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ECONOMICS OF MSF PLANTS: INFLUENCE OF VARIATIONS IN THE DESIGN PARAMETERS AND USE OF DIFFERENT CONSTRUCTION MATERIALS*

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SUMMARY

Different types of MSF plants are taken into consideration and a comparison between the two fundamental ones (i.e. cross-flow and long-flow) is made to find out the most economical solution. The comparison has been performed by studying and examining the different technological features of the two distiller types, the low cost material adoption possibilities and the allowable process design parameters which come from practical consideration. A final calculation of plant cost saving is made.

INTRODUCTION

During the last years of MSF history, we have witnessed the evolution or modification of some features affecting the philosophy of desalting. In particular, the following points should be noted:

— A substantial achievement of the "cross-flow" over the "long-flow" distiller type.
— An ever growing use of high cost materials.
— Negligible progress and change of main process design parameters which guide the sizing of the plant.

All these factors contribute to reduction of the supremacy of the MSF process allowing other processes — in particular reverse osmosis — to mature and conquer a large part of the market.

This paper aims to examine how MSF can be modified to meet the market demands of reliability and economics. Three aspects are particularly to be taken into account:

— Comparison between technological features of the long-flow against cross-flow MSF type.

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— Low cost material adoption possibilities.
— Comparison of process design parameters of the long-flow compared with the cross-flow MSF type.

TECHNOLOGICAL CHARACTERISTICS

A long-flow distiller is more economical than a cross-flow one when we compare them under the same conditions — mainly for the following reasons:
— Reduced number of water boxes.
— Reduced number of tube sheets.
— Possibility to adopt a higher value of the brine flow rate (BFR).
— No transversal obstruction to the two-phase flow with a consequent low space required between the distiller channel and the bottom of the stage.
— Distillate channel which is normally made of expensive materials has reduced or equal dimensions.
— No technological limits to increase the capacity of a single unit up to 20 MIGD.

In Table I the differences between two 7 MIGD units having the same GOR are shown, one of the cross-flow and the other of the long-flow type.

TABLE I

MAIN CHARACTERISTICS OF A 7 MIGD LONG-FLOW AND CROSS-FLOW DISTILLER

	Long-flow	Cross-flow
Capacity, MIGD	7	7
GOR	8.5	8.5
No. of stages	31	21
No. of tiers	7	2
Tube length, mm	25,800	14,000
Heat exchange surface, m^2	71,560	87,764
Stage height, mm		
Stage 1—20	3,300	3,700
Stage 21—31	3,500	3,700
Stage width, mm	6,500—10,500	13,600

MATERIAL CHOICE POSSIBILITIES

The first plants built during the sixties and early seventies were designed according to the philosophy of adopting low cost materials and to try to prevent corrosion by eliminating its cause. Failures were encountered (especially in acid-dosing make-up treatment plants) due to different reasons such as:

— No appropriate and reliable instrumentation (pH indicators and controllers, low oxygen content analyzer, corrosion rate monitoring system, etc.)

TABLE II

MATERIALS COMPARISON

Item	Expensive materials currently adopted	Low-cost material
Distiller shell in contact with brine	70/30 or 90/10 CuNi cladded plates	Bare C.S. Painted C.S. S.S. Cladded materials (in high temperature stages)
Distiller shell vapour space	as above	Bare C.S.
Tube bundle supports	90/10 CuNi S.S. AISI 316 integral plates	Bare C.S.
Non condensable ducts and pipes	Monel	S.S. 316L type
Distillate trays	90/10 CuNi or S.S. 316L type + 90/10 CuNi ext. cladding	Brine temp. $\geq 80°C$ S.S. AISI 316L Brine temp. $\leq 80°C$: Bare C.S.
Tube plates	70/30 CuNi 90/10 CuNi	Naval brass (welded to a tube plate collar)
Tubes:		
H.T. stages	66/30 2 Fe 2 Mn CuNi 70/30 CuNi	Cu Ni 90/10 or 66/30 2 Fe 2 Mn CuNi
Recovery section	90/10 CuNi	Al brass
Reject section	Titanium (electrowelded)	66/30 2 Fe 2 Mn CuNi
Water boxes	70/30 CuNi or 90/10 CuNi cladded	S.S. 316L: recovery sect 90/10 CuNi cladded: reject sect.
Seawater pipes	90/10 CuNi cladded or integral	F.R.P.
Brine pipes	As above	C.S. brine low velocity S.S. brine high velocity
Seawater or brine contacting valves	70/30 CuNi carpenter Ni Al bronze	Ni Al bronze, Austeno-ferritic S.S. with high Cr percentage

— Lack of experience by some plant manufacturers concerning corrosion problems and their prevention.
— Lack of quality control or appropriate specifications and standards which sometimes allowed an "open minded" politics to be carried out by some manufacturers.

This convinced clients and consulting engineers to use self-resisting materials even if they are more expensive. We think that the above deterents no longer exist so that it may be possible to go back to less expensive materials without losing reliability.

Table II lists materials most widely adopted (or specified) today with reference to the main parts of a plant. Besides that, a list of suggested applicable materials is indicated. Examples of plants designed according to these criteria are reported [1, 3].

PROCESS PARAMETERS

Process parameters which are chosen to size the distiller play an important role in the search for minimum cost. The most important are:

1. Specific brine flow rate
2. Vapour release rate
3. Demister entrainment factor
4. Space between droplet separators and bottom
5. Fouling factor
6. Non-equilibrium allowance
7. Hydraulic test pressure

The experimental work carried out, and reports written with the support of the U.S. Office of Saline Water during the sixties contributed to the development of the technology of the MSF process. From all these facts and figures, people involved in desalination drew some "magic" numbers and some "rules of thumb" which are applied (or imposed) also today.

While we think that the more appropriate way of designing a new plant is to adopt the similarity criteria for scaling up based on the fundamental parameters such as BFR, flashdown, type of fluodynamic behaviour (subcritical or supercritical), Froude number and Z_f [2], in Table III we compare some of the most currently adopted figures with the applicable ones.

COST COMPARISON

A comparison is made between the expensive alternative (EA) and low cost alternative (LCA) for a 7 MIGD distiller. Details of these two solutions are given in Tables I and II.

TABLE III

PROCESS PARAMETERS

Item	Currently adopted	Applicable
BFR	Less than 1000 t/h m	Up to 2000 t/h m (extreme values are applicable for long tube type only and adopting precautions against erosion phenomena)
Vapour release rate	A range lying between 1300 and 700 kg/h m² according to stage temperature	A range lying between 2000 and 1200 kg/h m² according to stage temperature
Velocity through mist eliminators	$U_s \leqslant 12$ m/s for low temperature stages	Adoption of Z_f = dimens. velocity $= \frac{U_s}{0.0694\sqrt{\frac{\rho_L - \rho_V}{\rho_V}}} \leqslant 1$ is closer to the reality of the phenomena and U_s up to 20 m/s may be allowed
Mist eliminators height from stage bottom	2.5 to 3 m	1.7 to 2.2 m
Fouling factor	Recovery section 0.00018 m² °C/W	Recovery section 0.00010 m² °C/W (taking into account the adoption of on-load type cleaning systems)
Non equilibrium allowance	0.3 to 0.5°C equal for all stages	0.01 to 0.5°C according to stage temperature and brine level
Hydraulic test pressure	Values of hydraulic test pressure up to 3 times the maximum operating pressure measured at the roof of the upper tier are encountered	HEI Standards or ASME VIII Div. II

A cost comparison is calculated using the following equations:

$$\frac{C_{TL}}{C_{TE}} = \frac{\sum_{i=1}^{N} P_{iL} C_{UiL} + \frac{C_H}{R_L} \sum_{i=1}^{N} P_{iL}}{\sum_{i=1}^{N} P_{iE} C_{UiE} + \frac{C_H}{R_E} \sum_{i=1}^{N} P_{iE}}$$

$$= \frac{\sum_{i=1}^{N} P_{iL} \left(C_{UiL} + \frac{C_H}{R_L} \right)}{\sum_{i=1}^{N} P_{iE} \left(C_{UiL} + \frac{C_H}{R_E} \right)}$$

$$= \frac{\sum_{i=1}^{N} \%_{iE} X_{Wi} \left(X_{Ci} C_{UiE} + \frac{C_H}{R_L} \right)}{\sum_{i=1}^{N} \%_{iE} \left(C_{UiE} + \frac{C_H}{R_E} \right)}$$

where

C_{TL}	Total cost of LCA
C_{TE}	Total cost of EA
$M_L = \frac{P_L}{R_L} C_H$	Labour cost of LCA
$M_E = \frac{P_E}{R_E} C_H$	Labour cost of EA
R	Productivity efficiency kg/h
C_H	Manhour cost lit/h
P_i	Weight of component i
X_{Wi}	P_{iL}/P_{iE} = weight ratio
X_{Ci}	C_{UiL}/C_{UiE} = unitary cost ratio
C_{Ui}	Rate for component i
$\%_i$	P_i/P = weight percentage
P	Total weight
L	Index for low cost alternative
E	Index for expensive alternative

TABLE IV

COST COMPARISON

$X_{W_1} = 1.2$	%1E = 0.40	$X_{C_1} = 0.3$
$X_{W_2} = 0.4$	%2E = 0.06	$X_{C_2} = 0.1$
$X_{W_3} = 1.2$	%3E = 0.04	$X_{C_3} = 0.4$
$X_{W_4} = 1.1$	%4E = 0.04	$X_{C_4} = 0.3$
$X_{W_5} = 0.4$	%5E = 0.03	$X_{C_5} = 0.7$
$X_{W_6} = 0.7$	%6E = 0.38	$X_{C_6} = 0.7$
$X_{W_7} = 0.4$	%7E = 0.05	$X_{C_7} = 0.9$

We obtain the results listed in Table IV if we choose the following main components: (1) shell, (2) tube bundle support, (3) internal part of the distiller, (4) distillate trays and channels, (5) tube sheets, (6) tube bundle, and (7) water boxes.

The cost reduction obtained is $C_{TL}/C_{TE} = 0.49$.

CONCLUSIONS

As previously shown, a substantial reduction of costs (up to 50%) can be obtained adopting a philosophy on material choice and process design criteria which is today fully reliable. This aim can be reached through two different steps:

(1) Choice of process parameters (connected to the long-flow geometry) to reduce the dimensions of the MSF evaporator.

(2) Choice of low cost materials (connected to the corrosion monitoring and control techniques) to reduce the unit cost of the MSF evaporator.

In this way, the annual capital cost is reduced lowering the initial capital cost and containing the life of the plant within usual terms. In conclusion, the cost of MSF product water is substantially reduced and can be comparable with the cost of water for other desalting processes.

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