COST ASPECTS - MSF

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Contents

1. Introduction

This section describes the cost aspects of multistage flash (MSF) systems. The development of MSF costs, both construction and operation, are, like other processes, dependent upon the parameters that are used for calculation. Plants of the same capacity and type but with different parameters can therefore, have very dissimilar costs.

Some of these factors include the following.

(a) Plant size (capacity).
(b) Plant performance ratio.
(c) Blending the product water with another source.
(d) The plant components included in the cost estimate.
(e) Concentrate disposal.
(f) Intake type.
(g) Pre- and post-treatment requirements.
(h) Indirect costs.

The first seven items in the above list are generally known as "Site-specific factors". That is, their costs are dependent upon the site chosen for construction of the facility. The last item in the above list is the method in which indirect costs are developed for the cost estimate. There are many different methods that can be used to present indirect cost factors.

The effect each of these factors has on the cost estimate are presented below.

2. Purpose

The purpose of this section is to determine how the above items impact on the construction and operating costs that are presented for MSF systems. This is accomplished by first presenting the costs for a specific "reference design". Then, using this design, compare the costs based on changes in the site-specific factors and indirect costing methods.

3. Reference Design

In order to determine how costs are affected by these factors, a reference design is proposed. The process flow sketch is given in Figure 1. The design parameters are given in Table 1, along with the economic basis.

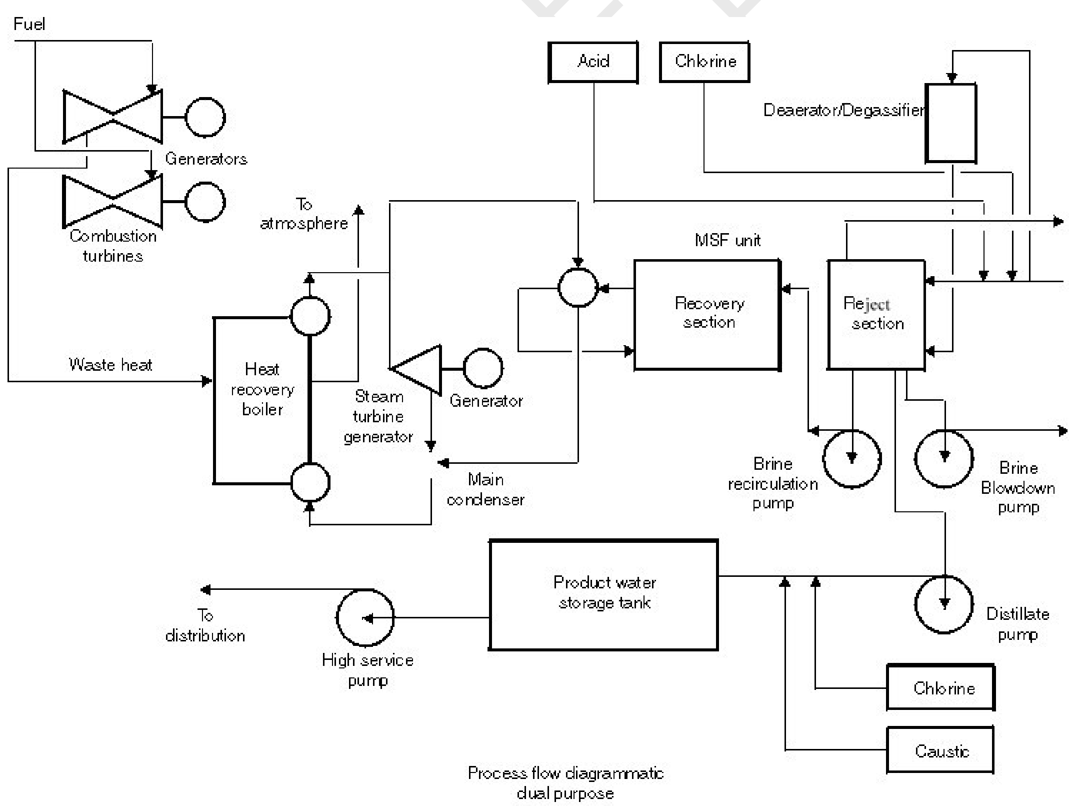

Figure 1. MSF schematic - recirculation.

Some of the important factors are as follows.

(a) Plant capacity of 1.0 mgal day^{-1}.
(b) No blending of the raw water is carried out.
(c) The feedwater to be treated is standard seawater with a concentration of 34 500 mg l^{-1}.
(d) One train is used for design.
(e) The components included in the design are listed in Section 3.

The capital cost of this reference design is presented in Table 2 for reference purposes. This information is summarized below:

(a) The total capital (construction) cost: $19 264 135.00.
(b) Unit capital cost: $19.26 gal day^{-1}.
(c) Operation and maintenance: $4.40 kgal^{-1}.
(d) Total cost of water: $9.25 kgal^{-1}.

Item	**Parameter**
Technical criteria	
Plant capacity (mgal day^{-1})	1.0
Feedwater quality (mg l^{-1})	34 500
Product water quality (mg l^{-1})	1.0
Blend water quality (mg l^{-1})	2000
Finished water quality (mg l^{-1})[a]	400
Performance ratio (lb distillate kBtu^{-1})	8.0
Number of trains	1
Seawater temperature (°F)	75
Pretreatment:	
Chlorine (mg l^{-1})	0.50
Sulfuric acid (mg l^{-1})	120.0
Post-Treatment:	
Caustic addition (mg l^{-1})	15.0
Chlorine (mg l^{-1})	3.0
Brine concentration limit (mg l^{-1})	62 000
Cost criteria	
Cost year	1999
Interest rate (%)	6
Service life	25
Plant factor (%)[b]	85
Electricity cost ($ kWh^{-1})	0.05
Steam coat ($ mmBtu^{-1})	1.25
Average labor rate (Salary) ($ h^{-1})	25 000.00
Contingency (% of direct costs)	10
Contractor overhead and profit (% of direct costs)	15.0
Owners costs (% of direct costs)	10.0
Freight and insurance (% of direct costs)	5.0
Plant staffing (operation, only)	6.0
Chemical costs ($/lb):	

Sulfuric acid	0.22
Chlorine	0.21
Caustic	0.31
Repair and spare parts (% of direct costs)	1.0
Yearly plant insurance (% of direct costs)	0.5
Building construction unit costs ($ ft^{-2})	100.00
Country of construction	USA

[a] Also to the World Health Organisation (WHO) Standards.
[b] The plant factor is the plant availability (in per cent) multiplied by the plant capacity (in per cent of design capacity).

Table 1. Design parameters.

Item	**Cost ($)**
Direct construction cost ($)	
Process equipment	11 600 515
Building	52 248
Feedwater supply	955 006
Pretreatment	274 625
Post treatment	56 471
Auxiliary equipment	821 231
Sub-total direct cost	13 760 097
Indirect cost ($)	
Freight and insurance	688 005
Contractors overhead and profit	2 046 015
Owners costs	1 376 010
Contingency	1 376 010
Subtotal indirect costs	5 504 039
Total construction cost	19 264 136
Unit capital cost ($ gal day^{-1})	19.26

Table 2. Capital operating costs - reference design.

Item	**Cost ($ $year^{-1}$)**
Annual operating cost	
Electricity	156 498
Steam	487 355
Labor	150 000
Labor overhead	60 000
Chemicals	221 450
Spares, repair parts and insurance	288 962
Total annual operating costs	1 346 265
Amortization (fixed cost)	1 506 970
Operation and maintenance ($ $kgal^{-1}$)	4.40
Total cost of water ($ $kgal^{-1}$)	9.25

Table 3. Operating costs - reference design.

It must be noted that the costs presented in this section are based on the assumptions given in Table 3. Costs prepared with a basis that varies from the above will be different.

4. Site-specific Factors

4.1. Plant Capacity

4.1.1. Single Train

The required plant capacity, in conjunction with the performance ratio, will establish the basic cost of the process, feedwater supply and pre-treatment costs. The capacity determines the basic size of the process (i.e. the required surface area, size of pumping equipment, etc.) and the size of the feed water and pre-treatment systems. Once this cost has been established for a particular performance ratio, the cost of differently sized plant capacities may be approximated from the following formula:

$$C_b = C_a \left(\frac{S_b}{S_a} \right)^f \qquad (1)$$

where

C_b is the cost of the new sized plant ($), C_a is the cost of the known plant ($), S_b is the capacity of new plant (mgal day^{-1}), S_a is the capacity of known plant (mgal day^{-1}), and f is the plant capacity scaling factor

In order to determine the scaling factor which applies for the reference plant design basis, a series of costs are prepared for plant sizes from 1 to 20 mgal day^{-1}. This information is presented in Tables 4 and 5 for capital and operating costs, respectively. Using the above formula, a scaling factor of 0.68 results. It requires mention, however, that this formula is accurate for size changes of a factor of approximately 2. The larger the size change, the less accurate the result.

	Plant size (mgal day^{-1})				
Item	**1.0**	**2.0**	**5.0**	**10.0**	**20.0**
Direct Cost ($1000)					
Process	11 601	19 067	36 020	55 823	88 515
Building	52	105	261	523	1 045
Feedwater	955	1 429	2 474	4 307	7 393
Pre-treatment	275	453	833	1 503	1 634
Post-treatment	57	57	75	94	116
Auxiliary equipment	821	1 303	2 325	3 953	7 493
Subtotal direct cost	13 760	22 413	41 988	66 202	106 195
Indirect cost ($1000)					
Freight and insurance	688	1 121	2 099	3 310	5 310
Contractors overhead and profit	2 064	3 362	6 298	9 930	15 929

Owners costs	1 376	2 241	4 199	6 620	10 620
Contingency	1 376	2 241	4 199	6 620	10 620
Subtotal indirect costs	5 504	8 965	16 795	26 481	42 478
Total construction cost ($1000)	19 264	31 379	58 783	92 683	148 672
Unit capital cost ($ gal^{-1} day^{-1})	16.24	13.35	10.09	7.82	6.20

Table 4. Capital costs - same performance ratio's.

	Plant size (mgal day^{-1})				
Item	**1.0**	**2.0**	**5.0**	**10.0**	**20.0**
Annual operating cost ($1000 $year^{-1}$)					
Electricity	157	258	631	1250	2475
Steam	487	993	2483	4965	9930
Labor	150	150	150	150	150
Labor overhead	60	60	60	60	60
Chemicals	222	443	1107	2215	4429
Spare parts and insurance	289	471	882	1390	2230
Total annual operating costs	1364	2374	5313	10 030	19 275
Amortization (fixed cost)	1507	2455	4598	7250	11 630
Operation and maintenance ($ $kgal^{-1}$)	4.40	3.83	3.42	3.23	3.11
Total cost of water ($ $kgal^{-1}$)	9.25	7.78	6.39	5.57	4.98

Table 5. operating costs - same performance ratio.

The following example demonstrates the calculation of costs using the scaling factor.

Example 1: scaling up the capital cost of MSF plants. The above formula is used to determine the capital cost of a unit at a capacity of 2.0 mgal day^{-1} when the cost for a plant of 1.0 mgal day^{-1} is known. For this case, the reference design has a capital cost of $19 264 135.00. Then, to estimate the cost of the new size

$$C_b = 19\,264\,135(2)^{0.68} = 30\,863\,837 \qquad (2)$$

Note that the unit cost has been reduced from $19.26 gal^{-1} day^{-1} (for the 1.0 mgal day^{-1} plant size) to $15.69 gal^{-1} day^{-1} (for the 2.0 mgal day^{-1} plant size). This indicates that the larger the plant size, the lower the unit cost. This is referred to as the "economy of scale" and can be seen in Figure 1 for the single train units.

The information plotted in Figure 2 is for the cost of the process only, that is no costs have been included for the auxiliary equipment, buildings, pre-treatment, etc. If the auxiliary equipment costs are included, the economy of scale is not affected significantly because the major portion of the total cost is made up from the process equipment (i.e. approximately 85 per cent of the total cost is from the process equipment). Thus, when estimating the cost of the MSF process only or the total plant cost, a scaling factor of 0.68 can be used for either.

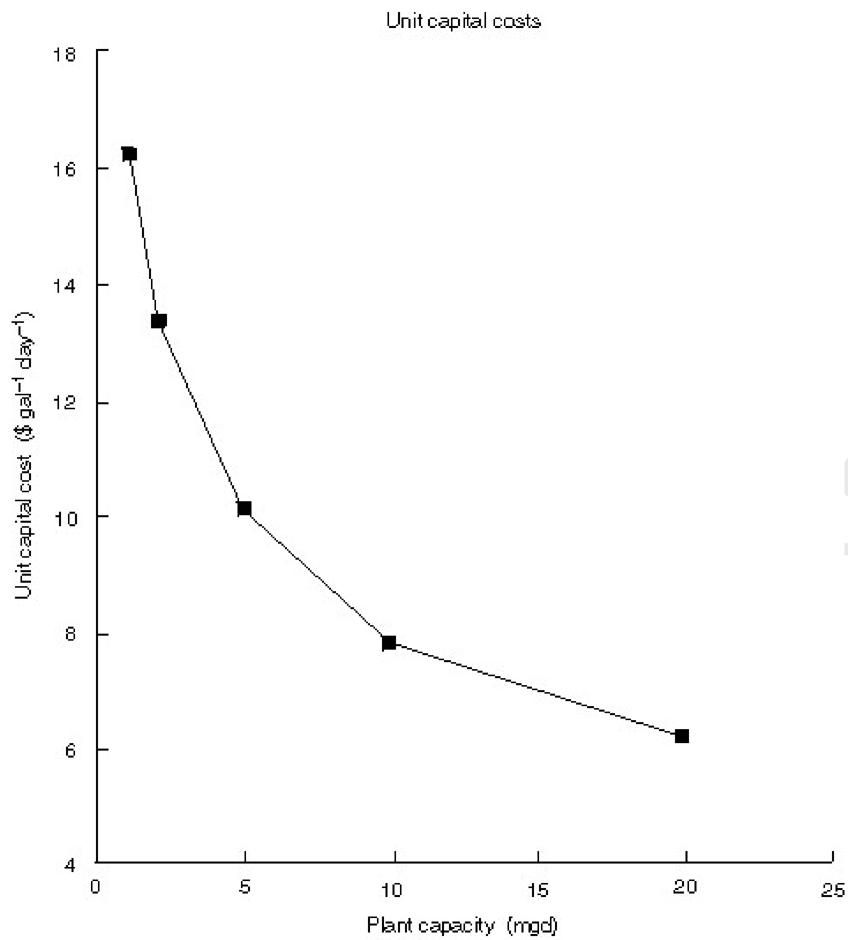

Figure 2. Unit capital costs versus plant capacity.

4.1.2. Multiple Trains

The above calculations estimate the cost of an MSF unit of one train. However, for most designs, in order to maximize the availability of the plant, a minimum of two trains are used and, in many cases, three trains are employed. In the case of using more than one train, savings also results from the economy of scale, but it is not as large because of the smaller-sized train capacities. For the case of more than one train a scaling factor of 0.92 can be used in the following formula:

$$C_b = C_a \times N^f \tag{3}$$

where

C_b is the new plant cost ($), C_a is the original plant cost ($), N is the number of trains, and f is the number of trains scaling factor.

This is demonstrated in the following example.

Example 2: scaling up for the number of trains. Using the above equation for the reference design and assuming that a 2 mgal day^{-1} facility is required gives the following results (once again the reference design has a cost of $19 264 135.00):

$$C_b = 19\,264\,135 \times 2^{(0.92)} = 36\,449\,645 \qquad (4)$$

Comparing this cost with the reference design for one train at 2.0 mgal day^{-1} from the previous example shows that the cost for two trains is some $5 585 808 higher than the cost for a single train. Thus, the economy of scale is not large.

4.2. Operating Cost

The operating costs are broken down in Table 5. A scaling factor can also be used to approximate the operating costs when they are known for a particular size. Using Eq. (1), a higher scaling factor of 0.80 is obtained. This higher scaling factor results because the total cost of water is made up of the operating costs as well as the construction costs. Unlike the construction costs, the operating costs increase proportionately with increased plant capacity. Thus, the operating cost tends to flatten the cost of the water curve and the resulting scaling factor is considerably higher. This scaling factor will change with changes in the performance ratio (see below). This is because the proportion of construction and operating costs changes with the performance ratio. Note that, in Table 5, the operation and maintenance cost is 48 per cent of the total cost and the amortization cost (construction cost) is 52 per cent.

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