Chemical Process Design / Diseño de Procesos Químicos

Topic 5.1. Equipment sizing and costing. Introduction

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1.- Introduction
   - Categories of total capital cost estimates
   - Cost estimation method of Guthrie
   - Example of Equipment Cost Estimation

2.- Shortcut procedures for equipment sizing
   - Vessel (flash drums, storage tanks, decanters and some reactors)
   - Reactors
   - Heat transfer equipment (heat exchangers, furnaces and direct fired heaters)
   - Distillation columns
   - Absorber columns
   - Compressors (or turbines)
   - Pumps
   - Refrigeration

3.- Cost estimation of equipment - Final Summary
   - Base costs for equipment units
   - Guthrie’s modular method

4.- Further Reading and References

PRACTICAL CHAPTER

RELEVANT TO LEARNING
1.- Introduction

Process Alternatives Synthesis (candidate flowsheet).
Analysis (Preliminary mass and energy balances).

**SIZING** (Sizes and capacities).

**COST ESTIMATION** (Capital and operation).

Economic Analysis (economic criteria).

**SIZING**

Calculation of all physical attributes that allow a unique costing of this unit:
- Capacity, Height.
- Pressure rating.
- Cross-sectional area.
- Materials of construction.

Shortcut, approximate calculations (correlations) → Quick obtaining of sizing parameters → Order of magnitude estimated parameters.

**COST**

- **Total Capital Investment or Capital Cost:** Function of the process equipment → The sized equipment will be costed.
  * Approximate methods to estimate costs.

- **Manufacturing Cost:** Function of process equipment and utility charges.
### Categories of total capital cost estimates

Based on accuracy of the estimate

<table>
<thead>
<tr>
<th>ESTIMATE</th>
<th>BASED ON</th>
<th>Error (%)</th>
<th>Obtaining</th>
<th>USED FOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORDER OF MAGNITUDE (Ratio estimate)</td>
<td>Method of Hill, 1956. Production rate and PFD with compressors, reactors and separation equipment. Based on similar plants.</td>
<td>40 – 50</td>
<td>Very fast</td>
<td>Profitability analysis</td>
</tr>
<tr>
<td>STUDY</td>
<td>Overall Factor Method of Lang, 1947. Mass &amp; energy balance and equipment sizing.</td>
<td>25 – 40</td>
<td>Fast</td>
<td>Preliminary design</td>
</tr>
<tr>
<td>DEFINITIVE</td>
<td>Full data but before drawings and specifications.</td>
<td>10 – 15</td>
<td>Slow</td>
<td>Construction control</td>
</tr>
<tr>
<td>DETAILED</td>
<td>Detailed Engineering.</td>
<td>5 – 10</td>
<td>Very slow</td>
<td>Turnkey contract</td>
</tr>
</tbody>
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Cost Estimation Method of Guthrie

• Equipment purchase cost: Graphs and/or equations.
  Based on a power law expression: Williams Law \( C = BC = Co (S/So)^\alpha \)
  \( \rightarrow \) Economy of Scale (incremental cost \( C \), decrease with larger capacities
  \( S \), due to the value of \( \alpha < 1 \)).

• Installation: Module Factor, \( MF \), affected by \( BC \), taking into account labor,
  piping instruments, accessories, etc.
  Typical Values \( 1 < MF < 4.23 \).
  Installation = \((BC)(MF) – BC = BC(MF – 1)\)

• For special materials, high pressures and special designs beyond base
  capacities (\( So \)) and costs (\( Co \)), the Materials and Pressure correction
  Factors, \( MPF \), are defined.

  Uninstalled Cost = \((BC)(MPF)\) \quad Total Installed Cost = \( BC (MPF + MF – 1) \)
Materials and Pressure correction Factors: MPF

Empirical factors that modified BC and evaluate particular instances of equipment beyond a basic configuration: Uninstalled Cost = (BC x MPF).

$$\text{MPF} = \phi \left( F_d, F_m, F_p, F_o, F_t \right)$$

- $F_d$: Design variation.
- $F_m$: Construction material variation.
- $F_p$: Pressure variation.
- $F_o$: Operating Limits ($\phi$ of $T$, $P$).
- $F_t$: Mechanical refrigeration factor. ($\phi$ of $T$ evaporator).

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>MPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Vessels</td>
<td>$F_m \cdot F_p$</td>
</tr>
<tr>
<td>Heat Exchangers</td>
<td>$F_m \left( F_p + F_d \right)$</td>
</tr>
<tr>
<td>Furnaces, direct fired heaters, Tray stacks</td>
<td>$F_m + F_p + F_d$</td>
</tr>
<tr>
<td>Centrifugal pumps</td>
<td>$F_m \cdot F_o$</td>
</tr>
<tr>
<td>Compressors</td>
<td>$F_d$</td>
</tr>
</tbody>
</table>

To obtain the COST ($C$) of the equipment $\Rightarrow$ Need S (Sizing) and MPF (Operation Conditions) $\Rightarrow$ required the flowsheet mass and energy balance (Flow, $T$, $P$, $Q$).
Cost Estimation Method of Guthrie

• To update cost from mid-1968 (Co and So), an Update Factor \( UF \), to account for inflation, is applied.

  \( UF: \) Present Cost Index / Base Cost index.

Updated bare (simple) module cost: \( BMC = UF(BC) \cdot (MPF + MF - 1) \)
An example of Cost Estimation: Shell and Tube Heat Exchangers

Equipment purchase price $C_p$

$C_p (\$)$

$UF = CI_{actual} / CI_{1982}$

Total Cost = $UF \cdot C_p \cdot MPF$

Pressure Factor

Design Factor $F_d$

Material Factor $F_m$

Materials and Pressure Factor (MPF)