The Plate Efficiency of a Continuous Alcohol Still¹

[ABSTRACT]

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THREE tests on a continuous alcohol still under varying conditions indicated average plate efficiency of from 24 to 56 per cent.

The equations developed by W. K. Lewis for the calculation of the number of plates for a fractionating column² require two things for their use, first, the relation between the vapor and liquid compositions, and, second, the plate efficiency. Up to the present time nothing regarding the latter has been available in the literature.

Fig. 1.

The writer has obtained three careful tests on a continuous still handling ethyl alcohol-water mixtures. This still is of the modern Barbet type with plates fitted with boiling caps as described by Barbet³ and by Mariller.⁴ The still is illustrated in Fig. 1.

It consisted of a rectifying column, F, of 30 plates, 1.52 m. in diameter and an exhausting column, G, of 16 plates, 1.65 m. in diameter. The dilute alcohol was taken from a

feed tank, J, through condenser A where it was partly heated, then to a heat interchanger, H, where it was heated nearly to the boiling point, and was then delivered on to the top plate of the exhausting column.

The vapor leaving the top of the rectifying column was partly condensed in the condensers A and B, and the residual vapor was totally condensed in the condenser C. The liquid from condensers A and B and a portion of that from C was returned to the top of the rectifying column as reflux, the remainder of that from C being withdrawn through suitable coolers to the receiver D. Cooling water flowed through condensers C and B in series.

The averaged data on an hourly basis are listed in Table I:

Test number	1	2	3
Alcohol fed, kg.	623	772	818
Water fed, kg.	491	591	636
Cooling water, kg.	13600	13250	13000
Water indistillate, kg.	45	68	59
Rise in temperature of feed in condenser A, °C.	45.2	43.3	42.3
Rise in temperature of water in condenser B, °C.	27.9	26.3	26.0
Rise in temperature of water in condenser C, °C.	25.5	29.0	27.2

In all cases the amount of alcohol in the waste was too small to be measured.

It was found possible to determine the average plate efficiency of the still for these tests by means of the equations:

$$\frac{dx}{dn} = k(y_n - x_n) - \frac{k}{R_n}(y_c - y_n) \text{ for the rectifying column and}$$

$$\frac{dn}{dm} = k(y_m - x_m) - \frac{k(R_f - 1)}{R_m}(y_m - x_w) \text{ for the exhausting column,}$$

these equations having the significance indicated in the above-mentioned paper.²

Test number	1	2	3
Kg. moles alcohol in product	13.5	16.7	17.7
Kg. moles water in product	2.5	3.97	3.28
Mole fraction alcohol in product	0.842	0.816	0.844
Heat removed in condenser C (Kal.)	346,000	384,000	354,000
Heat removed by product (ML = 9,500) (Kal.)	153,000	195,000	200,000
Heat removed by reflux from condenser C	193,000	189,000	154,000
Moles reflux from condenser C	20.3	19.8	16.1
Heat removed in condenser B (Kal.)	379,000	249,000	339,000
Moles reflux from condenser B	39.9	36.7	35.5
Heat removed in condenser A (Kal.) (Cp = 0.95)	48,000	56,000	58,000
Moles reflux from condenser A	5.05	5.9	6.1
Total moles reflux	65.2	62.4	57.7
Reflux ratio (reflux: product)	4.06	3.04	2.75
Mole fraction alcohol in reflux from condenser B assuming simple condensation	0.835	0.800	0.837
Moles alcohol leaving condenser A in vapor	63.9	62.3	61.1
Moles water leaving condenser A in vapor	12.3	14.8	11.6
Total moles leaving condenser A in vapor	76.2	77.1	72.7
Moles fraction alcohol in vapor from condenser A	0.839	0.808	0.840
Mole fraction alcohol in reflux from condenser A assuming simple condensation	0.830	0.790	0.833
Moles alcohol leaving column	68.1	67.0	66.2
Moles water leaving column	81.3	83.0	78.8
Mole fraction alcohol in vapor leaving column	0.838	0.807	0.839
Mole fraction alcohol in reflux entering column	0.835	0.803	0.837
Ratio moles feed to moles product	2.54	2.41	2.52
Mole fraction alcohol in feed	0.332	0.338	0.335

It was then possible to calculate values of $\frac{dn}{dx}$ and $\frac{dm}{dx}$ for varying values of x from the above formulas. This has been done for Test 1 as follows, the values of x and y being calculated from the vapor composition curve given by W. K. Lewis.⁵ Since no measurement of the alcohol in the waste was given, x_w was assumed to be 0.0001, a value probably somewhere near the fact. The calculated values are plotted in Fig. 2.

⁵ "Vapor Composition of Alcohol-Water Mixtures," THIS JOURNAL, 12 (1920), 496.

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² "The Calculation of the Efficiency and the Design of Rectifying Columns," see page 492, this issue.

³ "La Rectification et les Colonnes Rectificatrices en Distillerie," Paris, 1895, 2nd edition.

⁴ "La Distillation Fractionnée et la Rectification," Paris, 1917.