Introduction to Chemical Engineering

Chapter 13

Economics
(*Is It All Worth It?*)

13.1 Costs

- **Engineering costs**

Capital costs

- The initial costs
- Purchasing or building
- Reactors, heat exchangers, computers, control valves, piping and etc.

Operating costs

- Day-to-day costs
- Operating equipment and running the process
- Raw materials, pumping, heating, cooling, labor, maintenance

13.1 Costs

- **Overall costs**
  - capital costs + operating costs in entire lifetime of equipment

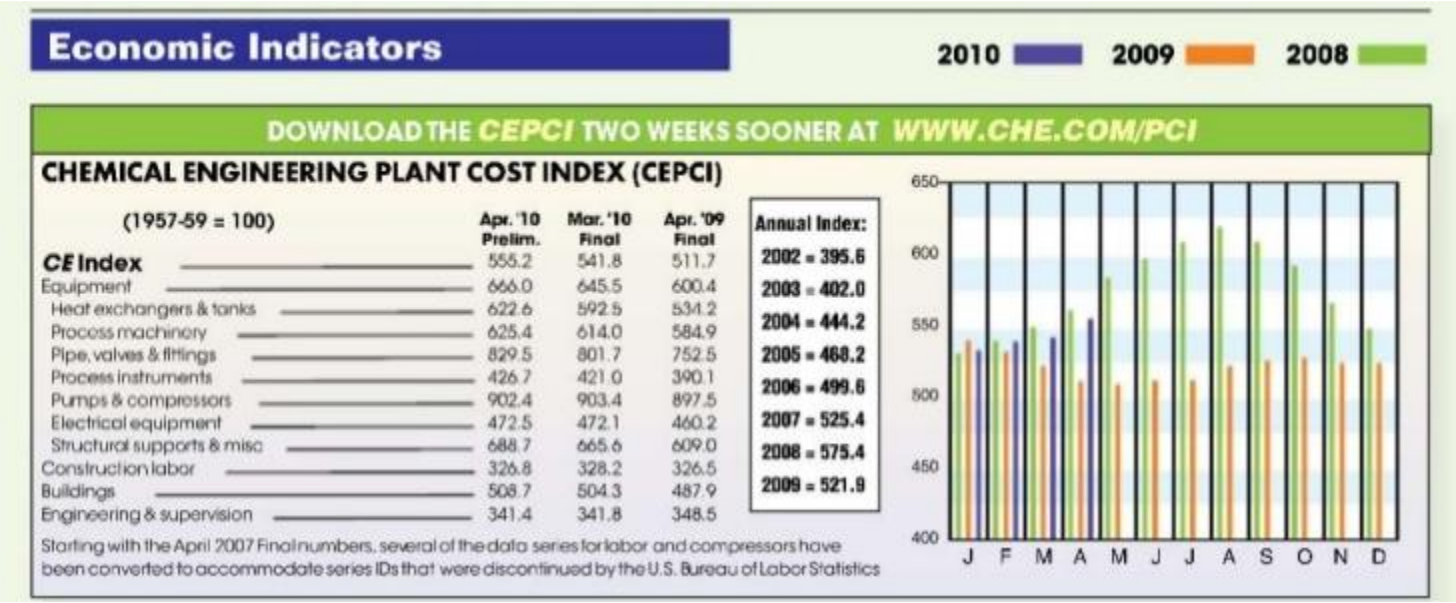
- **Capital and operating costs for two hypothetical water heaters**

	High-Efficiency Water Heater	Standard Water Heater
Purchase (capital) cost	$550	$338
Operating cost per year	$129	$172
Lifetime	10 years	10 years
Total cost	$1,840	$2,058

13.1 Costs

- **Capital costs (capital investment)**
  - purchase + delivery + installation
  - piping, instrumentation, buildings, service facilities, land…

- **Marshall & Swift Equipment Cost Index (M&S Index)**



Economic Indicators — 2010 2009 2008

DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT WWW.CHE.COM/PCI

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Apr. '10 Prelim.	Mar. '10 Final	Apr. '09 Final
***CE* Index**	555.2	541.8	511.7
Equipment	666.0	645.5	600.4
Heat exchangers & tanks	622.6	592.5	534.2
Process machinery	625.4	614.0	584.9
Pipe, valves & fittings	829.5	801.7	752.5
Process instruments	426.7	421.0	390.1
Pumps & compressors	902.4	903.4	897.5
Electrical equipment	472.5	472.1	460.2
Structural supports & misc	688.7	665.6	609.0
Construction labor	326.8	328.2	326.5
Buildings	508.7	504.3	487.9
Engineering & supervision	341.4	341.8	348.5

Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

Annual Index:
2002 = 395.6
2003 = 402.0
2004 = 444.2
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9

13.1 Costs

- **Estimation of equipments prices**

$$\textit{Tank or Reactor Cost}\,(\$) = \left(\frac{M\,\&\,S}{814}\right)\left(47.0\,V^{0.61}\right), \quad V: \textit{volume in gallons}$$

$$\textit{Heat Exchanger Cost}\,(\$) = \left(\frac{M\,\&\,S}{814}\right)\left(398.0\,A^{0.65}\right), \quad A: \textit{the area of heat exchanger in } ft^2$$

$$\textit{Centrifugal Pump Cost}\,(\$) = \left(\frac{M\,\&\,S}{814}\right)\left(421\dot{V}^{0.46}\right), \quad \dot{V}: \textit{the volumetric flow rate in gal} / \min$$

- **Estimation of delivery costs**
  - approximately 4 ~ 10%

- **Estimation of capital investment by using “Lang” factor**
  - multiplying 6.0 for major plant addition to an existing site

13.1 Costs

Example 13.1

The purchase prices of equipment needed for a plant expansion total $900,000. Use the guidelines for delivery costs and capital investment given above to estimate the capital investment for this expansion.

- **Operating costs**
  - raw materials, utilities, electric power, benefits, legal services, maintenance, advertising, public relations, insurance, transportation, and etc.

13.2 Profitability

- **Gross annual profit**

$$Gross\ annual\ \ profit = Sales - Operating\ costs - Depreciation$$

- **Net Annual Profit After Taxes (NAPAT)**

$$NAPAT = (1-\phi)\,Gross\ annual\ \ profit, \qquad \phi:\ fractional\ tax\ rate$$

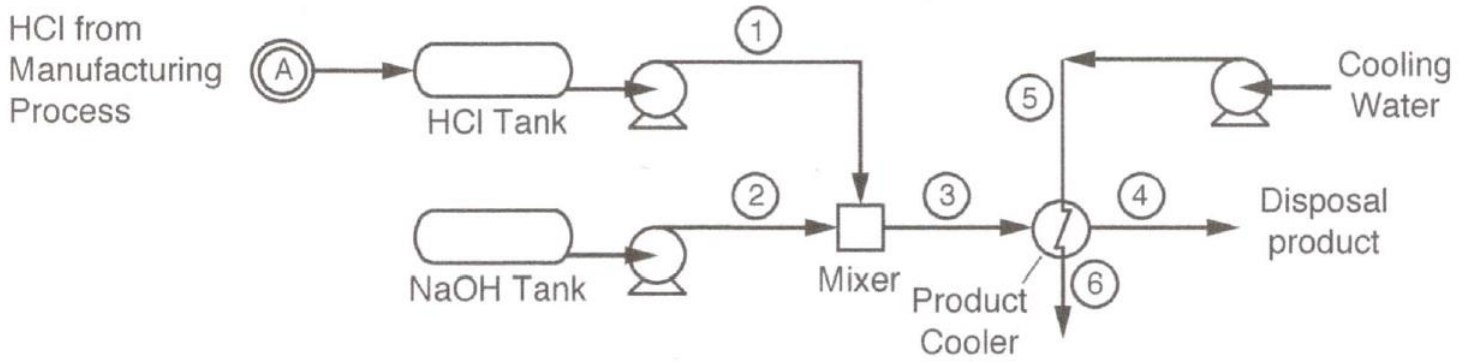
- **Return On Investment (ROI)**

$$ROI = \frac{NAPAT}{Capital\ \ Investment}$$

ROI value should be approximately 15% or greater.

13.3 Economics of the acid-neutralization problem

- **Equipment list**
  - HCl tank
  - NaOH tank
  - HCl pump
  - NaOH pump
  - Cooling water pump
  - Heat exchanger



13.3 Economics of the acid-neutralization problem

- **Purchase price of equipments**
  - Volume of HCl and NaOH tanks (capable for 7 days)

$$HCl\ tank: \frac{11,600\ L}{hr}\left(\frac{0.26417\ gal}{L}\right)\left(\frac{24\ hr}{day}\right)\left(\frac{7\ days}{week}\right)=514,814\ gal$$

$$NaOH\ tank: \frac{6,500\ L}{hr}\left(\frac{0.26417\ gal}{L}\right)\left(\frac{24\ hr}{day}\right)\left(\frac{7\ days}{week}\right)=288,474\ gal$$

  - Estimated purchase prices of HCl and NaOH tanks

$$HCl\ tank: Cost(\$)=\left(\frac{1469}{814}\right)\left[47.0\left(514,814\ gal\right)^{0.6}\right]=\$258,600$$

$$NaOH\ tank: Cost(\$)=\left(\frac{1469}{814}\right)\left[47.0\left(288,474\ gal\right)^{0.6}\right]=\$181,600$$

13.3 Economics of the acid-neutralization problem

- **Purchase price of equipments**
  - Estimated purchase prices of pumps

$$HCl\ \ pump: Cost(\$) = \left(\frac{1469}{814}\right)\left[421\left(51.1\ gal/\min\right)^{0.46}\right] = \$4,600$$

$$NaOH\ \ pump: Cost(\$) = \left(\frac{1469}{814}\right)\left[421\left(28.6\ gal/\min\right)^{0.46}\right] = \$3,600$$

$$Cooling\ water\ \ pump: Cost(\$) = \left(\frac{1469}{814}\right)\left[421\left(191.3\ gal/\min\right)^{0.46}\right] = \$8,500$$

  - Estimated purchase prices of heat exchanger

$$Heat\ exchanger: Cost(\$) = \left(\frac{1469}{814}\right)\left[398\left(818\ ft^2\right)^{0.46}\right] = \$56,200$$

Total purchase price of the equipments: $513,100

13.3 Economics of the acid-neutralization problem

- **Capital investment**

$$\textit{Purchase price}\,(\textit{as just calculated}):\$513{,}100$$
$$\textit{Delivered purchased cost}:(110\%)(\$513{,}100):\$564{,}400$$
$$\textit{Capital Investment}:(6.0)(\$564{,}400)=\$3{,}386{,}000$$

- **Gross annual profit**

$$\begin{aligned}\textit{Gross annual profit} &= \textit{Sales}-\textit{Operating costs}-\textit{Depreciation}\\ &=\$6{,}090{,}000-\$4{,}777{,}000-\$339{,}000\\ &=\$974{,}000\end{aligned}$$

- **Net Annual Profit After Taxes (NAPAT)**

$$\begin{aligned}\textit{NAPAT} &= (1-\phi)\,\textit{Gross annual profit}, \quad \phi:\ \textit{fractional tax rate}\\ &=(1-0.33)(\$974{,}000)\\ &=\$653{,}000\end{aligned}$$

13.3 Economics of the acid-neutralization problem

- **Return On Investment (ROI)**

$$ROI = \frac{NAPAT}{Capital\ Investment}$$
$$= \frac{\$653,000}{\$3,386,000}$$
$$= 19.3\%$$

ROI value should be approximately 15% or greater.

13.4 Reporting the results

ABC Chemical Company
Memorandum

To: Barbara Magelby, Supervisor, Chemical Process Group
From: ⟨your name⟩, Project Engineer

This memo is to provide an update on the progress our group has made toward finding a solution to the HCl disposal problem. As you know, it is anticipated that the company that has been disposing of our HCl byproduct will soon be out of business. Our group has been charged to propose a strategy, design, and preliminary cost analysis for safely and legally disposing of the acid waste. To this end, we have considered several options, including (1) changing our company process so that the waste acid stream is not produced, (2) contracting with another independent company to dispose of the acid, (3) long-term storage of the acid on site, (4) use of an evaporation pond to concentrate the waste solution, (5) treatment of the waste stream (acid neutralization) followed by discharge into the lake adjacent to the plant site, and (6) closing the plant. Our initial analysis indicated that the most economical and reliable of these options would be to neutralize the acid ourselves and then dispose of the stream (option 5). This conclusion is supported in the Appendix that accompanies this memo.

13.4 Reporting the results

In support of this option, we have completed the preliminary design of an acid-neutralization process for treatment of the waste stream. The process consists of storage tanks for the waste acid and the base (NaOH) that will be used to neutralize the acid, a mixer to facilitate mixing of the acid with the base, a heat exchanger to cool the stream to an environmentally acceptable outlet temperature, and the necessary pumps, piping, and instrumentation. The estimated capital cost for the project is $3.39 million. This option would allow the plant to continue operation at the current rate, which produces $6.09 million in gross sales annually. The annual operating cost for continued production, including the acid-neutralization process, is estimated as $4.78 million, where the current cost of acid disposal has been credited. The estimated ROI is 19.3%, well above the company minimum of 15%.

Given the above, we strongly recommend that the company pursue construction of the acid-neutralization process as quickly as possible. We estimate that the project can be completed in less than a year and be online when needed. In case of delays, or if the facility is needed sooner than anticipated, it will be necessary to temporarily store the acid on site. The treatment facility has been sized to accommodate acid flows in excess of those produced by our current process, so that the acid that must be stored can be treated at a later date. The excess capacity also provides the company with the option of increasing production rates in the future if desired. Additional costs associated with delays, and so forth, have been factored into the cost analysis.

Please do not hesitate to contact me if you have any questions or require additional information. We are ready to complete the final design and begin construction should the company choose the recommended option. In any case, we await your instructions.