

Design of Distillation column for Ethanol production from Molasses

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Abstract:

The rapid depletion of non-conventional energy sources enforced the study of different fuels such types are biofuels and bioethanol. Ethanol will be used as a pure fuel or blended with gasoline used for vehicles. Ethanol is often produced from various sources. When designing a separation system for mixtures containing close boiling point components, ordinary distillation is considered not feasible since high purity products require an oversized number of stages and reflux ratio. During the look phase of distillation processes, several problems may occur like the determination of an optimal number of plates, optimal location for feed, and optimal reflux ratio. the most objective of this paper is to work out the general material and energy balance for the 60,000 lit./day plant capacity of the distillation column and determine the economic aspects of the distillation column for the given net production capacity of ethanol. Then, similar feed information from the shortcut design was used for a replacement design which was developed per the smoker's equation can calculate the method conditions of the distillation column.

Key Words: Ethanol distillation column, energy balance, smoker's equation, etc.

Introduction:

Ethanol is that the largest volume liquid produced industrially by fermentation extending to 345 billion liters each year Brazil, is that the largest producer at 10 billion followed by the USA at 6 billion and India at 0.9 billion. Its great demand not only in industrial use but also in portable liquor made up of it. Its great scope not only in exchange severs but a possible interchange earner. The thought to use ethanol for fuel purposes has received importance and momentum in recent years the most reason is that the routine price hikes and extreme shortages of fossil oil. The speed at which conventional energy resources are depleting forces us to seem forward to the non-convectional resource. A awfully fuel-compatible product that comes into the image is ethanol. Ethanol is often used as fuel thanks to its high calorific value and clean emission it is used as fuel for an external combustion engine. Many nations and their government giving serious thought to develop fuel ethanol as a future energy resource. The government of India had allowed the

blending of fuel ethanol with gasoline up to five and after some years hiked it up to 10%. This itself is that the start line and will cause our complete independence from non-renewable fossil fuels. The assembly of ethanol is especially done by cane molasses and grains. As India is an agrarian nation, the thought of ethanol from grain becomes sensible but because of the increasing population, it'll not be sufficient to satisfy the need of ethanol for industrial, chemical, potable, and fuel purposes. So their attention moves toward the choice source which is molasses.

Alcohol, Spirit, and Ethanol are the varied names usually called by different people, producers further as user groups. It's a robust mind-altering drug and one among the oldest recreational drugs. Best called the kind of alcohol found in alcoholic beverages, it's also utilized in thermometers, as a solvent, and as an alcohol fuel. Traditionally people call the alcohol production units "Distillery Plant". Though various starting raw materials are available for alcohol production, raw molasses is one among the foremost popularly used raw materials. Ethanol is straight-chain alcohol and its formula is C_2H_5OH . Its formula is C_2H_6O . It's a constitutional isomer of dimethyl ether. Ethanol is commonly abbreviated as EtOH, using the common chemical science notation of representing the alkyl group (C_2H_5) with Et^[3] Distillation could be a physical process accustomed separate a fluid mixture of two (binary) or more (multi component) substances into its component parts. In most cases, the components to be separated are miscible liquids with different volatilities and boiling points. This separation process could be a thermal unit operation that utilizes the differences in pressure to provide the separation. during this process, the vapor or liquid mixture is heated whereby the more volatile components are evaporated, condensed, and allowed to drip or drip apart, i.e. distill or distillery, because it was originally called in Latin. It's from this fact of 'Dripping' that the name of the distillation process was derived. Distillation could also be applied in an exceeding intermittent or batch process or it's going to be distributed in a nonstop steady-state process with a continuous feed stream. Distillation systems might also operate at different pressures, with higher pressures used for the separation of the more volatile materials and reduced pressures, in vacuum distillation systems, for heavier higher boiling-point materials, lowering thereby their boiling points.

Simple distillation of alcoholic beverages and petroleum has been practiced for a awfully while. Within the middle Ages, Damascus played a component as a distilling center, where distillation came into its own because the best and quickest way of obtaining pure chemical substances ^[1]. Within the writings of the thirteenth-century Syrian Scholar, Al-Dimashki, we discover the earliest relation to the economic distillation of petroleum or petroleum. Al-Dimashki says: “Many forms of petroleum are water white naturally so volatile that they can't be stored in open vessels. Others are obtained from a sort of pitch or bitumen in an exceedingly turbid and dark condition, but by the further treatment, they'll be made clear and white by distilling them like rose-water” ^[1].

Fractional distillation, or fractionation, however, is of course a special kind of distillation, and as a separation technique, is way simpler than simple distillation and more efficient. In effect, fractionation is reminiscent of a series of distillations, where the separation is achieved by successive distillations or repeated vaporization-condensation cycles.

In fractionation, the components are separated through continuous heat and mass transfer between counter-current streams of a rising vapor and a descending liquid. As all told thermal separation processes, the driver for the separation is that the drive towards thermodynamic equilibrium between the various phases (VLE or vapors liquid equilibrium). This equilibrium is continuously disturbed by the blending of the colder descending liquid and therefore the hotter rising vapor, where the more volatile components of the descending liquid are vaporized and therefore the less volatile components of the rising vapor are condensed and therefore the thrust for the separation process is thereby maintained. The concentration of the lighter components are greater within the vapor phase and conversely, the concentration of the heavier components are going to be greater within the liquid phase, and only within the case of pure components or azeotropic mixtures will the equilibrium composition be the identical in both phases.

Replacing fractionation with other separation techniques in such industries as petroleum and petrochemical industries is, however, highly unlikely despite its energy intensiveness. The pre-eminence of distillation for

the separation of fluid mixtures is prime for both kinetic and thermodynamic reasons ^[9]. It's going to even be the foremost economical process for the separation and production of high-purity products. In general, distillation is favored over other separation techniques when large rates are desired of products that are thermally stable with relative volatility greater than 1.2 and where no extreme corrosion, precipitation, sedimentation, or explosion issues are present.

Analytically Determining the Specifications for a Distillation Column

Determine Process Operation Variables

- Assumed feed rate, composition, purity of distillate and bottoms, and the quality of the feed are known.
- Perform overall material and component balances to determine the compositions of the distillate and bottoms.

Material Balance

$$F=D+W \quad (1)$$

Component Balance

$$F \cdot X_F = X_D \cdot D + X_W \cdot W \quad (2)$$

Where,

F = Feed rate of input stream

X_F = Composition of light component in feed

X_D = Mole Fraction of light in distillate

X_W = Mole Fraction of light in Bottom

D = Total distillate amount

W = Total bottom amount

The Smokers Equation

Smoker (1938) derived an analytical equation which will be wont to determine the quantity of stages when the relative volatility is constant. Though his method may be used for any problem that the relative volatilities within the rectifying and stripping sections is taken as constant, it's particularly useful for problems where the relative volatility is low; as an example, within the separation of close boiling isomers. If the relative volatility is near one, the quantity of stages required is going to be very large, and it'll be impractical to draw a McCabe-Thiele diagram. The derivation of the equations is made public below. The equations may be easily programmed for solutions on Personal Computers.

Derivation of the equations:

A straight operating line can be represented by the equation:

$$y = Sx + C$$

and in terms of relative volatility the equilibrium values of y are given by:

$$Y = \frac{\alpha x}{1 + (\alpha - 1)x}$$

Eliminating y from these equations gives a quadratic in x:

$$S(\alpha - 1)x^2 + [S + b(\alpha - 1) - \alpha]x + b = 0$$

For any particular distillation problem equation 11.28 will have only one real root k between 0 and 1

$$S(\alpha - 1)k^2 + [S + b(\alpha - 1) - \alpha]k + b = 0$$

k is the value of the x ordinate at the point where the extended operating lines intersect the vapors-liquid equilibrium curve. Smoker shows that the number of stages required is given by the equation:

$$N = \frac{\log \left\{ \frac{x_0^* [1 - \beta x_n^*]}{x_n^* [1 - \beta x_0^*]} \right\}}{\log \left(\frac{\alpha}{S C^2} \right)}$$

Where,

$$\beta = \frac{SC(\alpha-1)}{(\alpha-SC^2)}$$

N = number of stages required to effect the separation represented by the concentration change from

$$x_n^* \text{ to } x_0^*; x^* = (x - k) \text{ and } x_0^* > x_n^*$$

$$c = 1 + (\alpha - 1)k$$

s = slope of the operating line between x_n^* and x_0^* ,

α = relative volatility, assumed constant over x_n^* and x_0^* ,

For a column with a single feed and no side streams:

Rectifying section

$$x_0^* = x_D - k$$

$$x_n^* = x_F - k$$

$$s = \frac{R}{R+1}$$

$$b = \frac{x_D}{R+1}$$

$$N = \frac{\log \left\{ \frac{(x_D - k)[1 - \beta(x_F - k)]}{(x_F - k)[1 - \beta(x_D - k)]} \right\}}{\log \left(\frac{\alpha}{SC^2} \right)}$$

Stripping section

$$x_0^* = x_F - k$$

$$x_n^* = x_W - k$$

$$s = \frac{Rx_F + x_D - (R+1)x_W}{(R+1)(x_F - x_W)}$$

$$b = \frac{(x_F - x_D)x_W}{(R+1)(x_F - x_W)}$$

$$N = \frac{\log \left\{ \frac{(x_F - k)[1 - \beta(x_W - k)]}{(x_W - k)[1 - \beta(x_F - k)]} \right\}}{\log \left(\frac{\alpha}{S C^2} \right)}$$

If the feed stream is not at its bubble point, z is replaced by the value of x at the intersection of operating lines, given by all compositions for the more volatile component.

Diameter of Column

The flooding condition fixes the upper limit of vapor velocity. A high vapor velocity is needed for high plate efficiencies, and the velocity will normally be between 70 to 90 per cent of that which would cause flooding. For design, a value of 80 to 85 per cent of the flooding velocity should be used.

The flooding velocity can be estimated from the correlation given by Fair (1961):

$$U_{\max} = C_{sb} \sqrt{\frac{\rho_L - \rho_G}{\rho_G}}$$

Where, $U_{\max}$ = flooding vapor velocity, m/s, based on the net column cross-sectional area A_n .

C_{sb} = a constant obtained

The liquid-vapor flow factor FLV

Where, L_w = liquid mass flow-rate, kg/s,

V_w = vapor mass flow-rate, kg/s.

The following restrictions apply to the use

1. Hole size less than 6.5 mm. Entrainment may be greater with larger hole sizes.
2. Weir height less than 15 per cent of the plate spacing.
3. Non-foaming systems.

4. Hole: active area ratio greater than 0.10; for other ratios apply the following corrections:

Hole:	Active area	multiply Csb by
	0.10	1.0
	0.08	0.9
	0.06	0.8

5. Liquid surface tension 0.02 N/m, for other surface tensions multiplies the value of K} by $[0-0.02]^{0.2}$.

To calculate the column diameter an estimate of the web area is required. As a primary trial take the down comer area as 12 percent of the entire and assume that the hole-active area is 10 %. Where the vapor and liquid flow rates, or physical properties, vary significantly throughout the column a plate design should be made for several points up the column. For distillation it'll usually be sufficient to style for the conditions above and below the feed points, Changes within the vapor flow will normally be accommodated by adjusting the opening area; often by blanking off some rows of holes. Different column diameters would only be used where there's a substantial change in flow. Changes in liquid rate are often allowed by adjusting the liquid down comer areas.

5. Entrainment -

Entrainment can be estimated from the correlation given by Fair (1961), which gives the fractional entrainment ty (kg/kg gross liquid flow) as a function of the liquid-vapor factor FW> with the percentage approach to flooding as a parameter.

The percentage flooding is given by:

$$\text{Percentage Flooding} = \frac{Uu * \text{actual velocity(basedonnetarea)}}{U_F \text{ from}}$$

The effect of entrainment on plate efficiency can be estimated using equation. As a rough guide the upper limit of can be taken as 0.1; below this figure the effect on efficiency will be small. The optimum design value may be above this figure, see Fair (1963)

Weep point

The lower limit of the operating range occurs when liquid leakage through the plate holes becomes excessive. This is often referred to as the weeping point. The vapor velocity at the weeping point is that the minimum value for stable operation. The entire area must be chosen so at rock bottom operating rate the vapors flow velocity continues to be well above the weeping point.

Several correlations are proposed for predicting the vapor velocity at the weeping point; see Chase (1967).

That given by Eduljee (1959) is one among the only to use and has been shown to be reliable.

The minimum design vapor velocity is given by:

Where, U_h = minimum vapor velocity through the outlets (based on the hole area), m/s,

d_h = hole diameter, mm,

K_2 = a continuing, passionate about the depth of clear liquid on the plate,

The clear liquid depth is up to the peak of the weir h_w plus the depth of the crest of liquid over the weir h (m);

Conclusion:

The discussion of ethanol distillation processes presented in this publication is intended to teach process design by using Smoker's Equation.

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