Chapter 7
Estimation of Capital Costs

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Types of Capital Cost Estimate

- 1. Order-of-Magnitude Estimate (Feasibility)
  - + 40%, - 20%
  - BFD , Process Modification
- 2. Study Estimate / Major Equipment
  - + 30%, - 20%
  - PFD , Cost Chart

Types of Capital Cost Estimate cont.

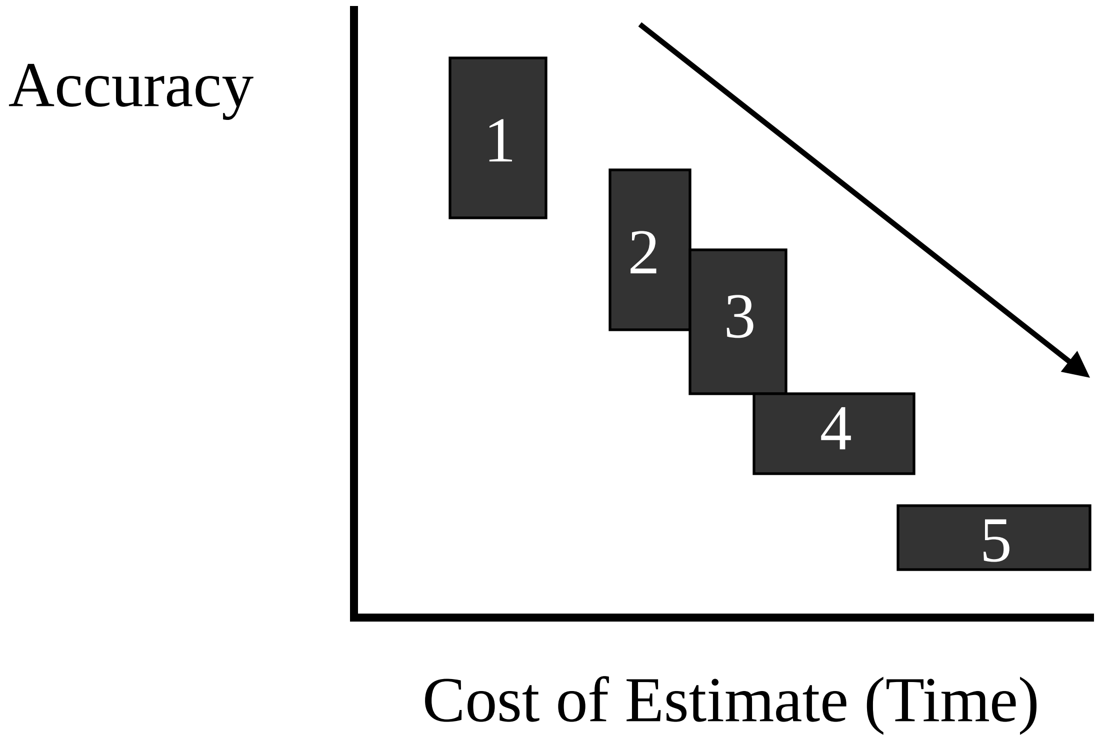
- 3. Preliminary Design (Scope) Estimate
  - + 25%, - 15%
  - PFD , vessel sketches , equip. diagrams
- 4. Definitive (Project Control) Estimate
  - + 15%, - 7%
  - PFD , P&ID, all vessel sketches, equip. diagrams, preliminary isometrics

Types of Capital Cost Estimates cont.

- Detailed (Firm or Contractors) Estimate
  - + 6%, - 4%
  - Everything included – ready to go to construction phase
- Estimate low so actual cost will be high (+)
- Estimate high so actual cost will be low (-)

Why is + # > - #.?

Cost of Estimate – See Also Table 7.2



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
  - Reasonably accurate
    - beware of large extrapolation
    - beware of foreign currency
- Use cost estimating charts and scale for time
  - Less accurate
  - Convenient

Effect of Size (Capacity)

$$\frac{C_a}{C_b} = \left(\frac{A_a}{A_b} \right)^n \qquad (7.1)$$

Cost Exponent

Cost

Equipment Cost
Attribute - Size

$$C_a = K A_a^{\ n} \qquad (7.2)$$

where $K = \dfrac{C_b}{A_b^{\ n}}$

Effect of Size (Capacity) cont.

- n = 0.4 – 0.8 Typically
- Often n ~ 0.6 and we refer to Eq.(7.1) 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 1

- A New Plant Ordered a Set of Floating Head Heat Exchangers (Area = 100 m^2) cost $92,000. What would cost be for a heat exchanger for similar service if area = 50 m^2 and n = 0.44 ?

Example 1 - Solution

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

$$92{,}000\left(\frac{50}{100}\right)^{0.44} \longrightarrow C_a = \$67{,}816$$

100 m^2 Exchanger is not twice as expensive as a 50 m^2 exchanger

$\Rightarrow$ Economy of Scale

Effect of Time

- Time increases – cost increases (inflation)
- Inflation is measured by cost indexes - Figure 7.3
  - 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 7.5

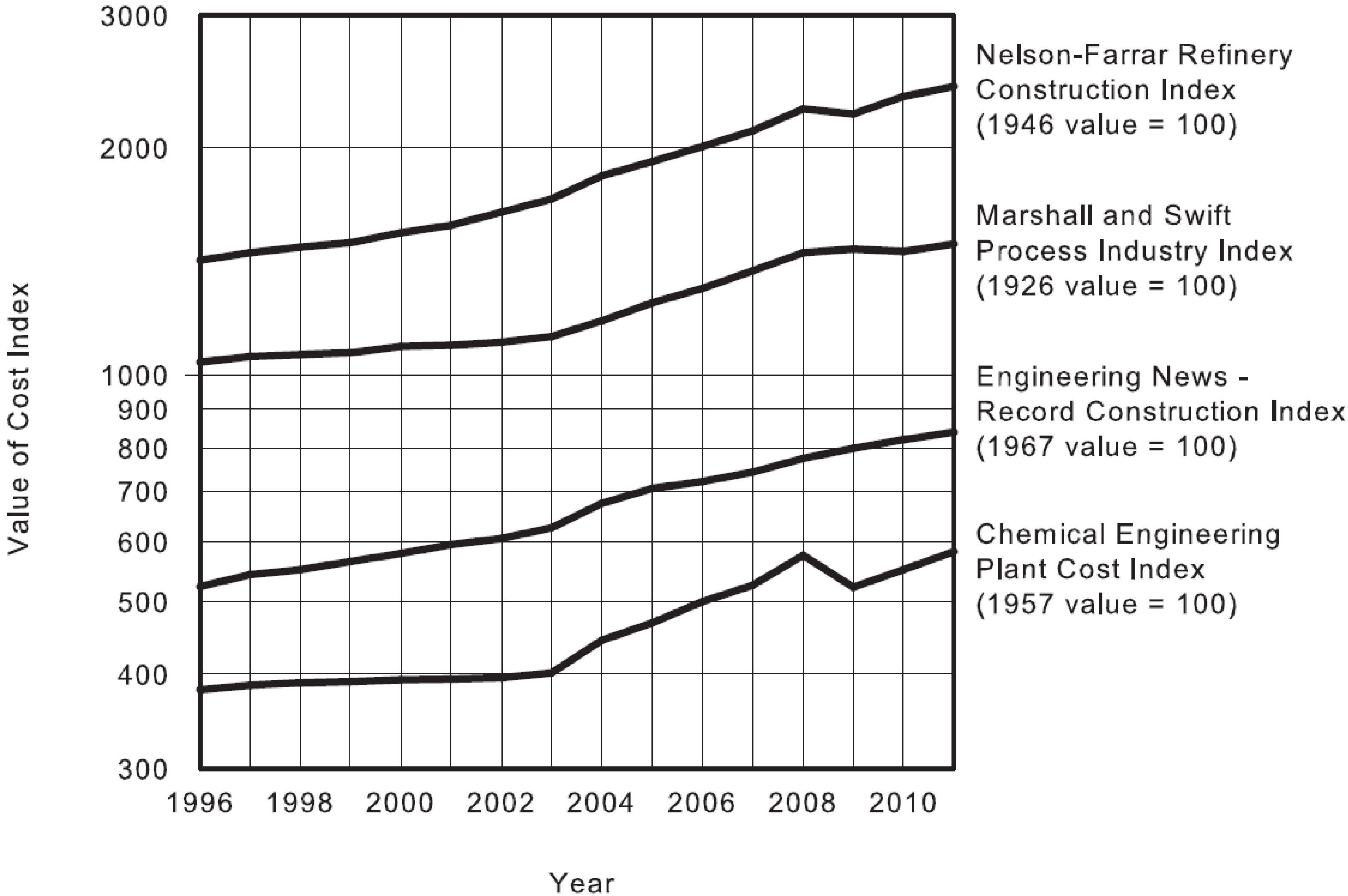


Figure 7.3 The Variations in Several Commonly Used Cost Indexes over the Past 15 Years (1996–2011)

Table 7.5: The Basis for the Chemical Engineering Plant Cost Index

Components of Index	Weighting of Component (%)
Equipment, Machinery and Supports: (a) Fabricated Equipment (b) Process Machinery (c) Pipe, Valves, and Fittings (d) Process Instruments and Controls (e) Pumps and Compressors (f) Electrical Equipment and Materials (g) Structural Supports, Insulation, and Paint	 37 14 20 7 7 5 10 <u>100</u> 61% of total
Erection and Installation Labor	22
Buildings, Materials, and Labor	7
Engineering and Supervision	10
Total	<u>100</u>

Equation for Time Effect

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

- *C* = Cost
- *I* = Value of cost index
- 1,2 = Represents points in time at which costs required or known and index values known

Example 2

- Cost of vessel in 1993 was 25,000, what is estimated cost today (Oct 2010 – CEPCI = 582)?

Example 2 - Solution

$$C_{now} = C_{1993}\left(\frac{I_{now}}{I_{1993}}\right) = 25{,}000\left(\frac{582}{359}\right) = \$40{,}529$$

Example 3 - 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 m^2	130 m^2
Time=	1990	1995
Cost =	17 K	24 K
I =	358	381

Example 3 (cont'd)

- What is the Cost of a 80 m^2 Heat Exchanger Today ? (I = 582)

Example 3 - Solution

- Must First Bring Costs to a Common Time

A = 70 m^2 $$C_a(2010) = 17{,}000\left(\frac{582}{358}\right) = \$27{,}637$$

A = 130 m^2 $$C_a(2010) = 24{,}000\left(\frac{582}{381}\right) = \$36{,}661$$

Example 3 - Solution (cont'd)

$$C = KA^n$$

$$27{,}637 = K(70)^n$$

$$36{,}661 = K(130)^n$$

$$n = \frac{\ln(36{,}661) - \ln(27{,}637)}{\ln(130) - \ln(70)} = 0.4564$$

$$K = \frac{C}{A^n} = \frac{27{,}637}{70^{0.4564}} = \$3{,}975$$

$$C = 3{,}975(80)^{0.4564} = \$29{,}374$$

Total Cost of Plant

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

Installed Cost of Equipment (Table 7.6)

- 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 7.6 (cont'd)

- 3. Contingency and Fee
  - Contingency
  - Contractor fee

- 4. Auxiliary Facilities
  - Site development
  - Auxiliary buildings
  - Off-sites and utilities

Lang Factors

- Table 7.7
- 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

Lang Factors (cont'd)

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

Total Module Cost

Purchased Cost of Major Equipment
From Preliminary PFD
(Pumps, Compressors, vessels, etc.)

Module Factor Approach

- Table 7.8
  - 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)

$$C_p = C_p^o F_p F_M$$

Module Factor Approach – Pressure Factors

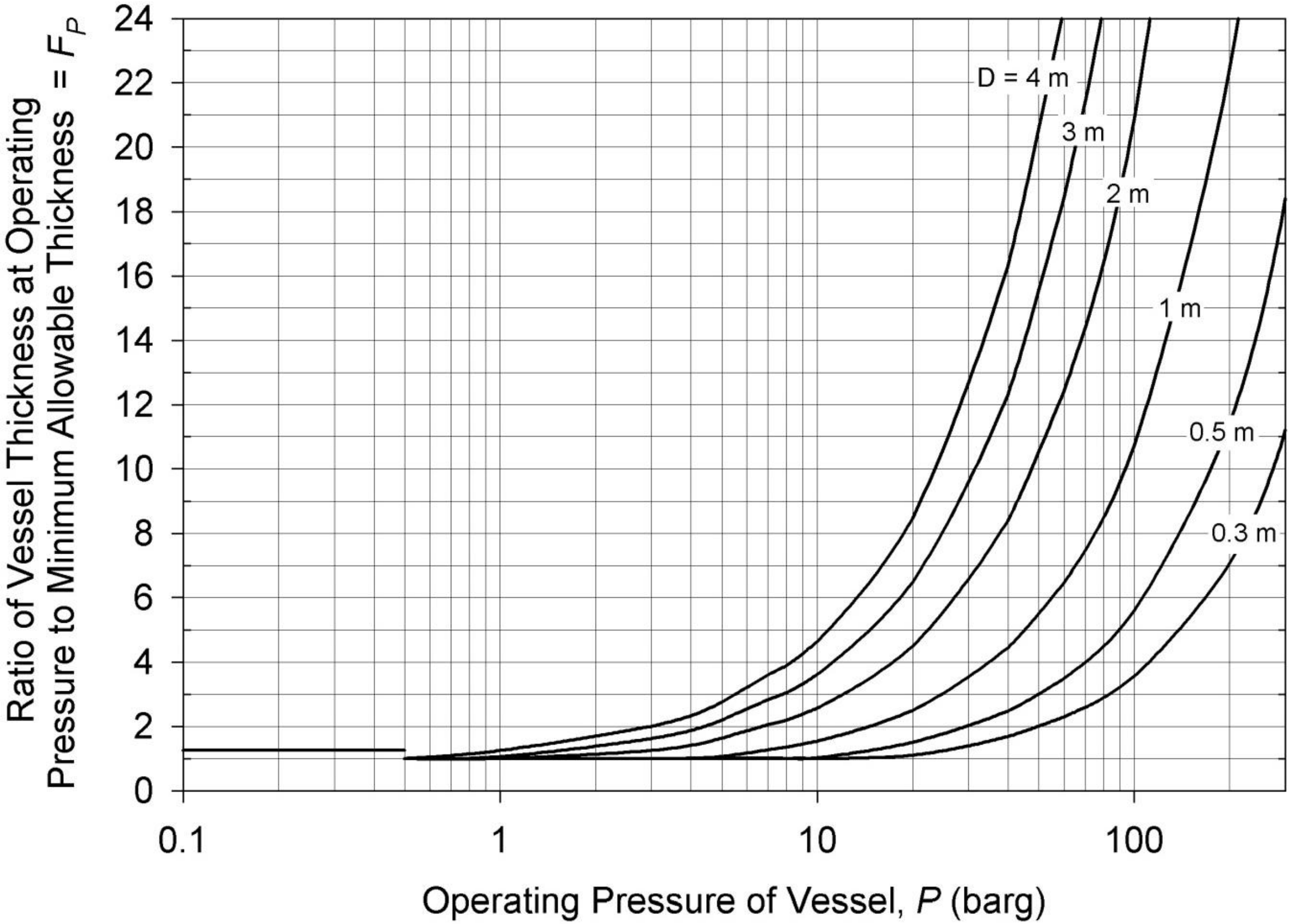


Figure 5.6: Pressure Factors for Carbon Steel Vessels

Module Factor Approach – Pressure Factors

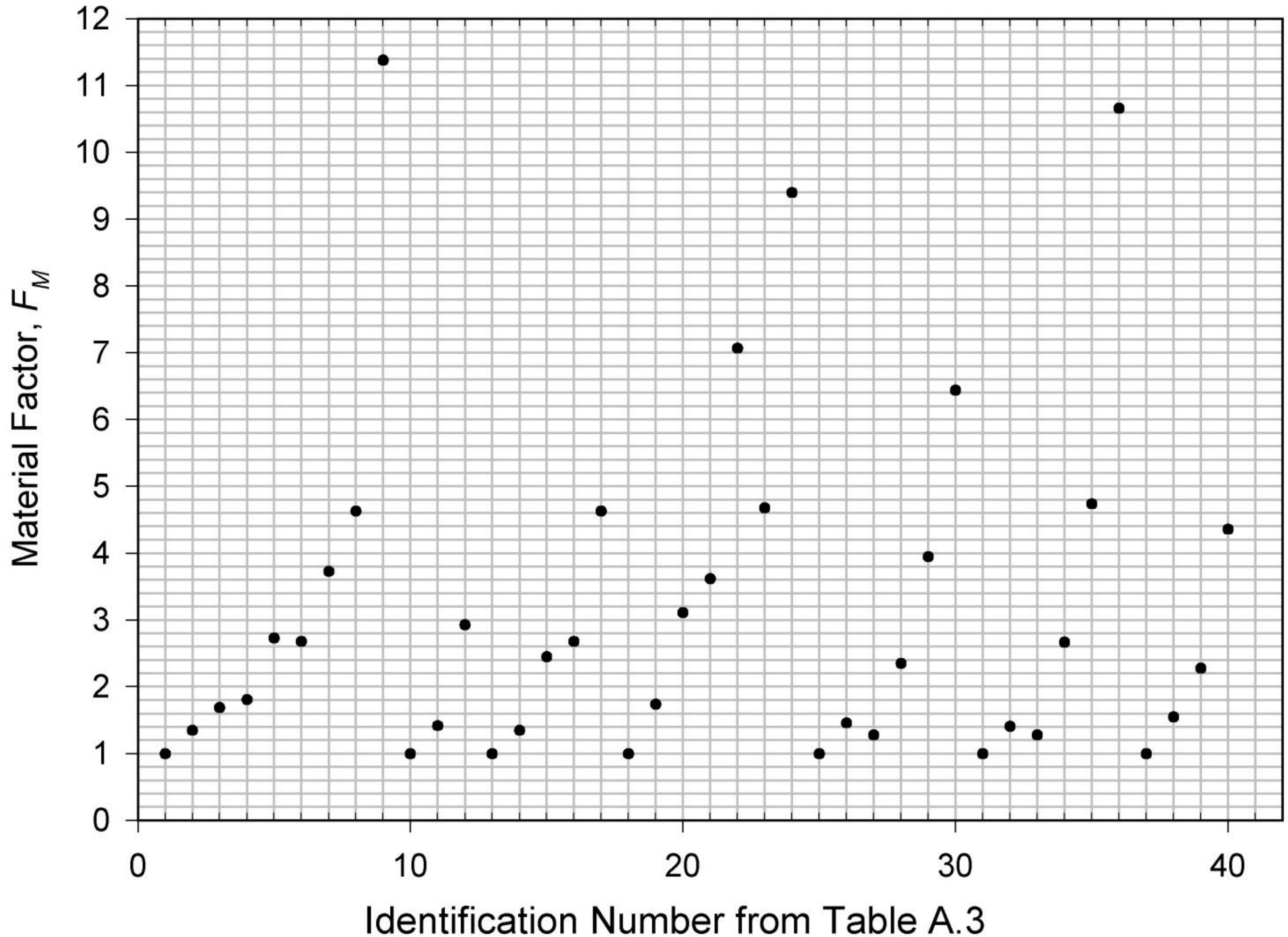


Figure A.8: Material Factors for Equipment in Table A.3 (averaged data from references [1, 2, 3, 6, 7, and 8])

Illustrative Example

- Compare Costs for

  Shell-and-tube heat exchanger in 2011 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 (all costs in $1000)

$C_p = C_p^o F_p F_m$ $\quad F_m = 2.73,\ F_m = 1.383$

P	MOC	C_p^o	C_p	C_{BM}^o	C_{BM}
1 bar	CS	36.6	36.6	120.7	120.7
1 bar	SS	36.6	99.9	120.7	225.8
100 bar	CS	36.6	50.6	120.7	143.8
100 bar	SS	36.6	138.2	120.7	289.3

Bare-Module and Total-Module Costs

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

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

Grass-Roots Costs

- GR – grass-roots cost includes costs for auxiliary facilities

$$C_{GR} = 0.50 \sum_{\text{all equip}} C^{o}_{BM} + C_{TM}$$

- Use base BM costs in GR cost (1 atm and CS) since auxiliary facilities should not depend on pressure or M.O.C.

Materials of Construction

- Very important
- Table 7.9 – rough guide
- Perry’s – good source

Capcost

- Calculates costs based on input
- CEPCI – use current value of 600 or latest from *Chemical Engineering*
- Program automatically assigns equipment numbers