CHE 425

Engineering Economics and Design Principles

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CHAPTER 5

Estimation of Capital Costs

Definition

Capital cost pertains to the costs associated with construction of a new plant or modification to an existing chemical manufacturing plant.

Types of Capital Cost Estimate

1. Order of Magnitude Estimate (Feasibility)
2. Study Estimate / Major Equipment
3. Preliminary Design (Scope) Estimate
4. Definitive (Project Control) Estimate
5. Detailed (Firm or Contractors) Estimate

Types of Capital Cost Estimate (cont.)

- **Order of Magnitude Estimate (Feasibility)**
  - **Data: Cost information for a complete process**
  - **Diagram: BFD**
- **Study Estimate / Major Equipment**
  - **Data: List of major equipments**
  - **Diagram: PFD**
- **Preliminary Design (Scope) Estimate**
  - **Data: Accurate equipment sizes, layout of equipment, piping, instrumentation and electrical requirements**
  - **Diagram: PFD and preliminary PI&D**

Types of Capital Cost Estimate (cont.)

- **Definitive (Project Control) Estimate**
  - Data: specification of all equipment, utilities, instrumentation, electrical and off-sites.
  - Diagram: Final PFD and a preliminary PI&D
- **Detailed (Firm or Contractors) Estimate**
  - Data: Complete engineering of the process and all related off-sies and utilities.
  - Diagram: Final PFD and P&ID

Types of Capital Cost Estimate

Table 5.2 Classification of Cost Estimates

Class of Estimate	Level of Project Definition (as % of Complete Definition)	Typical Purpose of Estimate	Methodology (Estimating Method)	Expected Accuracy Range (+/- Range Relative to Best Index of 1)	Preparation Effort (Relative to Lowest Cost Index of 1)
Class 5	0% to 2%	Screening or Feasibility	Stochastic or Judgment	4 to 20	1
Class 4	1% to 15%	Concept Study or Feasibility	Primarily Stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Mixed but Primarily Stochastic	2 to 6	3 to 10
Class 2	30% to 70%	Control or Bid/Tender	Primarily Deterministic	1 to 3	5 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	1	10 to 100

(From AACE Recommended Practice No. 17R-97 [4], reprinted with permission of AACE International, 209 Prairie Ave., Morgantown, WV; http://www.aacei.org)

Example 5.2

Example 5.2

Compare the costs for performing an order-of-magnitude estimate and a detailed estimate for a plant that cost $\$5.0 \times 10^6$ to build.

For the order-of-magnitude estimate, the cost of the estimate is in the range of 0.015% to 0.3% of the final cost of the plant:

$$\text{Highest Expected Value: } (\$5.0 \times 10^6)(0.003) = \$15{,}000$$

$$\text{Lowest Expected Value: } (\$5.0 \times 10^6)(0.00015) = \$750$$

For the detailed estimate, the cost of the estimate is in the range of 10 to 100 times that of the order-of-magnitude estimate.

For the lowest expected cost range:

$$\text{Highest Expected Value: } (\$5.0 \times 10^6)(0.03) = \$150{,}000$$

$$\text{Lowest Expected Value: } (\$5.0 \times 10^6)(0.0015) = \$7500$$

For the highest expected cost range:

$$\text{Highest Expected Value: } (\$5.0 \times 10^6)(0.3) = \$1{,}500{,}000$$

$$\text{Lowest Expected Value: } (\$5.0 \times 10^6)(0.015) = \$75{,}000$$

Estimating Purchased Equipment Costs

- Vendor quote
  - Most accurate
    - based on specific information
    - requires significant engineering
- Use previous cost on similar equipment and scale for time and size
  - Less accurate
    - beware of large extrapolation
    - beware of foreign currency
- Use cost estimating charts and scale for time
  - Reasonably accurate
  - Convenient

Effect of Size (Capacity)

$$\frac{C_a}{C_b} = \left(\frac{A_a}{A_b}\right)^n \qquad (5.1)$$

where: A = Equipment cost attribute
C = Purchased cost
n = Cost exponent

Subscripts: a refers to equipment with the required attribute
b refers to equipment with the base attribute

$$C_a = K A_a^{\ n} \qquad (5.2)$$

where

$$K = \frac{C_b}{A_b^{\ n}}$$

Effect of Size (Capacity)

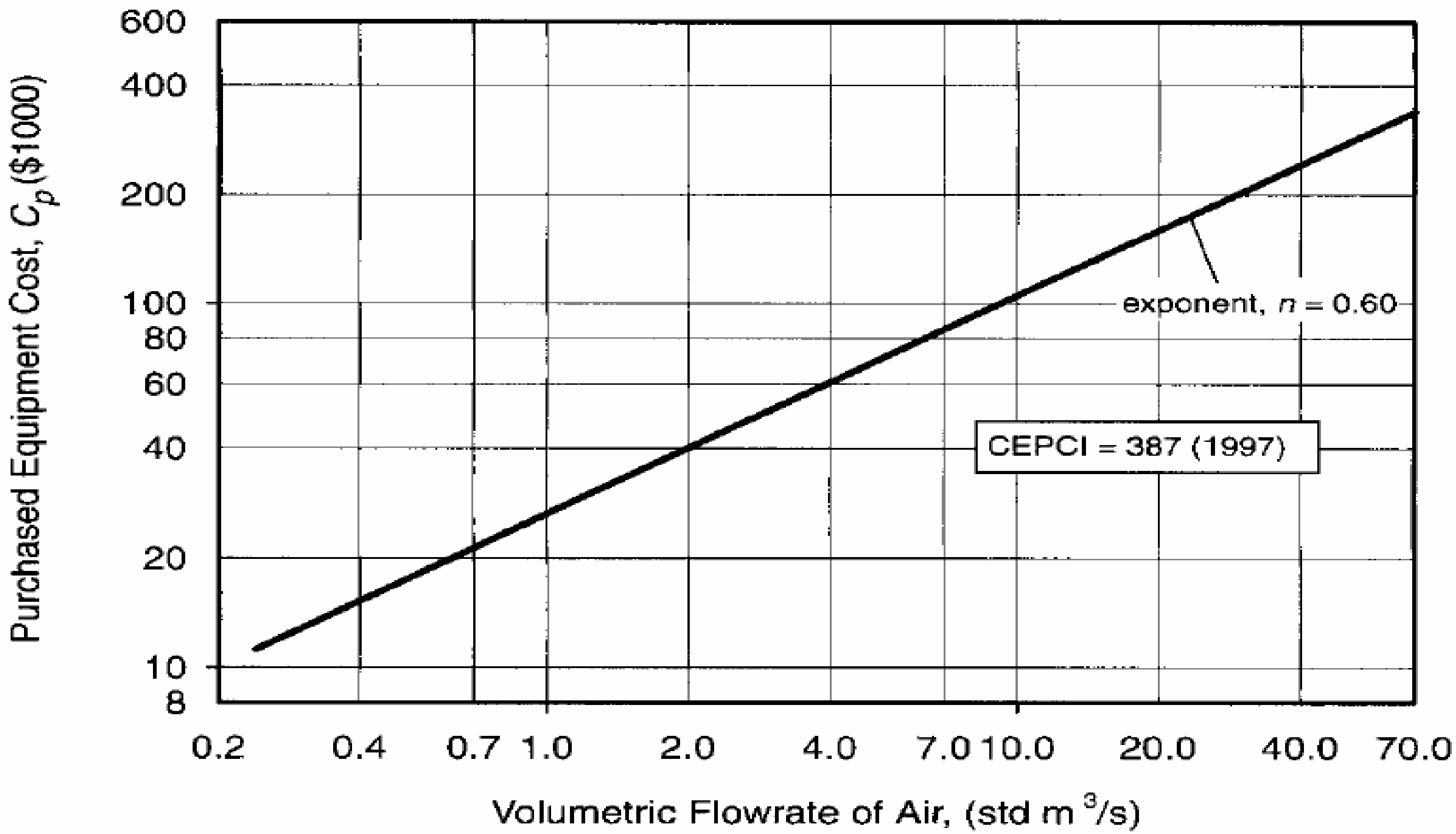


Figure 5.1 Purchased Cost of a Centrifugal Air Blower (Data from Reference [3])

Table 5.3 Typical Values of Cost Exponents for a Selection of Process Equipment

Equipment Type	Range of Correlation	Units of Capacity	Cost Exponent *n*
Reciprocating compressor with motor drive	0.75 to 1490	kW	0.84
Heat exchanger shell and tube carbon steel	1.9 to 1860	m^2	0.59
Vertical tank carbon steel	0.4 to 76	m^3	0.30
Centrifugal blower	0.24 – 71	std m^3/s	0.60
Jacketed kettle glass lined	0.2 to 3.8	m^3	0.48

Effect of Size (Capacity) **(cont.)**

- *n* = 0.4 – 0.8 Typically
- Often *n* ~ 0.6 and we refer to Eq.(5.1) as the (6/10)'s Rule
  - Assume all equipment have *n* = 0.6 in a process unit and scale-up using this method for whole processes
  - Order-of-Magnitude estimate

Example 5.3

Use the six-tenths-rule to estimate the % increase in purchased cost when the capacity of a piece of equipment is doubled.

Using Equation 5.1 with $n = 0.6$:

$$C_a / C_b = (2/1)^{0.6} = 1.52$$

$$\% \text{ increase} = ((1.52 - 1.00)/1.00)(100) = 52\%$$

The larger the equipment, the lower the cost of equipment per unit of capacity.

Example 5.4

Compare the error for the scale-up of a heat exchanger by a factor of 5 using the six-tenth-rule in place of the cost exponent given in Table 5.3.

Using Equation 5.1:

Cost ratio using six-tenth-rule (i.e. $n = 0.60$) $= 5.0^{0.60} = 2.63$

Cost ratio using ($n = 0.44$) from Table 5.3 $= 5.0^{0.59} = 2.58$

$\%\ \text{Error} = ((2.63 - 2.58)/2.58)(100) = 1.9\ \%$

Another way of looking at economy of scale

$$\frac{C}{A} = KA^{n-1}$$

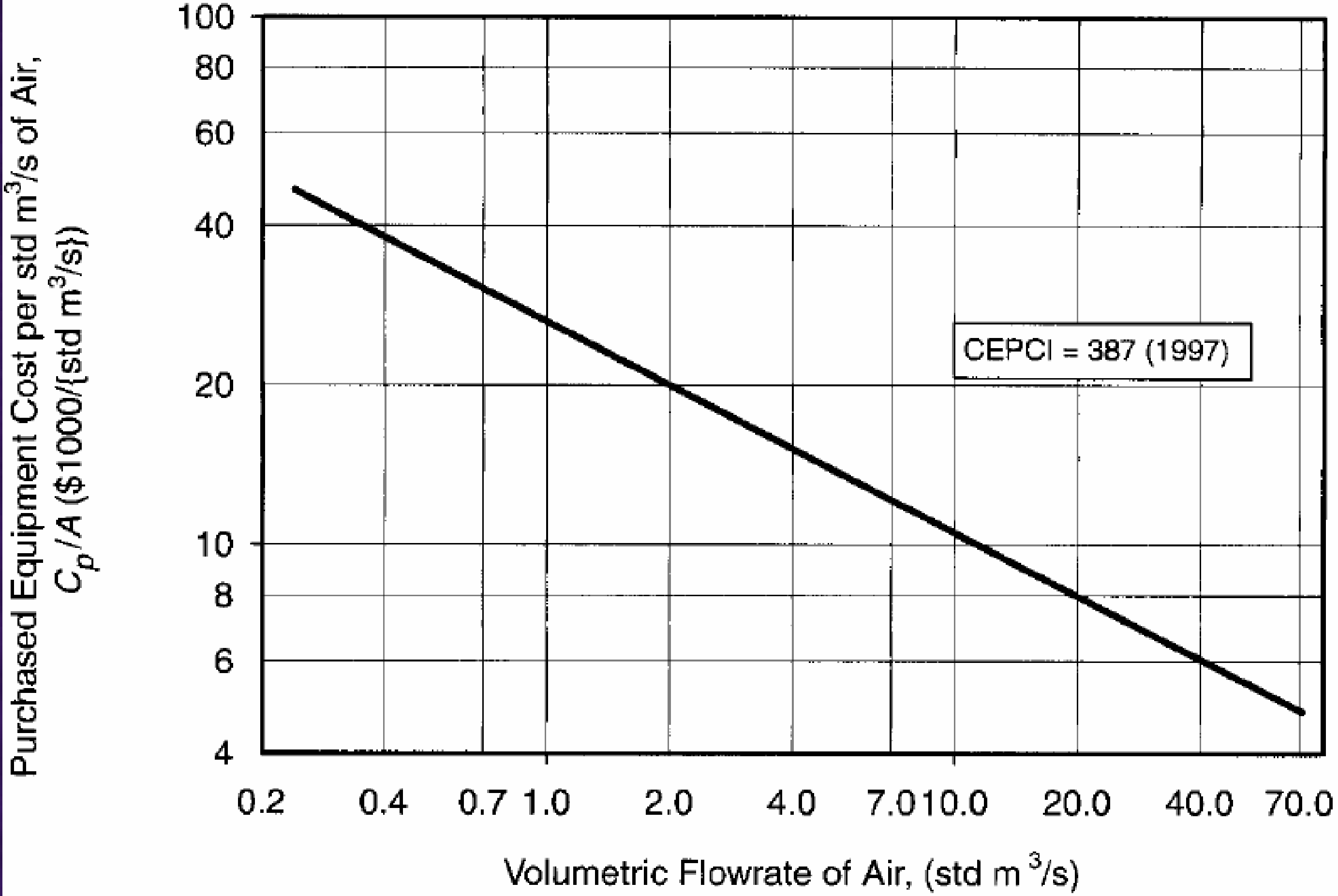


Figure 5.2 Purchased Cost per Unit of Flowrate of a Centrifugal Air Blower (Data from Reference [3])

Example 5.5

The purchased cost of a recently acquired heat exchanger with an area of 100 m^2 was $10,000.

Determine:

a. the constant K in Equation 5.2

b. the cost of a new heat exchanger with area equal to 180 m^2.

From Table 5.3: $n = 0.59$: for Equation 5.2:

a. $K = C_b/(A_b)^n = 10{,}000/(100)^{0.59} = 661\ \{\$/(m^2)^{0.59}\}$

b. $C_a = (661)(180)^{0.59} = \$14{,}200$

$\Rightarrow$ Economy of Scale

Effect of Time

- Time increases – cost increases (inflation)
- Inflation is measured by cost indexes - Figure 5.3
  - Chemical Engineering Plant Cost Index (CEPCI)
  - Marshall and Swift Process Industry Index
- Numbers based on “basket of goods” typical for construction of chemical plants - Table 5.5

Equation for Time Effect

$$C_2 = C_1 \left(\frac{I_2}{I_1} \right)$$

where: C = Purchased Cost
I = Cost Index

subscripts: 1 refers to base time when cost is known
2 refers to time when cost is desired

Table 5.4 Values for the Chemical Engineering Plant Cost Index and the Marshall and Swift Equipment Cost Index from 1986 to 2001

Year	Marshall & Swift Equipment Cost Index	Chemical Engineering Cost Index
1986	817	318
1987	814	324
1988	852	343
1989	895	355
1990	915	358
1991	931	361
1992	943	358
1993	964	359
1994	993	368
1995	1028	381
1996	1039	382
1997	1057	387
1998	1062	390
1999	1068	391
2000	1089	394
2001 (September)	1094	397

Table 5.5 The Basis for the Chemical Engineering Plant Cost Index

Components of Index	Weighting of Component (%)	
Equipment, Machinery, and Supports:		
(a) Fabricated equipment	37	
(b) Process machinery	14	
(c) Pipe, valves, and fittings	20	
(d) Process instruments and controls	7	
(e) Pumps and compressors	7	
(f) Electrical equipment and materials	5	
(g) Structural supports, insulation, and paint	10	
	100	61% of total
Erection and installation labor		22
Buildings, materials, and labor		7
Engineering and supervision		10
Total		100

Example 5.6

The purchased cost of a heat exchanger of 500 m^2 area in 1990 was $25,000.

a. Estimate the cost of the same heat exchanger in 2001 using the two indices introduced above.

b. Compare the results.

From Table 5.4:	1990	2001
Marshal and Swift Index	915	1094
Chemical Engineering Plant Cost Index	358	397

a. Marshal and Swift: Cost = ($25,000)(1094/915) = $29,891

Chemical Engineering: Cost = ($25,000)(397/358) = $27,723

b. Average Difference: (($29,891 − 27,723)/(($29,891 + 27,723)/2)(100) = 7.5%

Example

Question

Cost of vessel in 1993 was 25,000, what is estimated cost today (Sept 2003 – CEPCI = 402)?

Solution

$$C_{now} = C_{1993}\left(\frac{I_{now}}{I_{1993}}\right) = 25{,}000\left(\frac{402}{359}\right) = \$27{,}990$$

Example - Accounting for Time and Size

2 heat exchangers, 1 bought in 1990 and the other in 1995 for the same service

	A	B
Area =	70 m2	130 m2
Time =	1990	1995
Cost =	17 K	24 K
I =	358	381

What is the Cost of a 80 m^2 Heat Exchanger Today? (*I* = 402)

Example - Solution

- **Must First Bring Costs to a Common Time**

$A = 70$

$$C_a(2003) = 17\left(\frac{402}{358}\right) = 19.089$$

$A = 130$

$$C_b(2003) = 24\left(\frac{402}{381}\right) = 25.323$$

Example – Solution (cont.)

$$C = KA^n$$

$$19.089 = K(70)^n$$

$$25.323 = K(130)^n$$

$$n = \frac{\log(25.323) - \log(19.089)}{\log(130) - \log(70)} = 0.4565$$

$$K = \frac{C}{A^n} = \frac{19.089}{70^{0.4565}} = \$2.745$$

$$C = 2.745(80)^{0.4565} = \$20.288 = \$20,290$$

Total Cost of Plant

- Purchased equipment cost – equipment f.o.b.
- Installed cost – Often 3 to 8 times larger than purchased equipment cost

Installed Cost of Equipment (Table 5.6)

- **1. Direct Project Expenses**
  - Equipment
  - Material for installation
  - Labor for installation
- **2. Indirect Project Expenses**
  - Freight, insurance, and taxes
  - Construction overhead
  - Contractor engineering expenses

Installed Cost of Equipment (Table 5.6) (cont.)

- **Contingency and Fee**
  - Contingency
  - Contractor fee
- **Auxiliary Facilities**
  - Site development
  - Auxiliary buildings
  - Off-sites and utilities

Lang Factors

- Table 5.7
- Use multiplier depending on type of plant to escalate equipment costs to installed costs
- F_{lang} = 4.74 Fluid processing plant
  = 3.63 Solid-Fluid processing plant
  = 3.10 Solid processing plant
- This estimating technique is insensitive to changes in process configuration

Lang Factors (cont'd)

$$C_{TM} = F_{Lang} \sum_{i=1}^{n} C_{pi}$$

where:

C_{TM}	is the capital cost (total module) of the plant,
$C_{p,i}$	is the purchased cost for the major equipment units
n	is the total number of individual units
F_{Lang}	is the Lang Factor (from Table 5.7)

Lang Factors (cont'd)

Example 5.8

Determine the capital cost for a major expansion to a fluid processing plant that has a total purchased equipment cost of $6,800,000.

$$\text{Capital Costs} = (\$6{,}800{,}000)(4.74) = \$32{,}232{,}000$$

Module Factor Approach

- Table 5.8
  - Direct, Indirect, Contingency and Fees are expressed as functions (multipliers) of purchased equipment cost $\left(C_p^o\right)$ at base conditions (1 bar and CS)
  - Each equipment type has different multipliers
  - Details given in Appendix A

Module Factor Approach

$$C_{BM} = C_p^o F_{BM}$$

Bare Module Factor (sum of all multipliers)

Bare Module Cost

Purchased Equipment Cost for CS and 1 atm pressure - Appendix A

$$F_{BM} = B_1 + B_2 F_p F_M$$

$$F_{BM}^o = B_1 + B_2$$

F_p = pressure factor (= 1 for 1 bar)

F_M = material of construction factor (=1 for CS)

$$C_p = C_p^o F_p F_M$$

Table 5.8 Equations for Evaluating Direct, Indirect, Contingency, and Fee Costs

Factor	Basic Equation	Multiplying Factor to be used with purchased cost, C_p^o
1. Direct		
(a) Equipment	$C_p^o = C_p^o$	1.0
(b) Materials	$C_M = \alpha_M C_p^o$	α_M
(c) Labor	$C_L = \alpha_L(C_p^o + C_M)$	$(1.0 + \alpha_M)\alpha_L$
Total Direct	$C_{DE} = C_p^o + C_M + C_L$	$(1.0 + \alpha_M)(1.0 + \alpha_L)$
2. Indirect		
(a) Freight, etc.	$C_{FIT} = \alpha_{FIT}(C_p^o + C_M)$	$(1.0 + \alpha_M)\alpha_{FIT}$
(b) Overhead	$C_O = \alpha_O C_L$	$(1.0 + \alpha_M)\alpha_L\alpha_O$
(c) Engineering	$C_E = \alpha_E(C_p^o + C_M)$	$(1.0 + \alpha_M)\alpha_E$
Total Indirect	$C_{IDE} = C_{FIT} + C_O + C_E$	$(1.0 + \alpha_M)(\alpha_{FIT} + \alpha_L\alpha_O + \alpha_E)$
Bare Module	$C_{BM}^o = C_{IDE} + C_{DE}$	$(1.0 + \alpha_M)(1.0 + \alpha_L + \alpha_{FIT} + \alpha_L\alpha_O + \alpha_E)$
3. Contingency and Fee		
(a) Contingency	$C_{Cont} = \alpha_{Cont} C_{BM}^o$	$(1.0 + \alpha_M)(1.0 + \alpha_L + \alpha_{FIT} + \alpha_L\alpha_O + \alpha_E)\alpha_{Cont}$
(b) Fee	$C_{Fee} = \alpha_{Fee} C_{BM}^o$	$(1.0 + \alpha_M)(1.0 + \alpha_L + \alpha_{FIT} + \alpha_L\alpha_O + \alpha_E)\alpha_{Fee}$
Total Module	$C_{TM} = C_{BM}^o + C_{Cont} + C_{Fee}$	$(1.0 + \alpha_M)(1.0 + \alpha_L + \alpha_{FIT} + \alpha_L\alpha_O + \alpha_E)(1.0 + \alpha_{Cont} + \alpha_{Fee})$

Example 5.9

The purchased cost for a carbon steel heat exchanger operating at ambient pressure is $10,000. For a heat exchanger module, Guthrie [9, 10] provides the following cost information:

Item	% of Purchased Equipment Cost
Equipment	100.0
Materials	71.4
Labor	63.0
Freight	8.0
Overhead	63.4
Engineering	23.3

Using the information given above, determine the equivalent cost multipliers given in Table 5.8 and the following:

a. Bare module cost factor, F_{BM}^{o}

b. Bare module cost, C_{BM}^{o}

Item	% of Purchased Equipment Cost	Cost Multiplier (Table 5.8)	Value of Multiplier
Equipment	100.0	1.0	
Materials	71.4	α_M	0.714
Labor	63.0	α_L	$0.63/(1 + 0.714) = 0.368$
Freight	8.0	α_{FIT}	$0.08/(1 + 0.714) = 0.047$
Overhead	63.4	α_O	$0.634/0.368/(1 + 0.714) = 1.005$
Engineering	23.3	α_E	$0.233/(1 + 0.714) = 0.136$
Bare Module	**329.1**		

a. Using Equation 5.8:

$$F_{BM}^{o} = (1 + 0.368 + 0.047 + (1.005)(0.368) + 0.136)(1 + 0.714) = 3.291$$

b. From Equation 5.6:

$$C_{BM}^{o} = (3.291)(\$10{,}000) = \$32{,}910$$

Example 5.10

Find the bare module cost of a floating-head shell-and-tube heat exchanger with a heat transfer area of 100 m^2 at the end of 2001. The operating pressure of the equipment is 1.0 bar with both shell-and-tube sides constructed of carbon steel. The cost curve for this heat exchanger is given in Appendix A, Figure A.5, and is repeated as Figure 5.4. It should be noted that unlike the examples shown in Figures 5.1 and 5.2, the log-log plot of cost per unit area versus area is nonlinear. In general this will be the case, and a second order polynomial is normally used to describe this relationship.

From Figure 5.4: $C_p^o(2001) = (\$ 250)(100) = \$25{,}000$ (the evaluation path is shown on Figure 5.4).
The Bare Module Cost for shell-and-tube heat exchangers is given by Equation A.4,

$$C_{BM} = C_p^o [B_1 + B_2 F_p F_M] \tag{A.4}$$

The values of B_1 and B_2 for floating-head heat exchangers from Table A.4 are 1.63 and 1.66, respectively.

The pressure factor is obtained from Equation A.3.

$$\log_{10} F_p = C_1 + C_2 \log_{10} P + C_3(\log_{10} P)^2 \tag{A.3}$$

From Table A.2, for pressures <5 barg, $C_1 = C_2 = C_3 = 0$, and from Equation A.3, $F_p = 1$.
Using data in Table A.3 for shell-and-tube heat exchangers with both shell and tubes made of carbon steel (Identification Number = 1) and Figure A.8, $F_M = 1$. Substituting this data into Equation A.4 gives

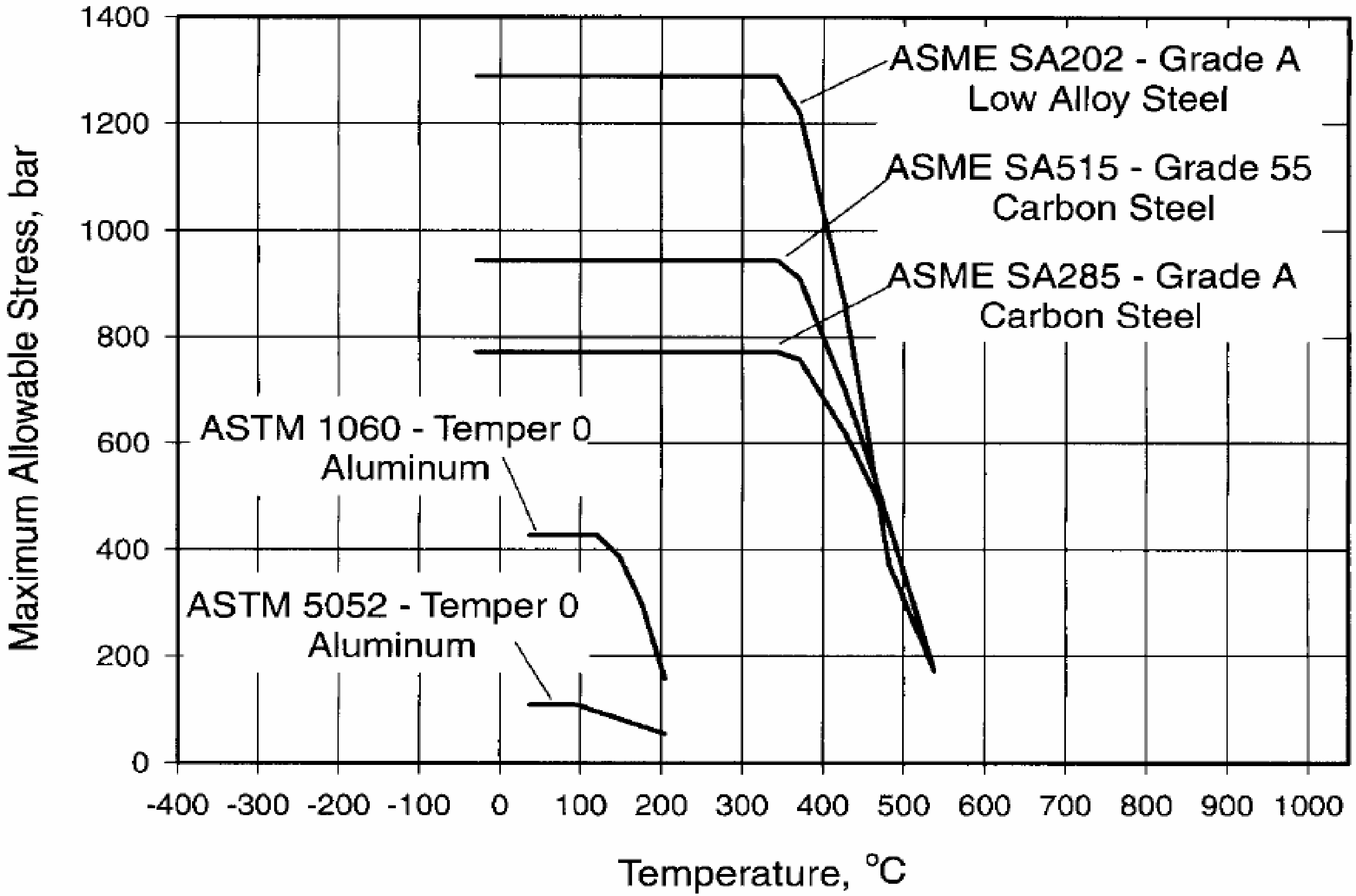
$$C_{BM}^o = C_p^o [1.63 + 1.66(F_p = 1)(F_M = 1)] = 3.29 C_p^o = (3.29)(\$25{,}000) = \$82{,}300$$

Pressure Factors

$$t = \frac{PD}{2SE - 1.2P} + CA$$

$$F_{P,vessel} = \begin{cases} = 1 & \text{for } t < t_{\min} \text{ and } P > -.05 \text{ barg} \\ = \dfrac{\dfrac{(P+1)D}{(2)(944)(0.9) - 1.2(P+1)} + CA}{t_{\min}} & \text{for } t > t_{\min} \text{ and } P > \; - 0.5 \text{ barg} \\ = 1.25 & \text{for } P < -0.5 \text{ barg} \end{cases}$$

Pressure Factors



Pressure Factors

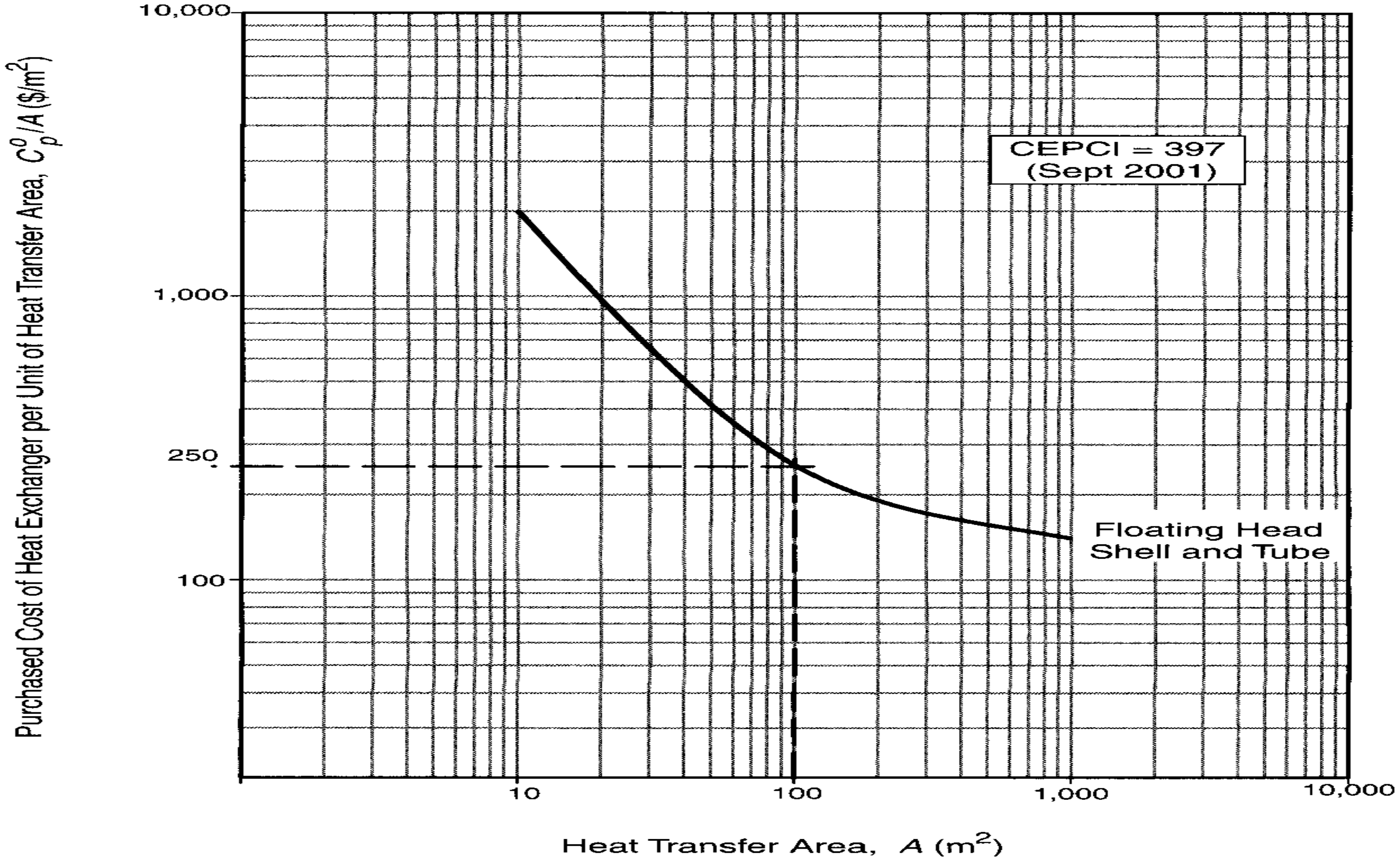


Figure 5.4 Purchased Costs for Floating Head, Shell-and-Tube Heat Exchangers

Pressure Factors

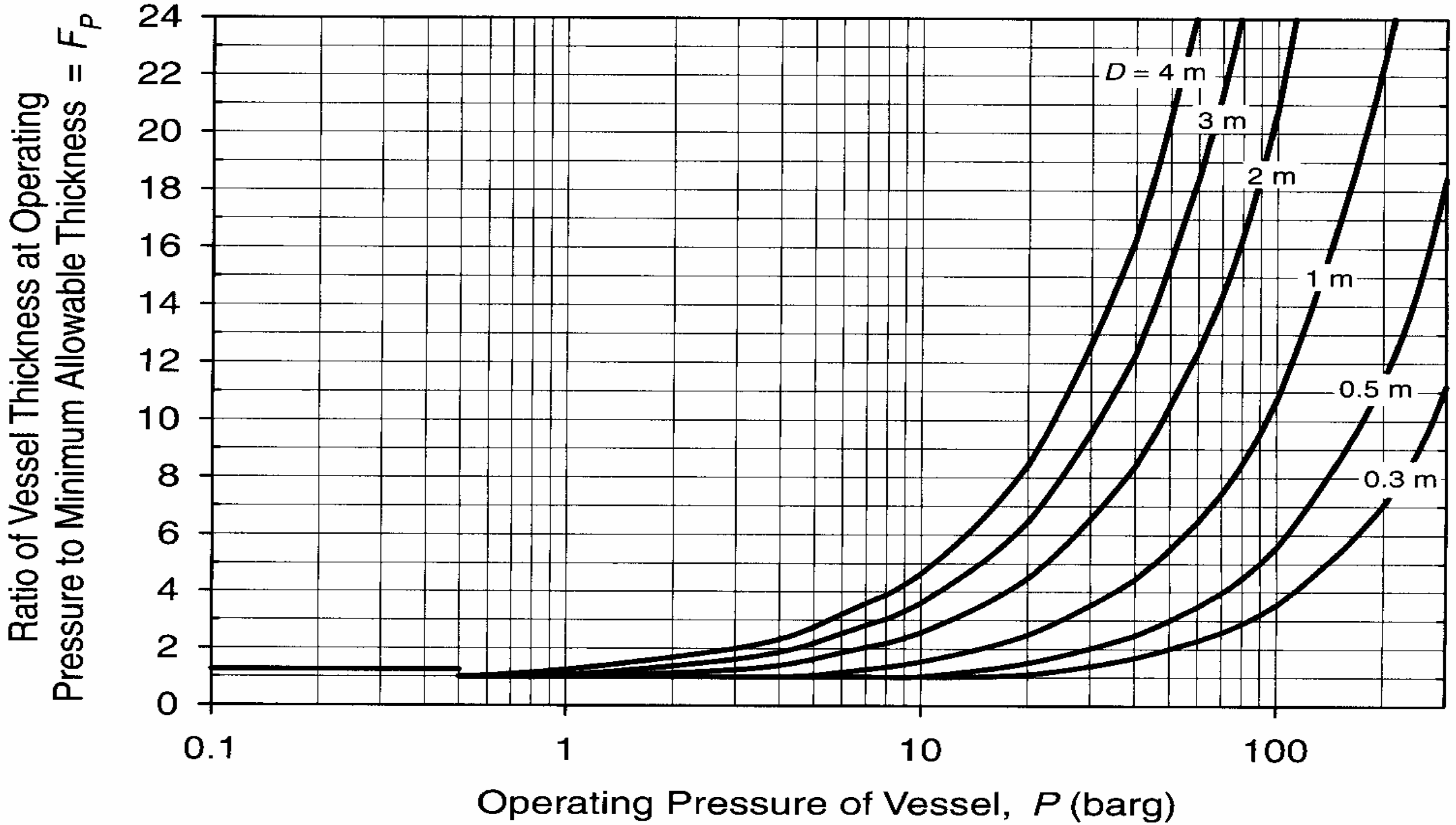


Figure 5.6 Pressure Factors for Carbon Steel Vessels

Illustrative Example

- Compare Costs for
  - 1. Shell-and-tube heat exchanger in 2001 with an area = 100 m^2 for :
    - Carbon Steel at 1 bar
    - Carbon Steel at 100 bar
    - Stainless Steel at 1 bar
    - Stainless Steel at 100 bar

Effect of Materials of Construction and Pressure on Bare Module Cost

P	MOC	C_p^o	C_{BM}^o	C_{BM}
1 bar	CS	25 K	82.3 K	82.3 K
1 bar	SS	25 K	82.3 K	154 K
100 bar	CS	25 K	82.3 K	98.1 K
100 bar	SS	25 K	82.3 K	197.4 K

Bare-Module and Total-Module Costs

- BM – Previously Covered
- TM – Includes Contingency and Fees at 15% and 3% of BM

$$C_{TM} = 1.18 \sum_{\text{all equip}} C_{BM}$$

Materials of Construction

- Very important
- Table 5.9 – rough guide
- Perry's – good source

Materials of Construction

Table 5.9 Corrosion Characteristics for Some Materials of Construction

Chemical Component	Carbon Steel	304 Stainless Steel	316 Stainless Steel	Aluminum	Cooper	Brass	Monel	Hastelloy™ C	Titanium	TFE	Graphite
Acetaldehyde	N		A			C		A	A	A	A
Acetic acid, glacial	N		A	A	A	C	B	A	A	A	A
Acetic acid, 20%	N	A	A	A	A	C	B	A	A	A	A
Acetic anhydride	N	A	B	A	A	C		A	A	A	A
Acetone	A	A	A	A	A	A	A	A	A	A	
Ammonia 10%	C	A	A	C	N	N	N	A	A	A	A
Aniline	A	A	A	N	N	N	A	A	A	A	A
Aqua regia	N	N	N	N	N	N	N	C	A	A	
Benzaldehyde		A	A	A	A	A	A	A	A	A	A
Benzene	A	A	A	A	A	A	A	A	A	A	A
Benzoic acid		C	A					A	B	A	A
Furfural	A	C	C	A	A	A	A	A	A	A	A
Gasoline	C	A	A	A	A	A	A	A	N	A	A
Heptane	A	A	A	A	A	A	A	A	A	A	A
Hexane		A	A	A			A	A	A	A	A
HCl, 0–25%	N	N	N	N	C	N	C	C	C	A	A
HCl, 25–37%	N	N	N	N	C	N	C	C	C	A	A
HF, 30%	N	B	B	N	N	N	A	A	N	A	A
HF, 60%	N	B	B	N	N	N	A	A	N	A	A
H_2O_2, 30%	C	C	A	C	C	N	C	A	A	A	A
H_2O_2, 90%	C	C	A	C	C	N		A	A	A	A
H_2S, aqueous	C	C	A	A	N	N	N	A	A	A	A
Maleic acid		A	A			A		A	A	A	A
Methanol		A	A	A	A		A	A	A	A	A
Methyl chloride		A	A	N			A	A	A	A	A

Materials of Construction

Table 5.9 Corrosion Characteristics for Some Materials of Construction (*continued*)

Chemical Component	Carbon Steel	304 Stainless Steel	316 Stainless Steel	Aluminum	Cooper	Brass	Monel	Hastelloy™ C	Titanium	TFE	Graphite
Methyl ethyl ketone	A	A	A	A	A		A	A	A	A	A
Methylene chloride		A	A		N		N	A	A	A	A
Napthalene		A	A	A			A	A	A	A	A
Nitric acid, 10%	N	A	A	B	N		N	A	A	A	A
Nitric acid, 50%	N	C	C	B	N		N	A	A	A	N
Oleic acid	C	A	A	A	C		A	A	A	A	A
Oxalic acid	C	C	B	C	C		A	A	A	A	A
Phenol	N	C	C	B	N		A	A	A	A	A
Phosphoric acid, 0–50%	C	C	C	N	C		C	A	B	A	A
Phosphoric acid, 51–100%	C	C	C	N	C		C	A	B	A	A
Propyl alcohol		A	A	A	A			A	A	A	
Sodium hydroxide, 20%	A	A	A	N	C	N	A	A	A	A	A
Sodium hydroxide, 50%	A	A	A	N	C	N	A	A	A	A	A
Stearic acid		A	A	A	A		B	A	A	A	A
Sulfuric acid, 0–10%	N	N	N	N	N		C	A	B	A	A
Sulfuric acid, 10–75%	N	N	N	N	N		C	A	C	A	A
Sulfuric acid, 75–100%	N	N	N	N	N		C	C	N	A	A
Tataric acid		A	A	A	A		C	A	A	A	A
Toluene	A	A	A	A	A		A	A	A	A	
Urea		A	A	A				A	A	A	A
Xylene		A	A					A	A	A	A

Algorithm for Calculating Bare Module Costs

1. Using the correct figure in Appendix A (Figures A.1–A.7), or the data in Table A.1, obtain C_p^o for the desired piece of equipment. This is the purchased equipment cost for the base case (carbon steel construction and near ambient pressure).
2. Find the correct relationship for the bare module factor. For exchangers, pumps, and vessels, use Equation A.4 and the data in Table A.4. For other equipment the form of the equation is given in Table A.5.
3. For exchangers, pumps, and vessels, find the pressure factor, F_P Table A.2 and Equations A.2 or A.3, and the material of construction factor, F_M Equation A.4 and Table A.3 and Figure A.8. Use Equation A.4 to calculate the bare module factor, F_{BM}.
4. For other equipment find the bare module factor, F_{BM}, using Table A.6 and Figure A.9.
5. Calculate the bare module cost of equipment, C_{BM}, from Equation 5.6.
6. Update the cost from 2001 (CEPCI – 397) to the present by using Equation 5.4.

Results of Example 5.14

Table E5.14b Results of Capital Cost Estimate for Example 5.14

Equipment	F_P	F_M	F_{BM}	C_p^o ($)	C_{BM} ($)	C_{BM}^o ($)
E - 101	1.0	1.0	3.29	33,000	108,500	108,500
E - 102	1.023	1.81	4.70	36,900	177,900	121,300
E - 103	1.0	1.0	3.29	3700	12,300	12,300
P - 101A/B	1.0	1.55	3.98	(2)(3200)	(2)(12,600)	(2)(10,300)
T - 101	1.681	1.0	5.31	54,700	290,700	222,800
32 Trays		1.83	1.83	(32)(2200)	131,200	71,700
V - 101	1.513	1.0	3.79	13,500	51,200	40,600
Totals				219,900	797,000	597,800
CEPCI = 397						

Capcost

- Calculates costs based on input
- CEPCI – use current value of 401 or latest from *Chemical Engineering*
- Program automatically assigns equipment numbers