RECTIFIER DESIGN FOR FUEL ETHANOL PLANTS

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Abstract

Fuel Ethanol plants have traditionally used trays in the distillation columns to produce fuels grade ethanol. Trays of various configurations have been adequate in this service and their technology is well founded. The ever present desire to reduce the energy needed to produce a gallon of Ethanol has opened the doors to structured packings being used in the rectification sections of ethanol distillation columns.

This alternative distillation tower internal has only really been used in the last 4 years, but has grown in popularity. Energy consumption is down & tower heights are reduced.

This paper will present real life experiences of using structured packings in new applications and the potential to retrofit towers in Fuels Grade Ethanol plants. Discussions will include economics, capacity, and other advantages of using structured packings in this service.

Background

Distillation is the purification of gases or liquids by taking advantage of their boiling point differences. Ethanol and water have a fairly large difference in boiling point, but only up to a certain concentration. At 1 atmosphere and about 95 volume % ethanol, the boiling point of this mixture has a boiling point less than either of the pure components and is known to be a minimum boiling azeotrope.

The earliest known distillation was between ethanol and water. For millennia, man has made spirits, or "strong drink", from the fermentation of various sugars and starches. These early distillations were typically a single stage, or more simply a pot boiling and a condenser to capture the vapors. This single stage would yield an alcohol content of 40 volume % ethanol (or 80 proof), hence your typical whiskey or brandy. If done twice you can improve the ethanol content further to 70 volume % ethanol, which is your typical cognac before aging.

For fuels ethanol we need an alcohol that has no water. Therefore we distill fermentation products with many stages. However, nature does not allow us to get past the 95 volume % azeotrope by distillation no matter how many stages we might have. The rectifier in a fuels ethanol plant is the tower that enables us to produce the azeotropic ethanol product (sometimes referred to as the 190 proof product). This 190 proof product typically has the remaining water removed by molecular sieve.

Ethanol Production

A typical modern ethanol plant has three main towers in its distillation system. These include a beer mash tower, the rectifier and a side stripper (sometimes called the water column). The beer mash tower takes feed directly from the fermenters complete with all the solids, proteins, remaining starches and other assorted "cats and dogs." This tower removes all the solids and other potentially fouling agents along with a majority of the water[1]. This tower will typically contain 22 trays. The rectifier takes the overhead vapor from the beer mash tower and concentrates the ethanol up to 190 proof which is the azeotrope. The rectifier also removes small amounts of some middle boilers such as propanol and heavier alcohols along with some aldehydes in a side stream a few trays from the bottom of the tower. These heavier alcohols are typically called fusels and need to be withdrawn or they can contaminate the ethanol or the water withdrawn from the system. The rectifier typically has 25 to 30 trays. The side stripper is basically a beer tower minus the solids. It takes the water from the bottom of the rectifier and, with about 16 trays, strips out any remaining ethanol. Figure 1 shows a schematic of a typical fuels ethanol distillation unit.

Pressure Drop

In a 30 tray rectifier, each tray contributes about 0.1 psi (690 Pa) to the total tower pressure drop. This adds up to a total pressure drop of 3.0 psi (20.7 KPa). If one continues to keep 8 trays in the bottom of the rectifier for fusel withdraw, then the top 22 trays can be replaced with structured packings. Typically, structured packing has about 1/10 the pressure drop of trays. For this application 20' (6.1 meters) of packing can be used for the top 22 trays. This packing has a pressure drop of 0.006 psi per foot (6.8 Pa/m) of packed height. The resulting tower pressure drop with 8 trays and structured packing is 0.92 psi (6.3 KPa). This is a 69% reduction in pressure drop for this tower! For the same top pressure, this translates into a temperature at the bottom of the beer mash tower that is 7.5 °F (4.2 °C) lower than with all trays. For a beer mash tower this may be important. If a beer mash tower is high pressure and has a bottom temperature of 260 °F (127 °C), this reduction in temperature will double the number of days between cleanings. This could actually increase unit production by about 3 to 4%.

Tower Size Reduction

Another advantage of using packing in the rectifier tower is that new towers can be smaller in size. Trays achieve about a 75% tray efficiency in this service which means 30 actual trays are equivalent to 25 theoretical stages. The 22 trays (at 18" tray spacings) replaced with packing in the upper section of the rectifier equals 16.5 theoretical stages. These 22 trays have a height of 31.5' (9.6 m). Replacing these trays with 20' (6.1 m) of packing reduces the column height considerably, see Figure 2. Here we see a net column height reduction of 11' (3.35 m) by using structured packing. In addition, the structured packing has more capacity. Therefore the column diameter can be reduced from 132" to 120" for a typical 40 mmGal/yr plant (3.35 to 3.05 meter for a 190 mmLiters/yr plant).

Economics

Because the tower is smaller, there would be a cost savings associated with the vessel. The packing material does cost about $20,000 more than the equivalent trays, see Figure 3 for a 40 mmGal/yr plant. However, the overall savings is about $36,000 or about a 10% savings on vessel plus internals. For revamp opportunities, a packed rectifier can provide as much as 15% extra capacity. At today's prices this translates into about a 1 month payback period (if nothing else were a bottleneck in the unit), see Figure 4.

Experience and Conclusions

Sulzer Chemtech has been employing packing in Rectification towers now for more than 5 years. To date we have packed over 50 rectifiers successfully in grassroots applications with diameters up to 180" (4.6 m) and look forward to providing structured packing for a revamp opportunity.

References

(1) Summers, D.R. and Ehmann, D., "Enhanced V-Grid Trays Increase Column Performance", AIChE Annual Meeting, Indianapolis, IN, Distillation Honors Session, November 2002, paper 101e, unpublished.

Figure 1 - Distillation Scheme

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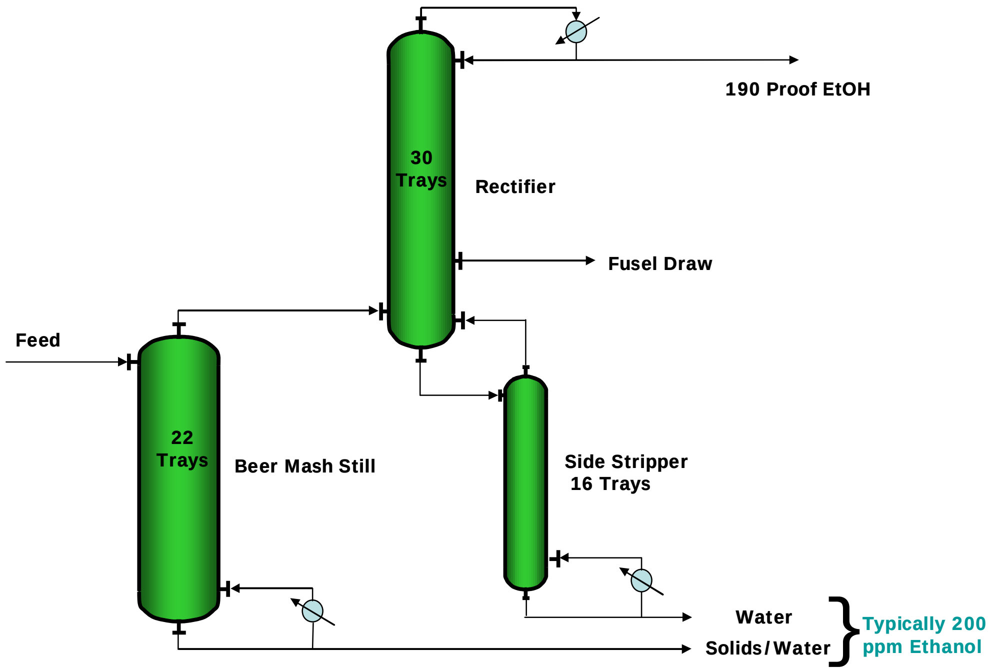

Figure 2 - Rectifier Height Difference

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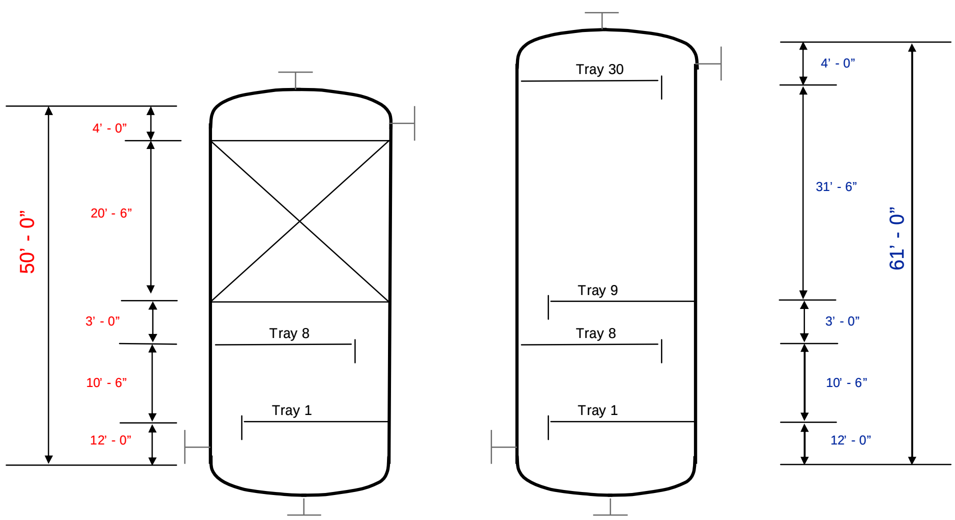

Trays vs. Packing, 18" Tray Spacing , 452Y Packing

Figure 3 - Cost Difference - New Plant

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Relative Costs for 2 Designs:

(Vessel and Internals only)

	132" Tower Diameter	120" Tower Diameter
Height	61'	50'
Vessel Thickness	1/2"	1/2"
Metal Volume	96 ft3	72 ft3
Metal Weight, Mlbs	46.4	34.9
Cost @ $5.10/lb	$236.90	$178.10
Internals	$87.20	$109.60
Total, M$	$324.10	$287.70

Figure 4 - Cost Difference - Revamp

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Revamp Cost vs. Capacity Boost:

	132" Tower Diameter	
Internals	$109.60	M$
Installation	$96.90	M$
Total	$206.50	M$
Tray Capacity	45	MMgal/yr
Packing Capacity	51.75	MMgal/yr
Delta Capacity	6.75	MMgal/yr
Extra Sales Margin	$2,700	M$
Payback	28	Days

Margin assumed to be $0.40/gal