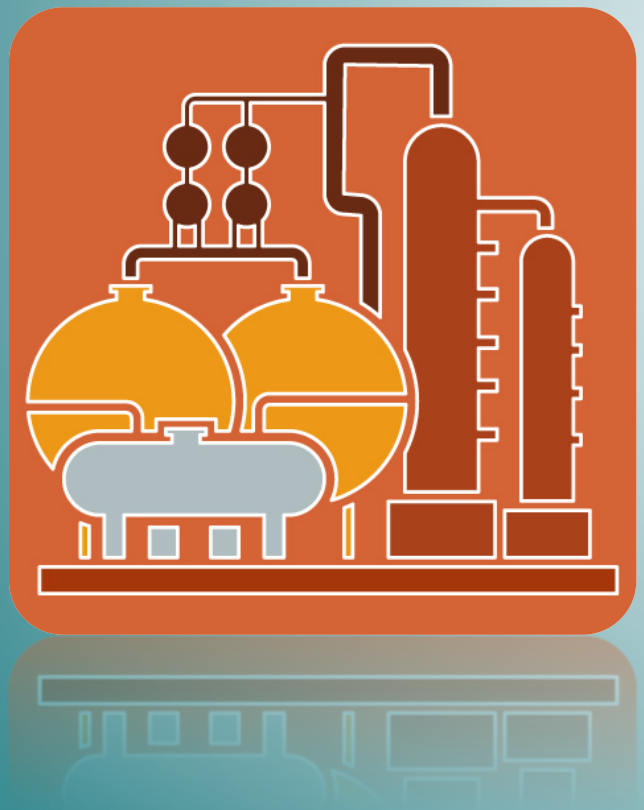
Chemical Process Design / Diseño de Procesos Químicos

Topic 5.8. Final summary sizing and costing



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3.- Cost Estimation of Equipment: Base Costs for Equipment Units

Biegler *(et al.)* (1997): Tables 4.11 - 4.12; p.134 → Seider *(et al.)* (2010): Table 22.32; p.591-595.

Base Costs for Pressure Vessels						
Equipment Type	**C_0 ($)**	**L_0(ft)**	**D_0(ft)**	**α**	**β**	**MF2 / MF4/ MF6/ MF8/ MF10**
Vertical fabrication 1 ≤ D ≤ 10 ft; 4 ≤ L ≤ 100 ft	1000	4.0	3.0	0.81	1.05	4.23 / 4.12 / 4.07 / 4.06 / 4.02
Horizontal fabrication 1 ≤ D ≤ 10 ft; 4 ≤ L ≤ 100 ft	690	4.0	3.0	0.78	0.98	3.18 / 3.06 / 3.01 / 2.99 / 2.96
Tray stacks 2 ≤ D ≤ 10 ft; 1 ≤ L ≤ 500 ft	180	10.0	2.0	0.97	1.45	1.0 / 1.0 / 1.0 / 1.0 / 1.0

$$C = BC = C_0 \, (L / Lo)^{\alpha} \, (D / Do)^{\beta}$$

3.- Cost Estimation of Equipment: Base Costs for Equipment Units

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Base Costs for Process Equipment

Equipment Type	C_0 ($\$10^3$)	S_0	Range (S)	α	MF2 / MF4 / MF6 / MF8 / MF10
Process furnaces *S = Absorbed duty (10^6 Btu/h)*	100	30	100 - 300	0.83	2.27 / 2.19 / 2.16 / 2.15 / 2.13
Direct fired heaters *S = Absorbed duty (10^6 Btu/h)*	20	5	1 - 40	0.77	2.23 / 2.15 / 2.13 / 2.12 / 2.10
Heat exchanger *Shell and tube, S = Area (ft^2)*	5	400	100 - 10^4	0.65	3.29 / 3.18 / 3.14 / 3.12 / 3.09
Heat exchanger *Shell and tube, S = Area (ft^2)*	0.3	5.5	2 - 100	0.024	1.83 / 1.83 / 1.83 / 1.83 / 1.83
Air Coolers *S = [calculated area (ft^2) / 15.5]*	3	200	100 - 10^4	0.82	2.31 / 2.21 / 2.18 / 2.16 / 2.15
Centrifugal pumps *S = C/H factor (gpm x psi)*	0.39 0.65 1.5	10 2.10^3 2.10^4	10 - 2.10^3 2.10^3 - 2.10^4 2.10^4 - 2.10^5	0.17 0.36 0.64	3.38 / 3.28 / 3.24 / 3.23 / 3.20 3.38 / 3.28 / 3.24 / 3.23 / 3.20 3.38 / 3.28 / 3.24 / 3.23 / 3.20
Compressors *S = brake horsepower*	23	100	30 - 10^4	0.77	3.11 / 3.01 / 2.97 / 2.96 / 2.93
Refrigeration *S = ton refrigeration (12,000 Btu/h removed)*	60	200	50 - 3000	0.70	1.42

$$C = BC = C_0 (S / S_0)^{\alpha}$$

3.- Cost Estimation of Equipment

Guthrie's modular method for preliminary design

Updated Bare Module Cost = UF · BC · (MPF + MF – 1)

Williams Law: $C = BC = C_0 (S / S_0)^{\alpha}$

BC

Non-linear behavior of Cost, C *vs.,* Size, S → Economy of Scale (incremental cost decrease with larger capacities).

Tables for each equipment unit

$$C = BC = C_0 (S / S_0)^{\alpha} \qquad \log C = \log (C_0 / S_0)^{\alpha} + \alpha \log S$$

C_0, S_0: Parameters of Basic configuration Costs and Capacities
α: Parameter < 1 → economy of scale.

Base Cost for Pressure Vessels: Vertical, horizontal, tray stack

$$C = C_0 (L / L_0)^{\alpha} (D / D_0)^{\beta}$$

Base Cost for Process Equipment

$$C = C_0 (S / S_0)^{\alpha} \text{ ; Range of S}$$

MF: **Module Factor**, **affected by BC, taking into account labor, piping instruments, accessories, etc.**

MF 2: If BC < 200.000
MF 4: If BC 200.000 - 400.000 $
MF 6: If BC 400.000 - 600.000 $
MF 8: If BC 600.000 - 800.000 $
MF 10: If BC 800.000 - 1.000.000 $

MPF: **Materials and Pressure correction Factors** Φ (F_d, F_m, F_p, F_0, F_t)

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

F_d: Design variation.
F_m: Construction material variation.
F_p: Pressure variation.
F_0: Operating Limits (Φ of **T**, **P**).
F_t: Mechanical refrigeration factor (Φ **T** evaporator).

UF: **Update Factor**, **to account for inflation.**

UF = Present Cost Index (CI_{actual}) / Base Cost Index (CI_{base})

CI: Chemical Engineering Plant Cost Index – CEPCI- (www.che.com)			
YEAR	CI	YEAR	CI
1957 - 1959	100	1996	382
1968	115 (Guthrie paper)	2003	402
1970	126	2010	550,8
1983	316	2015	556.8
1993	359	2016	541,7
1995	381		

UPDATE !!

4.- Further Reading and References

- Biegler, L.; Grossmann, I. & Westerberg, A. (1997): *«Systematic methods of chemical process design»*. Prentice Hall.
- Branan, C. (Ed.) (2005): *«Rules of thumb for chemical engineers»*. 4th Ed. Elsevier.
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- Green, D. & Perry, R. (2008): *«Perry's chemical Engineers' handbook»*. 8th Ed. McGraw-Hill.
- Mahajani, V. & Umarji, S. (2009): *«Joshi's process equipment design»*. 4th Ed. MacMillan Publishers India.
- Seider, W.; Seader, J.; Lewin, D. & Widagdo, S. (2010): *«Product and process design principles. Synthesis, analysis and evaluation»*. 3rd Ed. John Wiley & Sons.
- Sinnot, R. & Towler, G. (2009): *«Chemical engineering design»*. 5th Ed. Coulson & Richardson´s Chemical Engineering Series. Elsevier.
- **The Tubular Exchanger Manufacturers Association, Inc. (TEMA):** www.tema.org.
- Turton, R.; Bailie, R.; Whiting, W. & Shaeiwitz, J. (2003): *«Analysis, synthesis and design of chemical processes»*. 2nd Ed. Prentice Hall PTR.
- Ulrich, G. & Vasudevan, P. (2004): *«A guide to chemical engineering process design and economics»*. 2nd Ed. John Wiley & Sons.

Practical Chapter

- Application of the Guthrie Method to the Cost Estimation of the case study or other examples.
- Application of the Guthrie Method to the Cost Estimation of your process design project.

Relevant to Learning

- **Categories of total capital cost estimates (Table).**

- **Cost Estimation using the Method of Guthrie:**
  - **Terms, factors, modules, meaning, calculations and apply to your project.**

Specific Questions

- **Suppose you need to compress a gaseous stream from 10 to 50 bar. What are the economic design trade-offs between using a single compressor and using two compressors with a heat exchanger?**
- ***Suponer que necesitas comprimir una corriente gaseosa desde 10 a 50 bar. ¿Cuáles son los compromisos económicos de diseño entre usar un solo compresor y usar dos compresores con un intercambiador de calor?***

Relevant to Learning

Specific Questions

- **When estimating the costs of certain equipment working at high pressure, if pressure factors are not available for these pressure levels, what solution would you look for to carry out the estimation?**
- ***A la hora de estimar los costes de ciertos equipos que trabajan a alta presión, en caso de no disponer de factores de presión para dichos niveles, ¿qué solución buscarías para llevar a cabo la estimación?***

- **For the design of a G-L absorber, can it be assumed that the height is 4 times the diameter of the equipment?**
- ***Para el diseño de un absorbedor G-L, ¿se puede suponer que la altura es 4 veces el diámetro?***

- **When selecting parameters for the conceptual design of equipment and services with influence on costs (e.g. U, Tcw), would you choose those that provide higher costs (Yes, No, depends)? Justify the answer.**
- ***A la hora de seleccionar parámetros para el diseño conceptual de equipos y servicios con influencia en los costes (p.e. U, Tcw) ¿elegiría los que proporcionen mayores costes? (Si, No, depende). Justificar la respuesta.***