Process Systems Engineering

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Exercise # 6

Calculate the economic potential of fourth level by applying the following correlations, whereas the total cost of the column is given by the installation cost, and the fillers cost.

❖ Pressure vessels, Columns, Reactors

See Exercise #4.

❖ Distillation Tray-Columns

$$C.I._{trays} = \left(\frac{M\,\&\,S}{280}\right) 4.7 \cdot D^{1.55} \cdot H_{TOT} \cdot F_c$$

with D and H_{TOT} in [ft]. H_{TOT} is the total height of the column:

$$H_{TOT} = \left(N_{trays} - 1\right) H_{Spacing\,between\,trays} + H_{Top-Bottom}$$

with $H_{Top-Bottom} \cong 4-5\ \text{m}$.

The factor F_c is calculated as the sum of three factors: $F_c = F_s + F_t + F_m$.

Tray spacing [in]	24	18	12
F_s	1.0	1.4	2.2

Tray type	No down-comer	Sieve	Valve	Bubble cap	"Koch Kaskade"
F_t	0.0	0.0	0.4	1.8	3.9

Tray Material	Carbon Steel	Stainless Steel	Monel
F_m	0.0	1.7	8.9

❖ Heat exchangers

Installed cost: $C.I. = \left(\frac{M\,\&\,S}{280}\right) 101.3 A^{0.65} \left(2.29 + F_c\right)$ [equipment cost + installation cost]

with A = Area of heat transfer in [ft^2], e $F_c = \left(F_d + F_p\right) F_m$

The so called "installed cost" is the sum of the purchase cost and the installation cost.

Material $\frac{Shell}{Tube}$	$\frac{CS}{CS}$	$\frac{CS}{Brass}$	$\frac{CS}{Mo}$	$\frac{CS}{SS}$	$\frac{SS}{SS}$	$\frac{CS}{Monel}$	$\frac{Monel}{Monel}$	$\frac{CS}{Ti}$	$\frac{Ti}{Ti}$
F_m	1	1.3	2.15	2.81	3.75	3.1	4.25	8.95	13.05

N.B.: Brass = Brass, Mo = Molybdenum, Ti = Titanium

Pressure [psi]	≤ 150	300	400	800	1000
F_p	0	0.1	0.25	0.52	0.55

Heat exchanger type	Kettle	Floating Head	U-tube	Fixed tube
F_d	1.35	1.00	0.85	0.8

For the calculation of heat exchange area, the heat exchanged in the condenser is:

$$Q_c = U_c A_c \Delta T_{ml} = W_{H_2O}\, c_{p,H_2O} \left(T_{out} - T_{in}\right) = \Delta H_{ev}\left(T_{cond}\right)\overline{V}$$

where U_c is the global heat transfer coefficient, A_c is the exchange area of the condenser, ΔT_{ml} is the logarithmic mean temperature difference, W_{H_2O} is the flowrate of cooling water, T_{in} and T_{out} are the temperatures in inlet and outlet to the condenser (generally, $T_{in} = 30°C$ e $T_{out} = 50°C$), $\overline{V}$ is the condensing flowrate at the column head. In the case of stabilizer we recommend $T_{out} \cong 38°C$.

The logarithmic mean temperature difference is calculated as:

$$\Delta T_{ml} = \frac{\left(T_{cond} - T_{out}\right) - \left(T_{cond} - T_{in}\right)}{\log \frac{T_{cond} - T_{out}}{T_{cond} - T_{in}}}$$

Consider $U_c \cong 580\ W/m^2K$. Use condenser duty and T_{cond} from Unisim.

For the calculation of the heat exchange area of the reboiler, the heat exchanged in the reboiler is:

$$Q_r = U_r A_r \Delta T_r = W_{steam} \Delta H_{ev}^{steam} = \Delta H_{ev}\left(T_{reb}\right)\overline{V}$$

in which W_{steam} is the flow rate of steam to the reboiler, $\overline{V}$ is the evaporating flow rate in the reboiler (process side).

Consider $U_r \Delta T_r = 11250\,\mathrm{Btu/h\,ft^2}$. Use reboiler duty from Unisim.

The operating costs related to the reboilers can be calculated considering that the cost of 30 bar steam is 1.65€/1000lb, while that of the 70 bar steam is 2.25€/1000 lb. The cost of cooling water to calculate the operating costs related to the condensers is 0.06€/1000 gal.

❖ Antoine Equation - Water coefficients

$$P_i^0(T) = \exp(C_1 + {}^{C_2}/_{T} + C_3 \ln(T) + C_4 T^{C_5}) \qquad [Pa], [K]$$

C_1	C_2	C_3	C_4	C_5
73.649	-7258.2	-7.3037	4.17e-6	2