

MILESTONES IN THE DEVELOPMENT OF MULTI-STAGE FLASH DESALINATION PLANTS WORLDWIDE

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1. Introduction

The development of the Multi-stage Flash Desalination process can be divided into six clearly identified stages covering a period of twenty years, from 1957 to 1978.

1.1. Stage 1: 1957

Dr. Robert Silver filed the basic provisional patent specification defining multi-stage flash as a distillation system in which the number of stages is an integer greater than twice the performance ratio. The complete specification was lodged in 1958 and finally granted in March 1960.

The Italian "Encyclopedia della Chimica" published by *Uses Edizioni Scientifiche Firenze* defined the patent thus:-

"This crucial difference between MEB and MSF was first realised by Silver in 1957. Up to that time flash distillation plants had been designed on the same thermodynamic basis as MEB plants, i.e. if a performance ratio R was required, the number of stages used would be just greater than R ".

Thus for example the largest flash distillation plant before 1957 had $R = 3.3$ with 4

stages.

In 1957 Silver filed a patent application for multi-stage flash distillation claiming the basic feature that the number of stages should be an integer greater than twice the performance ratio.

In his first design for the Weir Company he in fact used $n = 3R$. These were 2 units each of 4,550 cubic meters per day for Kuwait with 19 stages and $R = 5.8$, and a unit of 2,775 cubic meters per day with 40 stages and $R = 10.5$ for the island of Guernsey. All of these were successfully commissioned in 1960, and since that date no major commercial plant for desalination has been other than MSF.

Before this, in 1955 the US Navy had built a flash distillation plant with $R = 3.5$, and five stages.

1.2. Stage 2: 1959

R W Goeldner/Aqua Chem patent. The principle of re-circulation of the brine blow-down was established and a patent application filed.

1.3. Stage 3: 1955-1968

Brine top temperatures were limited to 190/195°F(87.7°C/90.5°C) by the polyphosphate, which includes hexametaphate dosing used to control the formation of calcium and magnesium scale, which forms on the heat transfer surfaces.

1.4. Stage 4: 1962

Application of on-load ball cleaning systems to remove sludge and scale from the heat transfer surfaces.

1.5. Stage 5: 1968

Introduction of sulfuric acid dosing to control the formation of calcium carbonate and magnesium hydroxide scales in brine concentration up to a factor of 2 and top brine temperatures up to 250°F(121°C) where calcium sulfate scaling becomes a major problem. The only method of controlling calcium sulfate scale formation is to limit the concentration and temperature before CaSO_4 becomes insoluble. This was a major step forward in thermal performance but the resulting corrosion problems were not understood by the industry (see Materials Section). Major corrosion problems occurred on all the acid dosed plants built and commissioned in the late 1960s and early 1970s and resulted in poor plant performance, high maintenance costs and in extreme cases plants being prematurely shut down and written off.

1.6. Stage 6: 1977/78

Development of polyelectrolytes high temperature additives to control scale formation up to 225°F(107°C). The introduction of the high temperature additives improved the

overall performance of desalination plants, simplified the operation and improved the life of the plants by reducing corrosion (see Materials Section).

2. Milestones in Desalination Technology

The following installations are all cross-tubed multi-stage flash, unless otherwise stated. "Year" refers to the first year of commercial operation.

The above plants, which operated on the principle of flashing brine, have been listed as they were the development stage between the submerged tube plants, which had dominated the market up until the 1960s, and the multi-stage flash desalination plants which had provided the fresh water required for major development in arid areas of the world since the 1960s.

Year	Country	Owner	Unit size/day Cubic meter mg	GOR	No. of stages: Recovery Rejection	Location	Manufacturer	Desigation
1953	USA	US Navy	0.042 189	3.2	Once through 5	Navy yard	Bethlehem Steel Co.	Earliest identified test flash distillation plant
1955	USA	US Navy	0.042 189	3.5	Once through 5	Navy yard	Aqua Chem Inc	Earliest identified commercial flash distillation plant. Later installed on SS <i>Independence</i> constructed throughout in 90/10 Cu Ni. First identified plant with mesh type vapor separators
1956	USA	Cal. Edison Co.	0.042 189	3.2	Once through 5	California	Aqua Chem Inc	Test plant
1957	Kuwait	Ministry of Power and Water	0.5 2273	4	Vertical Stack Shuaikh 4		Westinghouse	Earliest land-based commercial flash distillation plant.

Table 1. Early MSF plants which helped in the development of the technology.

The first three major multi-stage flash desalination plants came on stream in 1960 and all incorporated the principles embodied in Dr Robert Silver's (Weir's) multi-stage patent and the brine recirculation patent of R W Goeldner (Aqua Chem). Weir and Aqua Chem agreed a cross patent arrangement in the late 1960s.

Year	Country	Owner	Unit size/day Cubic meter mg	GOR	No. of stages: Recovery Rejection	Location	Manufacturer	Desigation
1960	USA	Cal. Edison Co	0.1 455	6	20 6 Long-tubed	California	Aqua Chem Inc	First brine recirculation plant. R W Goeldner / Aqua Chem patent
1960	Channel Islands.	Guernsey Council	0.5 2273	10.5	37 3	Guernsey	Weir Westgarth	First plant designed on Dr. Silver's 1957 multi-stage distillation patent

1960	Kuwait	Ministry of Power and Water	1 4545	5.8	16 3	Shuwaikh	Weir Westgarth	First one million gallon per day plant based on Dr. Silver's patent (with circulation section)
1962	Bahamas	Ministry of Power and Water	0.6 2725	6.25	Once through 20	Clifton pr.	Weir Westgarth	First onload ball cleaning installation on a desalination plant
1962	US Virgin Islands	Water Authority	0.229 1041	7	Once through Long-tubed	St. Thomas	Aqua Chem Inc	
1962	USA	Government (OSW)	0.823 3740	11.2	32 4 Long-tube	Point Loma	Aqua Chem Inc	First acid dosed plant. US government (OSW) Acid dosed demonstration plant installed at Point Loma, later transferred to Guantanamo Bay, Cuba base in 1965/66 US military
1963	Qatar	Ministry of Power and Water	0.8 3826			Ras abu aboud	Weir Westgarth	All brass tubes, carbon steel shell, and cast iron pumps. Life 25 years
1965	Caribbean	Harvey Aluminium	0.75 3409			St. Criox	Westinghouse	First major titanium tubed plant
1968	Kuwait	MEW	2 9100	6.5	22 2	Shwaiba	Sasakura	First two mgpd plant in the Gulf area
1968	Malta	Govt of Malta	1 4500	6	22 2	Marsa II	Weir Westgarth	Earliest identified Cu Ni lined water boxes (TIG welded)
1968	Saudi Arabia	SWCC	0.65 2925			Alwaj and Duba	Aqua Chem Inc	First plants installed by SWCC
1968	USA	OSW authority	1 4545			Chula Vista, California	Aqua Chem Inc	First 250°F (121°C) top temp acid dosed plant
1969	Holland	Zeeland Elect.	3.19 14500			Terneuzen	Esmil	Mixed acid/polyphosphated for estuary water (tube failures)
1969	Gibraltar	Govt of Gibraltar	0.25 1022	9	30 4 Long-tubed	North Face	British Aqua Chem	First plant operated commercially on high temperature additives
1969	Mexico	CFT	3.145 14294	10	41 3 Long-tubed	Rosarita	Aqua Chem Inc	First major acid based plant. Top brine temp 235°F
1970	Kuwait	MEW.	4 18200	8.2	23 3	Shuwaikh	Sasakura	First four mgpd plant in the Gulf area

1971	Saudi Arabia	SWCC	2.08 9462	8	Long-tubed	Jeddah I	Aqua Chem Inc	First plant built on OSW design/materials specification
1972	Bahamas	Ministry of Power and Water	2 9000	14.7	54 4	Blue hills	British Aqua Chem	Long tubed, acid-dosed plant. Too many stages, poor material specification
1973	Italy	Industrial	7.92 36000	7.5	Long-tubed 28 3	Porto Torres	SIR	Largest plant constructed from 1973 to 1990
1975	Hong Kong	Govt of Hong Kong	6.7 30300	10.6	28 3	Lok on Pai	Sasakura	Largest unit outside Italy
1975	Oman	Ministry of Power and Water	5 22727	6	22 2	Ghubran	Demag	Largest plant designed for acid dosing operated on polymer
1978	Saudi Arabia	SWCC	2.5 11364	6.5	16 2 Long-tubed	Jeddah II	Sasakura	Earliest CU Ni clad steel used in water box construction
1980	Saudi Arabia	SWCC	5 22727	7	14 2	Jeddah III	Weir Westgarth	First plant designed to operate on either acid or polymer dosing
1982	Saudi Arabia	SWCC	5 22727	8	20 2	Yanbu	Sasakura/mhi	First major plant with stainless steel lining through the flash chambers
1982	Saudi Arabia	SWCC	5 22727	8	20 2	Jubail I	Sasakura/MHI	First fully titanium tubed major plant
1982	Abu Dhabi, UAE	WED	7.3 33200	7	16 3	Umm al Nar	Italimpianti	Largest plant in the Gulf area
1987	Abu Dhabi, UAE	WED	12.7 57727	8	18 3	Al Taweelah	Italimpianti	Largest plant installed up to 1995

Table 2. Installation of major MSF plants forming milestones in the history of desalination.

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Bibliography and Suggestions for further study

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