

Maximisation of the capacity span in a fully automated dehydration process

# Effective purification

**E**thanol as a consumer chemical has a long tradition for various applications. Whether for medical, chemical or energy purposes, ethanol plays a vital role in the commodities market. Subsequently, effective purification strategies for this substance are fundamental.

It is a generally known fact that ethanol forms an azeotrope with water, meaning that the latter is the most important "impurity". Since water cannot be completely removed by rectification alone, it may hinder the utilisation of ethanol for combustion or other purposes.

During the last decades, dehydration of ethanol using molecular sieves in a pressure swing adsorption process has become state of the art. Vogelbusch started to integrate this technology into its ethanol production process in the 1990's. Since then, a lot of effort has been invested in optimising the method. Adsorption isotherms, kinetics as well as ethanol co-adsorption behaviour were studied for a wide range of commercial zeolite materials.

The core concept of a molecular sieve dehydration system consists of two parallel adsorption vessels filled with zeolite. One is used for adsorption of superheated vapour and the other for regeneration. Regeneration takes place by evacuating the vessel and flushing with part of the water-free product vapour. This purge stream is subsequently condensed and re-distilled.

To achieve satisfying dehydration results for many years of operation, a few key factors are crucial and have to



Optimal use of space and accessibility in the pre-assembled skid

be considered when designing a molecular sieve drying unit:

- Correct amount of zeolite
- Adsorption pressure
- Desorption pressure
- Cycle time
- Vapour retention time
- Abrasion-minimising operation

A skid-mounted ethanol dehydration project for a Scandinavian biorefinery company is presented below.

For this client, the following major features were crucial factors for the plant design:

- Allowing a range of

- operation from 30 to 100% with constant specific steam consumption
- Performing capacity changes with only one key stroke of the operator
- Minimum footprint using space-saving skid construction design

## Basic dehydration unit concept

In most stand-alone dehydration plants, the basic concept of operation can be described within

a few sentences: high-concentrated liquid ethanol from a rectification process passes preheaters and enters a distillation column on top, where it is evaporated. After superheating, the vapour passes a molecular sieve bed where water is adsorbed and dehydrated ethanol leaves the bed at the bottom. Whereas most of it condenses in a product condenser, a small part of this dry ethanol vapour is directed to the other zeolite bed as purge stream for regeneration under vacuum. Lowering the operation pressure and providing the purge stream reduces the partial pressure of water and thus favours desorption and thus regeneration of the bed for the next cycle. The wet purge stream, carrying the desorbed water, is condensed and pumped back to the middle section of the column for distillation after preheating. Removed water leaves the plant via column bottom, whereas ethanol is concentrated on top before entering the molecular sieve beds again.

## Turndown limitation

In a distillation column, the required tray efficiency can usually only be reached as long as the vapour velocity is sufficient to prevent the trays from liquid weeping. If the capacity decreases below this limit, ethanol cannot be stripped off entirely from the regeneration stream in the bottom section of the column. This capacity limit depends on the type of tray used and is typically within a range of 60-70% of design.

However, in the presented project a turndown capacity

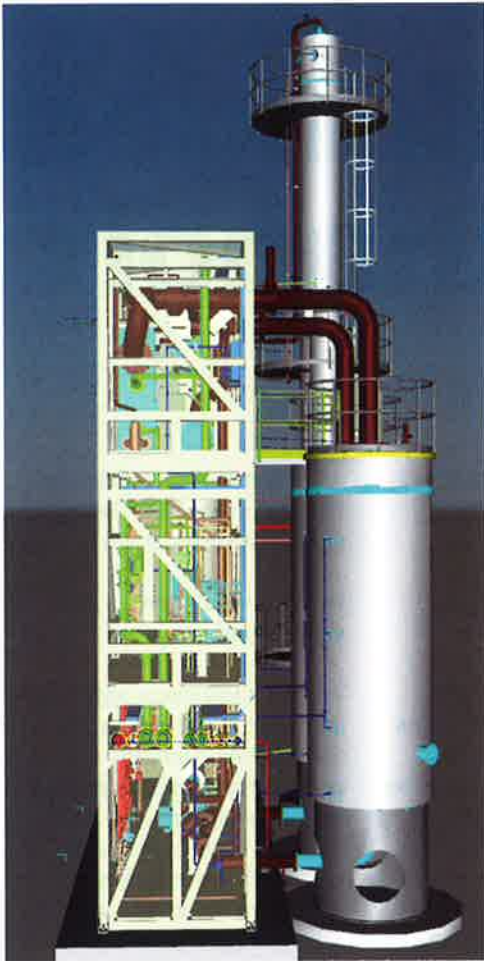


Figure 1: 3D Model of an ethanol dehydration plant with a skid footprint of 10mx5.5m for production of 105,000 liters per day of dehydrated ethanol

just one keystroke. All other process parameters follow automatically:

- Column pressure
- Molsieve cycle duration, valve ramps
- Adsorption pressure
- Recirculation flowrate set points to keep pumps inside of control range
- Control parameters

After finding the right control parameters for stable operation at the various working points of the plant, it was important also that the system did not start to swing when the pressure set point is adjusted along a linear ramp. A set of feed forward control loops helps stabilising the system after occurrent disturbances.

### Minimising the footprint

The plant was skid-mounted before shipping to the client in three skids. After shipping, the dehydration unit was erected, connected and ready for start-up within a few weeks. All electric and instrument cables inside the skid were collected in junction boxes and only had to be connected to the system by the client. ●

### For more information:

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of 30% was achieved, whereas the specific steam consumption remained constant for all capacities.

### Multipressure column

To keep the column working with optimum vapour velocities at every given capacity, it was decided to adapt the vapour density to the current capacity. Operating the column with high vapour density under high plant capacity and low vapour density under reduced plant capacity leads to an almost constant volume flow of vapour over a broad capacity range.

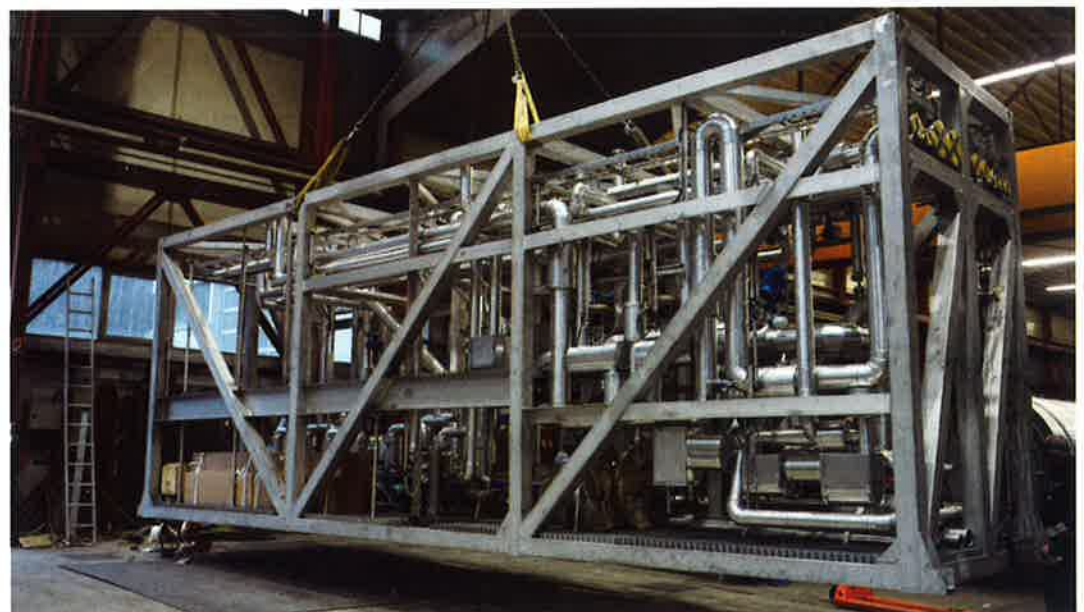
Subsequently, the set point of the column operation pressure is automatically adjusted depending on the actual capacity. By taking advantage of an operation pressure range from 2 to 6 bar, it is possible to keep the column working at a constant, specific steam consumption.

### Operating the dehydration plant with one keystroke

The dehydration plant is a small component of a large production facility with a multitude of different plants and processes. Only a very

small number of highly trained operators are responsible for the production, so it is important to reduce the required operator input for the dehydration unit to a minimum.

Switching to another capacity can be done with



Skid ready for shipping by truck (skid dimensions L 9.6m x W 2.35m x H 3.5m)