IDA

DESALINATION

ACADEMY

Inspiring Innovation and Excellence

About the IDA Desalination Academy



The IDA Desalination Academy aspires to increase knowledge that leads to innovation – but that is only the start. Attending the Academy creates a platform for sharing ideas, building new connections and exchanging insights as participants enhance their skills and expand their professional development.

At the IDA Desalination Academy, we focus on not only increasing practical skills and knowledge but putting these advances in a broader context. Everyone involved in today's desalination industry plays an important role in shaping the world's water solutions for future generations. We are committed to encouraging innovation, thinking "outside the box" and fostering excellence. That is the lasting role of the IDA Desalination Academy.

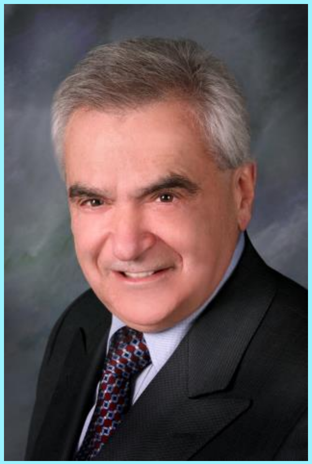
The WORKSHOP TITLE:

"Thermal and Hybrid Desalination Processes".

Course Instructor: Eng. Leon Awerbuch,
Dean of IDA Desalination Academy

About the instructor

Leon Awerbuch



Leon Awerbuch- President International Desalination Consultancy Associates (IDCA) LLC. Past President, International Desalination Association (IDA); Chairman of IDA Technical Programs; Dean, IDA Desalination Academy

Leon Awerbuch has been involved in the desalination industry for more than 35 years. He joined Bechtel Group in 1972 in R&D followed by increased responsibilities for power and water programs as International Bechtel Co. Ltd Vice President and Senior Regional Representative for the Middle East. Mr. Awerbuch was one of the early pioneers in Hybrid Power-Desalination concepts, Desalination (DASR) and Hybrid MSF-MED. Currently involved in providing technical and commercial consultancy to number of leading suppliers and utilities covering Reverse Osmosis and Thermal Desalination and Power Projects as well as assessment of new desalination technologies. He is Board member of Global Clean Water Desalination Alliance (GCWDA) and advisor to MASDAR renewable desalination program, evaluator of solar-desalination proposals of U.S. Department of Energy Office of Science. Chairman of an Evaluation Panel on Nuclear Desalination Program of IAEA in Vienna, reviewer of US and World Bank Roadmap for Desalination. He has been Chairman of 6 IDA World Congresses and chaired over 50 International Forums and Conferences related to desalination and water reuse. He is a member of the Research Advisory Board of the Middle East Research Center (MEDRC).

Mr. Awerbuch received a Master's Degree in Chemical Engineering and Chemistry from Warsaw Technical University. He has also undertaken Graduate Study toward a PhD in Chemical Engineering, at Warsaw Technical University and Polytechnic Institute of Brooklyn, New York.

Introduction

Overview of the course

The topics include theoretical and practical information about performance and operating conditions of thermal and hybrid desalination technology and systems for seawater desalting. This course will focus on the basic and advanced understanding of Design and Operation of Multistage Flash, Multi-Effect Distillation Technology (MED) and Vapor Compression (MVC and TVC) processes as well as hybridization of Thermal and Membrane processes. Although today membrane processes getting worldwide attention due to their low energy consumption, the understanding of benefits and the potential of use of low grade heat and renewable energies as well as industrial application s to ZLD and gas and oil industry requires good knowledge and ability to take advantage of thermal and hybrid processes

Thermal desalination Multistage Flash (MSF) and Multi-Effect Distillation (MED) are the most adopted desalination technology especially in the Middle East area where high capacity and adverse climate conditions are experienced. The Reverse Osmosis and nanofiltration membrane softening is rapidly adopted around the world. The new trend in hybrid systems combining the best features of thermal and membrane technologies is applied in more projects. Many of recent large plants adopted hybrid solutions to reduce cost, reduce energy consumption and minimize intake outfall structures. These technologies followed a continuous improvement especially in the reducing energy consumption, increased unit size and reducing environmental impact. The recent trends are to find solutions for use of renewable energy in desalination to substitute fossil energy and minimize environmental impact will be reviewed. The basic principles of mass and heat balance are applicable to all processes. Understanding of the differences between MSF, MED and MED TVC is a must for any student of desalination.

Course Outline

You will learn

1. History and Basics of Thermal Processes.

a. The principle of distillation

b. The Multi-Effect Distillation (MED)

c. Multi-Stage Flash (MSF) Process,

d. Basic Flow Patterns

e. Heat Input, Heat recovery and Heat reject

f. Basic Operational Parameters and Process Characteristics

g. Multiple Cells Concept

h. Differences Between MED, MED-Thermo Compression (MED-TVC) and Mechanical Vapor Compression (MVC)

2. Technological Advances of MSF, MED and MED-TVC and MED Distillation Proces

a. Comparison Multi-Stage Flash (MSF) and MED Distillation Process

b. Who are the Players in MED and comparison to MSF Manufacturers?

c. Unit Size of MSF and MED Technology

Course Outline

You will learn

3. Examples and Comparison of Different Large MSF and MED Projects

4. Energy Input Classifications, Energy Requirements for Desalination

a. Basic understanding of Heat and Mass Balances, Heat Transfer

b. Steam, Seawater, Distillate and Blowdown

c. Energy requirements, heat and electricity

d. Understanding of Process Efficiency, Performance Ratio, Gain Output Ratio (GOR)

Course Outline

You will learn specifically:

5. Hybrid Systems and Its Benefits

a. Simple Hybrids, MSF, MED and RO

b. Blending distillate and permeate

c. Extending life

d. Solving Boron problems

e. Integrated Hybrids, MSF, MED RO and NF

f. Taking advantage of available heat increasing flux

g. Controlling steady state

h. Reducing power consumption

i. Reducing Pre-Treatment and pressure

j. Increasing TBT with Nanofiltration

k. Increasing overall recovery

l. Tri-Hybrid systems

m. Minimizing intake and outfall

6. Dual purpose power and desalination

a. Steam turbine, Combined Cycle, Heat Recovery Steam Generators

b. Steam Extraction and Steam Backpressure

c. Typical Power to Water Ratios for Different Desalination Technologies

d. Matching demands for power and water

e. Integration of power and desalination and aquifer storage and recovery

Course Outline

You will learn specifically:

7. Review of Projects of MED, MSF and Hybrid Projects

   a. MED Hidd - Bahrain; EWA Power

   b. Marafiq Jubail Power and Water MED

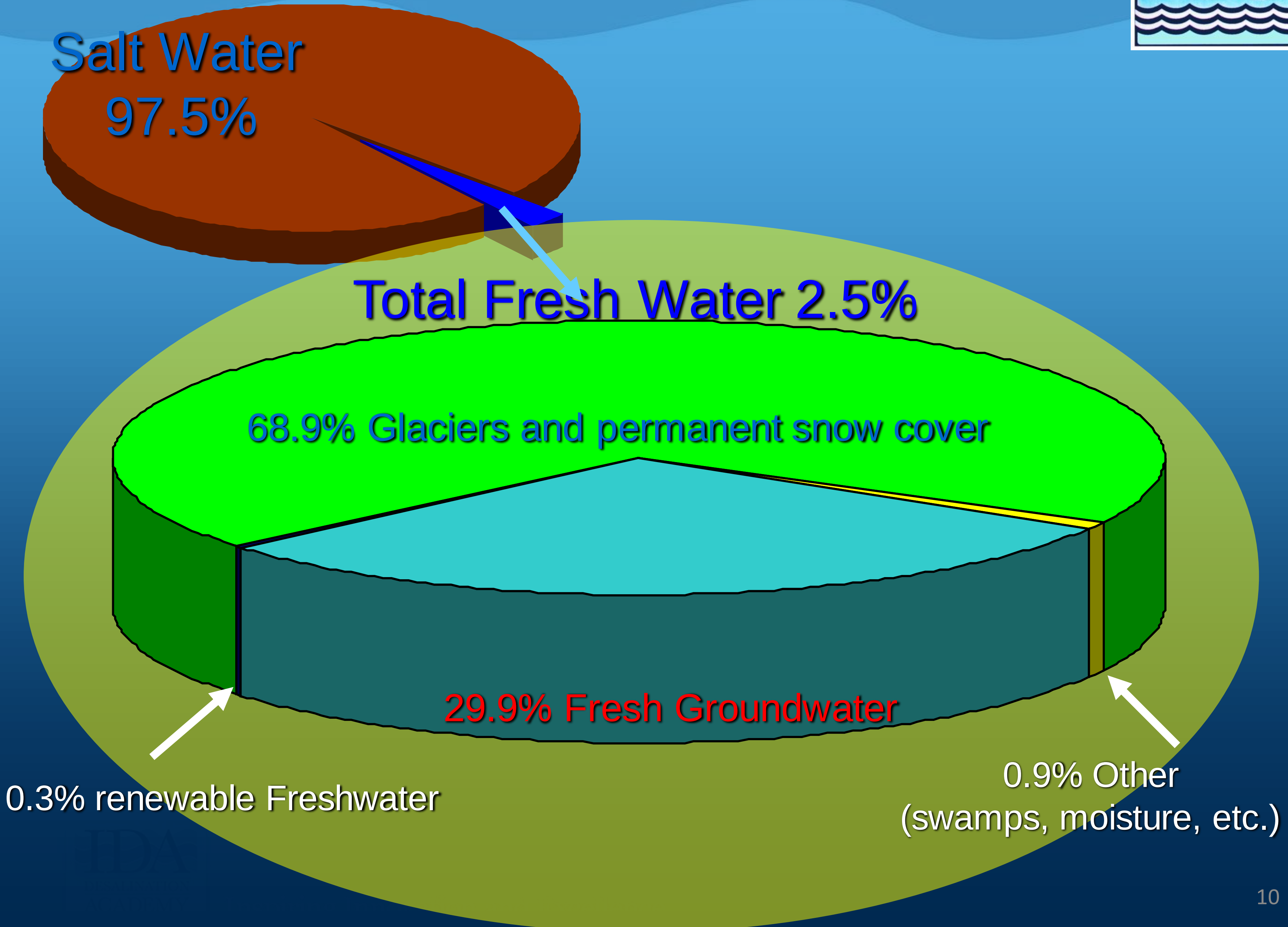
   c. Hybrid Fujairah 1 MSF RO and Fujairah 2 MED RO

   d. MSF Dubai-DEWA; Abu Dhabi-ADWEA; Al Khair-SWCC

   e. RO expansion in Al Zour South Kuwait

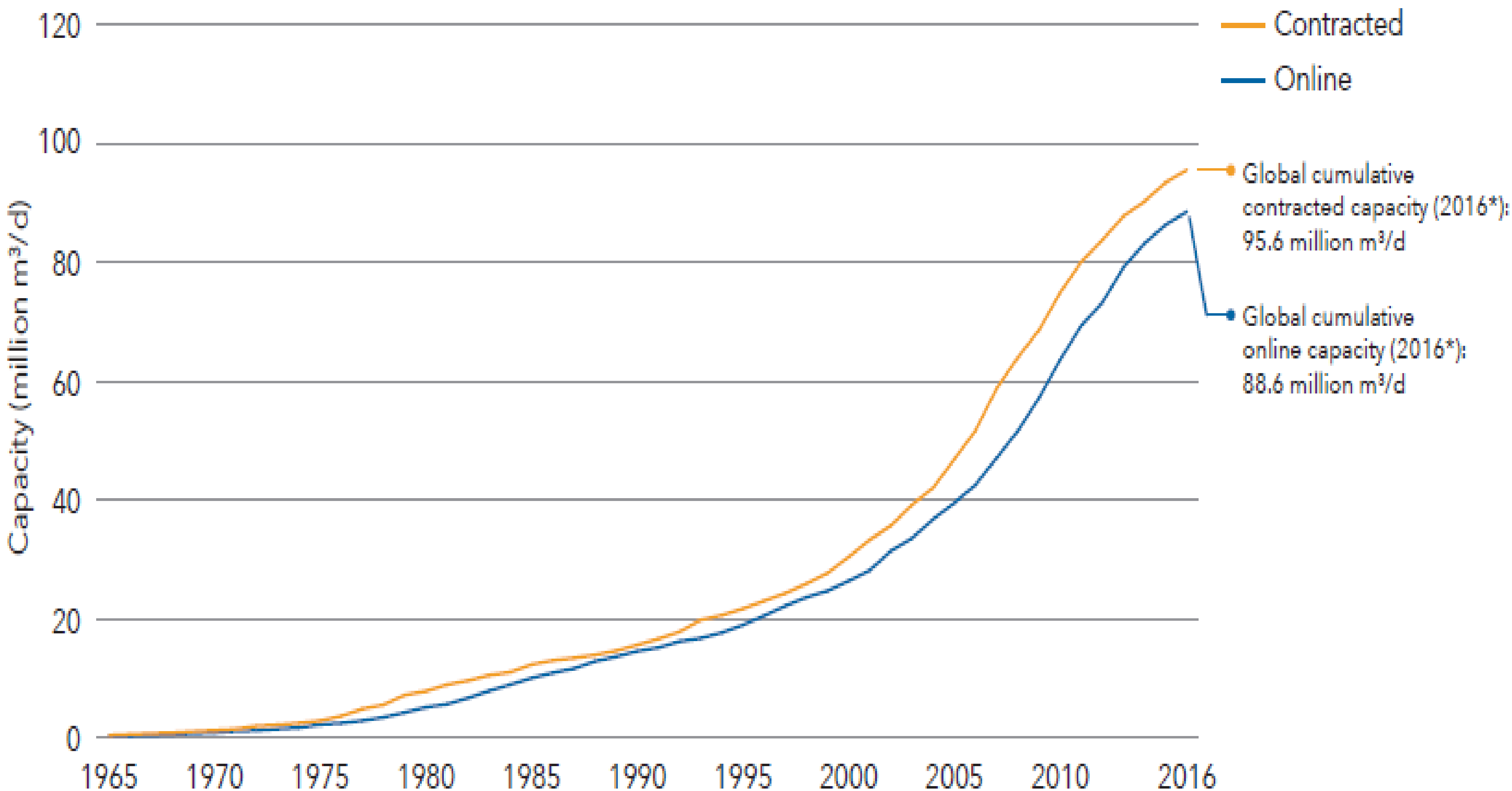
8. Summary and Discussion

World Water



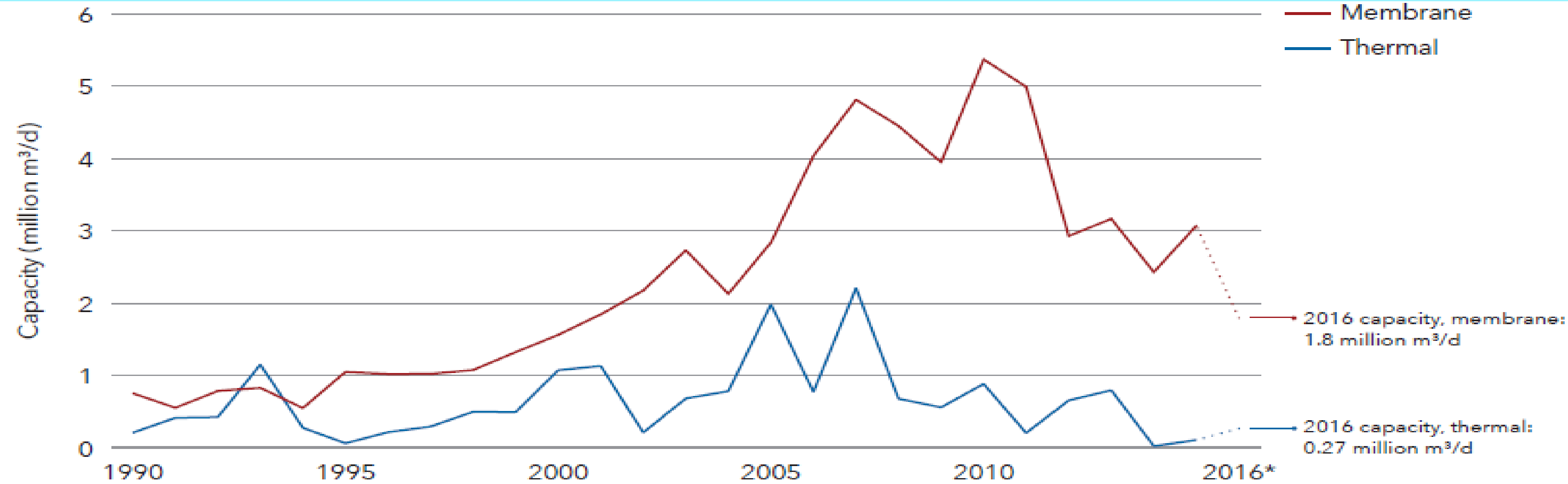
Salt Water
97.5%
Total Fresh Water 2.5%
68.9% Glaciers and permanent snow cover
29.9% Fresh Groundwater
0.3% renewable Freshwater
0.9% Other
(swamps, moisture, etc.)

Global cumulative installed contracted and commissioned desalination capacity, 1965 – 2016



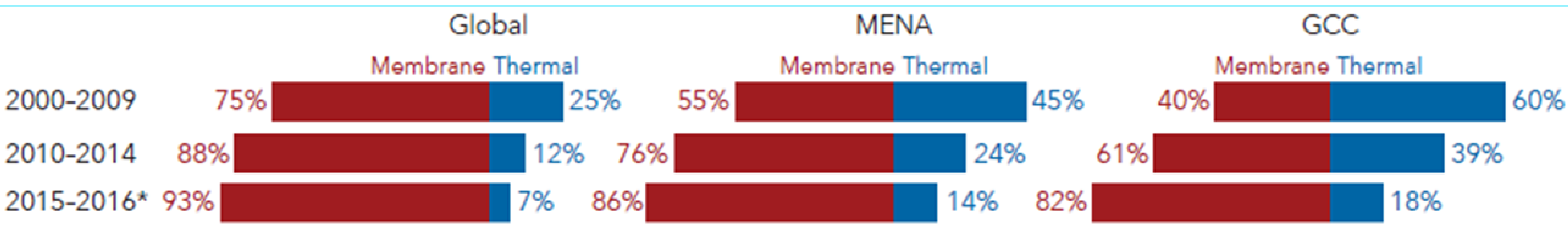
Source: GWI DesalData / IDA, 2016

Thermal versus membrane installed desalination capacity, 1990 – 2016



* Values through June 2016

Source: GWI DesalData / IDA



* Values through June 2016

Source: GWI DesalData / IDA

Source: GWI DesalData / IDA, 2016

How much desalinated water is produced worldwide?

The IDA/GWI Inventory data show that there contracted plants with a total capacity of 92.6 million m$^{3/}$d of which a total capacity of 88.6 million m$^{3/}$d have been commissioned.

How many desalination plants are there around the world?

***There are almost 19,000 desal plants*, in over 150 countries**

Energy Requirements for Desalination

Process/energy type	MED	MED -TVC	MSF	RO
Specific heat consumption, kJ/kg, PR kg/2326 kJ/kg	178 13	221-250 11.0-9.3	250-273 9.3-8.5	
Steam pressure, ata	0.3 - 0.4	2.5-3.5	2.5-3.5	_
Electric energy equivalent, kWh/m^3	3-4.5	5.4-8*	5.6-8.0	_
Electric consumption, kWh/m^3	1.0--1.5	0.9-1.8	3.4-4.5	3.3-4.0
Total electric energy equivalent, kWh/m^3	4.0-5.0	6.3-9.8	9.0-12.5	3.3-4.0

Courtesy of Leon Awebuch

The Global Clean Water Desalination Alliance – H_20 minus CO_2

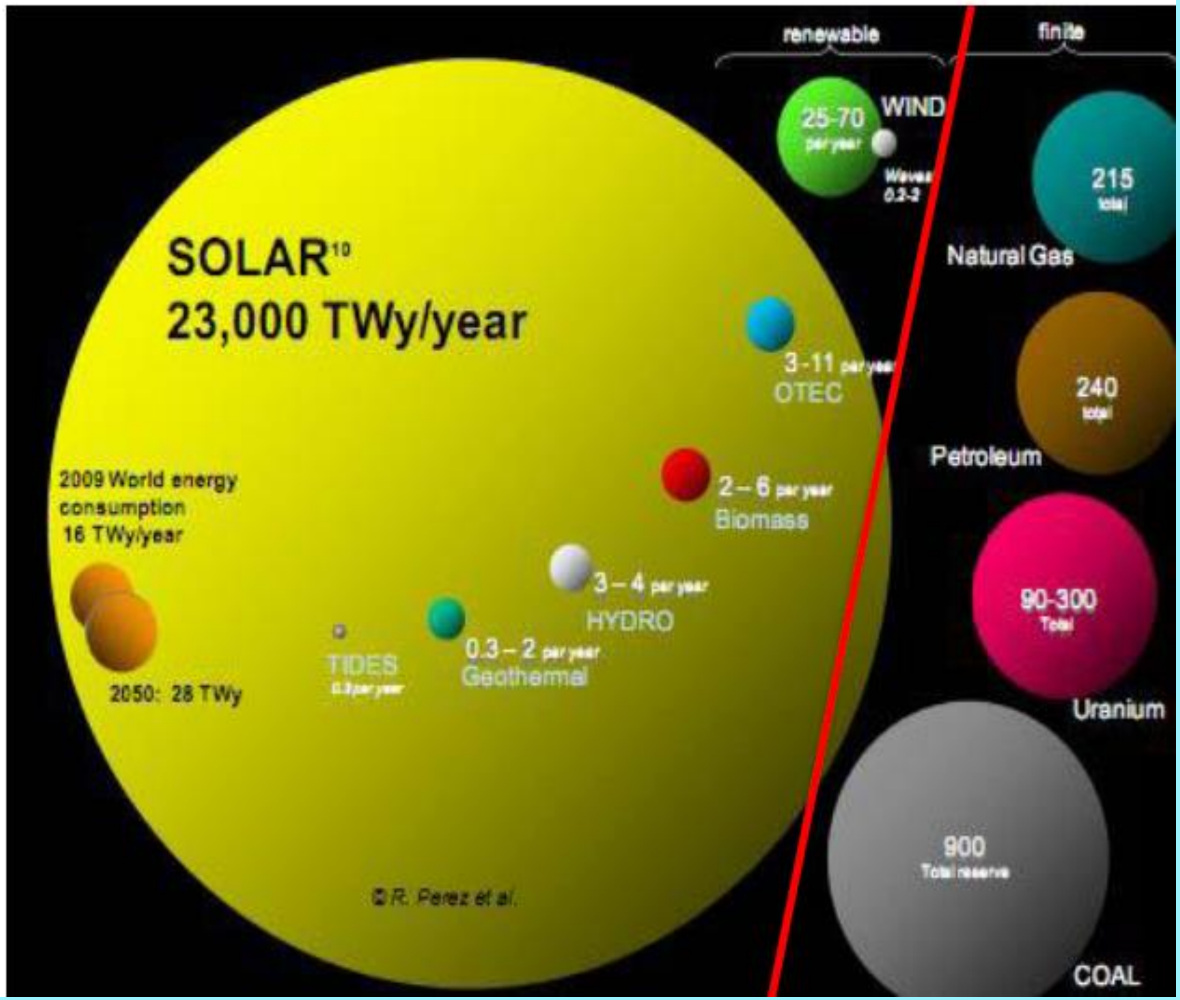
The Global Clean Water Desalination Alliance – H_20 minus CO_2, initiated by Masdar in collaboration with France and the International Desalination Association, launches in Paris during COP21

With access to drinking water already a major challenge for as much as one quarter of the world's population, and further forecasts predicting that by 2030, 47% of the global population will face water scarcity, The Global Clean Water Desalination Alliance – H_20 minus CO_2 is one of the few climate initiatives dealing with the water-energy nexus and climate change.

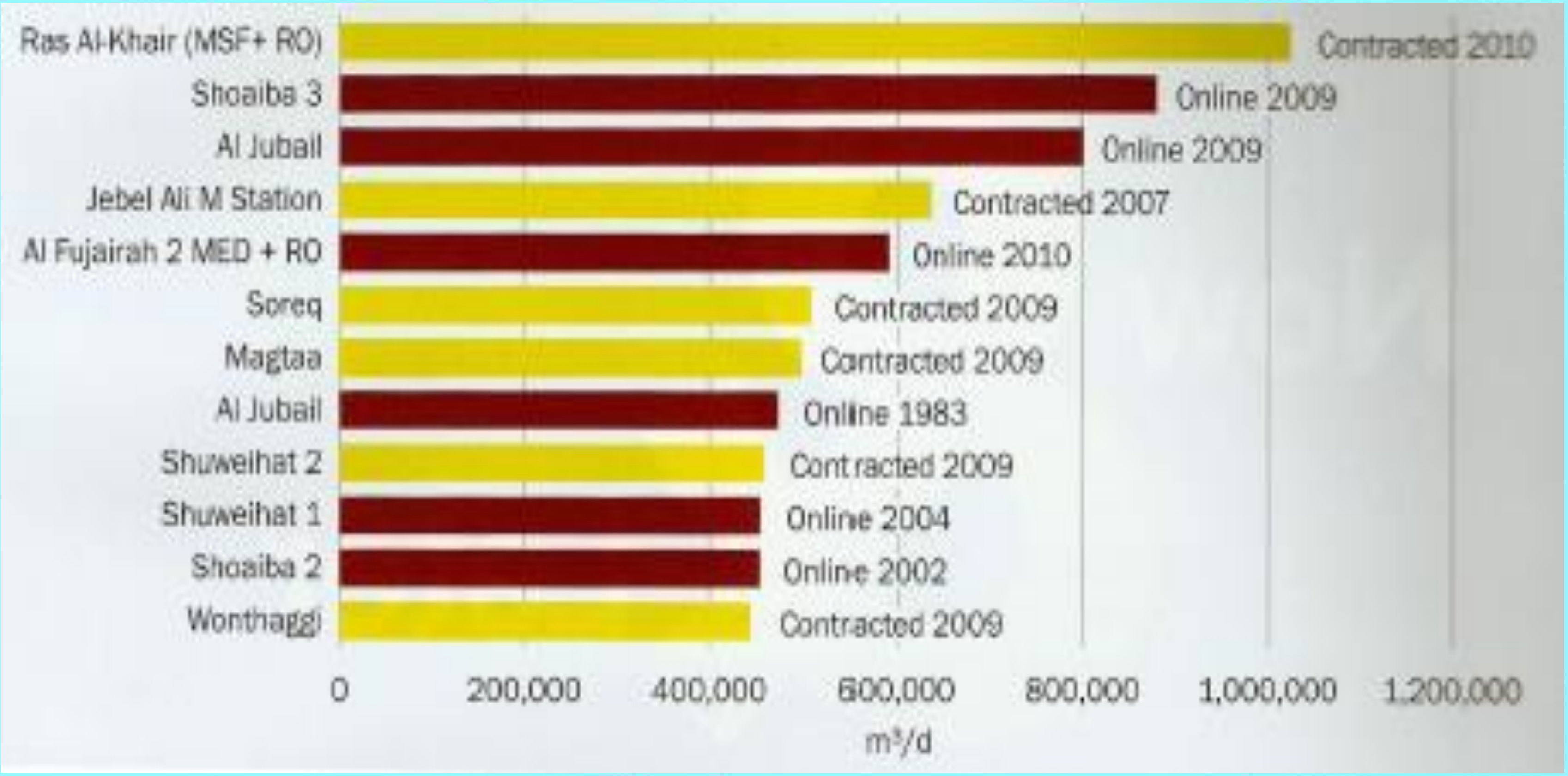
The Alliance's goal is to seek solutions that will substantially reduce the projected increase in CO_2 emissions from the desalination process, as global demand for drinking water continues to grow. The Alliance's action plan could see a decrease in emissions from 50MTCO_2 up to as much as 270MTCO_2 per year by 2040.

SOLAR ENERGY COMPARISON

The annual solar radiation on the earth surface is 1400 times higher than the annual world energy consumption and 25 times higher than the total coal reserves



Top 12 plants by capacity, with current status



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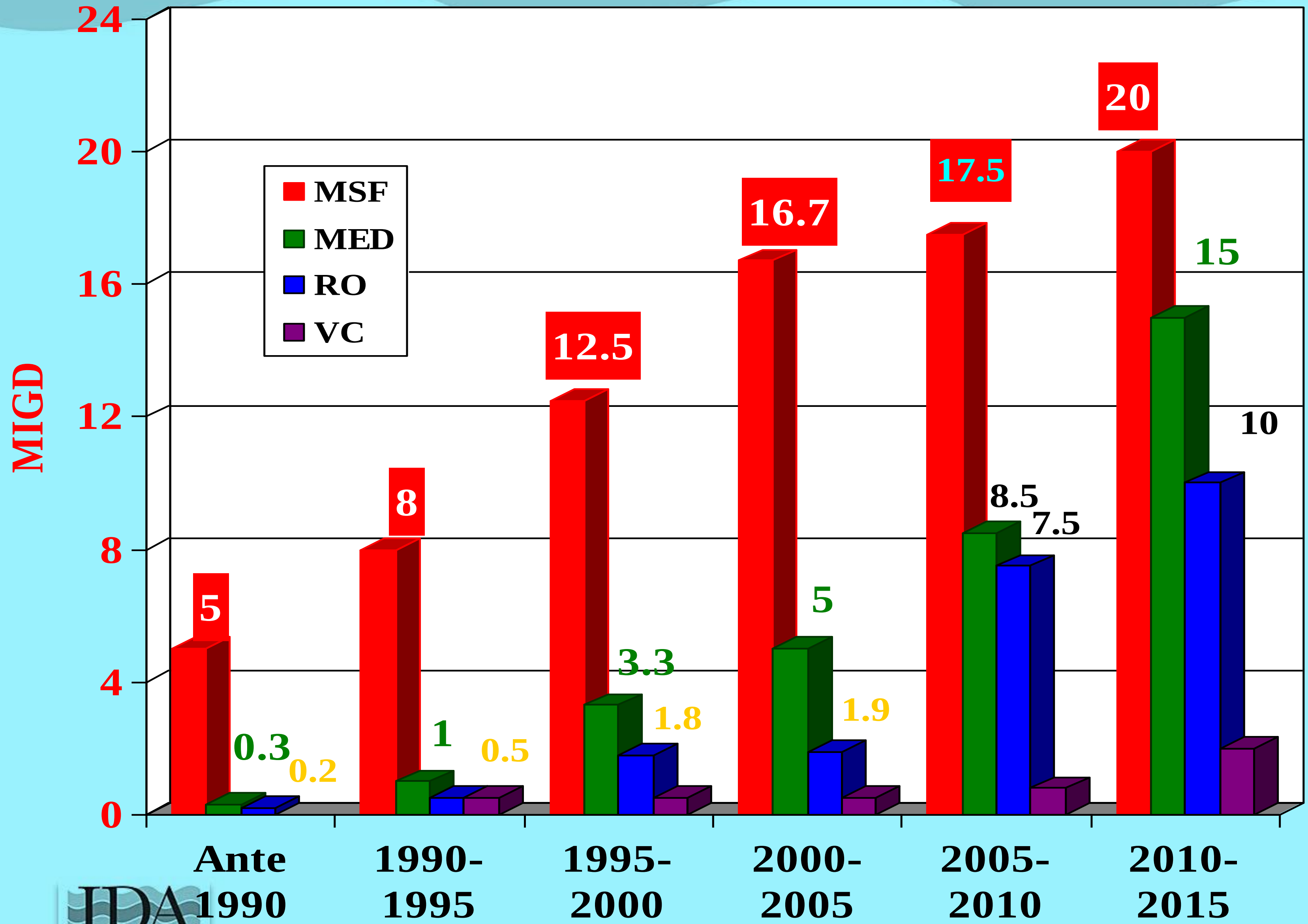
Unit Size Development of Desalination Technology



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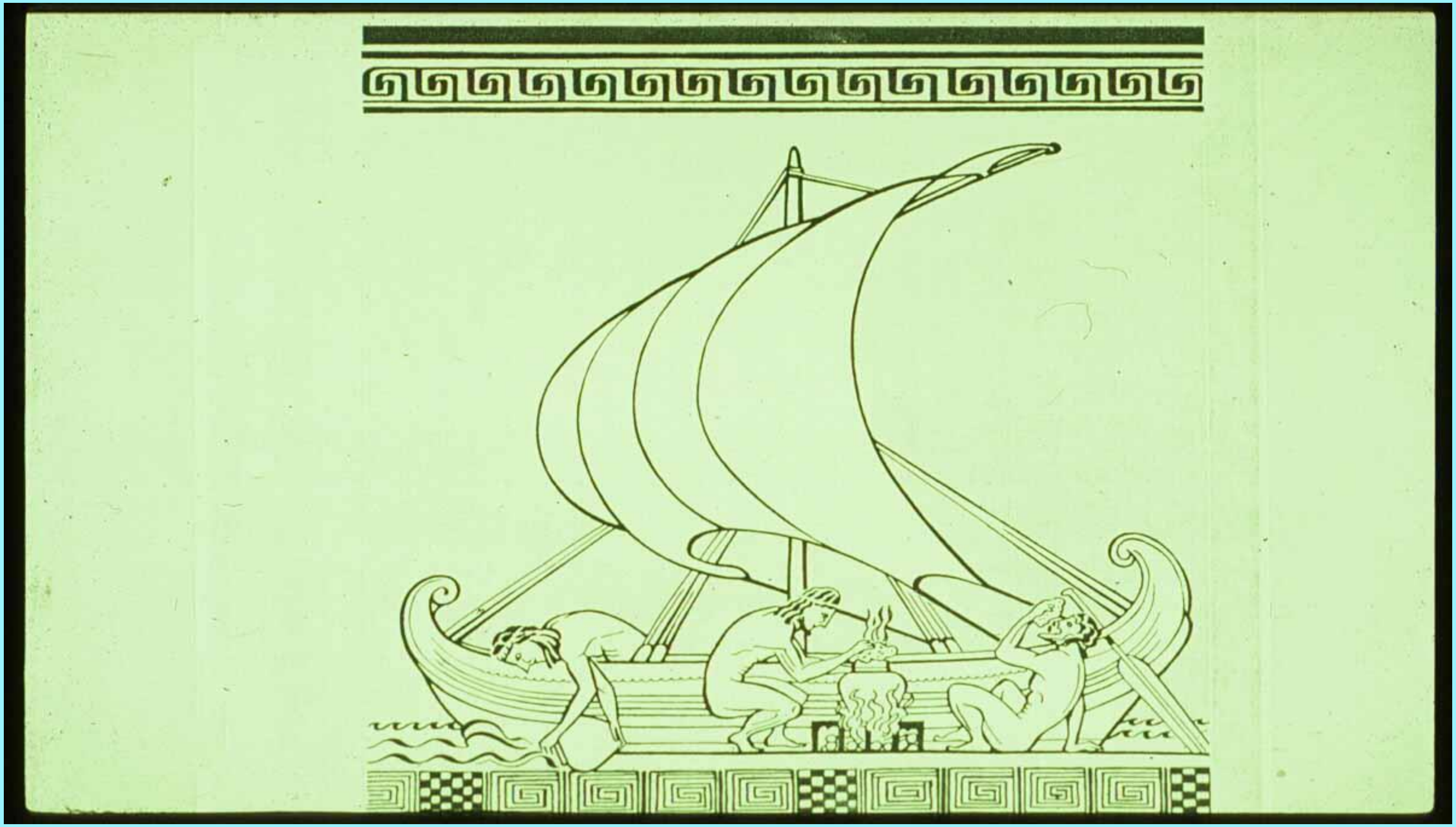
The Principle of Desalination by evaporation

Since the time of Aristotle it has been known that seawater could be distilled to produce fresh water



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Modern Thermodynamics

- Ancient process were based on a single evaporation and condensation
- Modern thermal desalination technologies are based on the repetition of evaporation and condensation phenomena at lower temperature and pressure which were understood with the discovery of modern physic thermodynamic.

• Energy input classifications

Evaporative processes rely on a phase change from liquid to the vapour phase.

In this process only the water molecules pass to the vapour phase leaving the other constituents behind in the liquid.

The two dominating systems that have evolved are Multi Stage Flash (MSF) and Multiple Effect Distillation (MED).

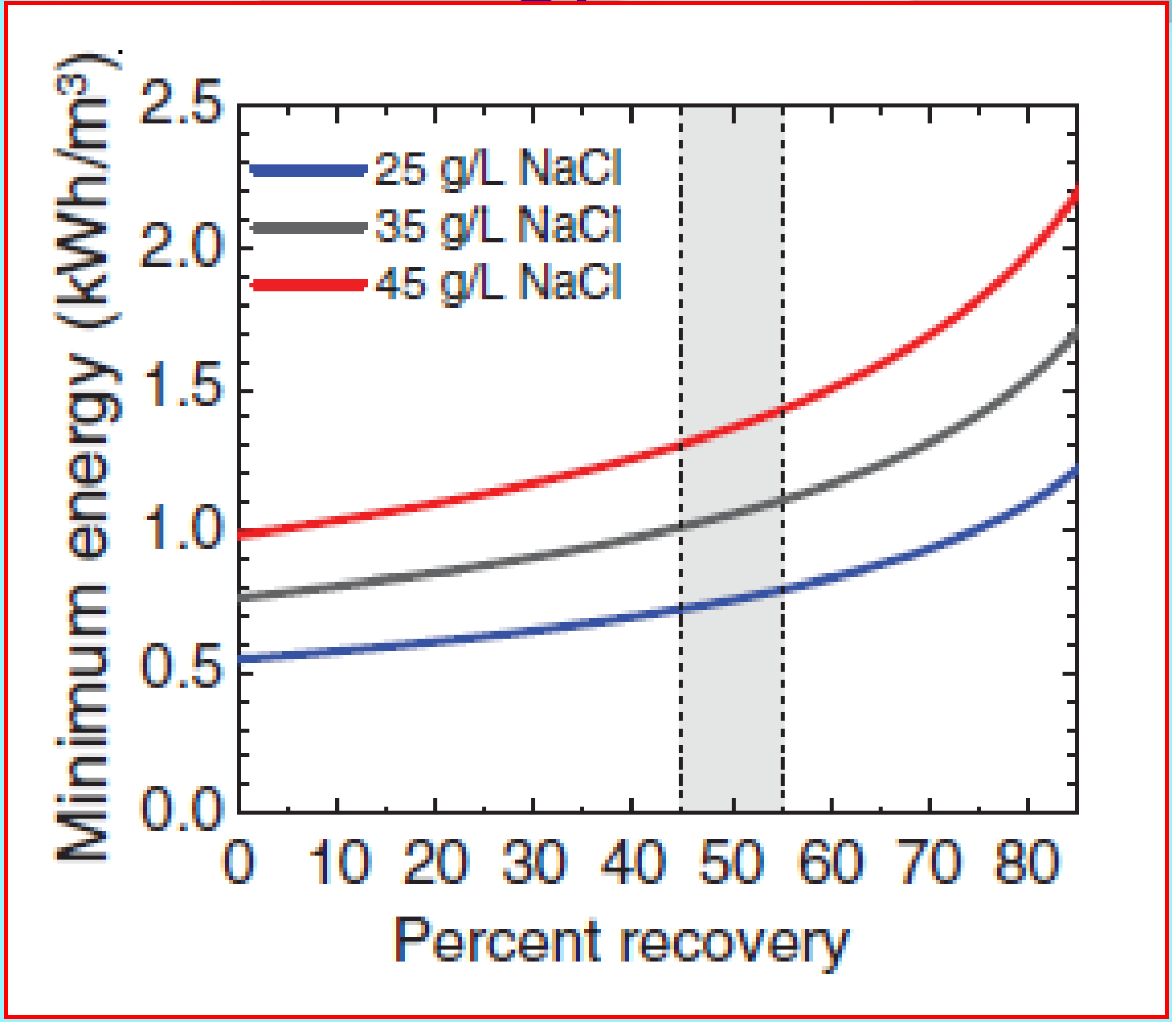
PRESENT STATUS OF THERMAL PROCESS ENERGY CONSUMPTION

Absolute minimum energy

A pertinent question before starting to discuss the present status of energy consumption in thermal processes is what kind and amounts of energy are required to desalt sea water in order to produce a kg of pure water.

This question was answered by many studies but the most intuitive is the one described in the next Figure where an ideal desalting process is shown; if we consider the first situation when the two large vessels one containing sea water and the second fresh water are not connected we can assume that the empty spaces above the water level are filled with vapour at a pressure in equilibrium with the temperature.

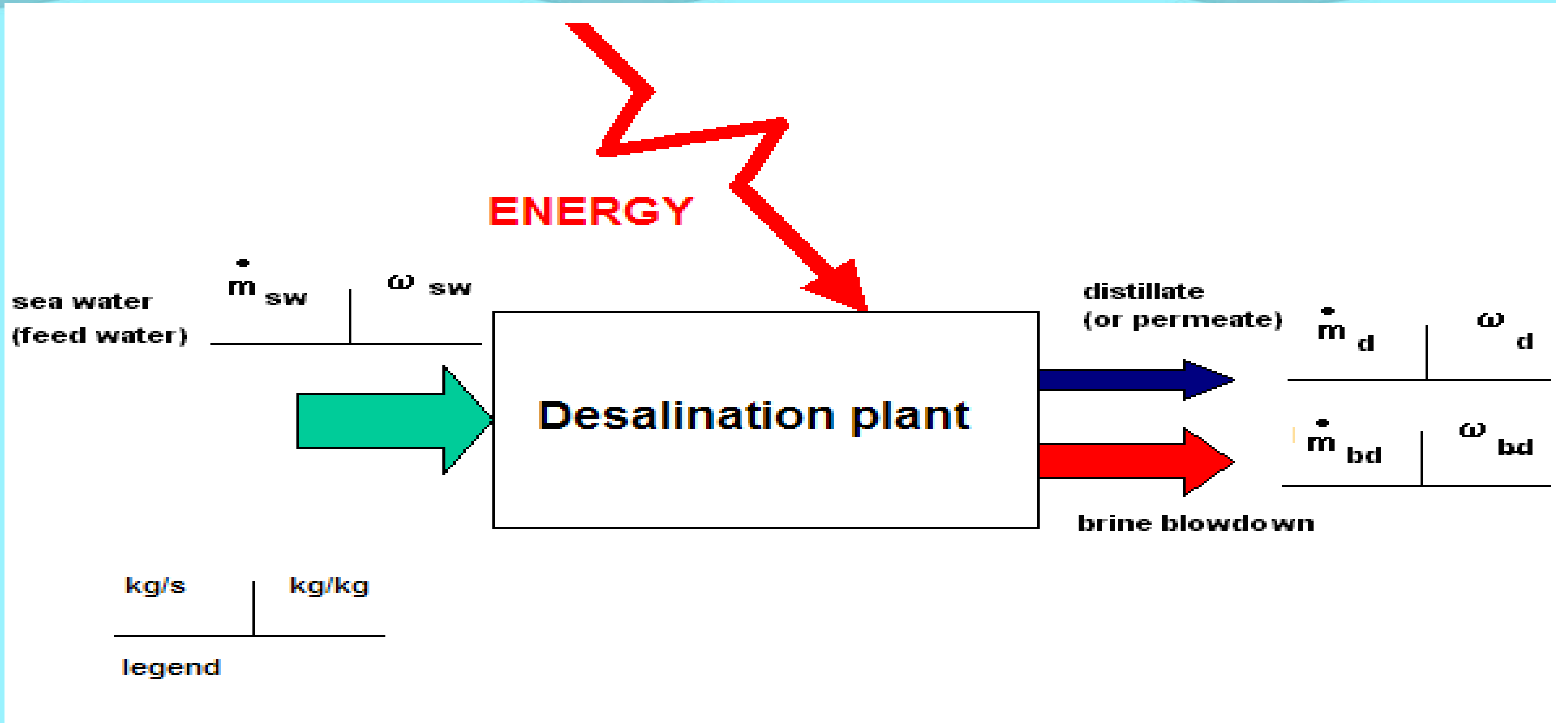
Minimum Energy for Desalination



Ref. M. Elimelech, W. Phillip, Science 5 August 2011, The Future of Seawater Desalination: Energy, Technology, and the Environment

- Energy input classifications

• Desalination plant Basic Mass Balances



Regardless of the type of process adopted desalination transforms seawater into concentrated brine and distillate by using energy.

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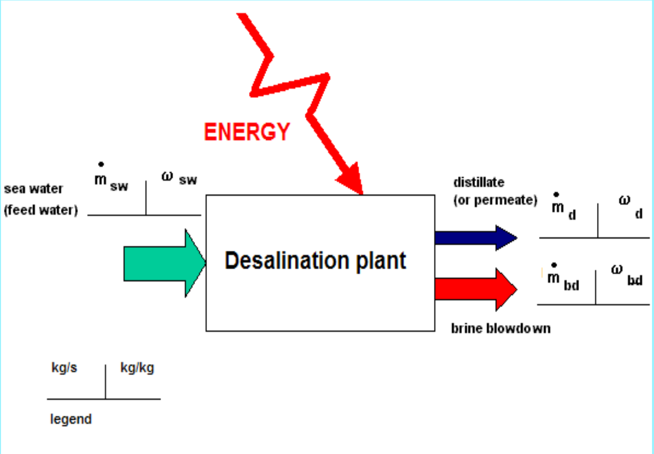
• Mass Balances relationships

1) mass conservation (overall mass balance)

$$\dot{m}_{sw} = \dot{m}_{bd} + \dot{m}_{d}$$



22) salt conservation (overall salt balance)

$$\dot{m}_{sw} \cdot \omega_{sw} = \dot{m}_{bd} \cdot \omega_{bd} + \dot{m}_{d} \cdot \omega_{d}$$

ω = Salt concentration (kg / kg)

$\dot{m}$ = Mass flow rate (kg / sec)

- Mass Balances relationships

Definition of concentration factor :

ratio between blowdown and seawater salt concentration

$$Cf_{bd} = \frac{\omega_{bd}}{\omega_{sw}}$$

- Mass Balances relationships

Rearranging equation 1) and 2)

and using the definition of concentration factor

we can obtain a formula relating seawater

requirement and product distillate capacity

$$\dot{m}_D = \dot{m}_{sw} \cdot \left(1 - \frac{1}{Cf_{bd}} \right)$$

- Note this formula is valid for all types of desalination processes including RO

Performance Ratio
Gain Output Ratio GOR

- Energy input : performance ratio

$$\eta = \frac{\dot{m}_d}{\dot{m}_s} \frac{\Delta H_{ref}}{\Delta H_{h.i.}}$$

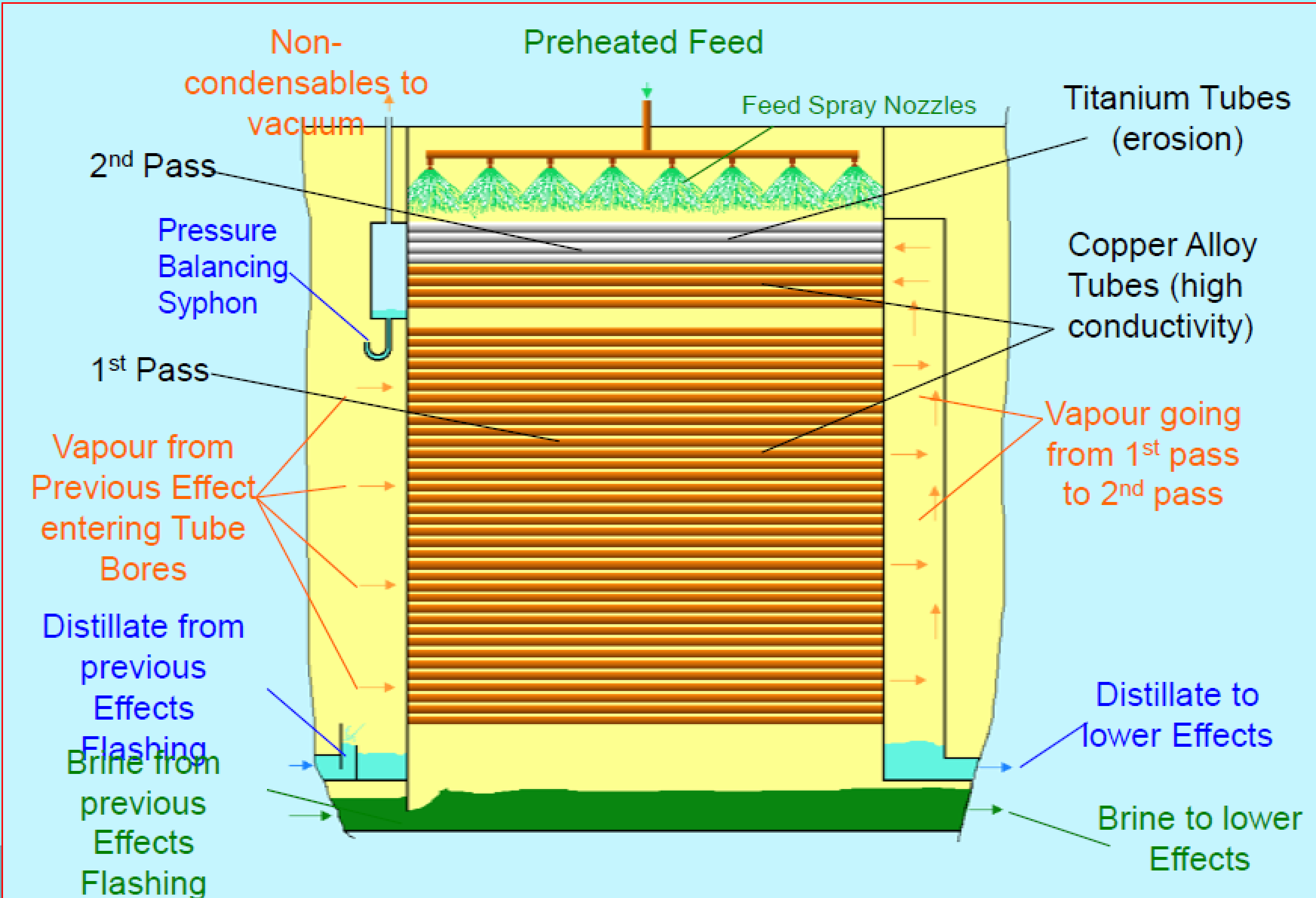
- Reference enthalpy = 2326 kJ/kg of steam

- Energy input : GOR

$$G.O.R. = \frac{\dot{m}_d}{\dot{m}_s}$$

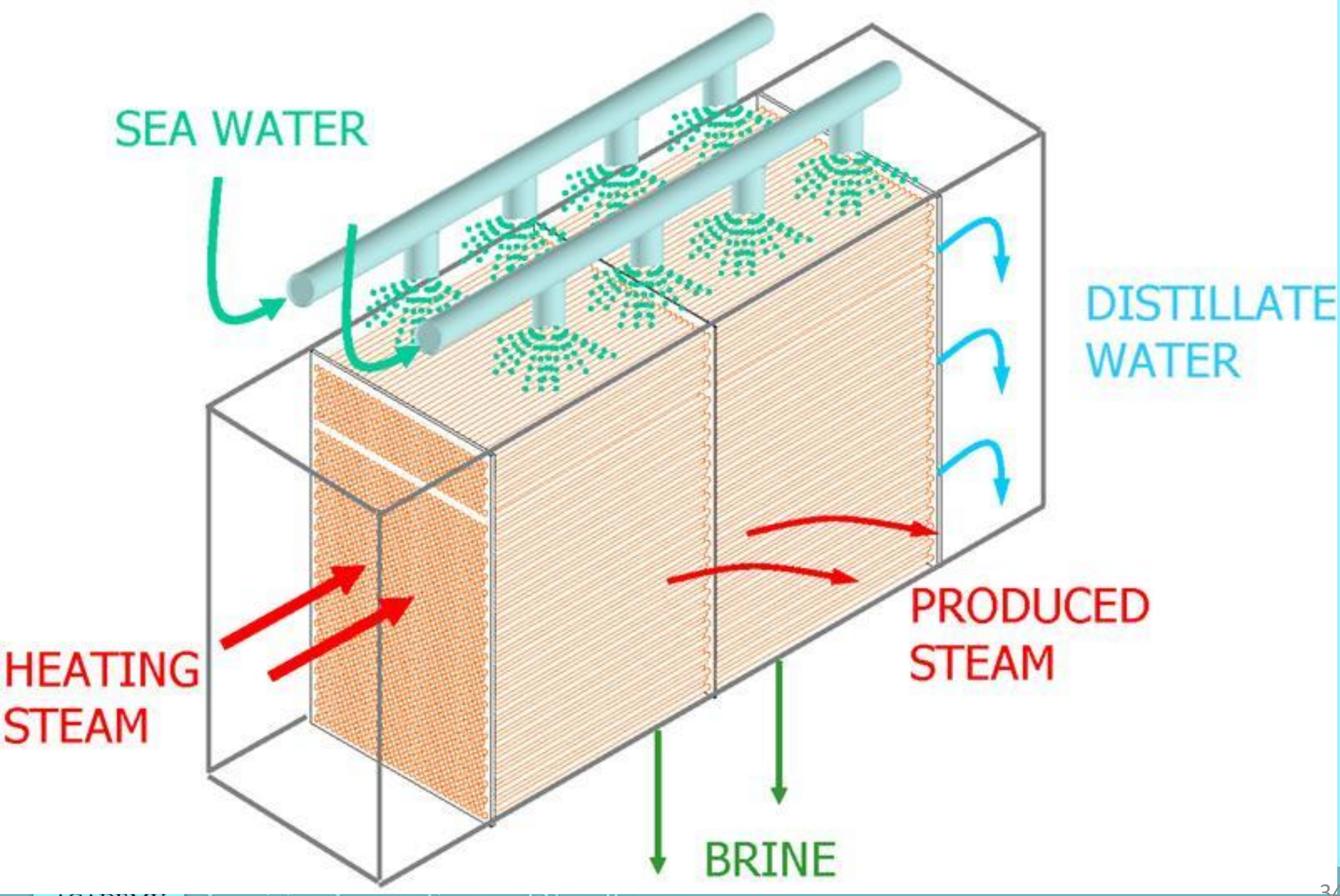
Multi-Effect Distillation(MED)

Typical MED Horizontal Tube Bundle



Horizontal Tube - Effect Distillation

Basic flow streams



Multiple- Effect Distillation (MED)

The basic principle is straightforward.

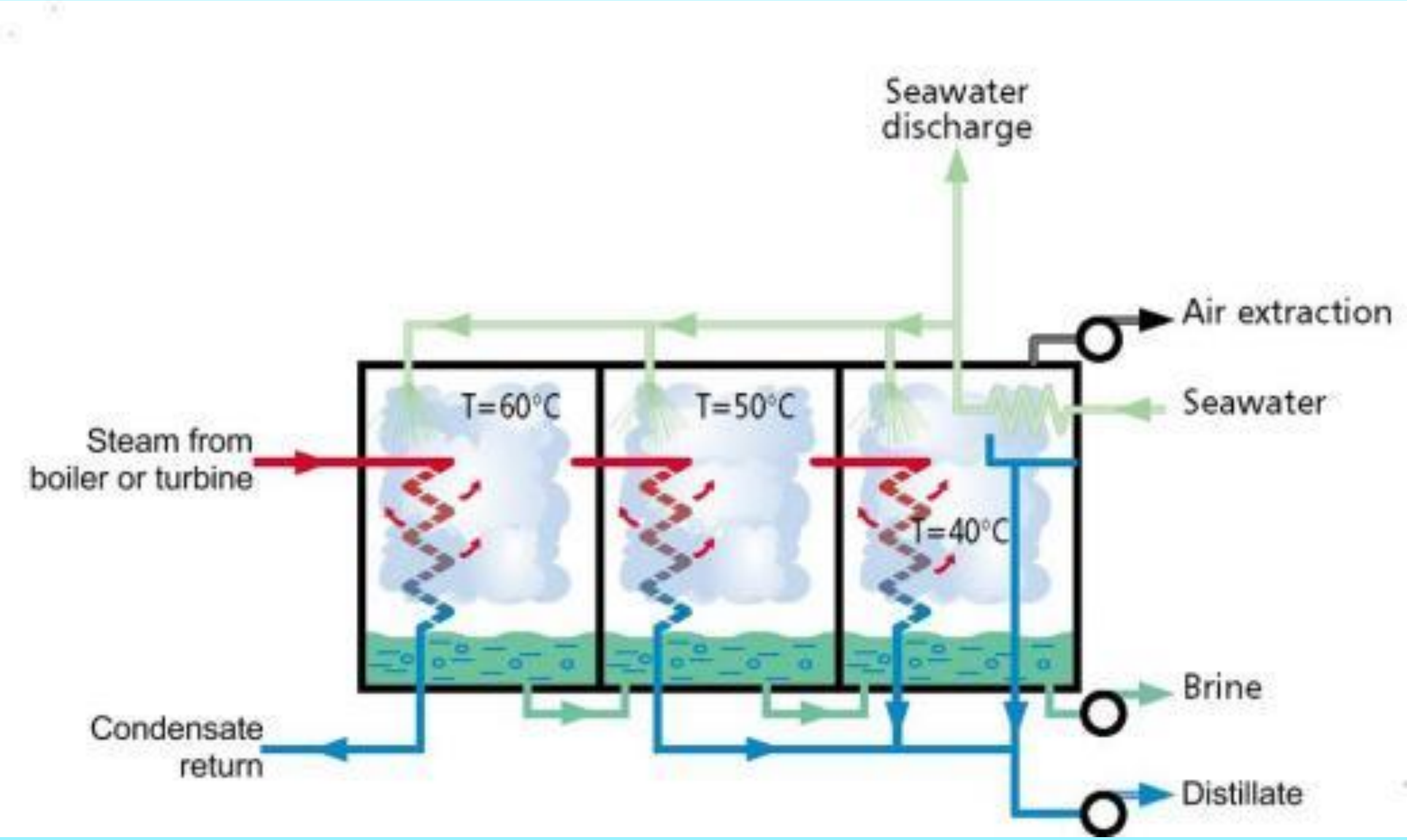
- The feedwater flowing over a heat transfer surface in the first cell (effect) Is heated by prime steam, resulting in evaporation of a fraction of the water content of the feed.

- The partially concentrated brine is delivered to second cell (effect), maintained at a slightly lower pressure than the first effect. Likewise, the vapor liberated from the first effect feed is sent to the second effect. There the vapor condenses on the heat transfer tubes, giving up its latent heat to evaporate an additional fraction of water from the brine flowing on the opposite wall of the tube.

- The process of evaporation-plus-condensation is repeated from effect to effect each at successively lower pressure and temperature. The combined condensed vapor constitutes the product water.

Multiple Effect Distillation Process

The heart of the process: the MED evaporator



http://www.sidem-desalination.com/en/process/MED/Process/

Multiple- Effect Distillation (MED)

Widely used multi-effect distillation plant of the horizontal-tube type, in which the prime steam and all the downstream vapors flow inside the horizontal tubes, where they condense and contribute to the product water stream.

The brine, meanwhile, is sprayed on the outside of the tubes, producing vapor.

The water vapor generated by brine evaporation in each effect of the horizontal-tube evaporator flows to the next effect, where it supplies heat for additional evaporation at a lower temperature.

Multiple- Effect Distillation (MED)

Each effect serves as a condenser for the vapor from the preceding effect;

however, the vapor generated in the last effect is condensed in a final condenser, where the heat is rejected to a stream of cooling water.

Thus, in the unlikely event of a leaky tube wall, the vapor (which is at a higher pressure than the brine)

would leak into the brine chamber, thereby avoiding contamination of the product water.

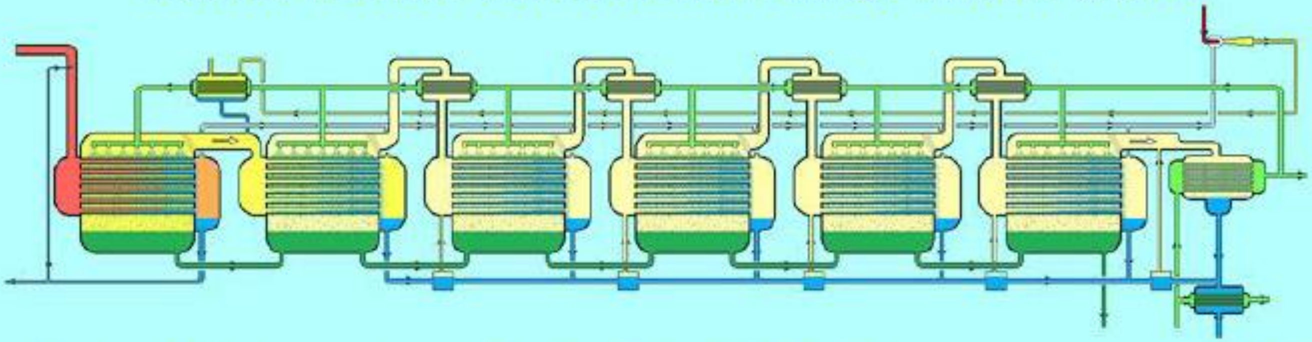
MED SCHEMATIC

- Simulation of IDE MED process

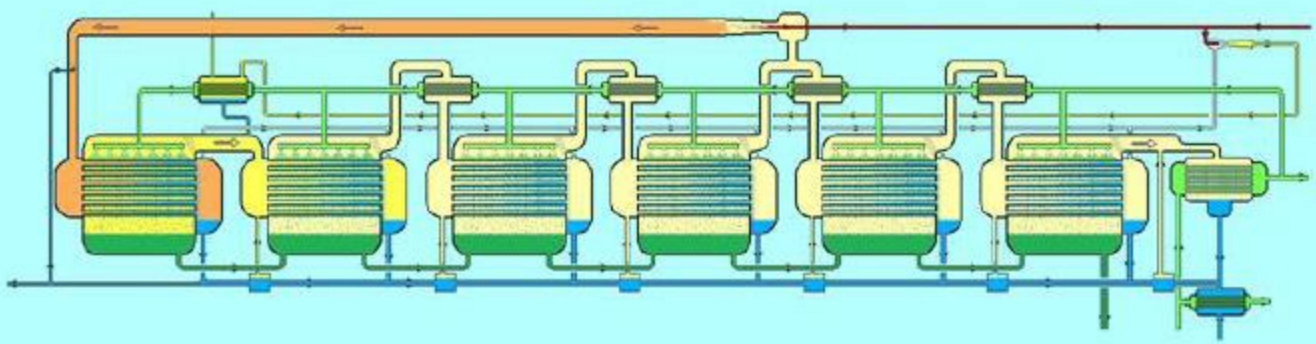
http://www.vertexwater.com.au/userfiles/flash/med_2-En.swfulation

Low Temperature MED with and without Thermo-compression

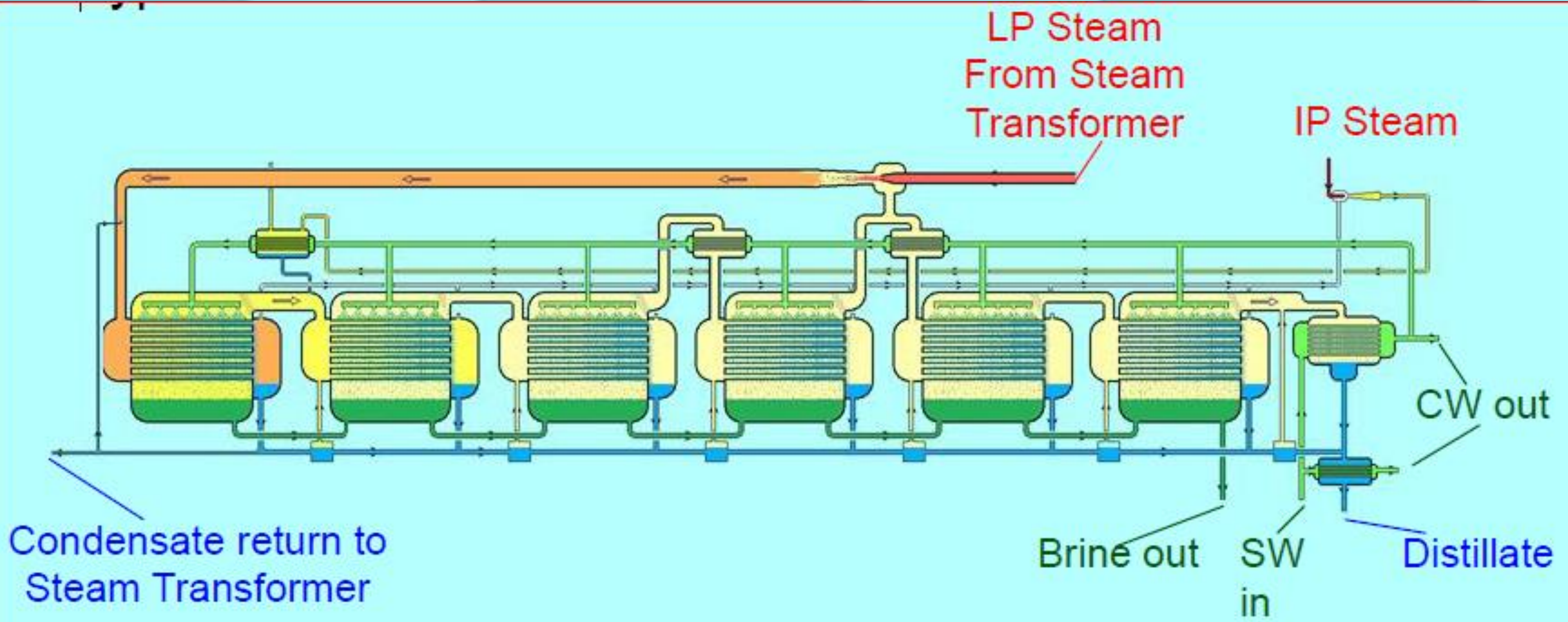
Classical Parallel Fed, Horizontal Falling Film (HFF), MED



A Parallel Fed, Horizontal Falling Film (HFF), Thermo-compressionMED



Typical TVC-MED Flow Diagram



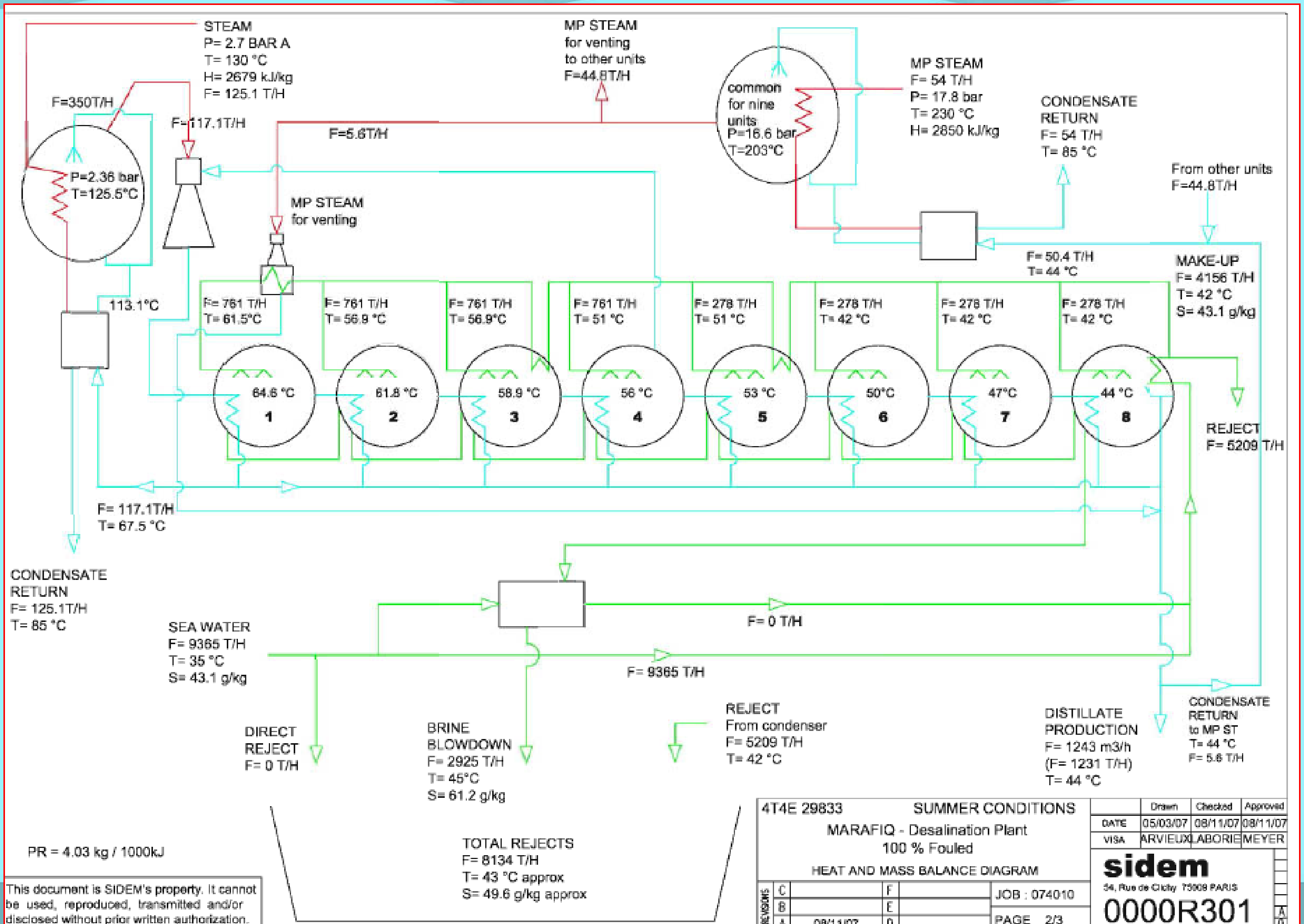
Typical Top Brine Temperature ~ 65°C

Typical Performance Ratio ~ 8 to 10

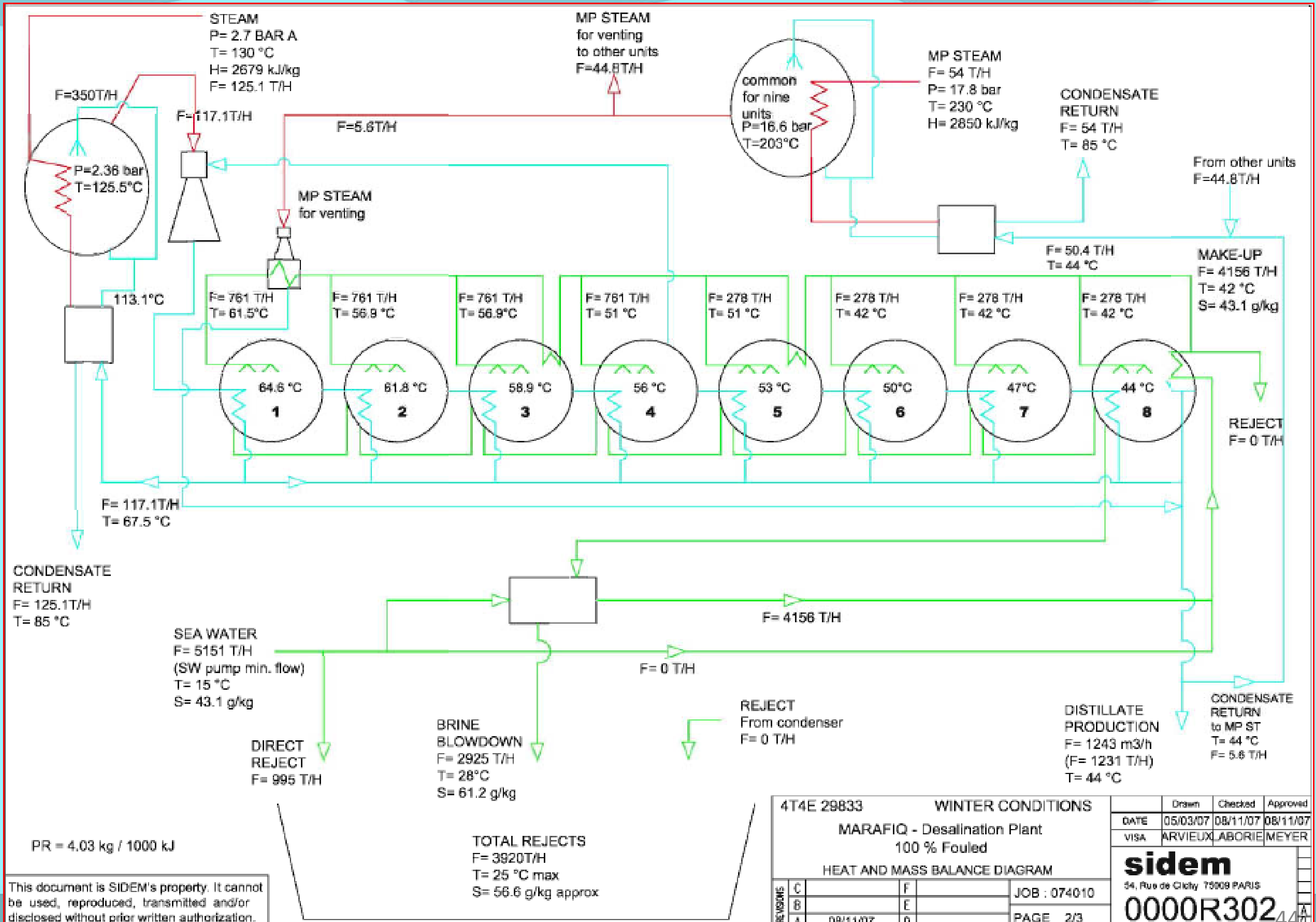
Typical Specific Surface ~ 3.0 days/m

Marafiq IWPP - Saudi Arabia ***MED-TVC - 27 units of 6.59 MIGD (178 million gallons daily production) Sidem.***

Marafiq MED Heat and Mass Flow Diagram Summer Conditions.



Marafiq MED Heat and Mass Flow Diagram
Winter Conditions.



MED distillation

- Unit size has increased from 1 to 5 MIGD (now 15 MIGD) in 8 years
- Potential for further increase?
- Improvements in thermal vapour compressors and plant configuration
- Reduce steam supply pressure
- Trade off between steam consumption and supply pressure
- Distiller performance v power plant output

MED KEY PARAMETERS

Capital Cost MED	5.4-7.0	US$ MM per MIGD
Capital Cost –Intake /Outfall	0.5	US$ MM per MIGD of cooling
MED GOR	8-14	Tons of product/ton of steam
LP Steam Supply	2.5-3	Bar A
Lost Power Potential	1.225	MW/MIGD
Power Consumption	1.8	KWh/m^3 of distillate
Steam Consumption	15.8	Tons/MIGD
Chemical Costs	40,000	US$/yr per MIGD
MED R&R	1%	TIC/yr
Labor	40,000	US$/yr per MIGD

Multi-Effect Distillation (MED)

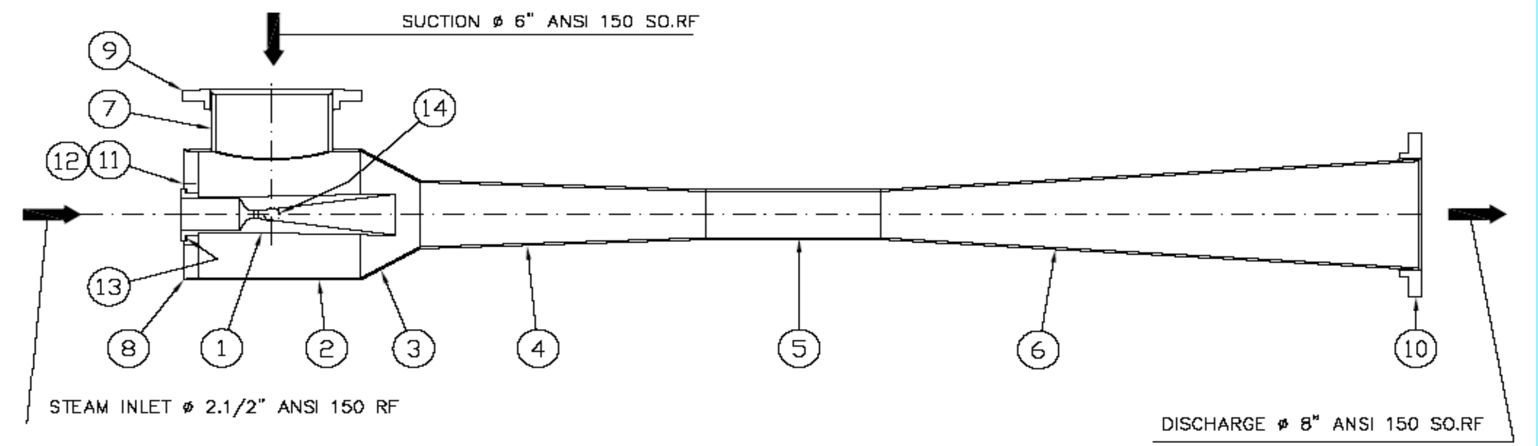
- **Not sensitive to seawater (TDS):**
- **Top brine temperature: 63-70^{o} C**
- **Performance ratio: 8-12**
- **Steam consumption 15.8 tons/1MIGD @ PR12**
- **Electrical power: 1.0-2 kWh/m^3**
- **High purity distillate**
- **Scale inhibitors used for scale control**
- **Dual purpose plant**
- **Capital cost 5.0-7.0 US MM$/1MIGD**
- **Unit size reached 8.33 MIGD in Fujeirah 2 , 11 MIGD in Az Zour North ph 1, and 15 MIGD unit constructed in Yanbu in KSA**

• The concept of thermocompression

The MED-TVC evaporator is basically an MED evaporator fitted with a *thermocompressor*. The purpose of the thermocompression of the vapour is to take advantage of the pressure of the available steam, when this pressure is sufficient (i.e. above 2 bar abs), to enhance the units' performance.

The incoming steam, called *motive steam*, is fed into the thermocompressor through a sonic nozzle. Its expansion will allow low pressure steam from a cell of the evaporator to be sucked out. Both steams will be mixed in the thermocompressor body. The mixture is then compressed to the pressure of the first bundle through a shock wave. The latent heat of the sucked vapour is thus recycled in the evaporator and is again available for desalination, leading to energy savings

A Simple Ejector-Compressor



Pos. Pos.	Q.ty Q.to'	Description Denominazione	Material Materiale	Note Note
14	1	COUPLING	ASTM A 182F-316L	
13	1	GASKET	GRAPHITE 92-R	
12	4	NUTS	ASTM A 194 Gr.2H	
11	4	STUD BOLTS	ASTM A 193 Gr.B7	
10	1	FLANGE	ASTN A 105+CLADDED	
9	1	FLANGE	ASTM A 105+CLADDED	
8	1	HEAD	ASTM A 240-316L	
7	1	NOZZLE	ASTM A 312-316L	
6	1	DIVERGENT	ASTM A 240-316L	
5	1	THROAT	ASTM A 240-316L	
4	1	CONVERGENT	ASTM A 240-316L	
3	1	CONE	ASTM A 240-316L	
2	1	SUCTION CHAMBER	ASTM A 240-316L	
1	1	NOZZLE	UNS N08904	

Fluid flowing in the pipeline (the "motive fluid") speeds up to pass through the restriction and in accordance with Bernoulli's equation creates vacuum in the restriction.

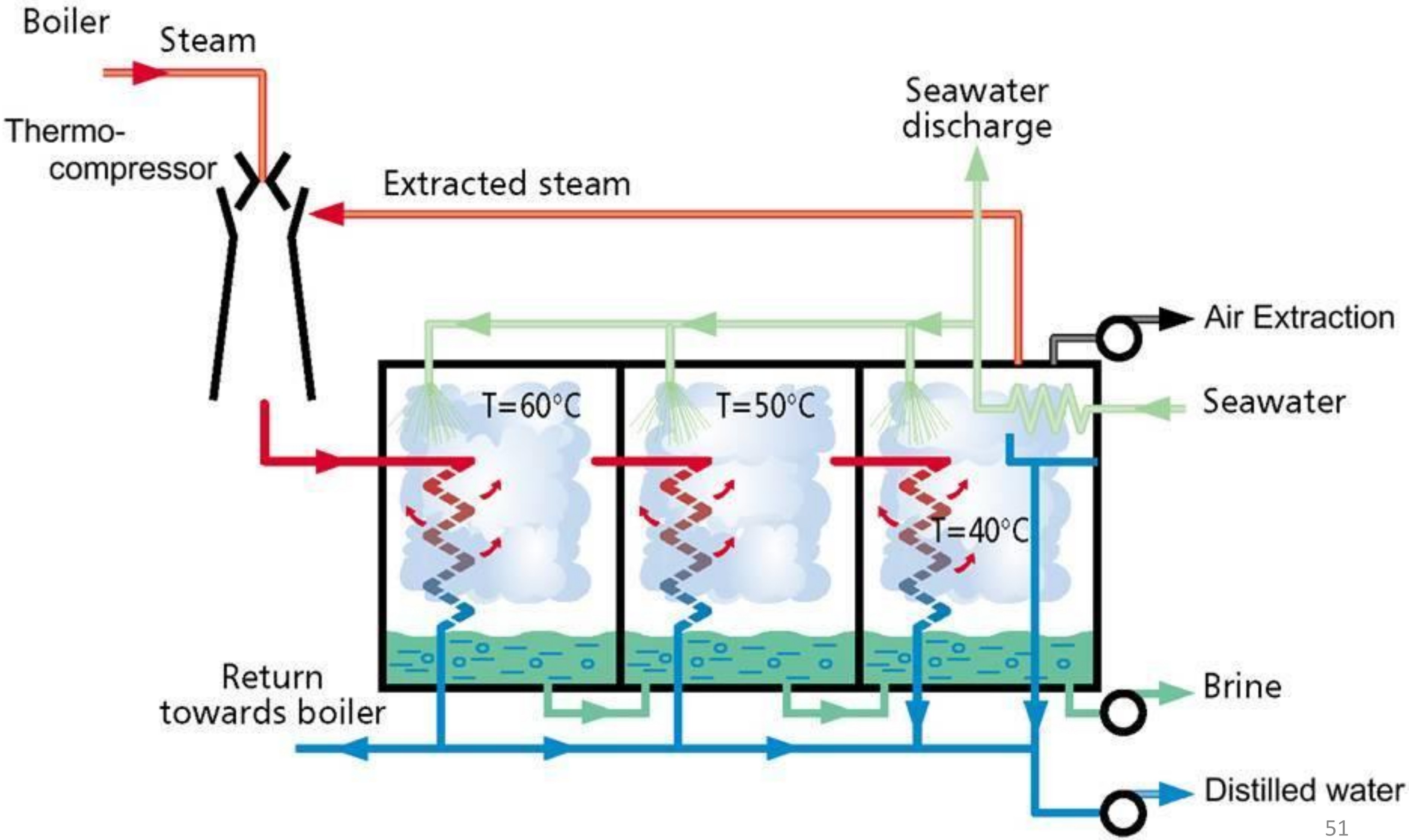
A side port at the restriction allows the vacuum to draw a second fluid (the "ejected") into the motive fluid through the port.
Turbulence downstream of the port entrains and mixes the ejected into the motive fluid.

Thermocompressor Ejector Performance.

The efficiency of the ejector is defined as the ratio between the product of the flow of the entrained vapor and the change of enthalpy during the compression at a constant entropy to that of the flow of the motive steam and the change of enthalpy during its expansion at the same reversible conditions (See the formula displayed in the drawing). The value of the ejector's efficiency for the present case calculated to be 22.6% as compared to turbo compressor system which value is 70%X70%=49%.

MED - TVC

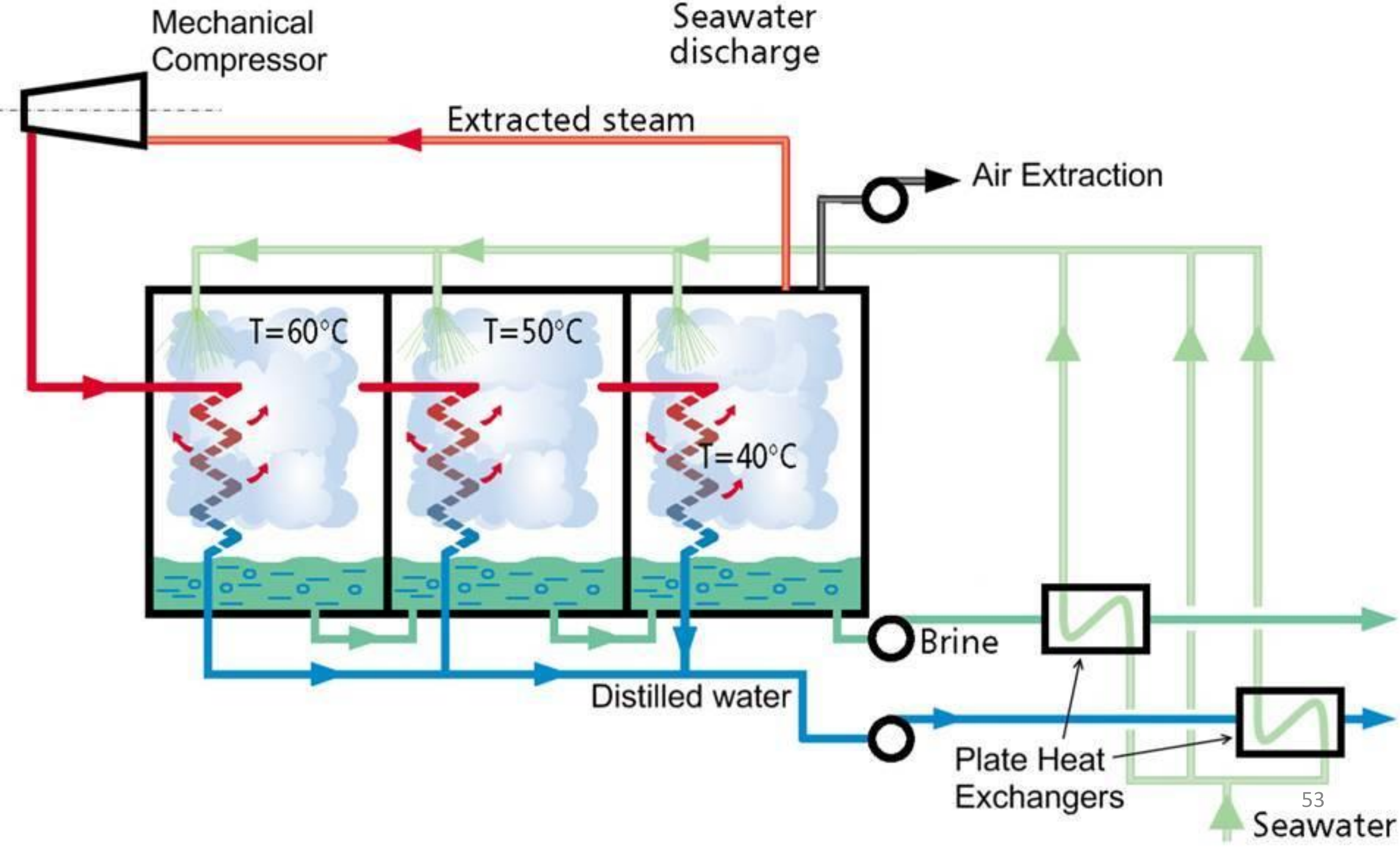
Or how the efficiency of the plant is improved by addition of vapour thermocompressor



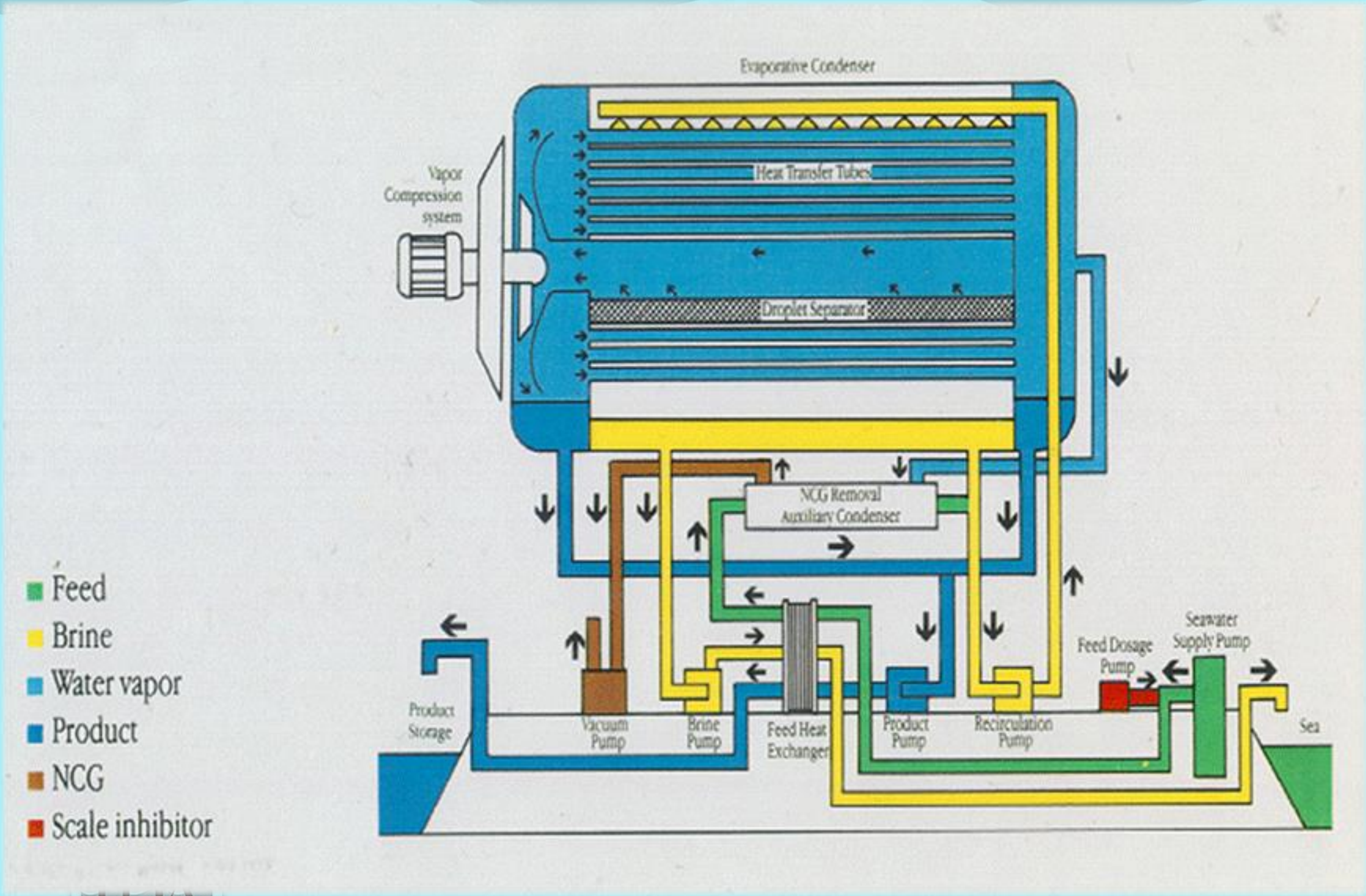
Mechanical Vapor Compression (MVC)

Multiple effect distillation using mechanical vapour compression

... or how MED can be applied without available vapour



MVC Process Schematic



MVC

The MED-MVC evaporator is a MED evaporator using only electrical energy. The evaporator itself is of the MED type and all the features described for the MED evaporator apply for MED-MVC process. This evaporator is equipped with a mechanical compressor. The compressor allows the vapour produced in the coldest effect to be brought to the pressure conditions prevailing inside the bundle of the first cell, thus enabling its latent heat to be re-available for distillation.

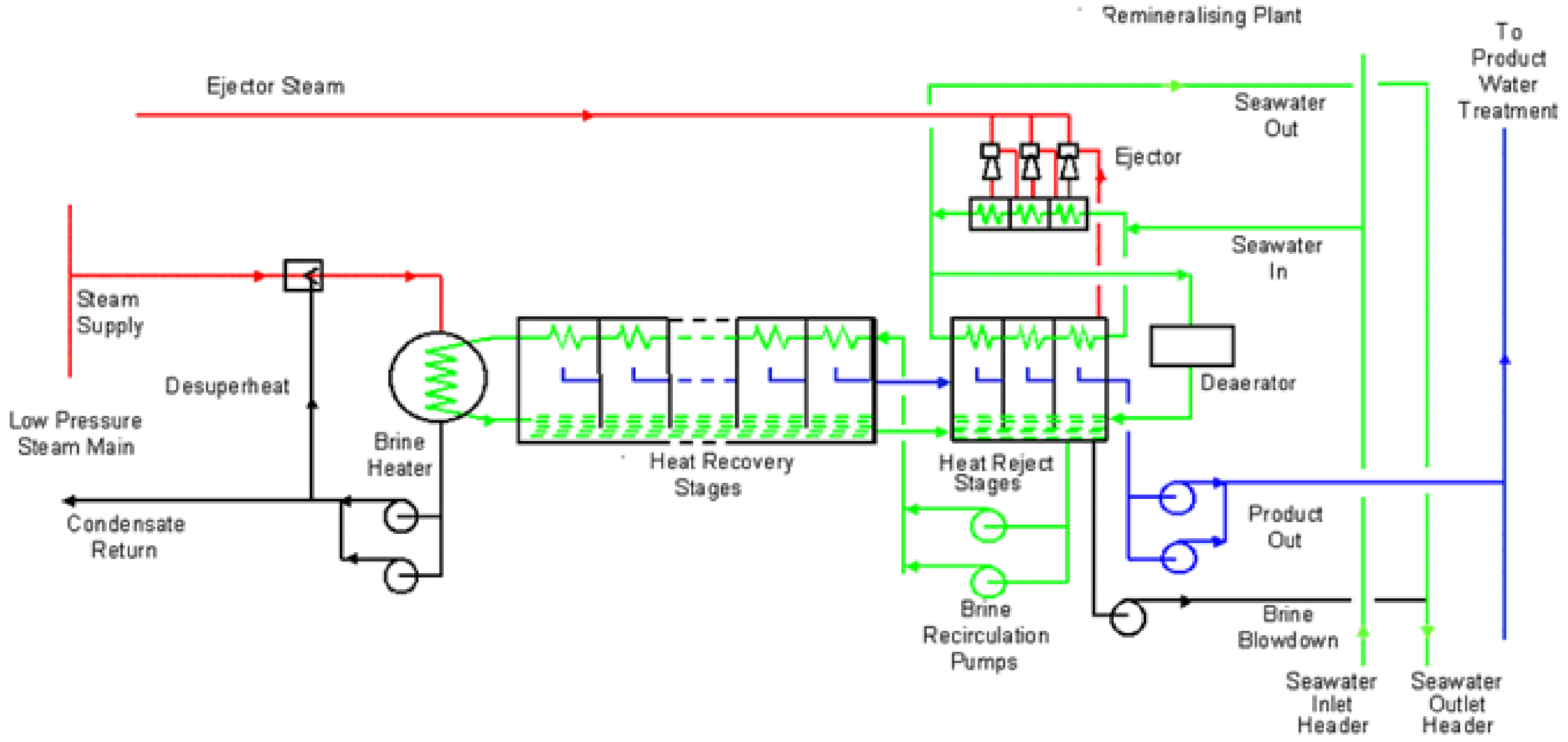
The input of energy ranges from around 18 kWh/m3 of distilled water for a single effect evaporator to around 8 kWh/m3 distillate water for a four-cell evaporator. This energy input being quite small, it is necessary to recover the heat from the distillate and the brine to preheat the sea water fed into the evaporator. This is done by means of two plate heat exchangers.

Multi Stage Flash (MSF)

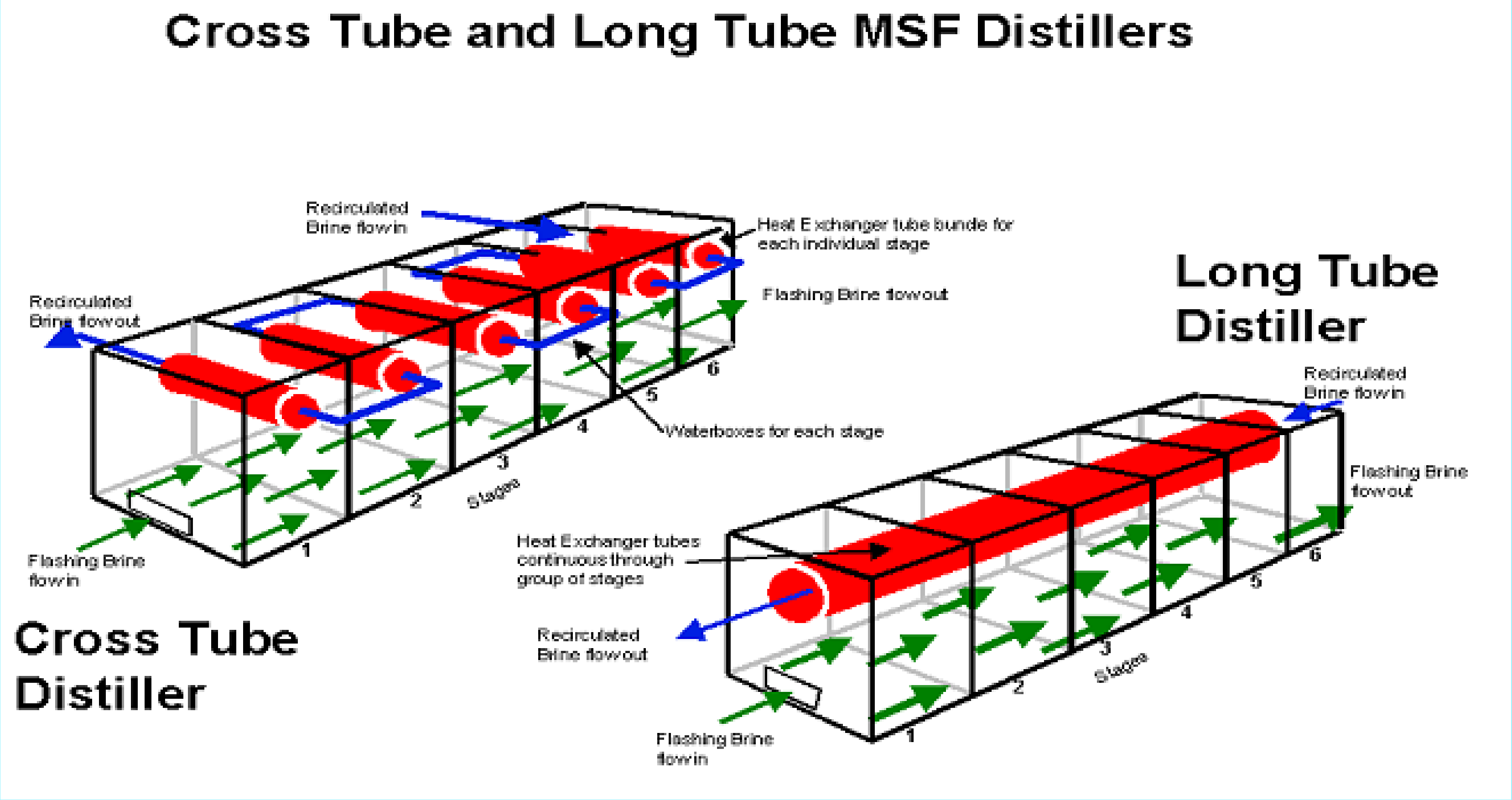
First MSF Plants

- In 1957 Silver applies for UK & US patents
- In 1958 Weir tenders MSF for Two 1Migd Kuwait plants
- Design 3-deck, cross-tube, brine recirculation, 19 stage, PR 6
- Kuwait E commissioned April 1960

Traditional MSF flow diagram



Multi stage flash



Multi Stage Flash (MSF)

- Raw seawater total dissolved solids (TDS): 35-47,000 mg/L
- Maximum brine temperature: 112^{o} C
- Performance ratio: 8-11
- Electrical power: 3-4 kWh/m^3
- Scale inhibitors used for scale control
- Recycle type plant
- Dual purpose plant

MSF KEY PARAMETERS

Capital Cost MSF	6.5-7.8	US$ MM per MIGD
Capital Cost –Intake /Outfall	0.5	US$ MM per MIGD of cooling
MSF GOR	8-11	Tons of product/ton of steam
LP Steam Supply	2.5-3	Bar. A
Lost Power Potential	1.225	MW/MIGD
Power Consumption	4	kW.hr/m^3 of distillate
Steam Consumption	23.7	Tons/MIGD
Chemical Costs	40,000	US$/yr per MIGD
MSF R&R	1%	TIC/yr
Labor	40,000	US$/yr per MIGD

Jebel Ali Station G

The Jebel Ali G plant on the west coast of the Dubai Emirates was constructed in 1994 and includes 8 MSF units later in 1999 one unit was also added to optimize the energy use and to give an overall production of 67.5 MIGD; details are shown in the Table below

Parameter	Phase I	Phase II
Number of MSF Units	8	1
Year of operation	1994	2000
Unit Production (m³/h)	1,420	1,420
Overall production (m³/d)	272,700	34,000
Top brine temperature (° C)	105-110	105-112
Performance ratio design		8.5
Specific power consumption kW/m3		
Number of stages		
Combined with Power Plant	GT/HRSG	BPST
Vessel material	CS clad SS	CS clad SS
Tube material	CuNi /AlBrass	CuNi /AlBrass
Heat recovery design fouling factor m^2K/W		

The demonstrated reliability and availability of MSF plants in the Gulf

The following are the results from the analysis on of major MSF installation in the Middle East area:

- Plant availability is always very high and is reported to be higher than 90% even after 20 years of operation and the MSF units do not show sign of capacity degradation.
- Plant lifetime which was normally expected to be around 25 years is practically exceeded and the best realistic figure is around 35 years ; it must also be considered that this unexpected performance is realized with a technology and with material of about 20 years ago.

It can be said that 40 years of experience in the Gulf area with MSF desalination is very positive in terms of energy performance and the extended life time can also be considered an energy benefit since less new plant installation were required.

Specific energy consumption for different design data of an MSF plant of high capacity.

In the Table below a summary of specific energy consumptions is reported for different design conditions. As it can be seen the total energy consumption which is required to desalinate sea water and to produce an high purity water with MSF technology is almost four times the minimum required by a non- ideal theoretical process.

Description	High energy consumption	Medium energy consumption	Low energy consumption
Design data			
MSF Unit size (MIGD/m^3/d)	17,6/80,000		
Performance ratio (Kg/Kg 2326 KJ/Kg)	8,5	9	9,5
Specific thermal consumption KJ/Kg	273,7	258,5	244,8
Fouling factor (m²K/W)	0,00012		
Recovery heat exchange surface m^2	182000	198000	216000
Recovery stage number	16	18	20
In tube Brine velocity (m/s)	2,1	2	1,9
Brine recirculation pump head (m)	90	85	80
Specific energy (Kwh/m^3)			
Power lost for steam sent to Brine Heater	8,9	8,5	8
Power lost for steam sent to vacuum system	0,3	0,3	0,3
Auxiliary electric power	3,6	3,2	2,9
Total specific energy consumption	12,8	12,0	11,2

Ref. Roberto Borsani, FISIA

Optimized specific energy consumption for MSF technology

Parameter	Data	Saved Energy consumption
Performance ratio	10,5	0,8
Low intube velocity (m/s)	1,8	0,3
Fouling factor (m^{2}K/W)	0,00008	
Advance MSF technology	yes	0,2
Brine recirculation variable speed	yes	0,3
Total saved energy		1,6
Total specific energy consumption (kWh/m^3)	**9.6**	

Ref. Roberto Borsani, FISIA

Ras Al Khair, 20 MIGD (91,000t/d) MSF unit the largest in the world first out of 8.

The evaporator is also the world's largest in size, as it measures 123 meters long, 33.7 meters wide, and weighs 4,150 tons

Summary Comparison MED versus MSF

Important Issues

- Flash vs. Film Evaporation.
- Mass Balance
- Heat Transfer Mechanism and HTC.
- MED Flow Patterns.
- TBT and Scaling Potential.
- Importance of TBT. Max GOR and PR, Steam Requirements
- Tube wetting
- The concept of vapor compression
- Final condenser solutions
- Number of MED Effects vs MSF stages.
- Power Requirements and Ejector steam requirements.
- Cooling Water Requirements.

MED vs MSF Process Overview

Process Features

- MED is one of the thermal desalination processes and it differs from the MSF mechanism of the heat transfer.
- While the brine is flowing through the inside of the tubes in MSF, it is sprayed over the outside of the tubes in MED.
- The basic process of MSF is flashing which is taking place when a heated liquid is introduced into a low pressure vessel. Instead, the distillation or the film boiling is the basic process of MED.
- Production of MSF is proportional to the temperature range and the brine flow rate. Therefore, large volume of brine should be recycled through the condensers in the stages, which explains more electricity consumption than MED.
- MED has once through design and the production is proportional to the temperature range and the steam flow rate to the first effect. Therefore, its electricity consumption is less than MSF.

MED Technology Providers

Experienced Players with Large Scale MED

- SIDEM
- IDE/AquaSwiss
- New players to Large MED
- Doosan
- Sasakura Engineering
- Aqua-Tech International
- FISIA
- HITACHI Zosen

MSF Technology Providers

Experienced Players with Large Scale MSF

- Doosan
- FISIA
- HITACHI Zosen

Experienced Players with Medium Scale MSF

- Sasakura Engineering
- Aqua-Tech International
- Regianne

Examples and Pictures of large MED -TVC plants

Layyah D12/D13 - United Arab Emirates (Sharjah) ***MED-TVC - 2 units of 8.0 MIGD (16 million gallons daily production)***

AL-HIDD IWPP – KINGDOM OF BAHRAIN

- Contract Award: April 06
- End User: Electricity and Water Authority
- Owner: Hidd Power Company
- 10 units x 6 MIGD
- 7 effects
- GOR: 9.03

Ras Laffan C IWPP - Qatar *MED-TVC - 10 units of 6.3 MIGD (63 million gallons daily production) GOR* 11.12

IDA DESALINATION ACADEMY

4 x MED 25,000 Units, Tianjin, China

Marafiq IWPP - Saudi Arabia *MED-TVC - 27 units of 6.59 MIGD (178 million gallons daily production)*

Fujairah II IWPP - UAE

A mixed MED 100 MIGD / SWRO 30 MIGD project, landmark in the hybrid IWPP market

Scope of work

Engineering, procurement, construction and commissioning of 12 desalination units of 38,640 m3/day (8.5 MIGD) each and 30 MIGD reverse osmosis plant, together with: Potabilization plant, CO_2 plant, limewater injection system, sea water pumps, 4 x 90,000 m3 storage tanks and other ancillary equipment

Contract data

Client: Fujairah Asia Power Company ; End-user: Abu Dhabi Water and Electricity Authority
The contract was awarded to a consortium made up of Alstom (for the power plant) and Sidem (water plant) in the frame of Fujairah II Independent Water & Power Production project.
Largest MED units to date (8.5 MIGD each)

Examples and Pictures of MSF plants

THE JEBEL ALI K2 INSTALLATION

DOOSAN's typical transportation methods of one MSF module type evaporator

Doosan Fujairah 1

THE SHUWEIHAT INSTALLATION

THE JEBEL ALI L1 INSTALLATION

70 MIGD + 750 MW

5 * 14 MIGD
p.r. 9.0 kg/2326 kJ

Overall heat transfer

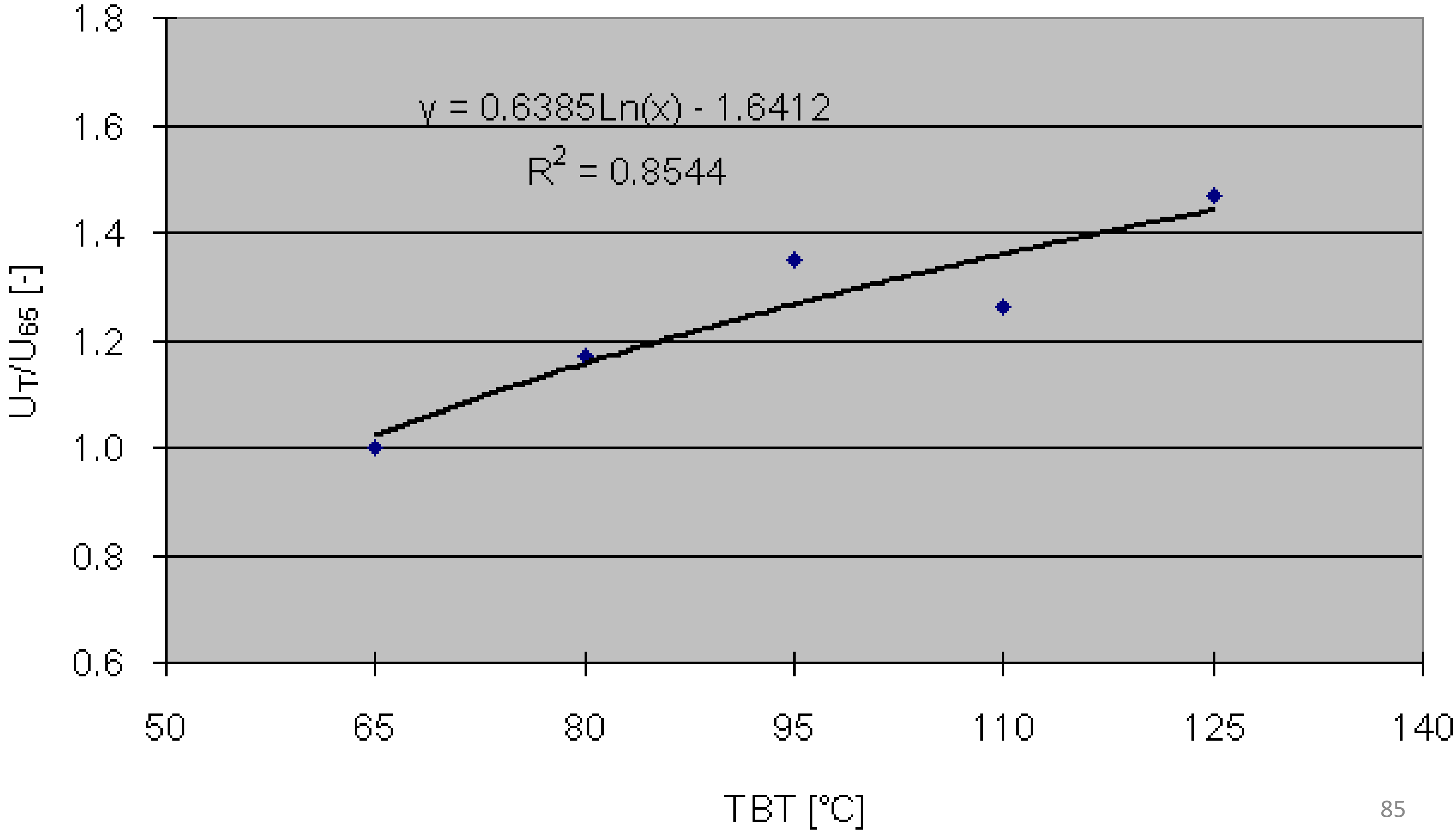
The horizontal falling film evaporator stage is the key element of any MED system. The most common technology is to disperse and partly evaporate seawater on a horizontal tube bundle.
The heat necessary is supplied by steam condensing inside the tubes. The design of the heat exchange area, i.e. the tube bundle, is decisive for the plant efficiency and its capital and maintenance costs. The overall heat balance for the tube bundle is:

$$Q\left[kW\right] = Ah\Delta t$$

In this equation, the overall heat transfer coefficient h
or its reciprocal respectively, the overall thermal resistance:

$$R\left[\frac{m^2 K}{kW}\right] = \frac{1}{h} = R_i + R_t + R_o + R_{fouling} = \frac{d_{t,o}}{d_{t,i}\alpha_i} + \frac{d_{t,o}}{2\lambda_t}\ln\left(\frac{d_{t,o}}{d_{t,i}}\right) + \frac{1}{\alpha_o} + R_{fouling}$$

The impact of variation of top brine temperature on the overall heat transfer coefficient

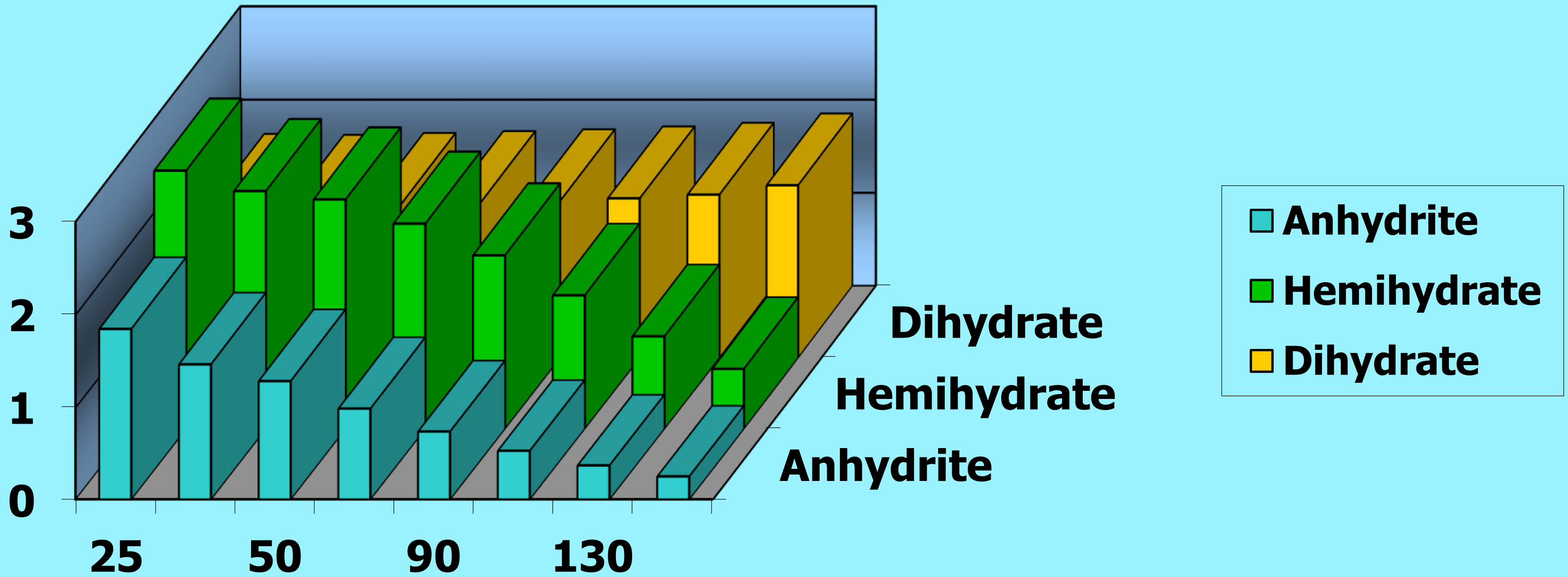


TBT and Scaling Potential

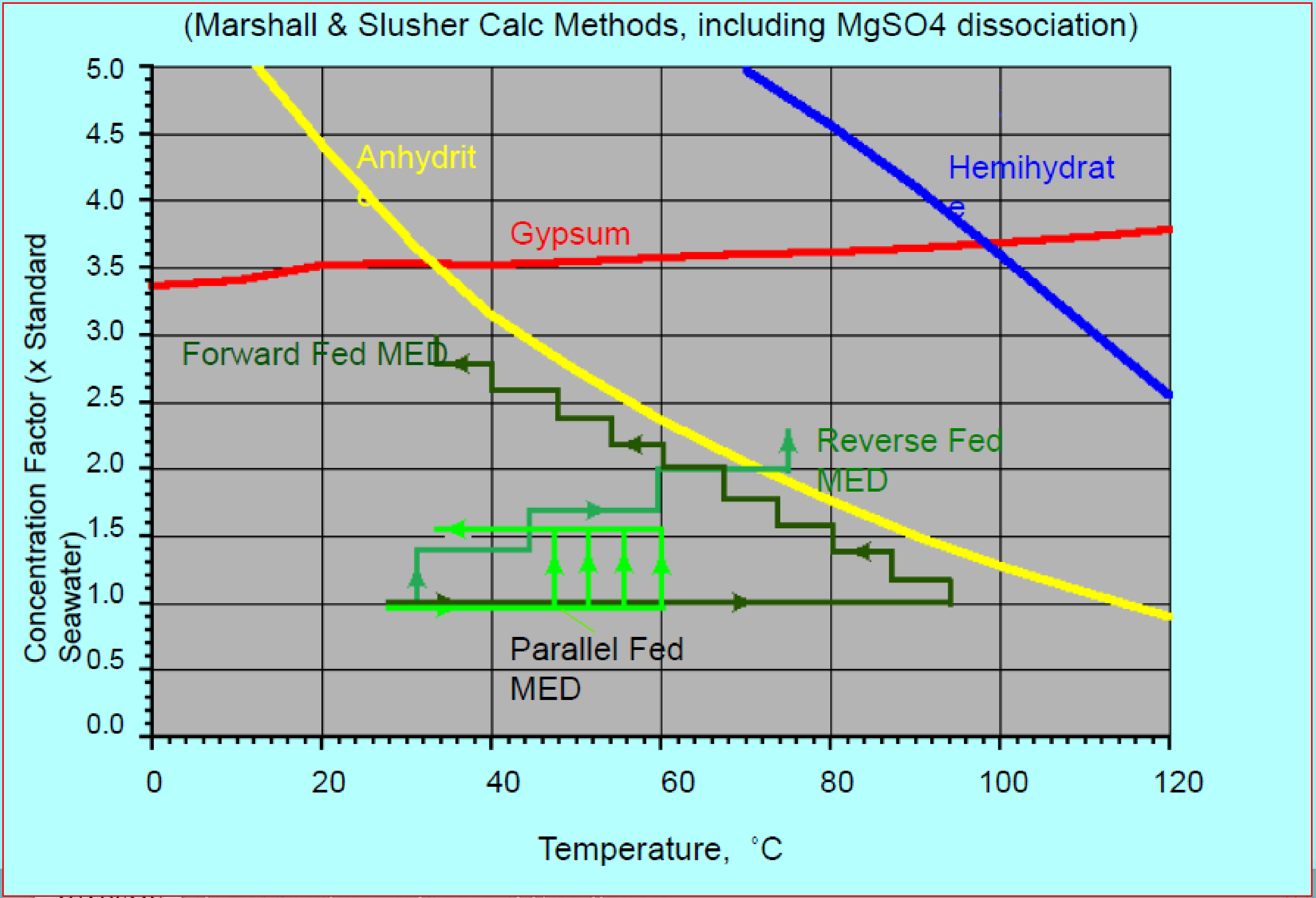
Scale formation

Scale formation on heat transfer surfaces is one of the major problems in (MED) and flash (MSF) distillers. The allowance for potential scale formation by over-sizing the heat transfer surface area, scale prevention measures, cleaning methods as well as production losses during plant shutdown for cleaning create considerable capital, operating, and maintenance costs. It is therefore essential to incorporate a cost effective scale control technique

Calcium Sulphate Solubility Limits brine concentration factor (saturation/initial) vs. temperature ° C



Solubility Limits of Calcium Sulphate in Seawater Concentrates



Alkalinity Breakdown

It was found that in the temperature and pH range prevailing in the flash chambers of MSF distillers and in the evaporators of MED distillers the alkaline reaction mechanism

$$CO_2 + OH^- \leftrightarrow HCO^-{}_3$$

$$HCO^-{}_3 + OH^- \leftrightarrow CO_2 + H2O$$

with the rate-determining first step predominates

CO_2 RELEASE

The total in MSF recycle distillers increases from about 66 g CO_2 per ton of distillate at a top brine temperature of 90ºC to about 97 g/t at 110ºC.

The total CO_2 release in MED distillers increases from about 49 g CO_2 per ton of distillate at a top brine temperature of 60ºC to about 64 g/t at 70ºC.
The calculations further suggest that the utilization of the CO2 released in MED distillers for re-carbonation using the limestone method seems feasible in principle but MSF has significantly better availability

Chemical Additives

Chemical additives or antiscalants have been used in desalination plants for decades. The scale inhibitors that have been used with varying success include polyacrylates, phosphonates, and polymaleics (or polymaleates). Most additives are designed to provide threshold inhibition and are typically fed in low doses. Of the antiscalants commercially available today, maleate based polymers (i.e. polymaleic acid) are most commonly used in MSF and MED distillers. This is due to its thermal stability.

Chemical Additives

Product	Chemistry	Usage	Features
Belgard EV 2030	Neutralized enhanced carboxylic acid based polymer	Scale control	MSF and MED plants
Belgard EV 2035	Enhanced carboxylic acid based polymer	Scale control	MSF and MED plants
Belgard EV 2050	Enhanced carboxylic acid based polymer	Scale control	MSF and MED plants
Belgard EV	Carboxylic acid based polymer	Scale control	MSF and MED plants
Belgard EVN	Neutralized carboxylic acid based polymer	Scale control	MSF and MED plants

Antiscalants Sokolan PM10 I polymaleic acid
Sokolan PM 15 I polycarboxylic acid manufactured by BASF

Hidd Power Company, Bahrain	MED	65	3.0
Marafiq Jubail IWPP, Saudi Arabia	MED	65	3.0

ALBRIVAP DSB(M) a proprietary polymeric product available from Albright & Wilson

Scale control

On-line ball cleaning operation of heat transfer tubes (Taprogge) has been an essential factor in keeping the thermal efficiency of MSF plants while using antiscalants to control scale formation TAPROGGE System that was named after its inventor, Josef Taprogge, sponge rubber balls are injected into the waterbox upstream of the hear recovery tubes inlet via a ball injection. The balls should have a certain oversize compared to the inner tube diameter, so that the cleaning effect is safeguarded. By means of the water flow the balls are pressed through the tubes and are afterwards separated by a strainer section. Subsequently they are transported back to the injection point via a ball recirculation pump

Where do we go from here?

- Nanofiltration of Seawater:-greatly reduced Scale Potential

- Top Brine Temperatures May be significantly higher for both MSF and MED
- Recoveries could also be increased significantly
- What would this imply for these processes?

Potential for MED technology improvements

- Increasing TBT from 63°C to 80-100°C with Nanofiltration

- Increase efficiency to PR 12-16 from current 10.

- Increase unit size to 15 MIGD from current 8.5 MIGD

- Improve HTC by oval and corrugated plates

- Hybridize with MSF-RO-NF

High Performance MED Plants

The Low Temperature Multi Effect Distillation (LT-MED) is among the most efficient thermal desalination process currently in use.

In order to improve this process even farther the following steps are being implemented:

1. **utilization of corrugated heat transfer surfaces to increase heat transfer coefficients.**
2. **Extending the operation range by increasing the top temperature from 70^0C to 95^0C.**

High Performance MED Plants

Increasing top temperature to 95 ^{0}C

- Allows to increase the number of effect thus increasing the M.E.D economy ratio with the following benefits:
- 1. Increases water production per a given amount of steam.
- 2. lower specific thermal energy consumption due to improved heat transfer at higher temperatures.
- 3. optimal utilization of very low cost 90 ^{0} C steam delivered to MED through LET modified Heller system would maximize power production and minimize cost of ducting.

NEW FRONTIERS

- **TOP BRINE TEMPERATURE :** the increase of so called TBT can allow higher production with almost same desalination trains
- **HYBRIDIZATION :** the application of hybrid technologies (MSF + RO or MSF + MED) can improve overall efficiency
- **THERMAL IMPROVEMENT :** new MSF and MED schemes and ancillary equipment

SULPHATE REMOVAL

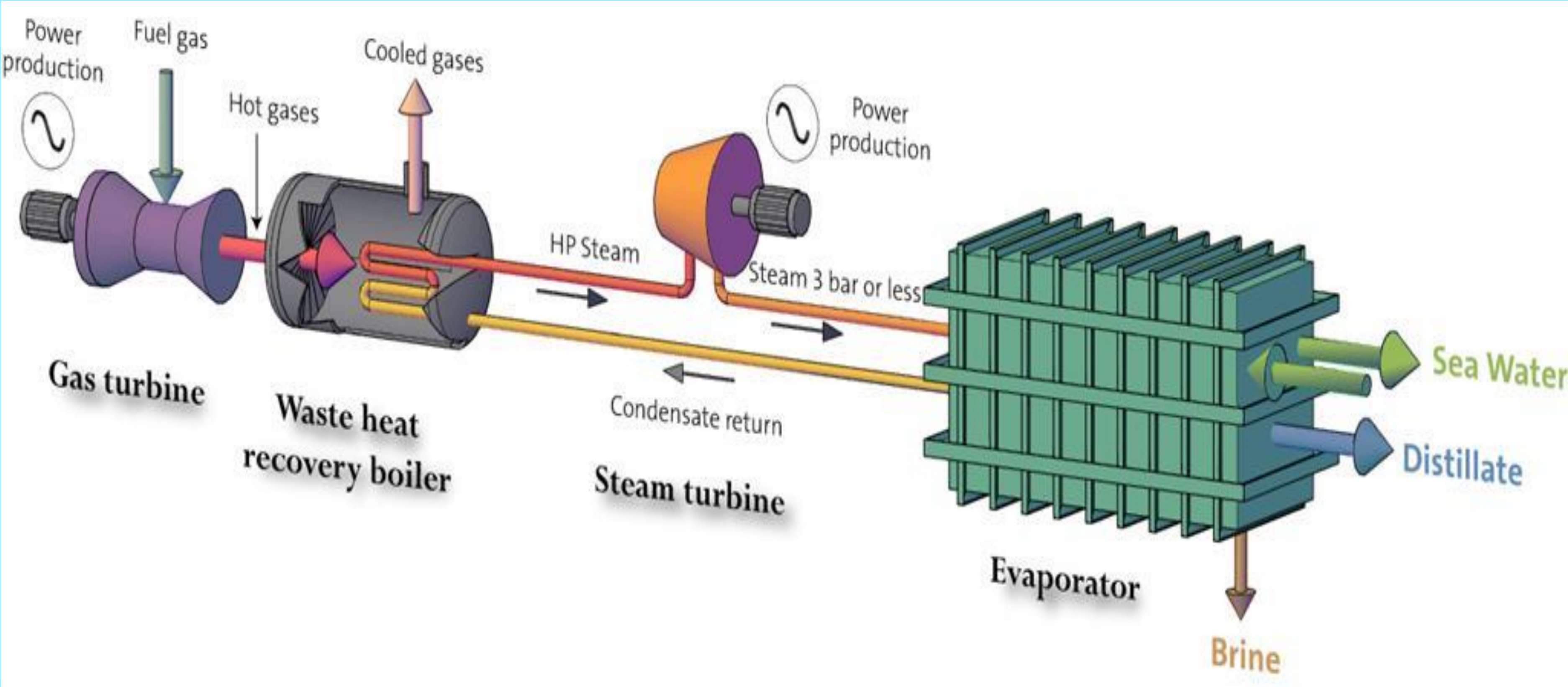
- **NANOFILTRATION : this technique which is normally applied in the oil injection plant to avoid sulphate precipitation has been recently applied also as pre-treatment for MSF plant and is actually covered by Patent (LET and SWCC)**

- Power and desalination plant combinations

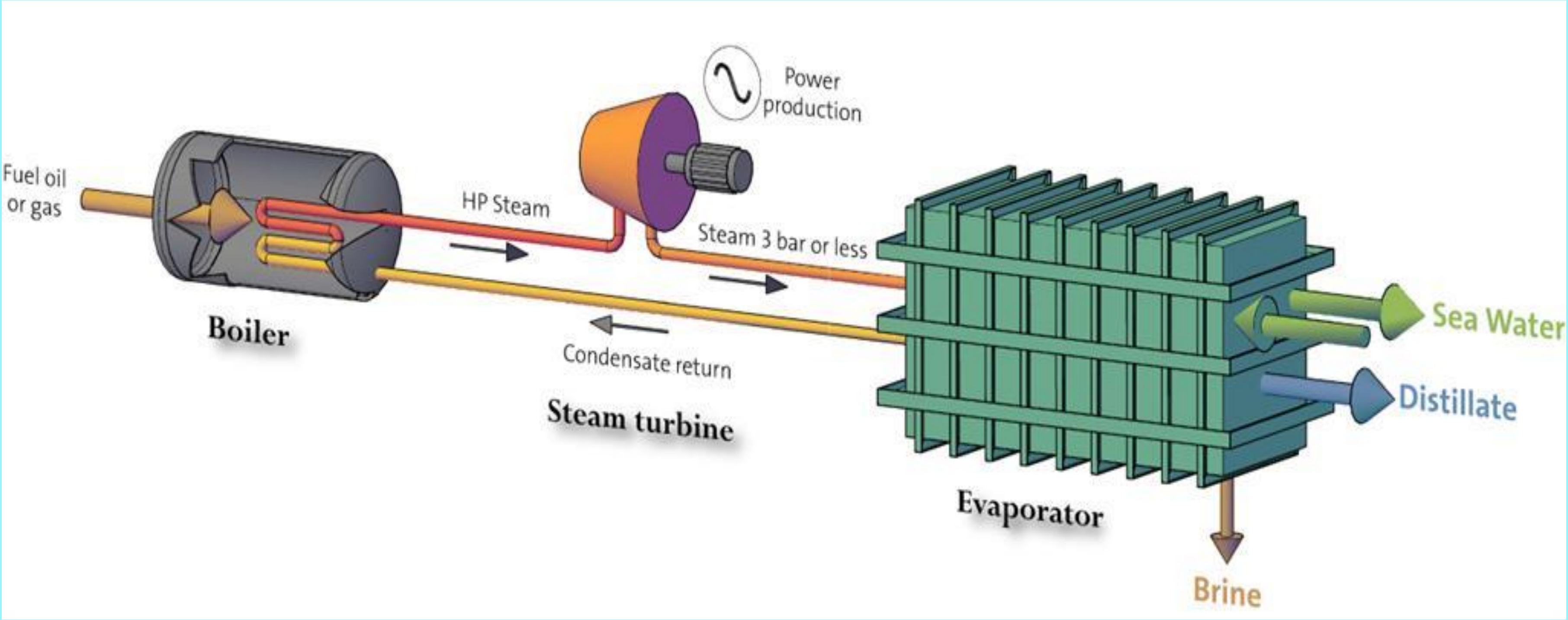
Dual Purpose Power Desalination

Large dual - purpose power desalination plants are built to reduce the cost of production of electricity and water.
Over 50,000 MW of power is combined with desalination plants in the largest use of cogeneration concepts.

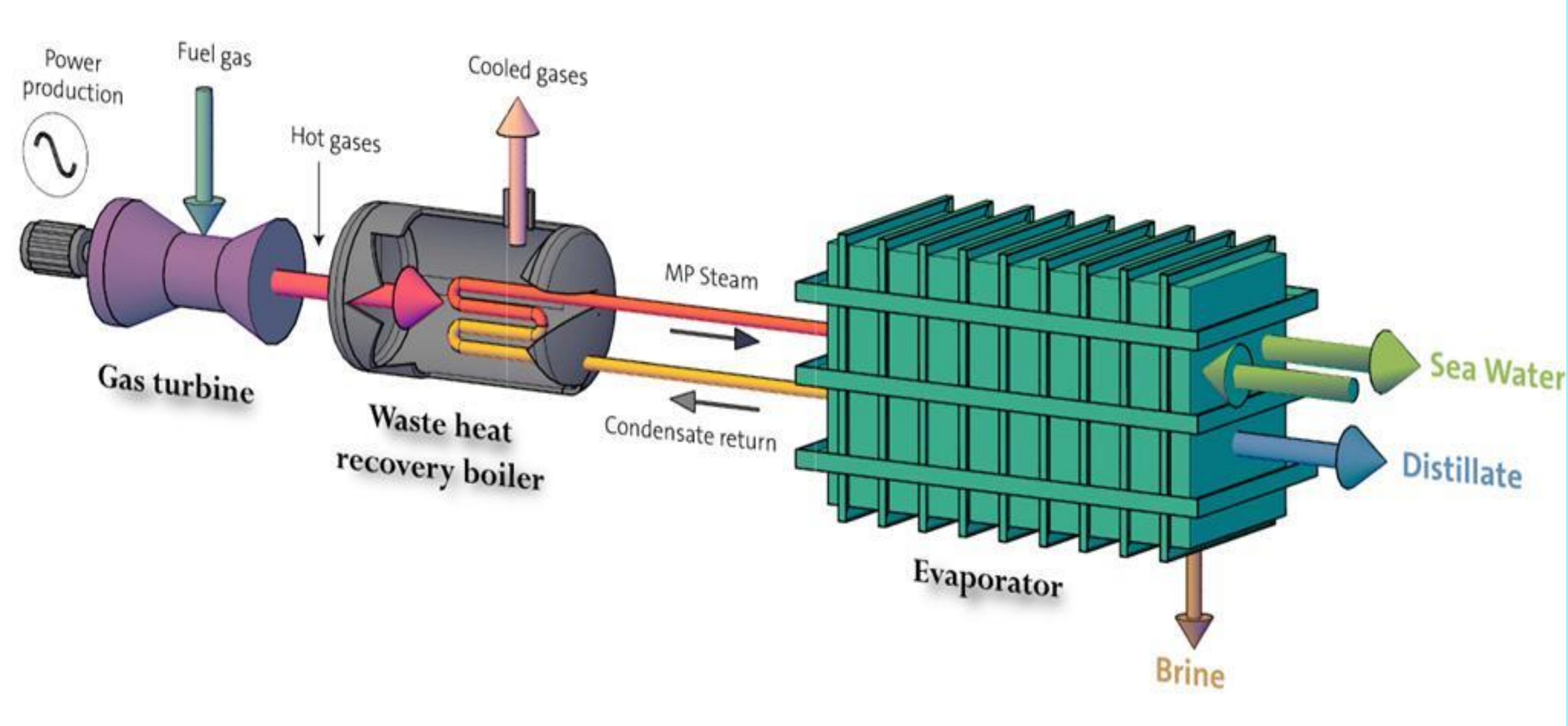
Combination of desalination plant with gas turbine, heat recovery boiler and steam turbine CCGT



Combination of desalination plant with high pressure boiler and steam turbine

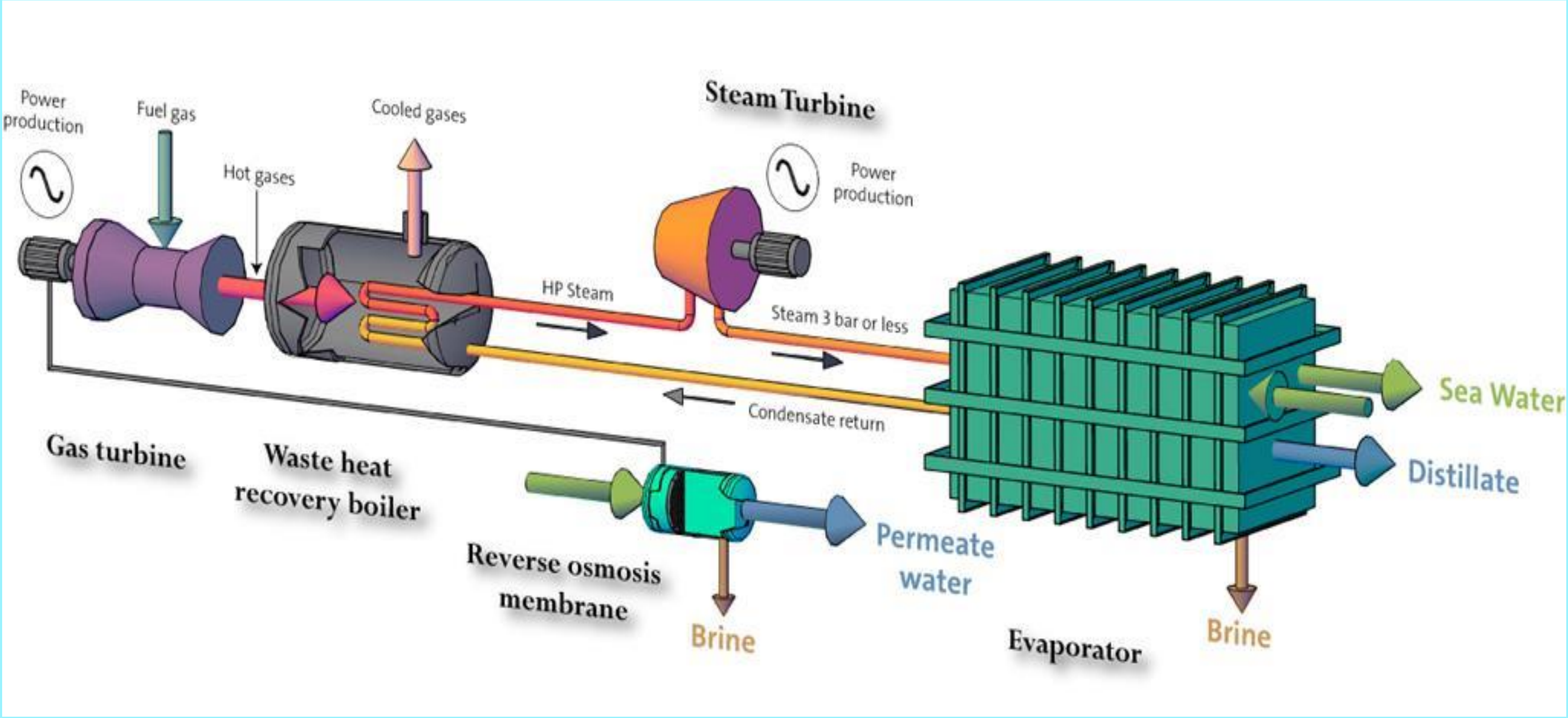


Combination of desalination plant with gas turbine and heat recovery boiler



Hybrid Plants

Coupling Power generation with thermal and RO desal plants



Power Generation Technologies

Combine-Cycle Units

These are the most efficient in producing base load electricity, but their water ratio is very much less. Combined cycle with BTG have efficiency of 44% and in condensing mode 53% . Combined cycle with condensing at ISO reached 60%. The capital costs 1000-1500 $k/W, design for 50^{o}C. We will review in details the Jubal-Marafiq project.

Today we will examine hybrid systems and hybrid technology for both simple and integrated approach in order to take full advantage of coupling of both thermal and membrane technologies. The hybrid systems is receiving significant attention and we will explore its potential benefits.

Ref. Chapter on Hybrid System and Technology included in *The Guidebook to Membrane Desalination Technology* edited by M. Wilf.

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HYBRIDIZATION

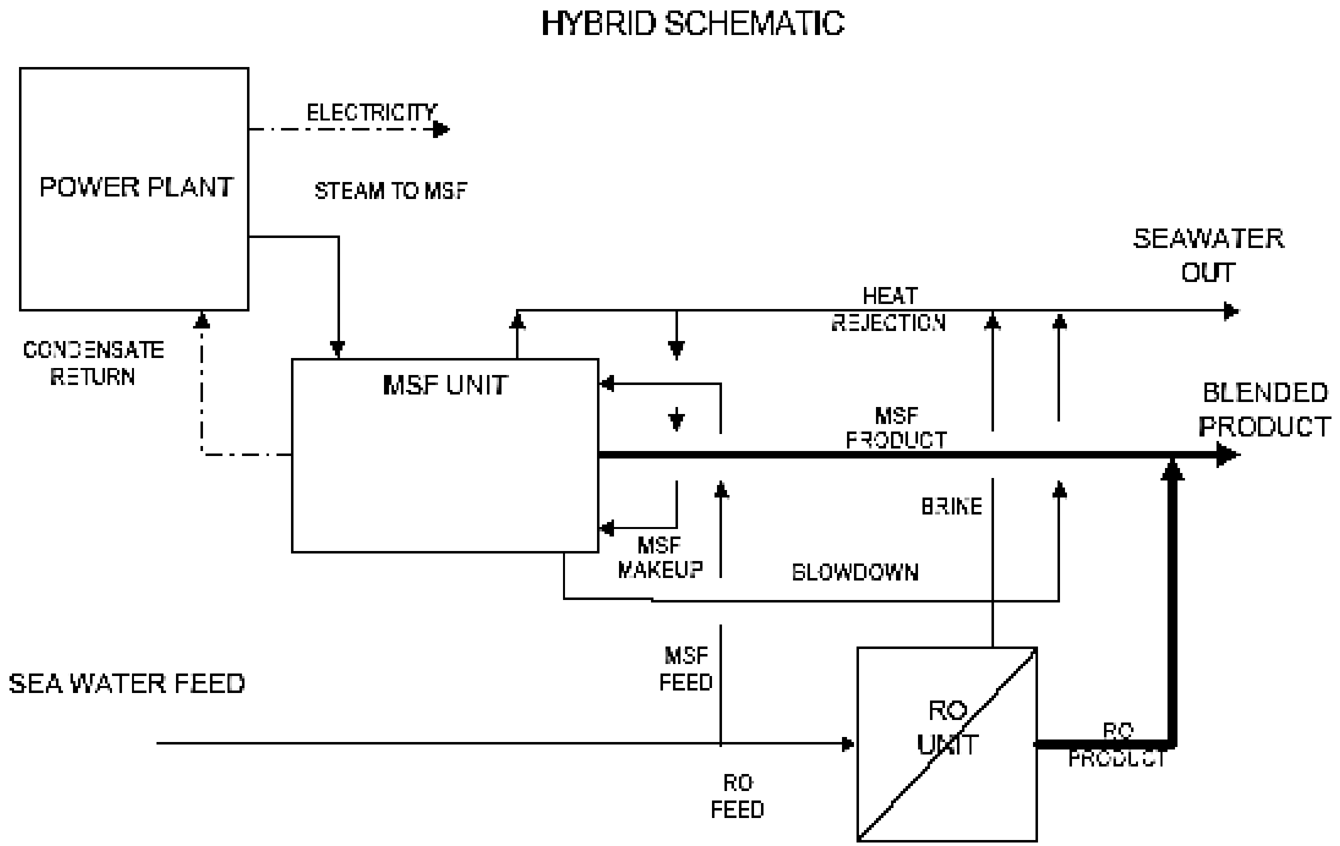
HYBRID MSF-MED/RO ALLOWS:

- **INCREASED RO PERFORMANCES: the use of hot discharge from thermal plants allows lower feed pressure to RO**
- **CONTROL OF BORON : the very low boron content in the distillate mixed with RO water allows single pass membrane**
- **DISCHARGE TEMPERATURE: the cold discharge from RO allows an higher reject ΔT while keeping a lower environmental impact**
- **OVERALL SEA WATER NEED : the sea water required is drastically reduced if the thermal reject sea water is used as RO feed**

Hybrid Concept Introduction

The hybrid desalting concept is the combination of two or more processes in order to provide better environmental solutions and a lower water cost product than either alone can provide.

In desalination, there are power providing steam to thermal distillation plants and electricity to membrane processes which under hybrid conditions can be combined to produce a more economic process.



The hybrid elements and the important connection between these elements

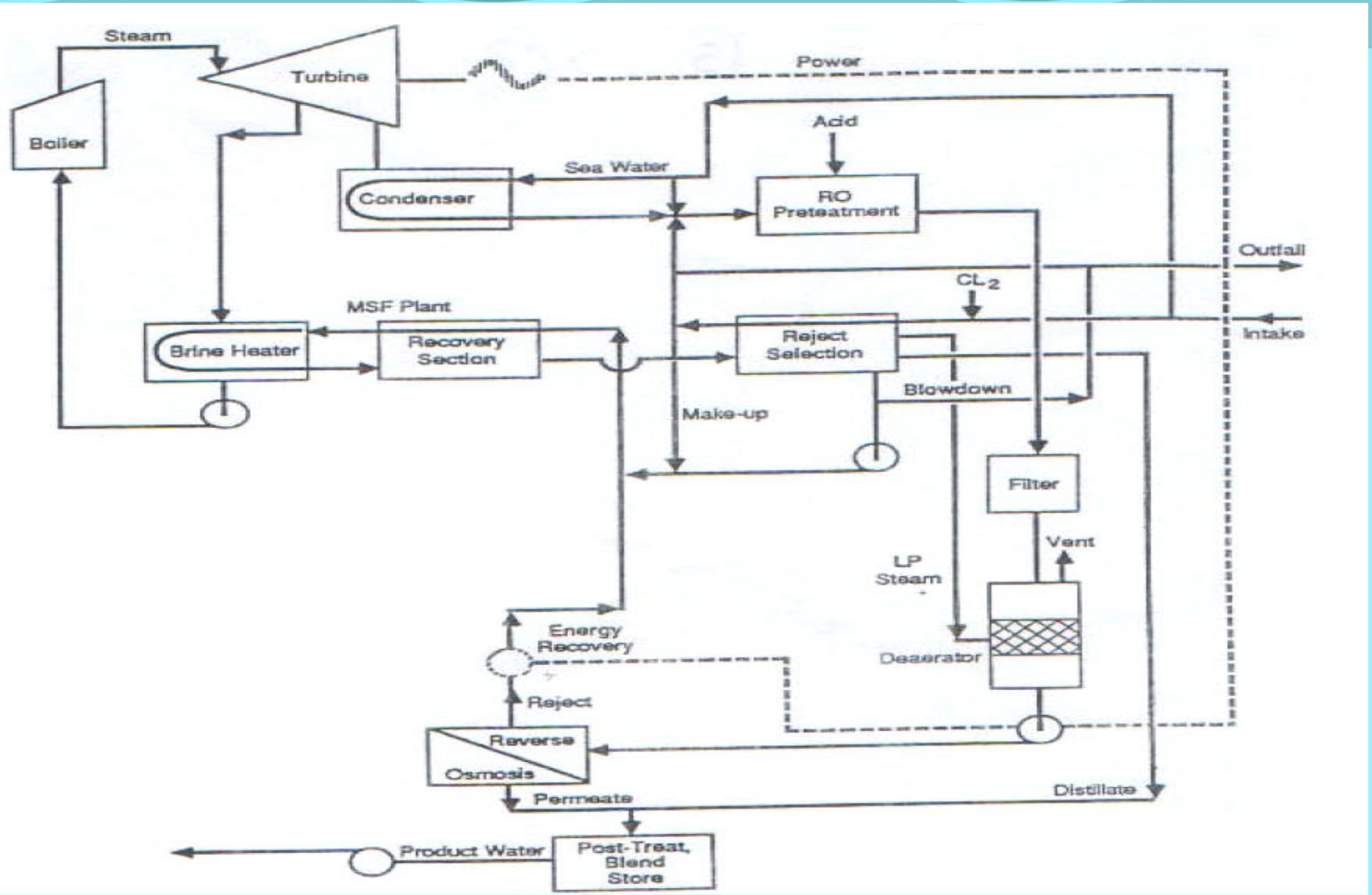
RO KEY PARAMETERS

Capital Cost RO	**5.7-6.4**	**US$ MM per MIGD**
Capital Cost –Intake /Outfall	**0.3**	**US $MM per MIGD feed**
Power Consumption	**3.0-4.5**	**Kwh/m^3 of Permeate**
Membrane Replacement Rate	**15-20%**	**Per yr**
RO Chemical Costs	**50,000**	**US$/yr per MIGD**
RO R&R	**2%**	**TIC/yr**
RO Labor	**50,000**	**US$/yr per MIGD**

Simple hybrid

In the simple hybrid MSF, MED+RO

- A common, considerably smaller seawater intake can be used.
- Product waters from the RO and MSF plants are blended to obtain suitable product water quality.
- Product waters from the RO and MSF plants are blended, therefore allowing higher temperature of distillate.
- A single pass RO process can be used.
- Blending distillation with membrane products reduces strict requirements on boron removal by RO.
- The useful RO membrane life can be extended.
- Excess power production from the desalting complex can be reduced significantly, or power to water ratio can be significantly reduced.



The "Classic" Integrated Hybrid SWRO/MSF desalination plant scheme as propose by L. Awerbuch et al [1987]

Figure 172. The alternative configuration of "classic scheme" hybrid system

Past Simple hybrid

- Products from the RO and Distillation plants are blended to obtain suitable product .
- Power to water ratio can be significantly reduced.

GOING TO THE NEXT STEP

- A single stage RO process can be used.
- Higher Recovery lower pretreatment

Seasonal Variability of Power

In many countries, particularly in the Middle East peak power demand occurs in summer and then drops dramatically to 30-40%, in contrast the demand for desalinated water is almost constant around the year. Therefore, the design of future plants requires careful consideration of power (MW) to water (MIGD) ratio PWR

Integrated hybrid

In general, the hybrid idea allows part of the distillation plant's heated seawater coolant reject to be de-aerated, using low-pressure steam from the distillation plant (to reduce corrosion and residual chlorine), and used as the feed to the SWRO plant. The higher temperature of the feed improves membrane performance (flux, at constant pressure, increases by 1.5–3% for each degree C). This is particularly important during the winter, when seawater temperatures can drop to as low as 15°C.

Hybrid

- A common, considerably smaller seawater intake can be used.
- Product waters from the RO and MED plants are blended to obtain suitable product water quality.
- Product waters from the RO and MED plants are blended, therefore allowing higher temperature of distillate.
- A single pass RO process can be used.
- Blending distillation with membrane products reduces strict requirements on Boron removal by RO.
- The useful RO membrane life can be extended.
- Excess power production from the desalting complex can be reduced significantly, or the power-to-water ratio can be significantly reduced

Integrated hybrid

- The feedwater temperature to the RO plant is optimized and controlled by using cooling water from the heat-reject section of the MED or power plant condenser.
- The low-pressure steam from the MED plant is used to de-aerate or use de-aerated brine as a feedwater to the RO plant to minimize corrosion and reduce residual chlorine.
- Some components of seawater pretreatment process can be integrated.
- One post-treatment system is used for the product water from both plants.

Integrated hybrid

- The feedwater temp. to the RO plant is optimized using cooling water from the heat-reject section of the MSF/MED or power plant condenser. Constant feed temperature
- The low-pressure steam from the MSF/MED plant is used to de-aerate or use de-aerated brine as a feedwater to the RO plant to minimize corrosion and reduce residual chlorine.

Integrated hybrid

- The brine discharged-reject from the RO plant is used as a feed to MED or MSF.
- The hybridization of Nanofiltration as softening membrane process for feed of distillation plants MED or MSF could lead to significant improvement in productivity of desalination plants.

Integrated hybrid

- **Blending distillate and membrane permeate will reduce requirements on Boron removal by RO.**

- **The RO and NF membrane life can be extended. (12 years)**

Integrated hybrid environmental benefits

- Cool RO Reject and Feed to be used as a cooling source for heat reject section of distillation plants.
- The blend of reject stream from RO with warm seawater and blowdown from distillation or power plants reduces heavy density plume of RO outfall.
- Blend of RO permeate reduces temperature of distillate.
- A common, smaller seawater intake & outfall.

Typical Power to Water Ratios for Different Technologies

Technology **PWR=MW required/Million Imperial Gallons per day**

Steam Turbine BTG - MSF	PWR = 5.0
Steam Turbine EST - MED	PWR = 7.0
Steam Turbine EST - MSF	PWR = 10.0
Gas Turbine GT - HRSG - MED	PWR = 6.0
Gas Turbine GT - HRSF - MSF	PWR = 8.0
Combined Cycle BTG - MED	PWR = 10.0
Combined Cycle BTG - MSF	PWR = 16.0
Combined Cycle EST - MED	PWR = 12.0
Combined Cycle EST - MSF	PWR = 19.0
Reverse Osmosis RO	PWR = 0.6-.75

Hybrid Using Nanofiltration - Membrane Softening

Membrane softening technology adapted to hybrid with distillation processes could lead to a significant increase in the productivity of existing and future distillation plants as well as resulting in better process economics. As a result, the selectivity of NF membranes for monovalent and bivalent anions is significantly different as compared to regular RO membranes. Specially designed NF membranes have the capability of high rejection for divalent ions (Ca, Mg and SO_4), while allowing relatively high passage of monovalent ions (Cl, Na and K).

THE SEWA CASE

- DESIGN TO INCREASE 44% THE CAPACITY OF EXISTING MSF FROM 5 MIGD to 7.2 MIGD, ACHIEVED 50 % to 7.5 MIGD
- MIMIMUM FOOT PRINT, NO ROOM FOR NEW DESALINATION PLANTS
- REDUCE OPERATING COST
- NO CHANGES TO INTAKE STRUCTURE
- NO INCREASE IN POWER FACILITIES
- CUTTING MSF CAPITAL COST FOR ADDITIONAL CAPACITY BY 40%

MSF 5MIGD Layyah Plant subject of Integrated Upgrading

Rejection and performance of NF membranes

SHARJAH ELECTRICITY AND WATER AUTHORITY
LAYYAH POWER STATION
CHEMICAL DEPARTMENT

Date : 03.09.06

ANALYSIS OF NANO FILTER WATER

ANALYSIS	RECORDED AS	UNIT	FEED STAGE # 1	FEED STAGE # 2	PERMEATE STAGE # 1	PERMEATE STAGE # 2	SW MU TO D9	TOTAL PERMEATE	TOTAL REJECTION
Conductivty		µS/cm	59,000	65,600	51,500	55,100	58,200	52,700	72,000
pH			8.04	6.68	6.51	6.53	8.10	6.60	6.71
T.D.S		mg/L							
Total Alkalinity	CaCO3	mg/L	118	116	54	69	115	60	146
Total Hardness	CaCO3	mg/L	7,400	13,200	1,300	1,700	6,500	1,400	21,800
Calcium Hardness	CaCO3	mg/L	1,070	1,740	380	520	980	420	2,560
% Ca Rejection					64.5	70.1		60.7	
Magnesium Hardness	CaCO3	mg/L	6,330	11,460	920	1,180	5,520	980	19,240
% Mg Rejection					85.5	89.7		84.5	
Chloride	Cl^-	mg/L	23,430	26,270	20,590	22,720	23,430	21,655	29,110
% Cl Rejection					12.1	13.5		7.6	
Sulphate	$SO4^{-2}$	mg/L	3,418	6,676	12.68	28.21	2,800	18.15	11,200
% SO4 Rejection					99.6	99.6		99.5	
Residual Chlorine	Cl_2	mg/L	Nil	Nil	Nil	Nil		Nil	Nil

Remarks : Feed flow : 720 m^3/hr Pressure : 12.6 Bar. Total Permeate Flow : 510 m^3/hr.
SDI =

CHEMIST

IDA DESALINATION ACADEMY

Date		03/05/06	03/05/06	04/05/06	04/05/06	04/05/06	04/05/06	04/05/06	05/05/06
Brine Heater (TBT)	°C	116	116	116	116	116	116	116	116
Distillate flow total	MIGD	7.544	7.587	7.544	7.502	7.502	7.502	7.486	7.502
Dist conduct 17th stage	µs	9.7	5.9	5.6	0	5.5	5.5	5.2	5
Dist conduct 1 to 14 stage	µs	465	471	481	468	464	464	451	478
Sea water flow	T/h	6370	6617	6649	6536	6561	6561	6603	6666
Recycle brine	T/h	12447	12473	12454	12461	12451	12451	12492	12524
Make up	T/h	2920	3080	3107	3040	3089	3089	3092	3127
Blow down	T/h	2014	2138	2158	2120	2174	2174	2180	2180
Seawater inlet stage 17	°C	28	28	28	28	28	28	28	28
BH condensate temp	°C	122	122	122	122	122	122	122	122
Distillate temp stage17	°C	43	43	43	43	43	43	43	43
NF SW SUPPLY	M3/H	820	780	778	789	730	730	775	780
NF PRODUCT	M3/H	510	514	516	510	516	516	510	510
NF SW supply °C	°C	27.3	27.48	27.6	27.67	30.8	30.8	30.8	28.27

F1's Power and Water Capacities

Power Plant

Gas Turbines : 4*109 MW
Steam Turbines : 2*119 MW
Extension Plant : 1*219 MW

Contractual Capacity = 760 MW

Net Capacity : 790 MW
Gross Capacity : 893 MW

Water Plant

MSF Plant : 5*12.5 MIGD
RO Plant : 1* 37.5 MIGD

Contractual Capacity = 100 MIGD

Courtesy W. Chang Ex.MD Emirates Sembcorp

Competitive specific power consumption (kWh/m^3)

- The optimization of the seawater feed to the RO Plant has allowed to achieve a very competitive specific power consumption.

- The specific power consumption offered were ranging between 3.3 to 4.0 kWh/m^3.

- This value included the electric utilities associated to the DAF (which has an inherent power consumption of 0.05 kWh/m^3.

IDA

شركة الإمارات سيمكورب للماء و الطاقة
EMIRATES SEMBCORP
WATER & POWER COMPANY

Fujairah 2

- The largest and the latest hybrid projects in the world. 130 MIGD of water. It uses five high-efficiency Alstom GT26 gas turbines in combined cycle mode hybridized with 100 MIGD, 12 SIDEM 8.33 MIGD Multi Effect Distillation desalination units with a 30 MIGD Reverse Osmosis desalination plant.
- Japan's Marubeni Corp with International Power (Suez). IWPP was formed with the Abu Dhabi Water and Electricity Authority in the 20-year project, which will oversee the entire power and water output from the Fujairah F2 IWPP in the UAE.

Fujairah II IWPP - UAE

A mixed MED 100 MIGD / SWRO 30 MIGD project, landmark in the hybrid IWPP market

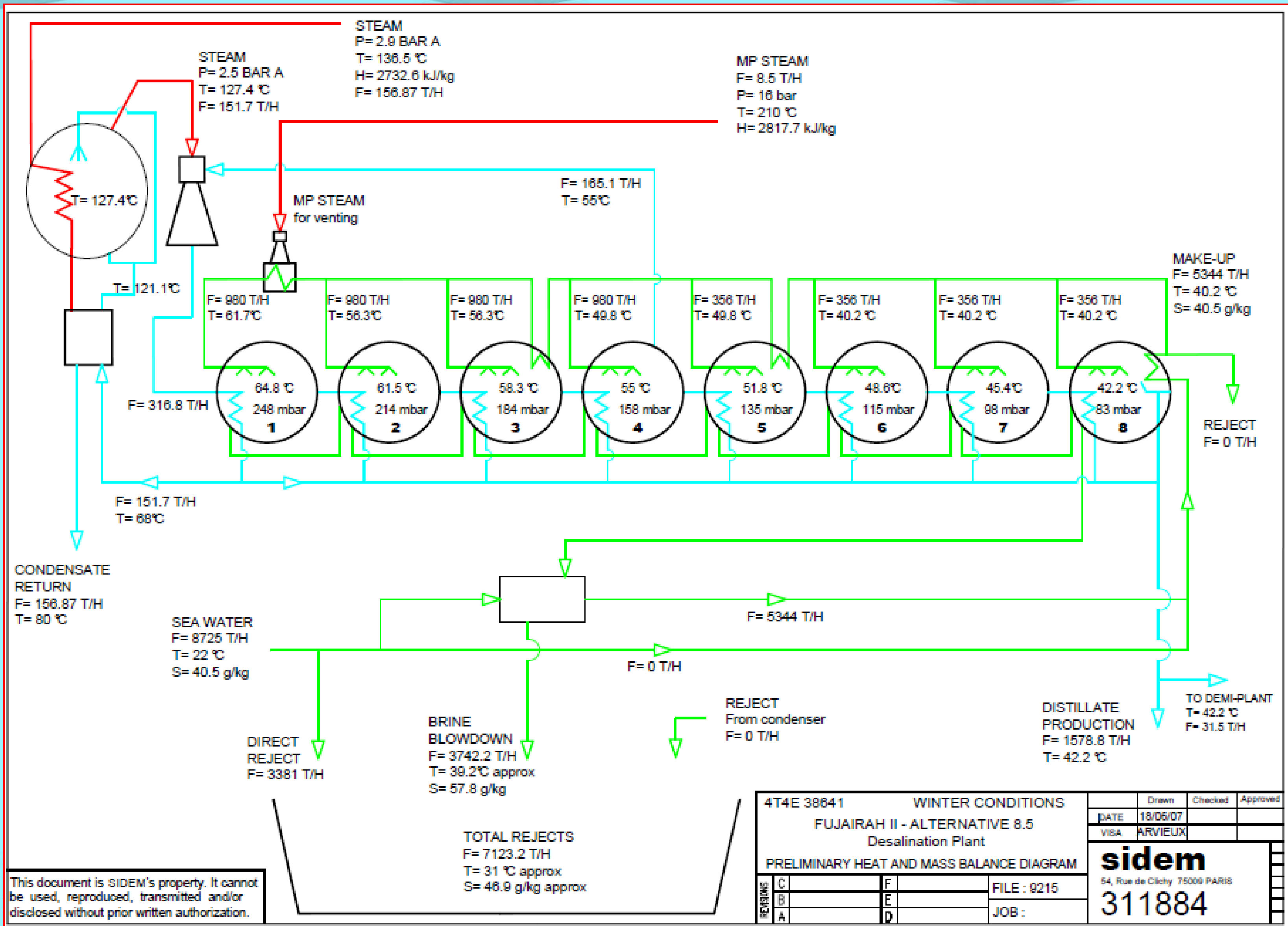
Scope of work

Engineering, procurement, construction and commissioning of 12 desalination units of 38,640 m3/day (8.5 MIGD) each and 30 MIGD reverse osmosis plant, together with: Potabilization plant, CO2 plant, limewater injection system, sea water pumps, 4 x 90,000 m3 storage tanks and other ancillary equipment

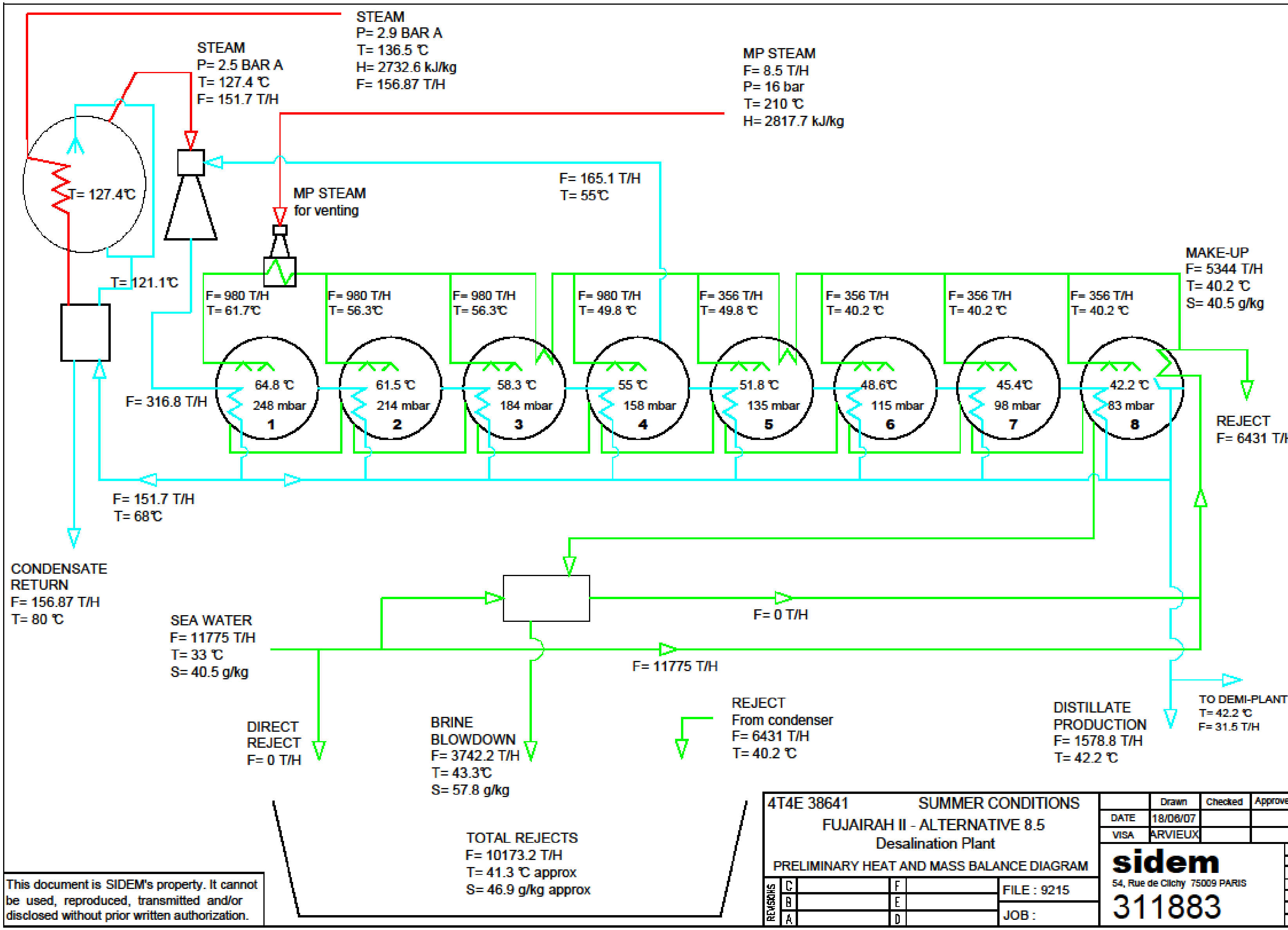
Contract data

Client: Fujairah Asia Power Company ; End-user: Abu Dhabi Water and Electricity Authority
The contract was awarded to a consortium made up of Alstom (for the power plant) and Sidem (water plant) in the frame of Fujairah II Independent Water & Power Production project.
Largest MED units to date (8.5 MIGD each)

Fujairah 2 MED Heat and Mass Flow Diagram
Winter Conditions.

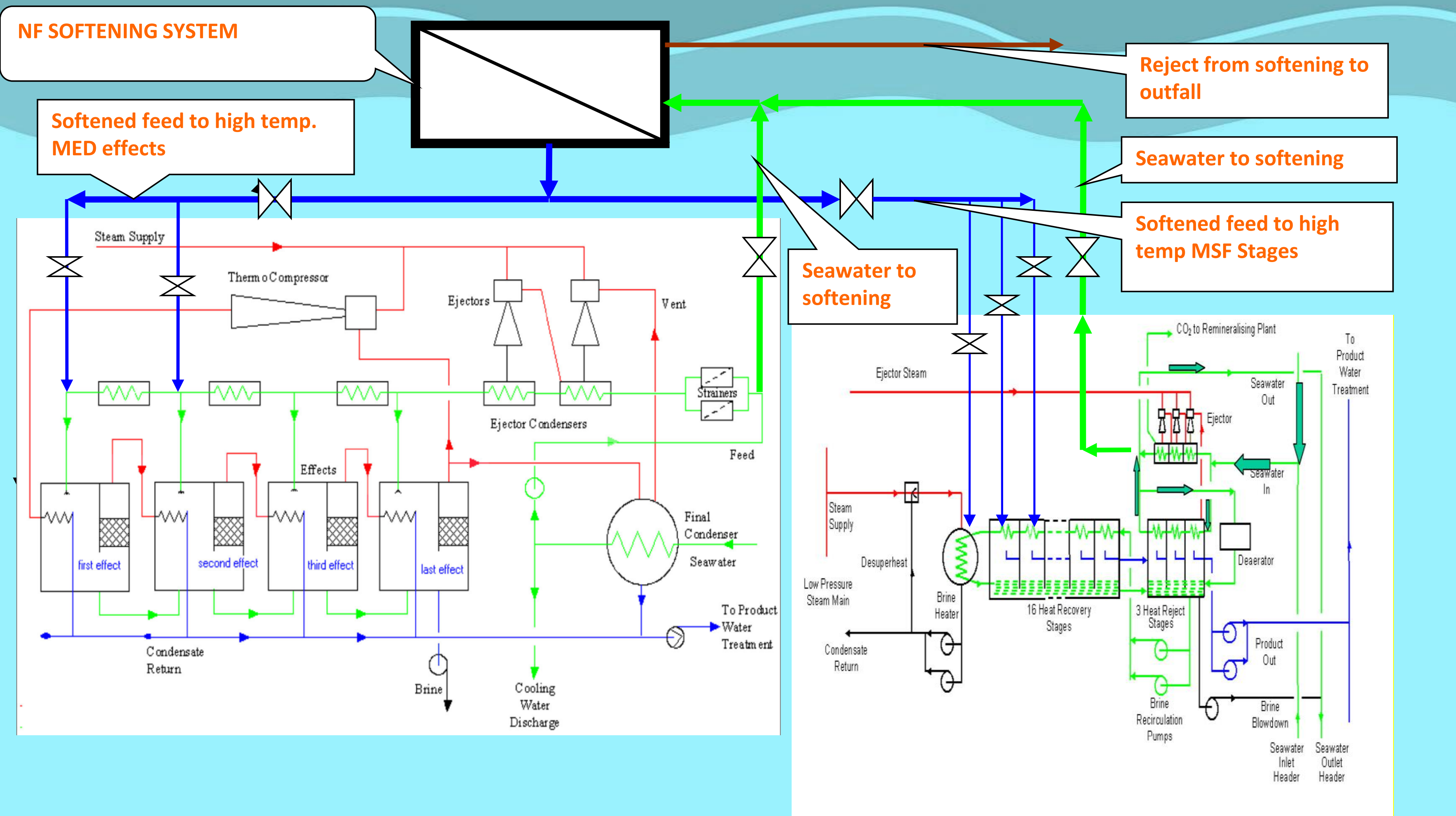


Fujairah 2 MED Heat and Mass Flow Diagram Summer Conditions.



Ras Al Khair, 20 MIGD (91,000t/d) MSF unit the largest in the world first out of 8.

The evaporator is also the world's largest in size, as it measures 123 meters long, 33.7 meters wide, and weighs 4,150 tons



Process and apparatus for partial blending of softened feed to high temperature effects of MED and/or high temperature stages of MSF, in order to increase TBT and Flow of Recycle or Feed

Seasonal variation in power and water

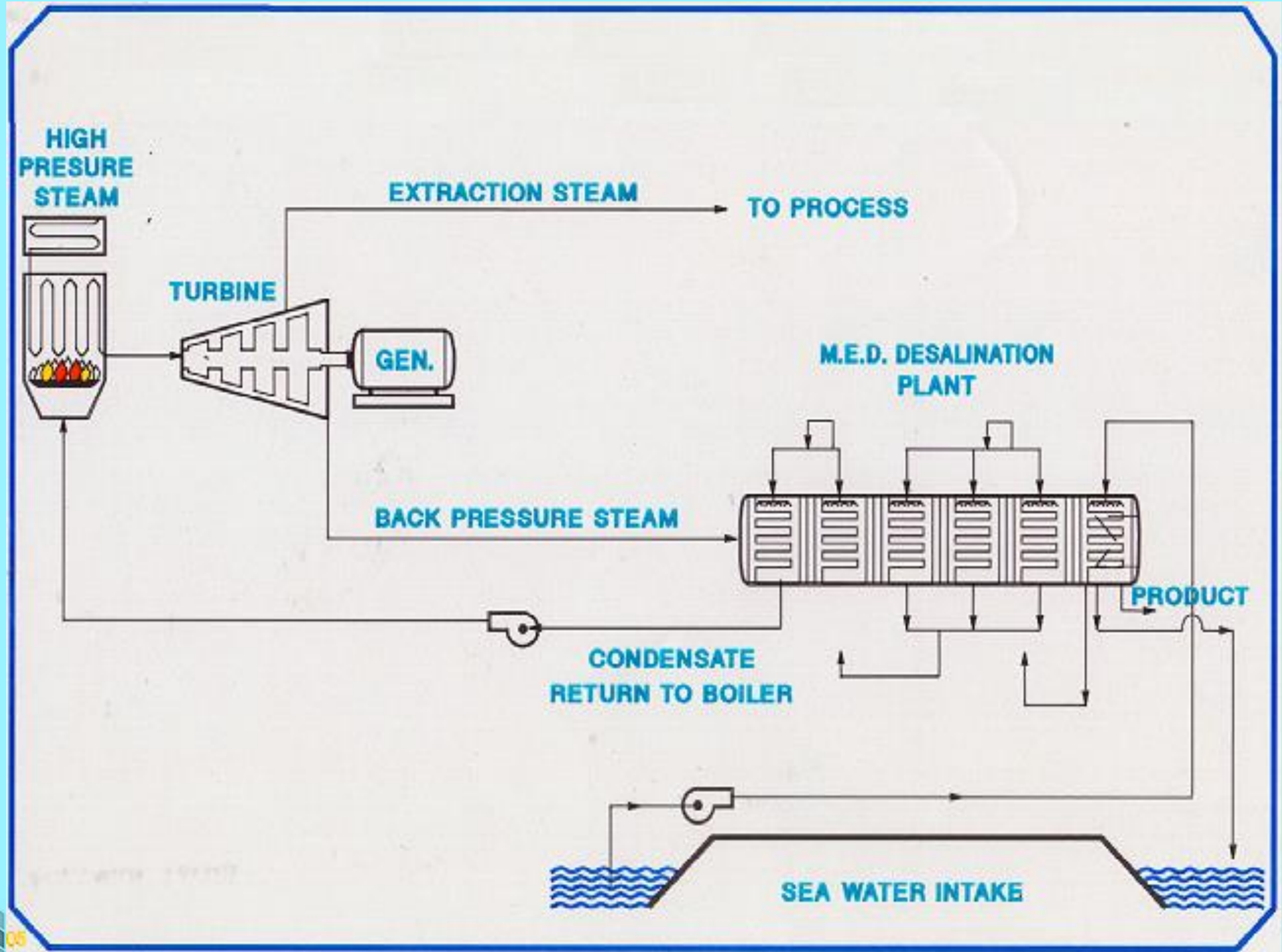
- In many countries, particularly in the Middle East, peak power demand occurs in summer and then drops dramatically to 30-40%. In contrast, the demand for desalinated water is almost constant throughout the year. This creates a situation where over 50% of power generation is idled.
- This inequality of demand between electricity and water can be corrected by diverting the excess of available electricity to water production.
- Water can be stored, while electricity storage is not practical.

DASR - Creating Storage and Recovery

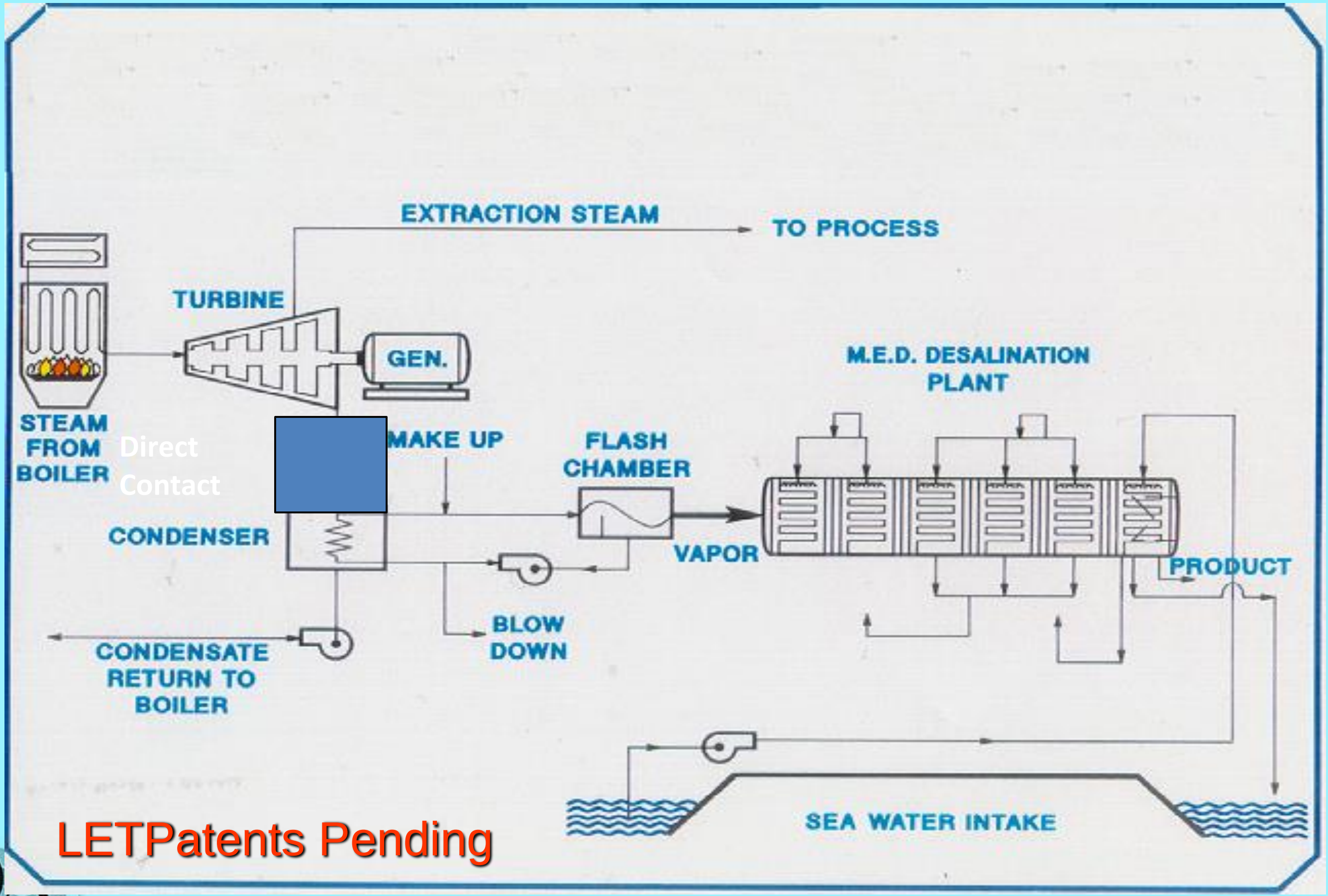
- Water can be stored, electricity cannot
- Desalinated water is stored in, and recovered from protected, underground aquifers using proven *Aquifer Storage Recovery (ASR)* technology
- Surface storage of large volumes of desalinated water is not economical

Energy Input

Back Pressure Steam (0.35 bara)



Direct Contact Condenser with Hot Water from Condenser at 85 ºC flashing in MSF type to provide steam to MED and return colder 67.5 ºC to condense steam



IDCA innovative system coupling steam turbine to MED

The significant results and changes of such design is listed below:

- The power plant produces significant more power considering that steam can be expanded to 80°C and absolute pressure .4741 bar versus current 2.8 bars. I estimate it will produce additional 110MW.
- Elimination of the steam piping from power plant to the evaporators, including heat and steam loss.
- Elimination of MED steam transformer as there is no thermocompressors. The condensate is re-flashed deareated and totally returns from first effect. No hydrazine contamination of the product.
- There is a need to add additional effects to achieve the same performance ratio.
- There is a need to add closed cooling water circuit piping and pumping

Conclusions

Technologies are made available that can reduce dependence on fossil energy for desalination.
We foresee use of renewable and nuclear energy to achieve reduction in carbon footprint and cost of desalinated water.

The integrated hybrids could be one of the approaches.
Application of hybrid NF-MED and RO couple with renewable or nuclear energy offers great opportunity.

DESALINATION IS THE SUSTAINABLE SOLUTION AND HOPE FOR THE FUTURE GENERATIONS

Desalination provides hope to the world community that we can provide water, the essence of life, at a reasonable cost, solving the scarcity of existing water supplies, avoiding regional and territorial conflicts, and providing the water resource for sustainable development.

IDA DESALINATION ACADEMY

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