Chapter 6
Lecture # 3-3

- Raw Material Cost
- Yearly Costs and Stream Factors
- Waste Treatment Cost
- Example

Raw Material Cost

- **Variable**
- **Supply-Demand**
- **Can be obtained from Chemical Marketing Report (CMR) Table 6.4**

Stream Factors

- Operating hours per year divided by total hours per year
  - Typical 8000 Operating Hours
  - 0.9 – 0.95 Typical

    8000/8760 = 0.913

*Flows on PFD are kmol/operating hour

Waste Treatment Cost

Table 6.3 Utilities Provided by Off-sites for a Plant with Multiple Process Units (Costs Represent Charges for Utilities Delivered to the Battery Limit of a Process) (*continued*)

Utility	Description	Cost $/Common Unit
Waste disposal (solid and liquid)	a. Non-hazardous	$36/tonne
	b. Hazardous	$200–2000/tonne°
Waste water treatment	a. Primary (filtration)	$41/1000 m^3
	b. Secondary (filtration + activated sludge)	$43/1000 m^3
	c. Tertiary (filtration, activated sludge, and chemical processing)	$56/1000 m^3

Example

Example 6.9

Estimate the quantities and yearly costs of the appropriate utilities for the following pieces of equipment on the toluene hydrodealkylation PFD (Figure 1.5). It is assumed that the stream factor is 0.95 and that all the numbers on the PFD are on a stream time basis. The duty on all of the units can be found in Table 1.7.

a. E-101, Feed Preheater
b. E-102, Reactor Effluent Cooler
c. H-101, Heater
d. C-101, Recycle Gas Compressor, assuming electric drive
e. C-101, Recycle Gas Compressor, assuming steam drive using 10 barg steam discharging to atmospheric pressure.
f. P-101, Toluene Feed Pump

Raw Material Cost

a. E-101: Duty is 15.19 GJ/h. From Table 6.3: Cost of High Pressure Steam = \$9.83/GJ

$$\text{Energy Balance: } Q = 15.19 \text{ GJ/h} = (\dot{m}_{steam})(\Delta H_{vap}) = (\dot{m}_{steam})(1699.3) \text{ kJ/kg}$$

$$\dot{m}_{steam} = 8939 \text{ kg/h} = 2.48 \text{ kg/s}$$

$$\text{Yearly Cost} = (Q)(C_{steam})(t) = (15.19 \text{ GJ/h})(\$9.83/\text{GJ})(24)(365)(0.95) = \$\,1{,}242{,}000/\text{yr}$$

Alternatively: Yearly Cost = (Yearly flowrate)(Cost per unit mass)

$$\text{Yearly Cost} = (2.48)(3600)(24)(365)(0.95)(16.64/1000) = \$1{,}236{,}000/\text{yr}$$

(same as above within round-off error)

Raw Material Cost

b. E-102: Duty is 46.66 GJ/h. From Table 6.3 Cost of Cooling Water = $0.354/GJ

$$Q = 46.66 \text{ GJ/h} = (\dot{m}_{cw})(C_{pcw})(\Delta T_{cw}) = (\dot{m}_{cw})(4.18)(10) = 41.8\,\dot{m}_{cw}$$

$$\dot{m}_{cw} = (46.66)(10^9/41.8)(10^3) = 1{,}116{,}270 \text{ kg/h} = 310 \text{ kg/s}$$

$$\text{Yearly Cost} = (46.66 \text{ GJ/h})(24)(365)(0.95)(\$0.354/\text{GJ}) = \$137{,}000/\text{yr}$$

Raw Material Cost

c. H-101: Duty is 27 GJ/h (7510 kW). Assume that an indirect, nonreactive process heater has a thermal efficiency (ξ_{th}) of 90%. From Table 6.3, natural gas cost \$6/GJ, and the heating value is 0.0377 GJ/m^3.

$$Q = 27\ \text{GJ/h} = (\dot{v}_{gas})(\Delta H_{natural\ gas})(\text{efficiency}) = (\dot{v}_{gas})(0.0377)(0.9)$$

$$\dot{v}_{gas} = 796\ \text{std m}^3/\text{h}\ (0.22\ \text{std m}^3/\text{sec})$$

$$\text{Yearly Cost} = (27)(6.0)(24)(365)(0.95)/(0.90) = \$1{,}498{,}000/\text{yr}$$

Raw Material Cost

d. C-101: Shaft power is 49.1 kW and from Figure 6.7 the efficiency of an electric drive (ξ_{dr}) is 90 %.

$$\text{Electric Power} = P_{dr} = \text{Output power}/\xi_{dr} = (49.1)/(0.90) = 54.6 \text{ kW}$$

$$\text{Yearly Cost} = (54.6)(0.06)(24)(365)(0.95) = \$27{,}300/\text{yr}$$

Raw Material Cost

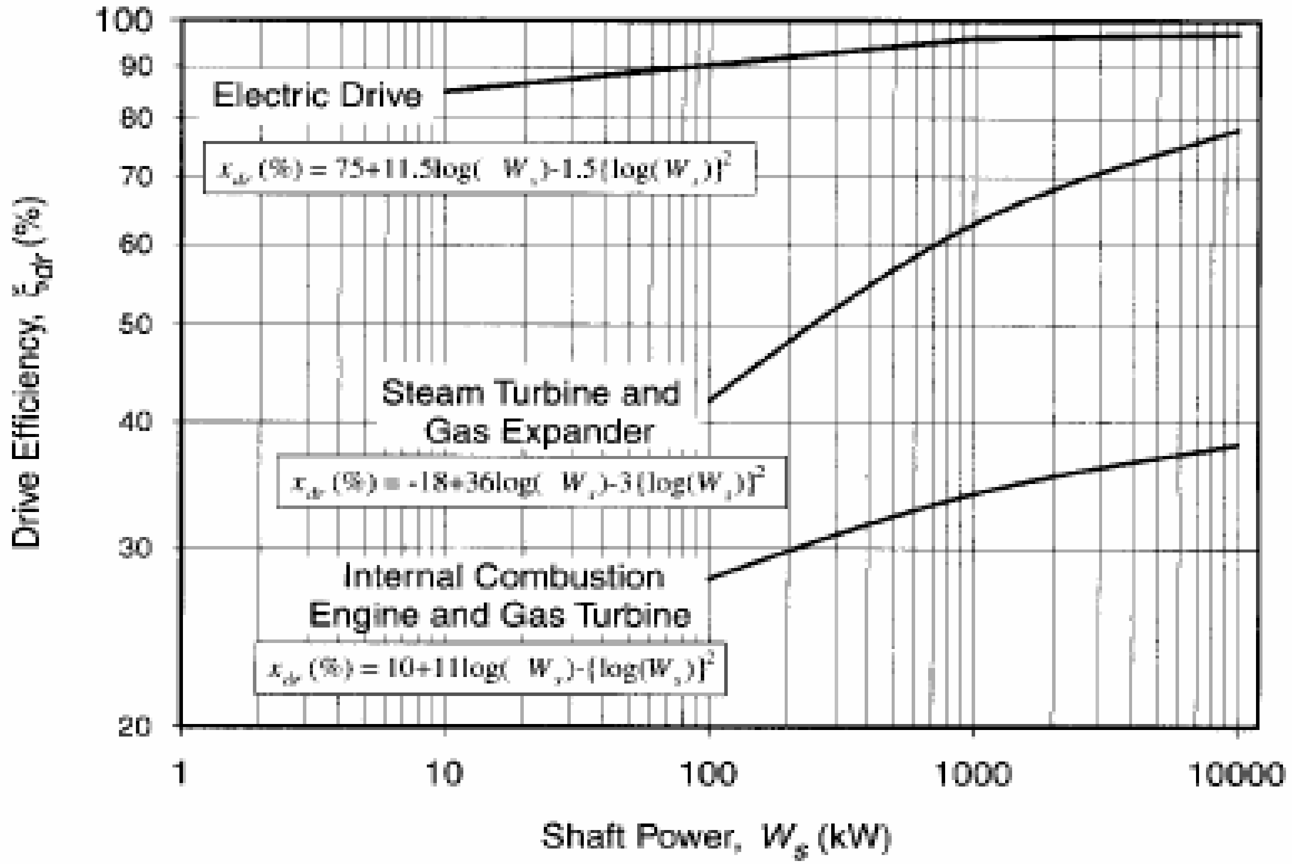

Figure 6.7 Efficiencies for Pumps and Compressor Drives (Data from Walas [9], Chapter 4)

Raw Material Cost

e. Same as Part d with steam driven compressor. For 10 barg steam with exhaust at 0 barg Table 6.5 provides a steam requirement of 8.79 kg-steam/kWh of power. The shaft efficiency is about 35% (extrapolating from Figure 6.7).

$$\text{Steam required by drive} = (49.1)(8.79/0.35) = 1233 \text{ kg/h } (0.34 \text{ kg/s})$$

$$\text{Cost of Steam} = (1233)(24)(365)(0.95)(13.71 \times 10^{-3}) = \$140{,}700/\text{yr}$$

Raw Material Cost

f. P-101: Shaft Power is 14.2 kW. From Figure 6.7 the efficiency of an electric drive is about 86%.

$$\text{Electric Power} = 14.2/0.86 = 16.5 \text{ kW}$$

$$\text{Yearly Cost} = (16.5)(0.06)(24)(365)(0.95) = \$8240/\text{yr}$$

Note: The cost of using steam to power the compressor is much greater than the cost of electricity even though the cost per unit energy is much lower for the steam. The reasons for this are (1) the thermodynamic efficiency is low, and (2) the efficiency of the drive is low for a small compressor. Usually steam drives are only used for compressor duties greater than 100 kW.