

Fundamentals and costing of MSF desalination plants and comparison with other technologies

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Abstract

Multistage Flash Desalination has a market share of over 60% of the worldwide desalination market, and in the Middle East Area this share jumps to almost 80%. The reason for such a strong position is the great reliability and proof of such a mature technology. The installation cost of MSF plants has dramatically decreased in the past years despite a normal inflation increase. The reason for such a trend can not be justified only by the competition but must be the result of a better plant design, larger unit size and also on a more realistic approach to the requirements by the owners.

This paper presents such an analysis and compares some past examples with most recent installations both in terms of technical requirements and installation costs. The water cost produced by MSF plants is almost in line with other technologies. The paper presents some examples and comparisons.

Keywords: Multistage flash; Desalination installation cost; Desalinated water cost

1. General considerations on the MSF market

The MSF technology for sea water desalination can only be compared with other technologies if sea water is considered as the feed to the process. In fact for brackish water the most conventional RO or ED process can give better performances with lower installation costs.

In the past ten years the request for MSF desalination plants has been limited only to the Middle East Region due to the low fuel cost there and to the difficulties of proper treatment of the seawater for a trouble free operation of RO plants.

Due to this situation, the installation of MSF plants worldwide in the past ten years dropped from 50% in the years 1984–1993 to

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37% in the years 1994–2003. This decrease is almost due to the increase of RO technology since the other desalination technologies remained at the same level or even decreased [1]. However in terms of installed capacity vs years, the MSF process has predominated in the past 20 years over RO with some exceptions as shown in the graph below (Fig. 1).

The reasons why the MSF technology survived well against the emerging RO technology are mainly the following:

- *Very high reliability of installed plant:* In their years of operation installed MSF plants have shown a very high reliability and also demonstrated a possible life much higher than that foreseen at the time of construction. It must be remembered that 30 years ago at the time of the first booming of sea water desalination the life expectation was limited to 15 years. Most of these installations are still performing today and those

which have been refurbished have another 10 years of estimated life.

- *Easy operation:* Operation of MSF desalination plants is very easy and have almost the same characteristics as a power plant with which they are always coupled. This means that operations and maintenance personnel can be easily found and do not represent a major problem for the owner.
- *Very low performance degradation during the years:* It is recognized worldwide that an MSF plant properly operated and maintained has practically no performance degradation in terms of water production and energy consumption.

For all the above reasons the use of Multi-stage Flash Desalination is still the preferred desalination technology among all others especially in those countries where the coupling of power generation and water generation is always necessary due to the high demand of both electric power and potable water.

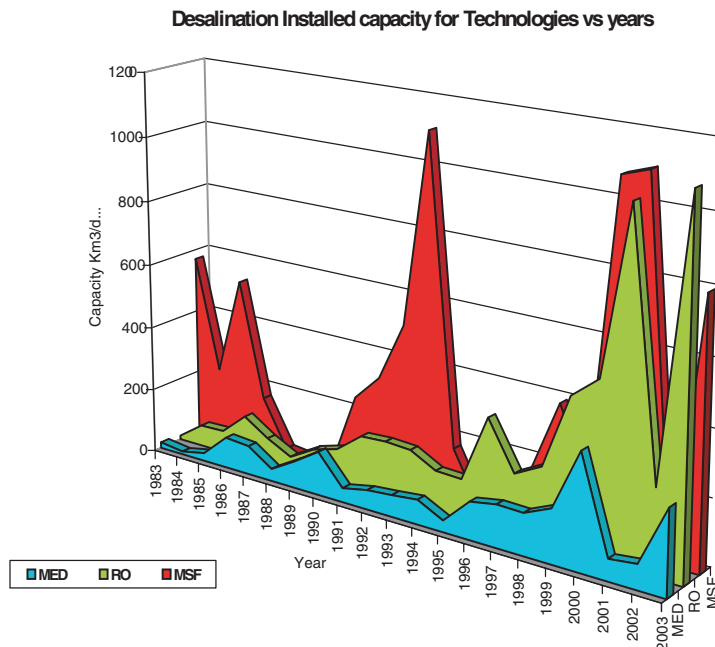


Fig. 1. Desalination installed capacity for technologies vs years.

It is useful to recall here that in 2004–2005 the desalination market in the Middle East area will contract new installations for about 350–400 MIGD (1.5–1.8 M m³/d) and all are based on the MSF technology.

2. MSF installation cost: an incredible decrease trend

The installation cost of MSF desalination plant showed a decrease in the past years which seems not reasonable with the increasing trend of the raw material and labour. In fact if we compare these trends we obtain the trends shown in Fig. 2.

Despite a cost increase in raw materials of more than 40% and a labour cost increase of more than 100% in the past 20 years the price of selling MSF desalination plant showed a reduction of about 50%.

Considering that almost all the major suppliers of MSF desalination almost all have survived for the past 20 years, one can argue that this price decrease is not a dumping effect but a real adjustment of the market in consideration of various effects.

3. The reasons of MSF installation cost decrease

As indicated above, the price decrease of MSF has been followed by almost all suppliers. The reason for such a market change can be explained by different factors.

3.1. The competition

The strong competition among the three desalination technologies put in serious

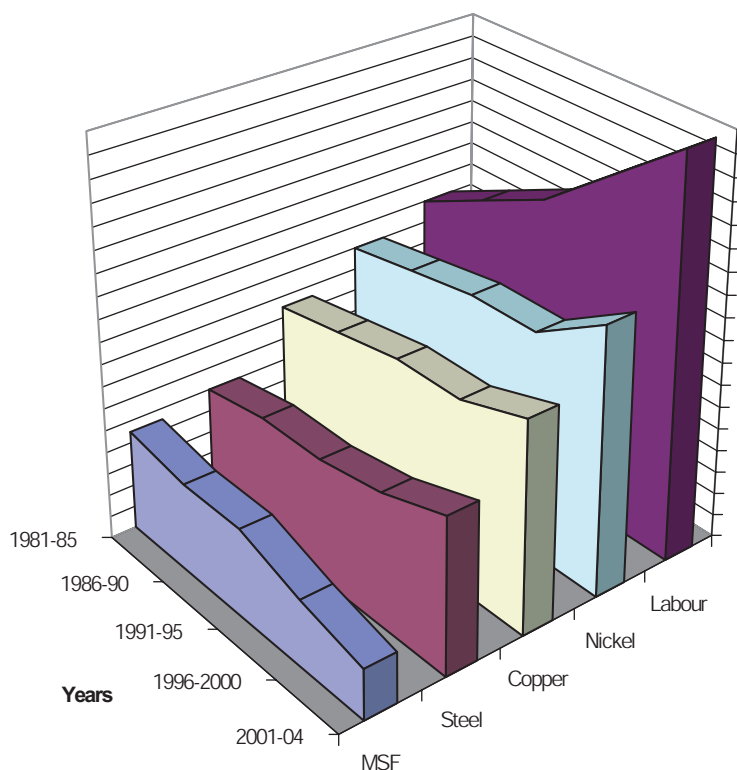


Fig. 2. Installation cost of MSF compared with the trend of costs of new materials.

jeopardy the survival of the thermal methods which had to find new costing approaches.

MSF desalination plants contracts are generally awarded after a strong competition. Tenders for turnkey or BOOT contracts are issued internationally and several referenced contractors are present on the market. Main reputable and experienced contractors are based in Europe, Japan and Korea.

For large size plant typically 3–5 different bidders are competing every project, however in the past ten years the Suppliers which got Contracts for plant of capacity higher than 100,000 m³/d have been the following (Wangnick Desalination inventory Report 18): (Fig. 3)

Improvements/deviations to the tender technical requirements are generally proposed by each tenderer to qualify their technical proposals and to increase the benefits of the customer in term of reduction of costs or increase of performance.

An addition contribution to lower the costs comes from strong efforts in selecting reliable and competitive sub suppliers from the world market (and no only on regional/national basis). Emerging companies from Far East area are growing technologically and are a wide and important source of potential qualified subcontractors.

3.2. The technical optimization

The development of several projects in the recent years is giving the opportunity to the manufacturers to improve and optimize their design and their technical solution by capitalizing the experiences. This activity, which fall under the name ‘technical optimization’, in mainly based on the feedback of the previous projects and consists in identify improvements to the technology and to the design

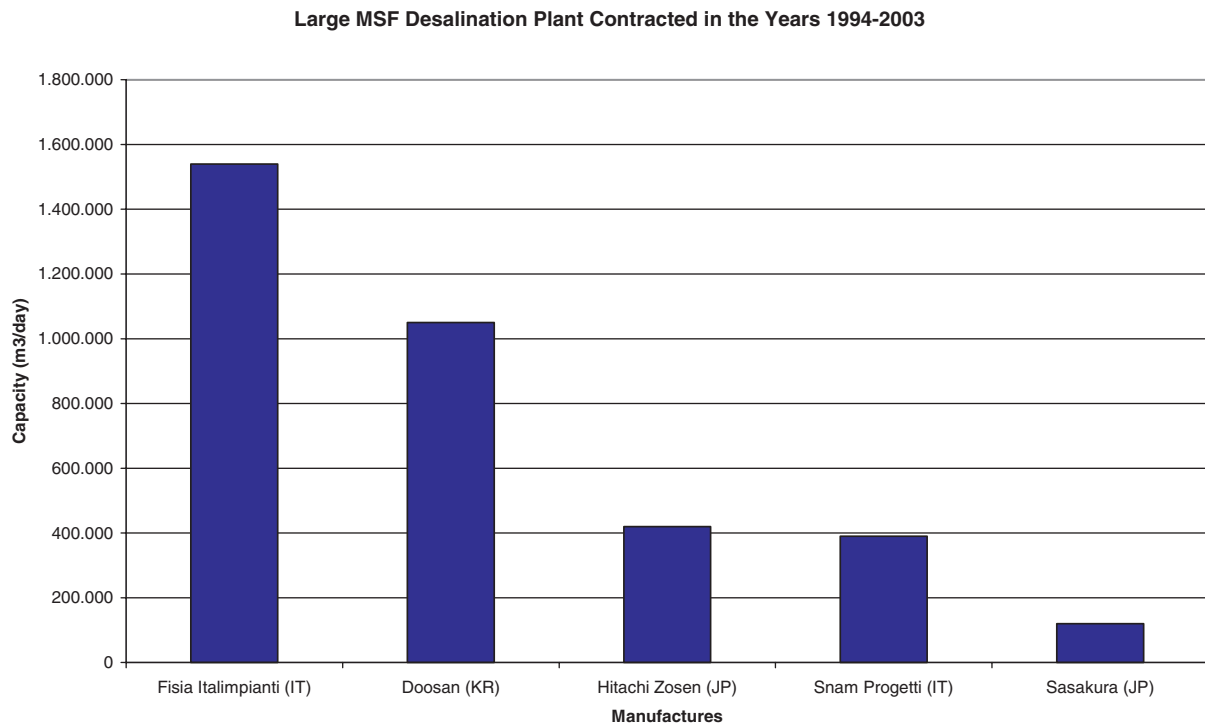


Fig. 3. Large MSF desalination plant contracted in the years 1994–2003.

(mechanical, electrical, etc) of the equipment in a learning by doing process.

This virtuous circle can be maintained by having a continuous turnover of new projects in a limited period of time in order to transfer experiences from/to the different projects. A significant help to this process can come from setting and reuse of standard design solutions which can be improved and shared between the projects.

A further area of technical optimization can also be identified in the selection of new and better alternative materials/alloys which are becoming competitive due to the recent increase of the prices of raw materials. Materials like AISI 316, 316L and 316Ti are now less attractive than in the past if compared of Duplex stainless steels both in term of mechanical properties, corrosion resistance and costs.

For the same reason the very well known copper nickel alloys used for the tube bundle has been in many places replaced by the thinnest titanium which gives better corrosion resistance and lower weight.

3.3. Less stringent specifications

The technical specifications issued for the early desalination projects were based on over sizing/redundancy criteria. In the recent years the restraints imposed by the specification have been significantly reduced, giving to the manufacturers the possibility and the opportunity to design the new plants by using design parameters coming from their direct experience from the field. Some of the specification requirement which have an heavier impact on the total plant costs are listed below:

- Process restraints (i.e. fouling factor, distiller hydraulic test pressure, distillate purity, brine load, etc.)
- Material selection and thickness of heat exchange tubes for reject and recovery sections (copper nickel, aluminum brass,

titanium) and of evaporator shell (carbon steel, stainless steel, clad materials)

- Plant accessories (by-pass on control valves, removable water boxes, acid cleaning equipment, redundancy of equipment and instrumentation)

A proper and careful selection of the above specification requirements gives a significant margin of improvement of the total plant costs without affecting the plants performances and reliability.

3.4. The BOOT influence

The recent experience with this new type of contracts gives a further opportunity to reduce the MSF costs. The main target of the tenderer is to propose the lowest water cost and not more the lowest plant installation cost. Operation and maintenance costs are playing an important and evident role in the proposals comparisons. Contract specifications are changing from technical to functional and the requirements are to design and build MSF plants to achieve the target of the *minimum total life cost*.

Several design parameters are not more specified and even the total plant production, the performance ratio and number/size of MSF units are usually left to the decision of the tenderer (which is required to optimize the total power and water costs by selecting the most convenient plant configuration).

This different approach is a new challenge which the MSF plant manufacturers are facing. It gives them the opportunity to apply their direct experience and produce cheap and reliable plants to meet the market demands.

4. MSF installation cost vs. other desalination technologies

The capital cost of MSF desalination plant is nowadays very attractive in respect to other technologies due also to the fact that very large

units can now be supplied with very high reliability and performance characteristics.

As already discussed in other articles the MSF unit size jumped from a nominal size of 3 to max 7.5 MIGD in the years 1990 up to 12 to max 17 in the first years of 2000; this tremendous increase of about 250–300% allowed a significant possible reduction in the capital cost as well as in operating cost (Fig. 4).

The overall installation cost for a turn key plant is not always simple to be compared since the peculiar site situation may influence significantly the overall cost; hence in order to compare in a correct manner the different technologies it is imperative to fix certain boundary conditions which for this example has been defined as follows:

- Project size: 45 MIGD of potable water
- Location: Middle East–Gulf sea water
- Type of contract: Turnkey EPC
- Main scope: Intake sea water and pump house, sea water treatment, sea water desalination plant, remineralization plant.

The main characteristics of the plants based on the three major desalination technologies are reported in Table 1.

The estimated installation cost of the three process based on an average value of the contracted plant in the last years for the Middle East area could be as follow:

- MSF: US \$180 M
- RO: US \$170 M
- MED: US \$195 M

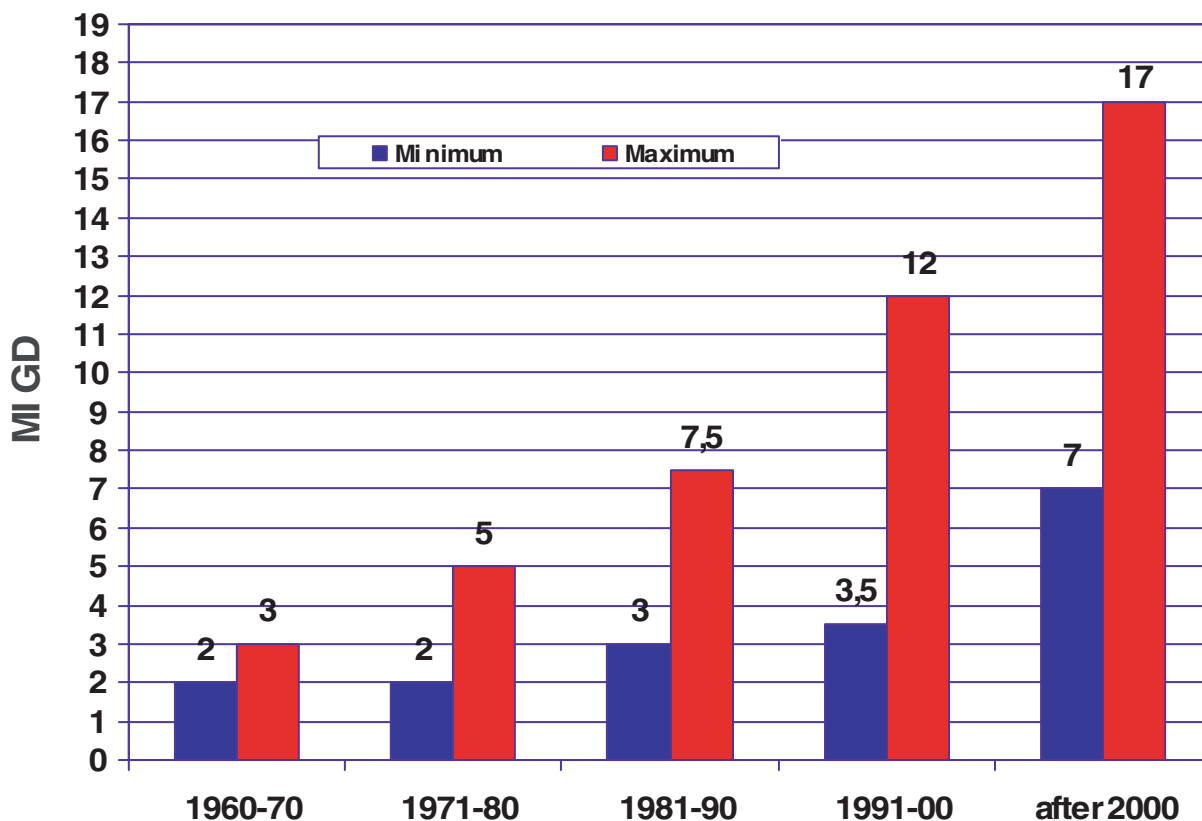


Fig. 4. Increase of MSF unit size over decades.

Table 1
Comparative characteristics of MSF, RO and MED plants

Parameter	MSF	RO	MED
Plant type	Cross flow–Brine Recirculation	Spiral wound membranes	MED-TVC
Production (m ³ /d)	205,000	205,000	205,000
Potable water quality	WHO	WHO	WHO
Number of Units/Trains	3	20 for 1st stage 12 for 2nd stage	9
Number of membrane 1st pass (8' dia. 1 m length)	NA	18,000	NA
Production per Unit (MIGD)	15	2,25	5
Performance ratio	8,5	NA	8,5
Sea water inlet temperature (°C)	35	35	35
Brine water outlet temperature (°C)	45	NA	45
Sea water TDS (ppm)	45,000	45,000	45,000
Top Temperature (°C)	112	NA	70
Recovery ratio	NA	40	NA
Number of stages/effects	19	2	6
Power required (Mw)	34	42	28
Sea water flow (m ³ /h)	58,000	22,000	58,000
Heat input (MJ/s)	650	0	650

As it can be seen all 3 technologies have a capital installation cost which is within +_7% of the average value and depending on the particular site constraints this difference may play no role in the choice of the best desalination technology to be applied.

5. Potable water production cost

If we consider the above comparison between the 3 technologies in following combination :

- MSF plant combined with a power generation plant of 500 MW
- MED plant combined with a power generation plant of 500 MW
- RO plant stand alone

and we consider the parameters in (Table 2) for estimating the investment cost and operational cost.

Furthermore for each type of desalination plant the following O & M cost can also be estimated on an annual basis (Table 3).

Considering all the above and using the following formula for the calculation of the water cost:

$$W_C = (C_F + C_P + C_D)/W_N$$

Where:

C_F = Cost of thermal energy = Annual cost of fuel*NPVF

C_P = Cost of electric power = Annual cost of electric power*NPVF

C_O = Cost of O & M = Annual cost of O & M*NPVF

C_D = Cost of desalination plant investment

W_N = Net present value of production = Annual production*NPVF

Table 2
Parameters for estimating cost of investment and operation

Parameter	Unit	Value
Depreciation time	years	20
Interest rate	%/y	7
Net present value factor	a	10,59
Annual operating time	h	8520
Cost of power energy	c\$/kh/h	3
Fuel price of natural gas	\$/MWh(th)	4,5
Cost of thermal energy for desalination	c\$/MJ	0,05
Membrane replacement ratio	%/y	20
Cost of manpower (mean value)	\$/year	25000

Table 3
Breakdown of O & M costs

Type of cost	Units	MSF	MED	RO
Chemical products for operation	KUS\$	1500	1000	2500
Chemical products for cleaning	KUS\$	50	100	250
Operational people	KUS\$	400	600	500
Maintenance people	KUS\$	100	175	100
Membrane replacement	KUS\$	NA	NA	2000
Other maintenance cost including spare parts	KUS\$	300	200	250

Table 4
Water cost for each process

Parameter	MSF	MED	RO
Cost of thermal energy (M\$)	105	105	0
Cost of electric power (M\$)	92	76	114
Cost of O & M	(M\$)	25	22 60
Cost of desalination plant investment (M\$)	180	195	170
Total cost (M\$)	402	398	344
Net present value of production (Mm ³)	770	770	770
Water cost c\$/m ³	52	52	45

Applying the above formula to our 3 cases we obtain (Table 4).

As it can be seen from the Table 4 the water cost produced by desalination is almost identical for all compared technologies for the proposed ME market with a better possible tariff for the RO process of about 15%.

Obviously from the cost it must be considered that the selling price could be higher depending on the ROI and other factors which must be considered case by case

however it is not far from the reality to say that a good selling price for potable water produced by desalination in the Middle East area may range between 53 and 60 c\$ per cubic meter of water produced.

5. Conclusions

From all the above considerations it appear clear that the two Thermal technologies give a very similar water cost whilst

the RO application give a certain advantage at least on the paper without considering any risk effect due to the high sensitivity of this type of plant to the raw sea water quality.

Obviously all the Thermal technologies have an higher environmental impact and due to the high temperature discharge and are reasonable only when coupled with Power generation Plant.

Looking at the future it can be said that the thermal plant and especially the MSF technology will still lead the Middle East market whilst the RO technology will consolidate in the other areas where stand alone desalination plant are preferred.

6. References

Wangnick Desalination Inventory Report 18, 2004.

