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Design of a Dehydration Tower for the Obtaining of Alcohol Anhídro

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Abstract

The design of a dehydration tower was carried out in order to obtain anhydrous ethyl alcohol of high degree of purity by adsorption with molecular sieves, for which, we proceeded to identify the process variables by laboratory tests varying the temperature and pressure in the feeding to the molecular sieve, with these data and the flow of feeding proceeded with the design of the dehydrator, determining the variables of the equipment (diameter, volume, internal bed, flow of feeding), as well as additional devices such as a preheater that works with a temperature of 120 ºC, which is essential to increase the enthalpy of the steam, and a condenser fed with water at a temperature of 25 ºC, which makes it possible to transform the anhydrous alcohol from vapor to liquid, having a yield of 86.6% and an efficiency of 92,9%, values that help to have an alcohol of 99,5% by weight in a time of 20 minutes.

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Keywords

Dehydration; Molecular sieves; Adsorption; Alcohol.

Introduction

The world faces the progressive exhaustion of its energy resources based mostly on non-renewable fuels, as well as the environmental problems generated by the burning of fuels and therefore the generation of polluting gases contributes to climate change and the deterioration of the planet. This problem is increasingly worrying governments, NGOs, communities and public opinion in general, an option to mitigate the impact generated by fuels is the use of biofuels, the most important among them is the fuel alcohol that can be used as oxygenating gasoline, raising its O2 content and increasing the octane rating, which allows a greater combustion of the same, decreasing polluting emissions, early ignition and engine rattle. In the world, countries such as France use sugar beet as a raw material, ethanol is used in Sweden (Grisales *et al.*, 2019) as a substitute for diesel (Brito *et al.*, Design and construction of a batch reactor for obtaining by transesterification of biodiesel from used cooking oil, 2008), as of 2004 almost all of its 95 octane gas contains 4 to 5% ethanol. In countries of America such as the USA use starch to produce fuel alcohol as an additive, in the year 2000 99.7% of ethanol was used as gasohol. Brazil has a long and successful tradition in the use of ethanol as a fuel either directly or mixed with gasoline, making it the largest producer and consumer of ethanol in the world. In addition to France, Sweden, the US and Brazil, several countries such as India, Thailand, Australia, China and Colombia are committed to using ethanol as an alternative automotive fuel, motivated by environmental concerns.

In Guayaquil since January 12, 2010, the National Biofuel Committee, which is made up of the Ministry of Agriculture, Aquaculture and Fisheries; Ambient; Industries and Productivity; Energy and Petrocomercial, managed and launched the pilot plan for the use of biofuel, which will be carried out until 2015. The new gasoline is composed of 5% fuel alcohol, called Ecopaís.

The dehydration of ethyl alcohol was performed in the ESPOCH Industrial Processes laboratory until obtaining 0,05% of water, this alcohol (Brito *et al.*, Design of an industrial process to obtain bioethanol from whey, 2017) can be defined as a colorless, pleasant-smelling liquid of formula C2H5OH, industrially it is a source of renewable and biodegradable calorific fuel obtained from sugar mixtures of sugarcane or beet (Brito *et al.*, 2016), also of other materials rich in starch.

This alcohol cannot be concentrated more than 96% by simple distillation (Brito, Basic Text of Unit Operations II, 2001) since it forms an azeotropic mixture with water (Brito, Basic Text of Unit Operations II, 2001) that boils approximately to 78,2 C. However, it is interesting to obtain anhydrous alcohol, 99,5 – 99,9% by weight (use of the dehydrator after the distillation tower) for various applications, among them the most important is to improve the octane rating of gasoline acting as an additive.

This research is oriented to the design and construction of a dehydration equipment that joins the fuel alcohol production line, using dehydration by adsorption with molecular sieves in the form of a bed composed of zeolites in a granular form that adsorbs the remaining water of the ethanol-water system increasing the percentage of ethanol in a range of 99,5%. This is the technology that has developed most in recent years in the fuel alcohol industry to dehydrate alcohol and that has been replacing azeotropic distillation (Brito, Basic Text of Unit Operations II, 2001). Molecular sieves are made from microporous aluminosilicates such as zeolite.

The equipment designed and that is coupled after the distillation towers has the following characteristics: diameter of 11 cm, a capacity of 9,5 L, an internal bed of 100 cm and 15 cm at the top and bottom for the entrance and output of the feed necessary to absorb from 3,5 to 20% of water contained in the ethanol, a preheater that works with a temperature of 120 ºC, which is essential to raise the enthalpy of the steam, and a condenser fed with water at a temperature of 25 ºC that allows to transform anhydrous alcohol in vapor state to liquid state.

As a result, an ethyl alcohol dehydrator with a yield of 86,6% and an efficiency of 92,9% was obtained, with positive results indicating that the alcohol content can be increased up to 99,5% by weight, in a 20 minutes' time.

Materials and Methods

This research work focuses on the design, selection and application of all the tools and components necessary for the dehydration of anhydrous alcohol, in response to possible questions that may arise during the course of dehydration.

By means of simulations in Excel, the mass of zeolite necessary to raise the alcoholic degree from 95,5 % to 99,5 % was obtained, while the optimum temperature and pressure, as well as the time required, were determined experimentally. Once the mass of the zeolite and the process and engineering variables were found, the ethyl alcohol dehydrator was sized to raise its degree to anhydrous.

For the proper dimensioning of the ethyl alcohol dehydrator, it is first known all its characteristics in a general way to get gradually into each one of them and in this way we perform the respective engineering calculations whose application will allow the search for limits of the variable operations of the dehydration system.

To quantify the amount of zeolite to be used, the determination of the density of the ethanol-water mixture is carried out, the mass of the mixture is calculated and the alcoholic strength of the mixture is measured, finally the amount of water to be eliminated is identified.

The dimensioning of the dehydrator is worked with a mass of A3 zeolite of 8 Kg due to the calculations made before, the volume of zeolite A3 to be used is identified and design data is considered for the sizing of the equipment itself having the following characteristics: diameter 11 cm, a capacity of 9,5 L, an internal bed of 100 cm and 15 cm at the top and bottom for the input and output of the feed necessary to absorb from 3,5 to 20% of water contained in the ethanol. To calculate the performance of the alcohol purification process, measure the volume and alcohol content of the ethanol-feed mix, to feed the distiller's reboiler, then collect the dehydrated product and measure the alcohol content, then determine the alcohol content. Percentage of yield of obtaining alcohol.

Results and Discussions

Once the design variables of the alcohol dehydrator were identified, the calculations were made to size the equipment, being these: 8,5 kg of zeolite needed to raise 3,5 GL to a volume of 30 L, a bed with a height of 100 cm, 15 cm in the upper part and 15 cm in the lower part of the screen required for a correct entry and exit of the feed in the gaseous state.

Through engineering calculations, it was determined that the process requires 1409,2 Kcal/h of water vapor needed to distill 30 liters of artisanal alcohol raising its purity percentage from 50 % to 89 % obtaining 19 liters of distillate.

The process requires 347,7 Kcal / h of steam, coming from the second boiler, suitable to dehydrate 19 L of distillate and raise its percentage of purity to 99,5 % starting from 95,5 %, which indicates that 9,62 moles of water / Kg absorbent are absorbed thanks to the Zeolite obtaining as product 5 L of anhydrous alcohol (Fig. 1–6 and Table 1–5).

Table.1 Data for the dehydrated process

No.	ρ_{OH} (Kg/L)	$X_{inicial\ OH}$	$X_{final\ OH}$	ρ_{H2O} (Kg/L)	X_{H2O}	$V_{inicial}$(L)	V_{final}(L)	Cp_{agua} (Kcal/Kg°C)	$Cp_{alcohol}$ (Kcal/Kg°C)	Cp_{steam} (Kcal/Kg°C)
1	0,79	0,89	0,96	0,99	0,11	19	5	1	0,6	0,48

FUENTE: ARELLANO, A.; RIOFRÍO, L. Industrial Processes Laboratory. ESPOCH 2014

Table.2 Data to build dehydrated curves

No.	heater			Sieve			Product
	t (min)	T (°C)	P (PSI)	V (mL)	T (°C)	P (PSI)	°GL
1	0	25	2	500	20	2	90
2	5	100	30	750	90	10	96
3	10	120	40	1000	115	20	96
4	***15***	***120***	***40***	***1500***	***125***	***15***	***96,5***
5	20	120	40	2000	125	13	96
6	25	120	40	3500	125	13	96
7	30	120	40	5000	125	13	96

FUENTE: ARELLANO, A.; RIOFRÍO, L. Industrial Processes Laboratory. ESPOCH 2014

Table.3 Temperature data for the dehydrated process

No.	T_{a1}	T_{a2}	T_{FT1}	T_{FT2}	T_{S1}	T_{S2}	T_{P1}	T_{P2}
1	19	27	85	120	141,5	80	125	13

FUENTE: ARELLANO, A.; RIOFRÍO, L. Industrial Processes Laboratory. ESPOCH 2014

Table.4 Results of the dehydrated variables

No.	Dehydrated result							
	$°GL_1$	$°GL_2$	Δ °GL	q	R	Ɛ	V_1	V_2
1	89	96	7	9,62	26,3	92,9	19	5

FUENTE: ARELLANO, A.; RIOFRÍO, L. Industrial Processes Laboratory. ESPOCH 2014

Table.5 Team design

No.	DIMENSIONS		
	ELEMENTSDIMENSIONS	DIAMETER (cm)	HEIGHT (cm)
1	SIEVE	11	130
2	SUPERHEATING	17	125
3	CONDENSER	14	47

FUENTE: ARELLANO, A.; RIOFRÍO, L. Industrial Processes Laboratory. ESPOCH 2014

Figure.1 Curve GL vs time of the sieve

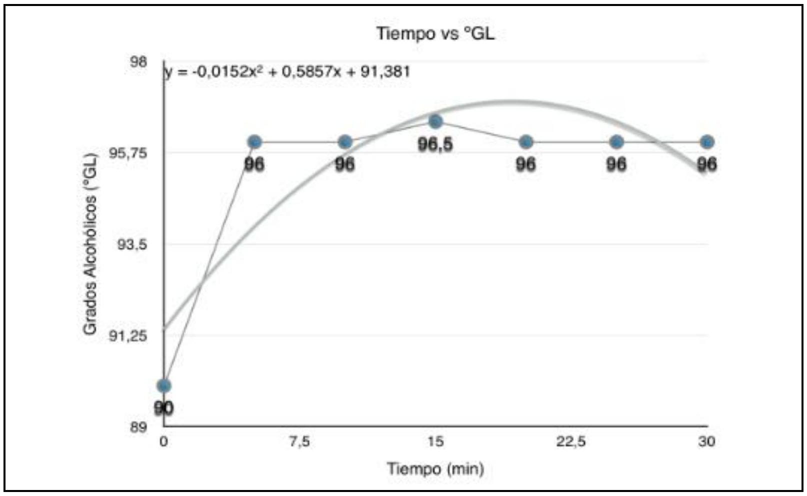


Figure.2 Curve ºGL vs size volume

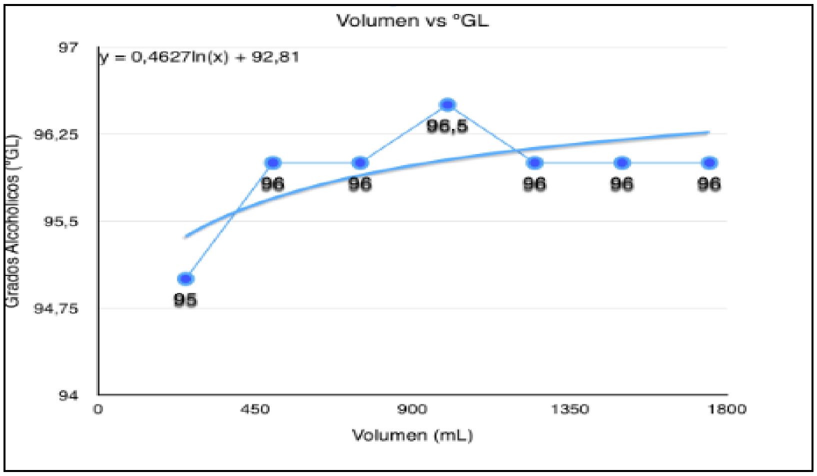


Figure.3 Pressure curve vs size time

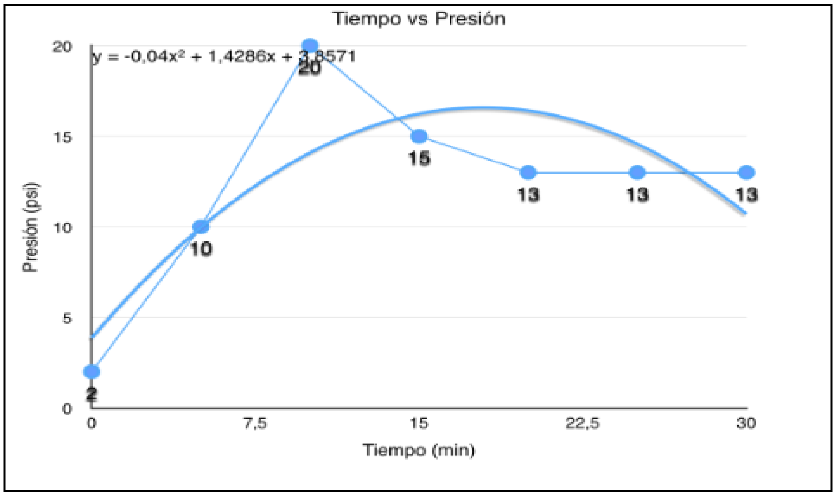


Figure.4 Curve temperature vs time of the sieve

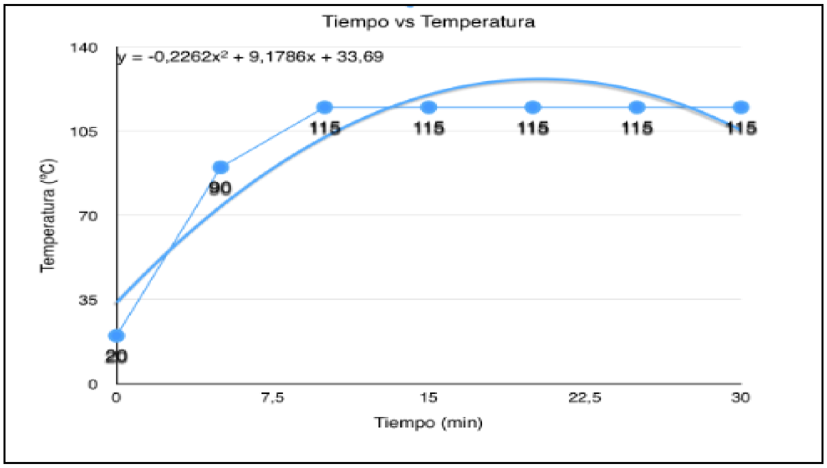


Figure.5 Curve temperature vs pre-heater time

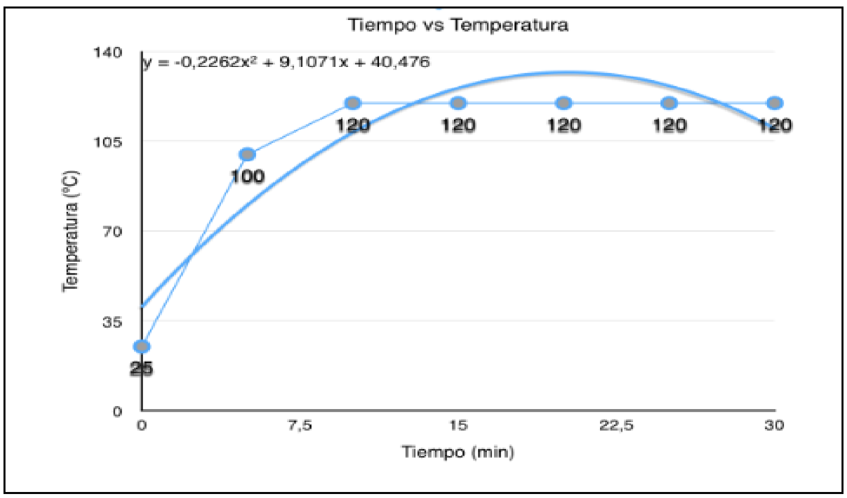
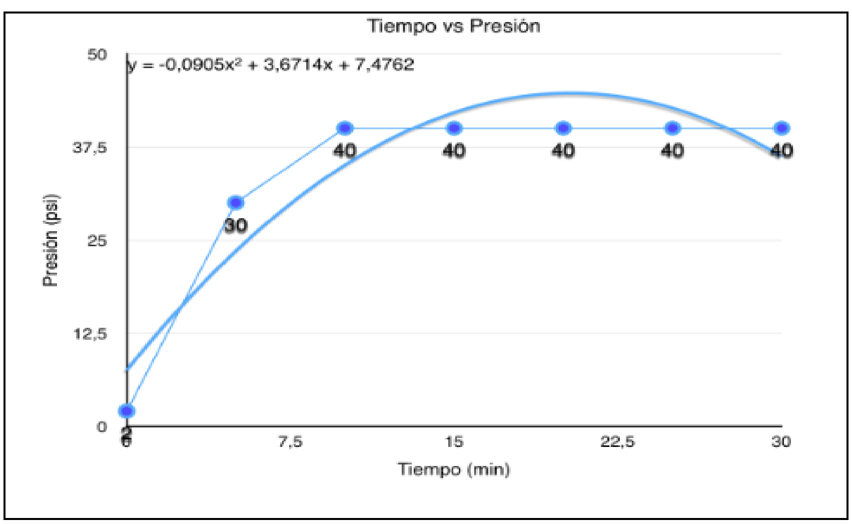


Figure.6 Pressure curve vs pre-heater time



The dehydrator works with a yield of 16,67%, which shows that it is a percentage of low yield, this because, our feed vapor contains a large amount of water that is retained in the molecular sieve resulting in a volume of anhydrous alcohol product substantially pure.

When working with a single boiler at a pressure of 40 PSI you get a heat production of 308,4 Kcal / h, but also knowing that our equipment works correctly with a pressure of 80 PSI, it is necessary to supply of a new boiler that provides the 40 PSI necessary to raise the production of heat to 347,7 Kcal / h, thus adjusting the variables of pressure 20 PSI and temperature 110 ºC to obtain the final product.

The machine works with an efficiency of 92,9 %, which shows that 7,1 % corresponds to the machine's own losses, whether these are in the preheater pressure drops, as the temperature rise of the condenser outside the ranges established.

CONCLUSIONS

The designed dehydrator has the following characteristics: diameter of 11 cm, a capacity of 9,5 L, an internal bed of 100 cm and 15 cm in the upper and lower part for the inlet and outlet of the feeding necessary to absorb from the 3,5 to 20 % of water contained in ethanol.

An alcohol with 99,5 % was obtained.

They were adsorbed in the sieve from 7,7 to 9 moles of water for each mole of desiccant.

The optimal variables were determined being: Super heater 120 ° C and 40 PSI, re boiler 40 PSI and the sieve of 125 ° C, 15 PSI.

It was determined that 8 kg of zeolite is required in the screen to work with a 95,5 % alcohol and take it to 99,5 %.

It was concluded that the reboiler feed should be a volume not less than 15 liters.

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