

Oving 7

Problem 1

- Do an order of magnitude estimation of the capital cost of a plant the produces 80,000 metric tons per year of caprolactam (use Table 6.2 in textbook)
- A reactor vessel cost USD 365,000 in 2012, estimate the cost in 2020
- Estimate the purchased cost of a distillation column, height 20 m, diameter 2 m and 10 bar (requires 20 mm shell), with 40 trays (bubble cap). The reboiler is a kettle type heat exchanger, area 100 m². The condenser is a U-tube heat exchanger, area 50 m². All need to be in stainless steel.
- Estimate the purchased equipment cost on a 2020 basis of a reciprocating compressor (stempelstømkompressor), driver power 2.0 MW.

a) Frn tabell: Enhet: tpy, $S_{lower} = 40\ 000$

$S_{upper} = 120\ 000$

$a = 0,321$

$n = 0,6$

Trenger i tpy : $\frac{80\ 000\ \text{ton/year}}{0,907\ \frac{\text{ton/year}}{\text{tpy}}} = 88185\ \text{tpy}$

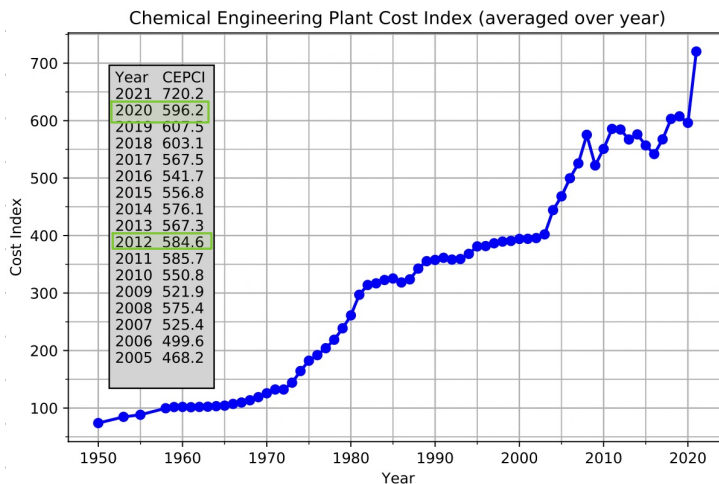
$$C_2 = C_1 \left(\frac{S_2}{S_1} \right)^n = a S_2^n = 0,321 \cdot 88185^{0,6}$$

$$\underline{C_2 = 298\ \text{mill USD (2007)}}$$

b)

Vil bruke $C_{2020} = C_{2012} \frac{I_{2020}}{I_{2012}}$

Trenger indeks



$$C_{2020} = 365\ \text{k} \cdot \frac{596,2}{584,6}$$

$$\underline{C_{2020} = 372,24\ \text{k USD}}$$

c) Distillation column $\Rightarrow$ Pressure vessel

$$h = 20 \text{ m}$$

$$D = 2 \text{ m}$$

$$p = 10 \text{ bar}$$

$$\delta = 20 \text{ mm}$$

$$N = 40$$

Skall: Volum stål

$$\text{Topp + bunn: } 2 \cdot \pi \cdot \left(\frac{D}{2}\right)^2 \cdot \delta$$

$$\text{Sylinder: } \pi \cdot D \cdot h \cdot \delta$$

$$V = \pi \cdot 2 \cdot 20 \cdot 0.02 + 2 \cdot \pi \cdot \left(\frac{2^2}{4}\right) \cdot 0.02 = 2.64 \text{ m}^3 \text{ stål}$$

$$M = 2.64 \text{ m}^3 \text{ stål} \cdot 8000 \text{ kg/m}^3 \text{ stål}$$

$$M = 21112 \text{ kg}$$

Tabell 6.6

$$C_e = a + b S^m \text{ stål}$$

Kostnad for man ser på material cost factor

$$f_m = 1.3 \text{ (alred med i kolonnen)}$$

$$\text{Kolonne: } C = 15\,000 + 68 \cdot 21\,112^{0.85} = 337\,373 \text{ USD}$$

$$337\,373$$

$$\text{Steg: } C = 40 \cdot (290 + 550 \cdot 2^{1.9}) = 93\,707 \text{ USD}$$

$$121\,819$$

$$\text{Reboiler: } C = 25\,000 + 340 \cdot 100^{0.9} = 46\,453 \text{ USD}$$

$$60\,388$$

$$\text{Condenser: } C = 24\,000 + 46 \cdot 50^{1.2} = 29\,029 \text{ USD}$$

$$37\,738$$

$$\text{Total kostnad} = \text{sum} = 557\,318 \text{ USD (2007)}$$

$$d) C = 220\,000 + 2300 \cdot (2 \cdot 10^3 \text{ kW})^{0.75}$$

$$C = 907\,860 \text{ USD (2007)}$$

$$2020: 907\,860 \cdot \frac{596.2}{525.4} = 1\,030\,198 \text{ USD}$$

Tabell i oppg b

Problem 2

Make a rough estimate of the cost of steam per ton, produced from a packaged boiler. 20 ton/h of steam are required at 15 bar. Natural gas will be used as the fuel, calorific value 39 MJ/m³ (roughly 1 MMBtu/1000 scf). Price of natural gas is 7 USD/MMBtu. Take the boiler efficiency as 80%. No condensate will be returned to the boiler. Convert the investment of the boiler to be annualized cost as 20% of the investment (annualized capital charge factor is 0.2).

Investeringen: Utstyr, packaged boiler.

$$\text{Fra tabell 6,6: } C = 106\,000 + 8,7 \cdot (20 \cdot 10^3)^{1/4}$$

$$C = 280\,000 \text{ USD}$$

$$\text{Årlig capital cost} = C \cdot 0,2 = 56\,000 \text{ USD/år}$$

Brenselkostnad

Fra hysys, vann koker ved 471,85 K når $p=15$ bar

Antar innløps temp på 25°C = 298 K, energiforbruket blir.
($C_p \approx$ konstant over intervallet)

$$\text{Tabeller: } \Delta_{\text{vap}} H(471,85 \text{ K}) \approx 1951,8 \text{ kJ/kg}$$

$$C_p = 4,1379 \text{ kJ/kg} \cdot \text{K}$$

$$dH_b = C_p \Delta T + \Delta_{\text{vap}} H$$

$$dH_b = 4,1379 \text{ kJ/kg} \cdot \text{K} \cdot (471,85 \text{ K} - 298,15 \text{ K}) + 1951,8 \text{ kJ/kg}$$

$$= 2671 \text{ kJ/kg}$$

$$P_{\text{HPS}} = P_F \times \frac{dH_b}{\eta} + P_{\text{BFW}}$$

$$P_{\text{HPS}} = 7 \text{ USD/MMBtu} \cdot \frac{2671 \text{ kJ/kg}}{0,8} \cdot \frac{1 \text{ MMBtu}}{1,055056 \text{ GJ}} + 5 \cdot 10^{-4} \text{ USD/kg}$$

$$P_{\text{HPS}} = 0,02265 \text{ USD/kg}$$

Mengde vann per år: Anter 350 dager med produksjon:

$$M_{H_2O} = 350 \cdot 24 \cdot 20\,000 \text{ kg} \\ = 168 \cdot 10^6 \text{ kg}$$

$$\text{Kostnad} = P_{HPS} \cdot M_{H_2O} = 3805\,480 \text{ USD}$$

Vedlikehold ansies til 3% av ISBL

$$\Rightarrow 280\,000 \cdot 0,03 = 8400 \text{ USD}$$

$$\text{Total kostnad i året: } 56\,000 + 3\,805\,480 + 8400$$

$$= 3\,869\,880 \text{ USD}$$

$$\text{Kostnaden av damp blir da: } \frac{3\,869\,880 \text{ USD}}{20 \text{ ton/h} \cdot 24 \text{ h/d} \cdot 350 \text{ d}} = \underline{\underline{23,1 \text{ USD/ton}}}$$