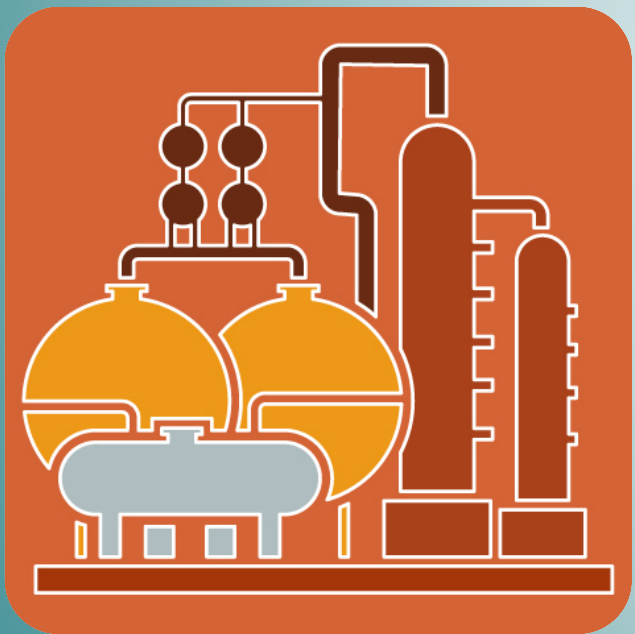
# Chemical Process Design / Diseño de Procesos Químicos

## Design Project. Specific information for the Design Project



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# Valuable Information for the Design Project

## 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.

# Valuable Information for the Design Project

## 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 K).
   - Steam, 150 Psig (T = 455 K).
   - Cooling water temperature (302.6 K → 320 K).

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# Valuable Information for the Design Project

## Memo 3

**1. Economic data** (Jan. 2010) **(UPDATE !!!)**
**Raw material**: 0.149 €/Kg (barley) (dry basis)
**$CO_2$ tax:** 15.60 €/ton $CO_2$
**Sequestered $CO_2$**: 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 €/$m^3$; Process Water: 0.1958 €/$m^3$

**Wastewater treatment**: 0.577 €/$m^3$
**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 $€/(km \cdot m^3)$
**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 €/$m^3$/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.

# Valuable Information for the Design Project

**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:**

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

**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 $0.196\ \frac{€}{kg}$ 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: $m_{ads}$ x t =Mads [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 ( ie mass of adsorbed gas/mass of bed = 0.1), the mass of the molecular sieves is: Mms=$m_{ads}$/0.1 (kg)
- So the volume of the bed can be determined by:

V [$m^3$]=1.1 Mms/(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: 1000$/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:

$$C_{MS} = 2 \cdot (cost\ of\ adsorbent + 209 \cdot Weight^{0.72}) \quad (1)$$

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.

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

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

$$e = 0.0023+0.003 \cdot D_c \qquad \text{(Sinnot, 1999)} \quad (3)$$

The volume of the bed is given by:

$$Volume\ of\ bed = \frac{Bed\ size}{Bulk\ density} = \frac{1.1 \cdot Mass(1kg\ per\ 0.1kg\ of\ gas)}{\rho\ \frac{lb}{ft^3} \cdot 0.454 \frac{kg}{lb} \cdot \left(\frac{1\ ft}{0.3048\ m}\right)^3} \quad (4)$$

Molecular sieves with a bulk density (ρ) of 45 lb/ft$^3$