Chapter VI

Economic Analysis Of Heat Exchanger Networks

This chapter is concerned with the preliminary estimate of economic performance for HENs by calculating the annual costs of a new project or the payback period for a retrofit project. Since the final selection of a HEN configuration is usually made by comparing the annual costs or payback periods of possible HENs, the HEN which has the minimum total annual cost or the shortest payback time, will be selected.

6.1 Capital Cost

Since the major contribution to the capital costs of each HEN design are the heat exchanger cost, piping cost and installation cost, whereas investment costs for other items are more or less the same. Therefore we shall here consider the sum of the heat exchanger cost, piping cost and installation cost as the total capital cost of interest in comparing the economic performance of each HEN.

6.1.1 Heat exchanger cost

The most reliable method of determining process equipment costs is to obtain firm bids from approved fabricators or suppliers. A second best in reliability is to rely on cost data from the file of past purchase orders. When used to price new equipment, past purchaseorder prices must be corrected using the current cost index, an index value showing the cost at a point of time relative to a certain base time. The equivalent cost at the present time can be determined by multiplying the old pricing cost by the ratio of present index value to the index value appplicable when the old cost was obtained.

$$\text{present cost} = \text{original cost} * \frac{\text{index value at present time}}{\text{index value when original cost was obtained}} \quad \ldots.(6\text{-}1)$$

In this thesis the second method is used for calculating heat exchangers costs. It is assumed that the floating head type shell and tube heat exchanger at design pressure of 14 bars is used for all units which required heat transfer areas in excess of 100 square feet. Below that double pipe heat exchangers are to be used.

The cost of the floating head heat exchanger in 1958 which has an index value of 100, and that of the double-pipe heat exchanger in 1979, which has an index value of 273.7, are used as reference (original) cost. The reference costs of these two type of heat exchangers are shown respectively in Figure 6-1(a) and (b), which can be written in emprical formulas as

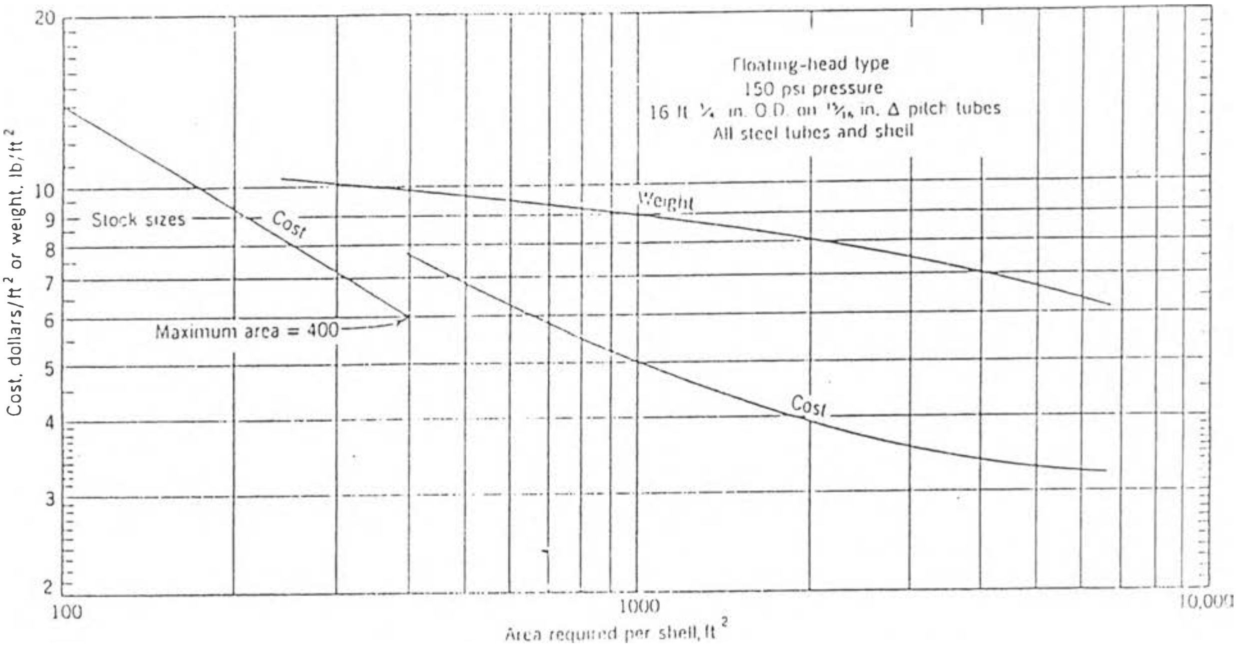
$$C = 43 + 10.93\mathrm{Ln}(A) \qquad A < 100 \quad \ldots\ldots\ldots(6\text{-}2)$$

$$C = 2.334A^{0.389} \qquad 100 < A < 400 \quad \ldots.(6\text{-}3)$$

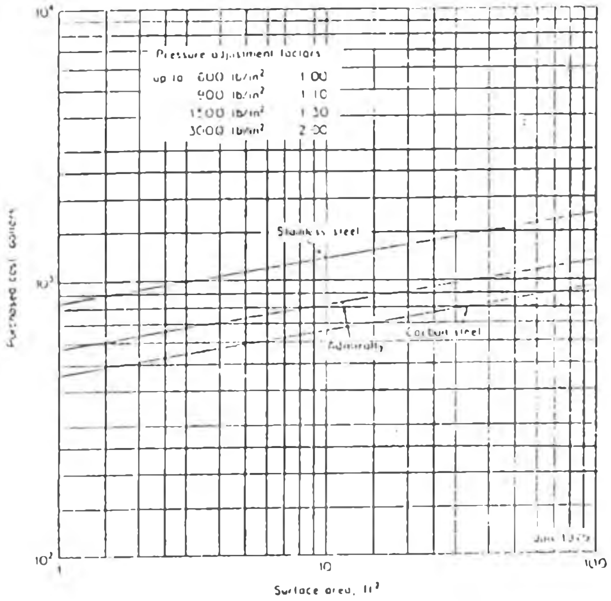
$$C = 1912 + 2.9764A \qquad A > 400 \quad \ldots\ldots\ldots(6\text{-}4)$$

where: C = original cost of heat exchanger, US$

A = heat transfer area, ft^2



(a) Floating head type [36: 371]



(b) double-pipe type [37: 671]

Figure 6-1 Reference costs of heat exchangers

Using the above correlations, the present costs of heat exchangers can readily be calculated if the present cost index and the required heat transfer area are known. Usually, the present cost index is available from the Economic Indexs published by some chemical engineering journals whereas the required heat transfer area is calculated from the given data (see Appendix A).

6.1.2 Piping cost and installation cost

A simple and reasonable method for obtaining these two predesign cost estimates is based on the approximate percentage, or certain factor, that is applicable to a particular plant or process under consideration. For example, the piping cost typically ranges from 10 to 80 % of the purchased-equipment cost. Installation, including insulation and painting typically ranges from 25 to 55 % of the purchased-equipment cost [37: 207]. Anyway, it should be realized that the given value can vary depending on many factors, such as plant location, type of process, complexity, etc.

In this analysis the piping and installation costs are assumed to be proportional to the total heat exchanger cost.

6.2 Calculation of Annual Cost

Annualised investment cost can be calculated from equation (6-5)

$$R = P * \frac{I * (1+I)^N}{(1+I)^N - 1} \qquad \ldots\ldots\ldots\ldots\ldots(6\text{-}5)$$

Here: P = total investment cost

R = annualized cost, equal payments

I = compound interest rate

N = working life of the heat exchanger

The total annualized cost is the sum of annualized investment cost and annual expenditure for utilities.

6.3 Calculation of payback period

To calculate payback period, equation (6-5) can be rewritten as

$$N = \frac{-\,\mathrm{Ln}(R - P * I)}{\mathrm{Ln}(I + 1)} \qquad \ldots\ldots\ldots\ldots\ldots(6\text{-}6)$$

In this case N represents the payback period with consideration for interest and R represents the annual savings which is the difference in the utility expenses between the existing and the retrofited processes.

6.4 Example of Economic Analysis

The network shown in Figure 5.5(d), of which the matching results are shown in Table 6-1, will be used to illustrate the economic analysis procedure. Saturared steam at 300 °C , which has unit cost of 60 US$/kW.yr, is used as hot utility for cold stream no. 1. It is estimated that the useful life of all the exchangers is 15

Table 6-1. Matching results for the network shown in Figure 5.5(d).

unit no.	stream pair	load (kW)	THin (°C)	THout (°C)	TCin (°C)	TCout (°C)
1	H2-C1	1014.6	141.9	65.6	37.8	126.9
2	H1-C2	1506.5	211.7	121.1	65.6	182.2
3	H2-C3	830.0	204.4	141.9	93.3	157.0
4	H1-C3	617.6	248.9	211.7	157.0	204.4
5	St-C1	883.0	300.0	300.0	126.9	204.4

years, and the loan is obtained at nominal annual interest rate of 16 percent compounded.

Solution

(1) Calculation of heat transfer areas.

Assume that all the units have the same overall heat transfer coefficient of 0.8 kW/(M^2 °C). Hence from the rate equation

$$Q = U * A * DTLM$$

where Q = heat load

A = heat transfer area

U = overall heat transfer coefficient

DTLM = log mean temperature difference

the required area for each unit is calculated and summarized in Table 6-2.

Table 6-2. Heat transfer areas requied

unit no.	U (kW/m^2/°C)	area (m^2)
1	.80	61.012
2	.80	45.744
3	.80	21.609
4	.80	15.613
5	.80	8.455

(2) Caculation of heat exchanger costs.

Cost of heat exchanger no.1:

The reference cost of the exchanger is calculated using eq.(6.4)

Reference H/E cost = 2.9764 * A + 1912
= 2.9764 * (61.012 * 10.76) + 1912
= 3866.69 US$

Since the reference cost index is 100 and the present cost index is 350, hence from eq.(6-1)

Present cost of the H/E = 350 * 3866.69 / 100
= 13533.42 US$

The present costs of the other exchangers are calculated in the same manner, and the results are summarized in Table 6-3.

Table 6-3 Present costs of heat exchangers

unit no.	area (m^2)	reference cost (US$)	present cost (US$)
1	61.012	3,866.7	13,533.4
2	45.744	3,377.5	11,821.3
3	21.609	1,944.1	6,804.2
4	15.613	1,713.2	5,996.2
5	8.455	33.8	118.3
		Total	38,273.4

(3) Calculation of annual costs.

It is assumed that the installation, piping, contingency costs amount to 30, 30 and 5 percent of the basic heat exchanger cost, respectively. Hence

Basic exchanger cost	=	38,273.50	
Installation cost	=	11,482.05	
Piping cost	=	11,482.05	
Contingency	=	1,913.67	
Total capital, P	=	63,151.27	US$
Interest rate, I	=	16 %	

Working life of exchangers, N = 15 years

Annualized capital, R

From equation (6-5)

$$R = P * \frac{I * (1+I)^{N}}{(1+I)^{N}-1}$$

$$= \frac{63151.27 * 0.16 * (1 + 0.16)^{15}}{(1 + 0.16)^{15} - 1}$$

$$= 11,327 \quad \text{US\$}$$

Annual expenditure for utility = 883 kW * 60 US$/kW

= 52,980 US$

Total annual cost = 11,327 + 52,980 = 64,307 US$