Chapter 5
Lecture # 2-4

- Estimating Purchased Equipment Costs
  - **Effect of Capacity.**
  - **Effect of time .**

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

Estimating Purchased Equipment Costs

Effect of 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

Estimating Purchased Equipment Costs

Effect of Capacity

$$C_a = K A_a^{\,n}$$

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

Estimating Purchased Equipment Costs

Effect of Capacity

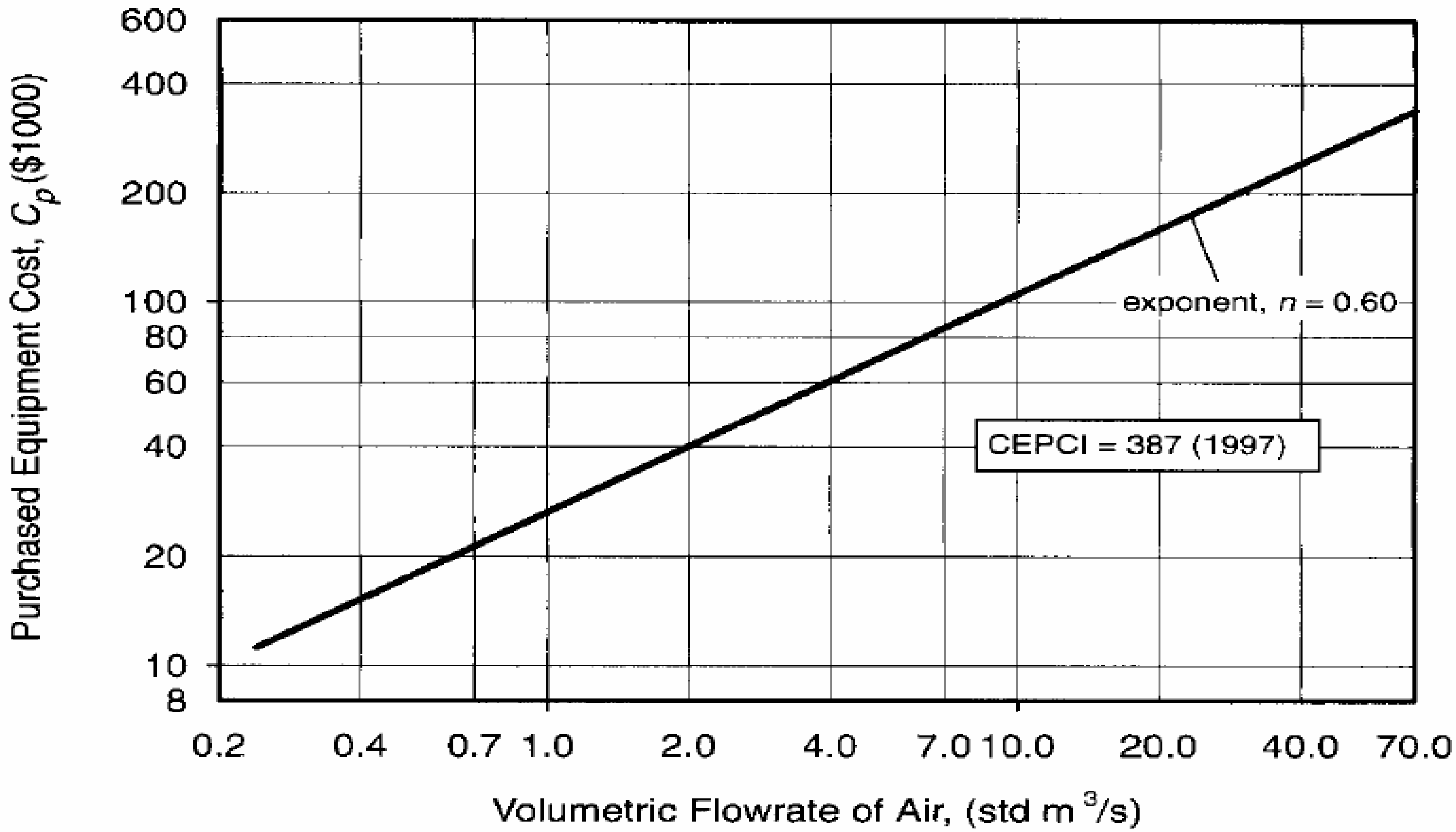

Figure 5.1 Purchased Cost of a Centrifugal Air Blower (Data from Reference [3])

Estimating Purchased Equipment Costs

Effect of Capacity

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

Estimating Purchased Equipment Costs

Effect of Capacity

- *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

Estimating Purchased Equipment Costs

Effect of Capacity

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.

Estimating Purchased Equipment Costs

Effect 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:

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

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

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

Estimating Purchased Equipment Costs

Effect of Capacity

Another way of looking at economy of scale

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

Estimating Purchased Equipment Costs

Effect of Capacity

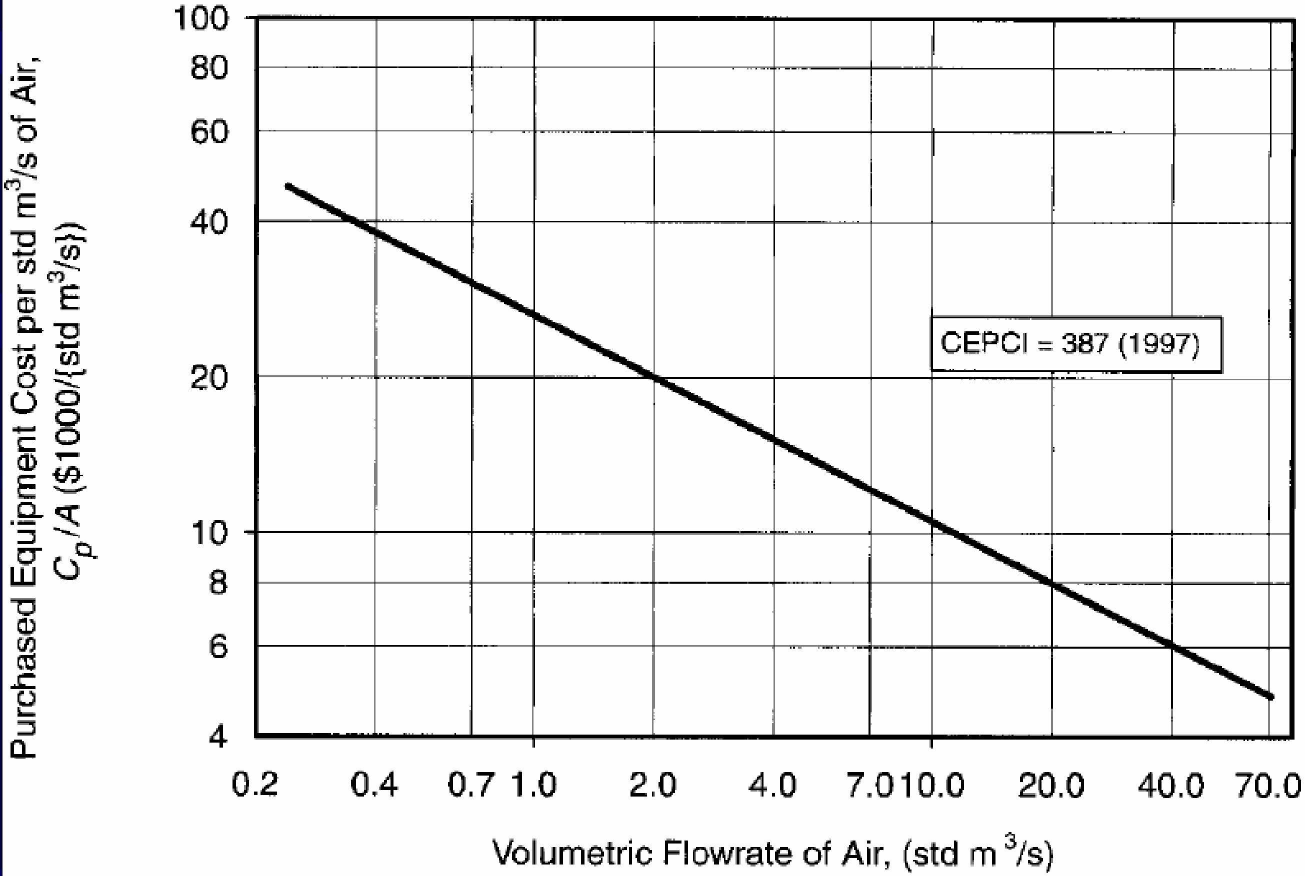

Figure 5.2 Purchased Cost per Unit of Flowrate of a Centrifugal Air Blower (Data from Reference [3])

Estimating Purchased Equipment Costs

Effect of Capacity

Economy of Scale

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

Estimating Purchased Equipment Costs

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

Estimating Purchased Equipment Costs

Effect of Time

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

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

Estimating Purchased Equipment Costs

Effect of Time

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

Estimating Purchased Equipment Costs

Effect of Time

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

Estimating Purchased Equipment Costs

Effect of Time

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%

Estimating Purchased Equipment Costs

Example

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**

What is the Cost of a 80 m^2 Heat Exchanger In 2003 ? (*I* = 402)

Estimating Purchased Equipment Costs

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

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

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

Estimating Purchased Equipment Costs

$$C = KA^n$$

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

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

Estimating Purchased Equipment Costs

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

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

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