Al-Mustaqbal University College
Chem. Eng. Petroleum Industries Dept.

Chem. Eng. Economics

4th Stage

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Lecture 4

2. Study Estimates

The information needed to prepare a study estimate includes a project scope, preliminary material and energy balances, preliminary flowsheets, rough sizes of equipment, rough quantities of utilities, rough sizes of building and structures.

- Lang Factor Method (Factorial Method)

Lang, developed a method for obtaining quick estimates of the capital investment based upon information gathered on 14 processing plants of various sizes and types. He recommended that the delivered equipment cost be multiplied by a factor based upon the type of processing plant to obtain the fixed capital investment. These factors include process equipment, instrumentation and automatic control equipment, piping, insulation, electrical, engineering costs, etc., but do not include a contingency (emergency) factor. The Lang factor method has a tendency to produce high results. The factors are found in Table 1. If C= Fixed cost , LF = Lang factor, and $\sum Ceq$ is the sum of all delivered costs of all major items in the flow sheet, Ceq=Cost of equipment then;

$$C = LF * \sum Ceq$$

Table 1 Lang Factors

Type of plant	Factor
Solids processing	3.10
Solids–fluid processing	3.63
Fluid processing	4.74

Example 1

A small fluid processing plant is considered for construction adjacent to a larger operating unit at a large plant site. The present delivered equipment costs are as follows:

Equipment	Delivered cost
Distillation tower	\$500,000
Trays and internals for tower	435,000
Receivers	320,000
Accumulator drum	175,000
Heat exchangers	620,000
Pumps and motors	215,000
Automatic control equipment	300,000
Miscellaneous equipment	150,000

Estimate the battery-limits fixed capital investment, assuming a 15% contingency factor.

Solution:

Sum of the delivered equipment cost = \$2,715,000

Because this is a fluid processing plant, the Lang factor is 4.74.

Battery – limits fixed capital investment = (\$2,715,000)(4.74)(1.15)

= \$14,799,000, or \$14,800,000

ESTIMATION OF PURCHASED EQUIPMENT COSTS for Common Chemical Processes Equipment

The cost of purchased equipment is the basis of several predesign methods for estimating capital investment. ***Sources*** of equipment prices, methods of adjusting equipment prices for capacity, and methods of estimating auxiliary process equipment are therefore essential to the estimator in making reliable cost estimates.

The various types of equipment can often be divided conveniently into

1. processing equipment,
2. raw-materials handling and storage equipment
3. finished-products handling and storage equipment.

Equipment Cost Data

Equipment cost data are stated as purchased, delivered, or installed costs. Purchased cost is the price of the equipment FOB (free on board) at the manufacturer's plant. Delivered cost is the price of the equipment plus delivery charges to the purchaser's plant FOB. installed cost. This means the equipment item, for instance, a centrifugal pump has been purchased, delivered, uncrated, and placed on a foundation in an operating department but does not include piping, electrical, insulation costs. Perhaps a more accurate term would be set-in-place cost. *Equipment cost data are correlated as a function of equipment parameters.* This correlation technique is used whether the costs are purchased, delivered, or installed equipment costs. Typical capacity parameters are presented in Table 2. ***Estimating Equipment Costs by Scaling*** is often necessary to estimate the cost of a piece of equipment when cost data are not available for the particular size or capacity involved. Predictions can be made by using the power relationship known as the six-tenths factor rule, if the new piece of equipment is similar to one of another capacity for which cost data are available. According to this rule, if the cost of a given unit b at one capacity is known, the cost of a similar unit **a** with **X** times the capacity of the first is $X^{0\ 6}$ times the cost of the initial unit. The equation above is known as the **six-tenths or 0.6 rule**. The preceding equation indicates that a log-log plot of capacity versus cost for a given type of equipment should be a straight line with a slope equal to 0.6. Figure 1 presents a plot of this sort for shell-and-tube heat exchangers. The application of the 0.6 rule of thumb for most purchased equipment is, however, an oversimplification, since the actual values of the cost capacity exponent vary from less than 0.3 to greater than 1.0, as shown in Table3. Because of this, the 0.6 power should be used only in the absence of information.

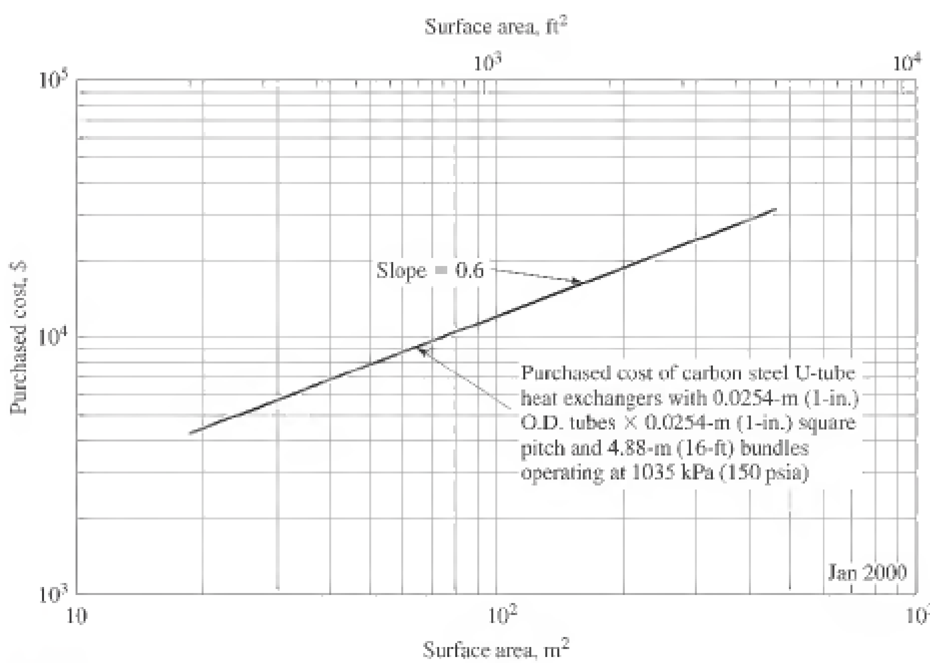

Figure 1 Application of "six-tenth factor" rule to costs for U-tube heat exchangers

Table 2 Cost-capacity parameters

Equipment	Capacity factors[b]
Heat exchangers	Surface area, number of passes, pitch, type head, pressure
Tanks, receivers	Volume, pressure, vertical or horizontal
Pumps	Head, capacity, type of pump, motor size
Blowers, fans	Flow rate, pressure, motor size
Compressors	Capacity, discharge pressure, number of stages, motor size
Towers	Height, diameter, internals (plates or packing), operating pressure
Filters	Filter area, pressure, type
Dust collectors	Flow rate, pressure, type
Wet scrubbers	Flow rate
Cyclone separator	Flow rate, type
Cooling towers	Capacity, approach temperature
Conveyors	Length, type
Dryers	Drying area, or volume
Evaporators	Heat exchanger area, type
Furnaces	Heat transferred, type
Mills	Mill capacity, type
Reactors	Reactor volume, pressure, type

Example 2

Recently a cast iron leaf pressure filter with 100 ft^2 was purchased for clarifying an inorganic liquid stream for $15,000. In a similar application, the company will need a 450 ft^2 cast iron leaf pressure filter. The size exponent for this type filter is 0.6. Estimate the purchased price of the 450 ft^2 unit.

$$\text{Cost}_{450} = \text{cost}_{100}\left(\frac{\text{capacity}_{450}}{\text{capacity}_{100}}\right)^{0.6}$$

$$= \$15,000\left(\frac{450}{100}\right)^{0.6} = \$15,000(2.47) = \$37,050$$

Table 3 Typical exponents for equipment cost as a function of capacity

Equipment	Size range	Exponent
Blender, double cone rotary, carbon steel (c.s.)	1.4–7.1 m^3 (50–250 ft^3)	0.49
Blower, centrifugal	0.5–4.7 m^3/s (10^3–10^4 ft^3/min)	0.59
Centrifuge, solid bowl, c.s.	7.5–75 kW (10–10^2 hp) drive	0.67
Crystallizer, vacuum batch, c.s.	15–200 m^3 (500–7000 ft^3)	0.37
Compressor, reciprocating, air-cooled, two-stage, 1035-kPa discharge	0.005–0.19 m^3 (10–400 ft^3/min)	0.69
Compressor, rotary, single-stage, sliding vane, 1035-kPa discharge	0.05–0.5 m^3/s (10^2–10^3 ft^3/min)	0.79
Dryer, drum, single vacuum	1–10 m^2 (10–10^2 ft^2)	0.76
Dryer, drum, single atmospheric	1–10 m^2 (10–10^2 ft^2)	0.40
Evaporator (installed), horizontal tank	10–1000 m^2 (10^2–10^4 ft^2)	0.54
Fan, centrifugal	0.5–5 m^3/s (10^3–10^4 ft^3/min)	0.44
Fan, centrifugal	10–35 m^3/s (2×10^4–7×10^4 ft^3/min)	1.17
Heat exchanger, shell-and-tube, floating head, c.s.	10–40 m^2 (100–400 ft^2)	0.60
Heat exchanger, shell-and-tube, fixed sheet, c.s.	10–40 m^2 (100–400 ft^2)	0.44
Kettle, cast-iron, jacketed	1–3 m^3 (250–800 gal)	0.27
Kettle, glass-lined, jacketed	0.8–3 m^3 (200–800 gal)	0.31
Motor, squirrel cage, induction, 440-V, explosion-proof	4–15 kW (5–20 hp)	0.69
Motor, squirrel cage, induction, 440-V, explosion-proof	15–150 kW (20–200 hp)	0.99
Pump, reciprocating, horizontal cast-iron (includes motor)	1×10^{-4}–6×10^{-3} m^3/s (2–100 gpm)	0.34
Pump, centrifugal, horizontal, cast steel (includes motor)	4–40 $m^3/s\cdot kPa$ (10^4–10^5 gpm·psi)	0.33
Reactor, glass-lined, jacketed (without drive)	0.2–2.2 m^3 (50–600 gal)	0.54
Reactor, stainless steel, 2070-kPa	0.4–4.0 m^3 (10^2–10^3 gal)	0.56
Separator, centrifugal, c.s.	1.5–7 m^3 (50–250 ft^3)	0.49
Tank, flat head, c.s.	0.4–40 m^3 (10^2–10^4 gal)	0.57
Tank, c.s., glass-lined	0.4–4.0 m^3 (10^2–10^3 gal)	0.49
Tower, c.s.	5×10^2–10^6 kg (10^3–2×10^6 lb)	0.62
Tray, bubble cap, c.s.	1–3 m (3–10 ft) diameter	1.20
Tray, sieve, c.s.	1–3 m (3–10 ft) diameter	0.86

Cost indexes

Most cost data which are available for immediate use in a preliminary or predesign estimate are based on conditions at some time in the past. Because prices may change considerably with time due to changes in economic conditions, some method must be used for updating cost data applicable at a past date to costs that are representative of conditions at a later time.? This can be done by the use of cost indexes.

A cost index is merely an index value for a given point in time showing the cost at that time relative to a certain base time. If the cost at some time in the past is known, the equivalent cost at the present time can be determined by multiplying the original cost by the ratio of the present index value to the index value applicable when the original cost was obtained.

$$\text{Present cost} = \text{original cost}\left(\frac{\text{index value at present time}}{\text{index value at time original cost was obtained}}\right)$$

Cost indexes can be used to give a general estimate, but no index can take into account all factors, such as special technological advancements or local conditions. The common indexes permit fairly accurate estimates if the time period involved is less than 10 years.

Many different types of cost indexes are published regularly. Some of these can be used for estimating equipment costs; others apply specifically to labor, construction, materials, or other specialized fields. The most common of these indexes are the ***Marshall and Swift all-industry and process-industry equipment indexes,*** the ***Engineering News-Record construction index,*** the ***Nelson-Farrar refinery construction index,*** and the ***Chemical Engineering plant cost index.*** Table 1 presents a list of values for various types of indexes.

Marshall and Swift Cost Index (M&S): Originally known as the Marshall and Stevens Index, was established in the base year, 1926, with a value of 100. The index is reported as a composite of two major components, namely, a process-industry equipment average and all industry equipment average. The process-industry equipment average is based upon selected process industries. The percentages used for this average are cement, 2; chemicals, 48; clay products, 2; glass, 3; paint, 5; paper, 10; petroleum products, 22; and rubber, 8. Related industries such as electric power, mining and milling, refrigeration, and steam power are also included. The M&S Index tracks equipment costs and installation labor, thereby reflecting changes in installed equipment costs. The all-industry average is a simple arithmetic average of individual indexes for 47 different types of industrial, commercial, and housing equipment. Included in the Marshall and Swift Index is a correction for changes in labor productivity. This index is found in each issue of Chemical Engineering, on the pages entitled Economic Indicators [20].

Chemical Engineering Index (CE): It was established in the early 1960 s using a base period of 1957–1959 as 100. The index consists of four major components:

Component	Weight factor, %
Equipment, machinery, and supports	61
Construction labor	22
Building materials and labor	7
Engineering and supervision	10
Total	100

The dominant components, equipment, machinery, and supports consist of the following subcomponents:

Subcomponent	Weight factor, %
Heat exchangers and tanks	37
Process machinery	14
Pipe, valves, and fittings	20
Process instruments	7
Pumps and compressors	7
Electrical equipment	5
Structural supports and miscellaneous	10
Total	100

The CE Index is updated monthly and reflects short-term changes in chemical industry plant costs. In 1982, a correction was introduced to reflect changes in labor productivity; in January 2002, it was revised by updating the components making up the index and in revising the productivity factor.

Nelson–Farrar Indexes (NF): The Nelson–Farrar Indexes were originally known as the Nelson Refinery Construction Indexes. These indexes are calculated and published in the first issue each month of the Oil and Gas Journal. The original indexes were established in 1946 with a value of 100 and are heavily weighted towards the petroleum and petrochemical industries. The NF Indexes are based upon the following components: Pumps, compressors, etc. Heat exchangers Electrical Machinery, Miscellaneous equipment, Internal combustion engines, Materials, Instruments, Labor. A more detailed breakdown of each of the above components may be found in annual index summaries and how the index was determined may be found in the November 29, 1978 issue of the Oil and Gas Journal. This index does account for changes in labor productivity.

Engineering News Record Index (ENR). The Engineering News Record Index is the oldest cost index. It was established in 1913 with an arbitrarily set value of 100 and has been adjusted twice as a result of inflation in 1926 and in 1949. The 1913 index today (late 2001) is 6391. The ENR Index is more suitable for the general construction business than for the CPI. It is based upon labor craft rates, the cost of lumber, steel and other construction materials based upon a 46-city average. This index does not account for adjustment in labor productivity, and, therefore has a tendency to increase more rapidly than other indexes. The ENR Index may be found weekly in Engineering News Record.