethanolanlage von Lantmännen Agroetanol

Effiziente Energieverwendung ist eine bewährte, kostensparende Methode um Treibhausgasemissionen zu reduzieren und damit zur Nachhaltigkeit beizutragen. Die neue Bioethanolanlage von Lantmännen Agroetanol AB in Norrköping, Schweden, setzt Prozesstechnologie von Vogelbusch für die Destillation und Dehydration ein. Das Multipressure System von Vogelbusch reduziert den Dampfverbrauch um mehr als 50% im Vergleich zu traditionellen Destillationsverfahren. Darüber hinaus führt die optimale thermische Integration von Destillation und Dehydration zu einer signifikanten Verrringerung des Energieverbrauchs.

Introduction

In 2001, when the Swedish ethanol producer Lantmännen Agroetanol AB commenced operations in Norrköping, bioethanol was not much talked about in Europe. When Sweden introduced legislation in 2003 aimed at making the country independent of oil, there was no further doubt that Agroetanol was in the right business. The company responded to the growing demand for bioethanol by building a second bioethanol plant which went on stream in late 2008 (Figure 1).

The plant processes wheat for the most part as well as rye and barley. Some 540,000 tons of grain per year will be supplied by local farmers. With a daily production capacity of 470,000 litres the new plant is the biggest in northern Europe. Annually both plants together can produce 210 million litres of ethanol and 175,000 tons of DDGS for the Swedish market.

Energy efficient production

With the experience from their first plant, Agroetanol used its in-house expertise to design the feedstock preparation and fermentation units, while other process groups were assigned to contractors. For the distillation and dehydration units (figure 2), Agroetanol opted for Vogelbusch's Multipressure system that delivered optimum energy efficiency.

Cutting process energy consumption plays a key part in modern bioethanol plant design; not only for cost benefits but also because it is tightly connected to the reduction of greenhouse gas emissions in production. New measures incorporated into the EU renewables directive include a clearly positive energy balance for biofuels.[1]

The sustainability of bioethanol production at the Norrköping plant is fostered through a biomass power station nearby which supplies its power needs. Thanks to this combination of state-of-

Figure 1. Agroetanol's new bioethanol plant was installed right next to the existing one

Figure 2. Distillation and dehydration units from Vogelbusch

the-art technology for the processes with high energy consumption - namely distillation and dehydration - and the access to biomass power, the bioethanol plant is ideally equipped to meet EU's sustainability criteria.

Vogelbusch Multipressure distillation

The most advanced energy saving system used to date in the production of bioethanol is the Vogelbusch Multipressure distillation system with split columns in combination with thermal integration of rectification and dehydration. This innovation based on earlier developments by Vogelbusch was first installed back in 2001 in the world's largest ethanol plant in Jilin, PR China. The Multipressure system achieves its exceptional energy efficiency by recycling the steam used in the distillation process. This benefit is generated by the finely-balanced use of several distillation columns with different steam pressures, which combine to bring about a significant reduction in steam consumption. The system uses over 50% less steam than conventional technologies, thus generating equivalent savings in the energy required to produce it. The plant's reduction in energy demand is boosted further by the optimum thermal integration of both the distillation and dehydration processes.

Minimizing energy demand by thermal integration

By recovery and re-use of secondary energy from recycled process streams (like stillage, lutter water and condensates) and thermal integration within individual process steps and the plant as a whole, there is tremendous scope for reducing the overall energy demand through combination of process units.

Process description

The system installed by Agroetanol is a highly integrated VOGELBUSCH Multipressure distillation/rectification and dehydration (Table 1).

Table 1. Columns used for distillation/rectification and dehydration

Distillation column I	MC1
Degassing part of MC1	DC
Distillation column II	MC2
Aldehyde column	AC
Rectification column I	RC1
Rectification column II	RC2
Purification column	PC
Molecular sieve vessel A	MSU A
Molecular sieve vessel B	MSU B

General heat flow through the column system

The columns operate at different pressure levels so that one column can be heated with the overhead vapours of another. The rectification column RC1 is indirectly heated by live steam across the thermosyphon reboiler. The overhead vapours of RC1 are condensed in reboilers to heat the distillation column MC2 and the rectification column RC2 (concentrating part of MC2), respectively. MC2 operates under slight overpressure. Product vapours from the top of RC2 are fed directly to the dehydration unit, while the residual part of overhead vapours is used to heat the distillation column MC1 (via reboiler) which operates under vacuum.

Due to the integrated use of heat, the live steam consumption of this plant is reduced to 1.25 t steam per cubic meter of dehydrated alcohol.

Process steps from alcoholic mash to concentrated alcohol (as vapour)

The alcoholic mash is preheated by the condensers of the aldehyde column AC and MC1 and the dehydrated alcohol condenser of dehydration plant. This preheated mash is fed to the top of the degassing part DC of distillation column MC1. While flowing down the degassing section, CO_2, aldehydes and esters are stripped off from the boiling mash. The degassed mash partly flows to the bottom of MC1 and leaves it as thin stillage. The other part of the degassed mash is fed to the top of the MC2 after being preheated. In MC2, the mash flows to the bottom of the column and leaves it as thin stillage, which is used to preheat the mash feed.

The thin stillage (bottoms) from both distillation columns is pumped to the DDGS section of the factory. The raw alcohol vapours from MC2 are used to heat RC2 directly. The degassing vapours from top of MC 1 are used to heat AC directly where the aldehydes are concentrated on the top. Via head vapour condensers of AC the CO_2 together with an aldehydes and ester enriched flow can be removed by a vacuum pump. For extra-low content of aldehydes and esters in the product, the bottom product of the aldehyde column AC goes to the top of purification column PC for removal of residues of these highly volatile substances. In PC, the bottom product of AC flows against the residual vapours out of the second head vapour condenser of MC1. The heads containing vapours from top of purification column PC are fed to the bottom of AC.

Similar to distillation by means of two mash columns the rectification is also split in two columns for more economic use of heat. The raw alcohol is purified and concentrated up to the desired final concentration. The top product of RC1 is fed to top of RC2 where the alcohol vapours are taken from to be fed to a molecular sieve unit of dehydration plant. The bottoms of RC2 are preheated with the above mentioned top product of RC1.

For product qualities allowing a reduced amount of fusel oil, a fusel oil decanter as well as a fusel oil scrubber is installed in connection with RC1. The separated fusel oil can either be fed to the dehydrated alcohol product or taken out to a separate storage tank.

To achieve extra low content of higher alcohols, a small propanol enriched fraction can be drawn off RC1.

The residual water leaving the bottom of rectification column RC 1 is called singlings (lutter), which is partially used as ring water for vacuum pumps or wash water for fusel oil. The rest can be reused for other purposes (cleaning, liquefaction).

If reduced product acidity is desired, caustic soda can be dosed to the process at several points.

In conclusion, this distillation/rectification plant is capable of removing highly volatile substances such as aldehydes and esters (heads) as well as higher alcohols such as propanol and fusel oil (tails) to achieve a product with a extra low content of said substances without any additional energy demand.

Molecular sieve dehydration

The alcohol vapour feed coming from the distillation plant (RC2) goes to a live steam driven superheater. From there the superheated crude alcohol vapour is fed to one of the molecular sieve beds A or B.

In the molecular sieve system ethanol and water in the vapour are separated. The smaller water molecules are adsorbed by a bed of zeolites (3Å) but the larger ethanol molecules cannot enter and, therefore, pass through the bed. This dehydrated alcohol vapour is condensed in the product condenser while preheating the alcoholic mash. The condensates are collected in product drums and pumped to storage, passing through a filter system and a product cooler.

As soon as MSU A is saturated with water, the automatic control system switches the feed stream to the regenerated MSU B. The loaded MSU A is switched to regeneration mode. During regeneration, the top of the MSU A is connected to the vacuum system and under low pressure the water molecules are desorbed. A small amount of the product vapour stream from MSU A is fed through a live steam driven superheater, to the bottom of MSU B where it takes up the desorbed water and carries it to the purge condenser. After condensing the purge vapour by cooling water the condensate is collected in the purge drum. Small amounts of non-condensables are sucked off by a vacuum pump. The purge condensate is pumped back to the distillation section.

Vogelbusch provided the process engineering for the plant as well as commissioning support and technical commissioning.

Endnotes

[1.] Minimum greenhouse gas reduction targets for biofuels in the EU are set at 35 percent less than from fossil fuels, gradually rising to 60 percent for new producers after 2017.