Chemical Process Design / Diseño de Procesos Químicos

Design Project. Specific information for the Design Project

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Memo 1

1. **Raw Material**: To choose:
   - Size of ethanol plant: 200 ML per year of bioethanol.
   - Plant service factor: 0.956.

2. **Ethanol specifications** (Grade Fuel):
   - Ethanol content 99.85% by weight min.
   - Water content 0.1% by weight max.
   - Other impurities 0.05% by weight max.
Memo 2

1. **Raw Material**: Lignocelullosic material:
   - Size of ethanol plant: 200 ML per year of bioethanol (Plant: Biocarburantes Castilla y León, located in Salamanca).
   - Plant service factor: 0.956.

2. **Ethanol specifications** (Grade Fuel):
   - Ethanol content: 99.85% by weight min.
   - Water content: 0.1% by weight max.
   - Other impurities: 0.05% by weight max.
   - Steam, 600 Psig ($T = 525 \text{ K}$).
   - Steam, 150 Psig ($T = 455 \text{ K}$).
   - Cooling water temperature ($302.6 \text{ K} \rightarrow 320 \text{ K}$).
Valuable Information for the Design Project

Memo 3

1. Economic data (Jan. 2010) (UPDATE !!!)
   Raw material: 0.149 €/Kg (barley) (dry basis)
   CO₂ tax: 15.60 €/ton CO₂
   Sequestered CO₂: zero cost

2. Operating Data
   Wage rate (fringe benefits included): 33.93 €/hr.
   Supervision salary rate (fringe benefits included): 67.86 €/Hr.
   Utilities
     - Steam, 600 Psig: 0.023 €/kg
     - Steam, 150 Psig: 0.015 €/kg
     - Exhaust Steam: 0.006 €/kg
     - Electricity: 0.07 €/kWh
     - Cooling Water (302.6 K): 0.031 €/m³; Process Water: 0.1958 €/m³
   Wastewater treatment: 0.577 €/m³
   Payroll Charges (Benefits): 20% of Wages
   Repairs, Onsite 4%/yr. of Onsite Investment
   Offsite 2%/yr. of Offsite Investment
   Supplies & Material: 2%/yr. of Onsite Investment
   Taxes, Insurance, etc.: 3%/yr. of Investment
   Straight line depreciation over 10 years
   Offsite, Utility Investment: 40% Onsite Investment
   Royalties for catalyst: 1.5% Sales
   Transport costs biomass to plant: 0.000112 €/Ton·Km
   Collection radius (miles) = 13.996 (Raw material consumption (Kg/s))^{0.4828}
   Ethanol transport Truck: 0.000068 €/(km·m³)
   Inventory cost barley and spent liquor in plant: 30 days at 5.11 €/year/dry ton
   Inventory cost bioethanol in Chicago and Pittsburgh: 2 weeks at 5.95 €/m³/month
   Net Present Value, for 20 Yrs. life of project, 8% interest rate, 40% tax rate.
   Also report cost of bioethanol in €/L, energy use as kW/l, and water consumption as l water/l ethanol.
3. **Pervaporation**

The equipment contains the inlet pump, the vacuum pump that removes the vapors of permeate, the warm up heat exchangers and tubes and fittings and assembly units.

*Cost pervaporation (€2010) = 61600 Area$^{0.37}$*  

The units of the pervaporation equipment can be divided into two major parts. The membrane unit itself, that costs 10–30% of the whole instrument and ages over 2–4 years, and the stainless steel acid proof parts, the amortization of which is 10 years.

4. **Fermenters:**

\[
\text{Cost reactors (\$2010) } = 62148 \sqrt{\text{Volume}} \\
\text{Volume (m}^3\text{) } = \tau \cdot \text{Flow rate}
\]

5. **Storage tank.**

*Cost tanks(\$2010) = 5723.3 Volume$^{0.65}$*  

Volume is in m$^3$. This cost is already updated.

6. **Lignin:** The energy that can be obtained is 26100 kJ/kg (lignin). Translated as economic income from steam generation, its value is 0.196 $\frac{\epsilon}{kg}$ of lignin.

Assume that the given cost correlations are for January 2010. They do include the MPF factors, but not the module factor MF for installation and shipping.

7. **Molecular Sieves**

- The mass flow of water that would be adsorbed in the Molecular Sieve (MS) in [Kg/s] = $m_{ads}$
- Search for the typical residence time for water in an adsorption column (for methane is $t = 9.8$ min). So the mass of adsorbed gas in the adsorption column is: $m_{ads} \times t = M_{ads}$ [kg]
- The gases will be adsorbed by molecular sieves with a bulk density of (i.e. 45 lb/ft$^3$)

- Given that the ratio of mass of gas adsorbed per kg of molecular sieve is 0.1 (i.e mass of adsorbed gas/mass of bed = 0.1), the mass of the molecular sieves is: $M_{ms} = m_{ads}/0.1$ (kg)
- So the volume of the bed can be determined by:

\[
V [m^3] = 1.1 \frac{M_{ms}}{\text{density}} \]

Be careful with units !!!!
- The adsorption column is a cylindrical vessel with a length to diameter ratio of 4 --> You can obtain L [m].
7.- Molecular Sieves (Continued)
For the cost estimation: vessel
You can obtain the thickness \( e \) this allows us to calculate the weigh \( W \) of the vessel made of steel (DENSITY steel = 7850 kg/m\(^3\)) →
Based on the weight of the adsorption column and the cost of the molecular sieve being $1000/ton (Cost of adsorbent = $1000/ton x Mms), the cost for two adsorption columns is \( C \)
The molecular sieves are cost estimated using the price of the absorbent and vertical vessels. Two beds are needed to ensure continuous operation. Please use an over-design factor of 10%.

Molecular sieves data: 1000S/ton (Adsorption 0.1kg of gas per kg of bed)
The molecular sieves are assumed to be a combination of two vertical vessels and the cost will be estimated as:

\[
C_{MS} = 2 \cdot (\text{cost of adsorbent} + 209 \cdot \text{Weight}^{0.72})
\]  

(1)

Weight of the vessel is in kg for the steel is given by eq. (2). We assume L/D=4 (Wallas, 1990) and the volume of the cylinder of the vessel must contain the volume of the bed of adsorbent material.

\[
\text{Weight} = \rho_{\text{steel}} \left( \pi \left[ \left( \frac{D_c}{2} + e \right)^2 - \left( \frac{D_c}{2} \right)^2 \right] L + \frac{4}{3} \pi \left[ \left( \frac{D_c}{2} + e \right)^3 - \left( \frac{D_c}{2} \right)^3 \right] \right)
\]  

(2)

Where the thickness \( e \) (m) is taken to be:

\[
e = 0.0023 + 0.003 \cdot D_c \quad \text{(Sinnott, 1999)}
\]  

(3)

The volume of the bed is given by:

\[
\text{Volume of bed} = \frac{\text{Bed size}}{\text{Bulk density}} = \frac{1.1 \cdot \text{Mass (1kg per 0.1kg of gas)}}{\rho \, \text{lb} \, \text{ft}^3 \cdot 0.454 \, \text{kg} \, \text{lb} \left( \frac{1 \, \text{ft}}{0.3048 \, \text{m}} \right)^3}
\]  

(4)

Molecular sieves with a bulk density \( (\rho) \) of 45 lb/ft\(^3\)