Design of SWRO Desalination Plant for Nuclear Research Center

Albashir KH. Elfaqih
Center for Solar Energy Research and Studies
Tajura, Libya
engbkf1982@yahoo.com

Mohammed E. Said
University of Tripoli
Department of Chemical Engineering
Tripoli, Libya
msaid.2000@yahoo.com

Husam R. Shames
Libyan atomic energy Establishment
Janzour, Libya
h.shames@aee.gov.ly

Abstract— **Libya has an infinite water resource available in the coastal towns and cities being located on Mediterranean Sea with 1950km coast. Therefore, the need for desalinated water for Nuclear Research Center NRC located in Tajura is currently about 1200 m^3/day. To cover the center present and future water needs for research and development activities, two thermal sea water desalination plants have been assembled in the site. One of the plants uses Multi Stage Flash technology and the other one uses Multi Effect Desalination technology with capacity of 1200m^3/day each one. Detailed design for 1200m^3/day seawater reverse osmosis SWRO unit is carried out using ROSA Software to make the technical comparison with other MSF and MED units. The unit labeled an SW30XLE-440i by the results of the Software is selected since it required the lower feed pressure of 55.5bar and highest salt recovery of 45% with total dissolved solid of 190ppm. From the technical point of view, the study showed that SWRO required lower sea water inlet flow rate than MSF and MED. The units efficiency are 43%, 10.5% and 25% for SWRO, MSF, and MED, respectively. Further the Product quality TDS 190ppm for RO unit is suitable for drinking water, while those of MSF and MED 50ppm. Energy consumption as heating steam is not required for the SWRO unit; however, a steam flow rate 7.3m^3/hr is required by MSF and MED units. These make SWRO unit friendlier to the environment and most proper technically under these situations.**

Index Terms — **desalination, Nuclear Research Center, SWRO**

I. INTRODUCTION

Desalination is a separation process used to reduce the dissolved salt content of saline water to a usable level. The desalination technology is suitable in regions where seawater is readily available [1]:

- Distillation (Thermal Processes):
  1. Multistage flash distillation (MSF)
  2. Multi effect distillation (MED)
  3. Vapor compression (VC)
- Membrane processes:
  1. Reverse osmosis (RO)
  2. Electro dialysis (ED)
- Other processes:
  1. Freezing desalination
  2. Solar desalination
  3. Ion exchange

Received 3 March 2015; revised 20 March 2015; accepted 27 March 2015.
Available online 2 April 2015.

Distribution of the various desalination technologies are presented in Fig. 1. It is evident that the highest used technology is the reverse osmosis due to the many advantages associated with the technology.

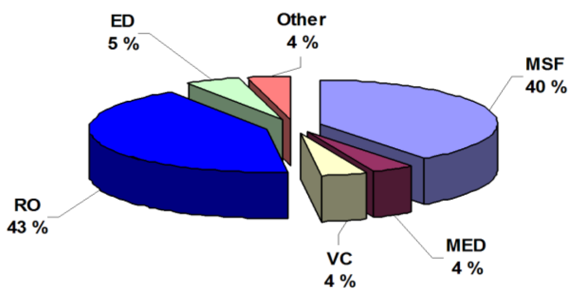


Figure 1. Distribution of Desalination Technologies [1]

Libya as many other countries in the arid region is heavily dependent on groundwater resources. It has an infinite water resource available in the coastal towns and cities being located on Mediterranean Sea with 1950 km coast, albeit a highly saline nature in the range between 35000 ppm to 38000 ppm. The Nuclear Research Center (NRC) located in Tajura currently needs desalinated water with capacity of 1200 m³/day. The center has assembled two new thermal desalination plants (MSF & MED) with capacity of 1200 m³/day, in the site waiting for operation. The basic points to compare these plants technically with designed SWRO plant with the same capacity will be shows as follows: The seawater inlet flow rate, distillate and brine outlet, type of feed chemical dosing, the electrical consumption, efficiency of plants, energy requirement and product quality TDS.

II. THE PROCESS DATA OF TAJURA DESALINATION PLANT

The process data given to as the follow. The daily production of desalinated water (Permeate flow rate) M_d is 1200m^3/day, so the hourly production rate of desalinated water (M_h) is 50 m^3/hr.

The open intake system of Tajura desalination plant consists of raw seawater feed pipes and raw seawater basin. Seawater from Mediterranean Sea is fed by gravity through submersed two pipelines 1300 m, 60 cm Length and Diameter pipe respectively, and the seawater basin capacity of 2880 m^3, and the distillate water of these plants is pumped to an underground storage tank, the capacity of this tank is 50,000m^3 [2].

Table 1. Tajura Raw Seawater Analysis

Components	Sweater composition (mg/l)
Calcium Ca++	455
Magnesium Mg++	1427
Sodium Na+	11600
Potassium K+	419
Silica Si+	2
Sulphate SO4	2915
Chloride Cl-	20987
Bicarbonates HCO3	133
Nitrate NO3	0
TDS	37938
PH	8 (without unit)

A. Multistage Flash Distillation(MSF) plant

MSF plant in NRC has the main equipment's [3]:

1. Evaporator: Cylindrical vessel with rectangular horizontal condenser tube bundles.
2. Brine Heater.
3. Dosing Stations: One Antiscale and one antifoam.
4. Piping & Valves: Pipes for vent and distillate are made from stainless and Steam pipes from carbon steel.
5. Ejectors: 8 bar and 170 °C Motive steam pressure and temperature respectively.
6. Process Pumps: Horizontal, single stage pumps are used.

Process description: As shown in Fig. 2 and Table 2. The treated seawater (make-up) is flowing through 12 condensers and is heated stepwise up to the brine heater inlet temperature (98.6°C) by recovering the heat of condensation of the vapors released in the flash stages. In the brine heater it is heated up to the brine top temperature (108 °C) by condensing heating steam at a temperature of 115 °C. The heating steam supplied to the brine heater has a pressure of max. 9 bar / min. 8 bar and saturation temperature (approx. 180 °C). The steam is passing a fast closing steam valve which automatically closes the steam supply in case of power failure of other dangerous events in the plant. The steam pressure is then reduced to 3 bar in a pressure reduction valve.

The heated seawater is entering via an integrated spray pipe the first flashing chamber. As the brine is superheated, spontaneous boiling takes place and vapor is released until the brine has reached its saturation temperature. This procedure takes place in all following stages at decreasing temperature and pressure. The brine is flowing from stage to stage by specially designed inter-stage brine flow devices; being designed for optimum flexibility in operation and minimized stage-to-stage vapor leakages.

The residual concentrated brine is discharged to the blow down pump, while controlling the brine level in stage. The distillates forming in each stage are collected in an external distillate pipe in parallel to the evaporator Stage to stage and the Process data of MSF plant shown in Table 3.

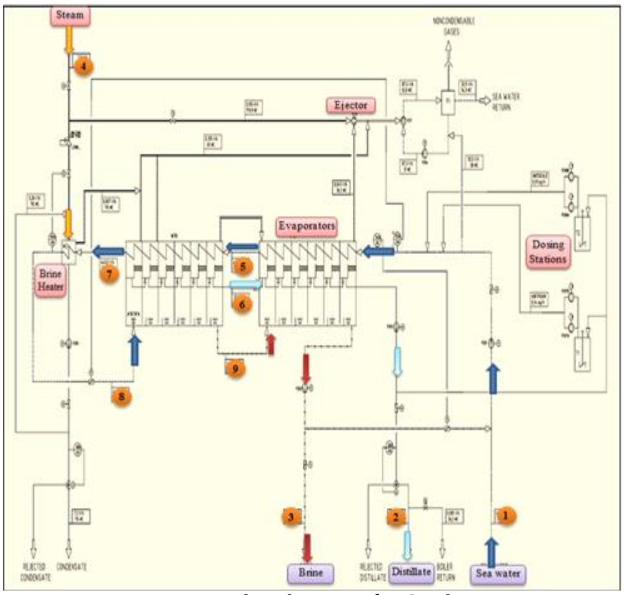


Figure 2. Flow diagram of MSF plant

Table 2. Stream Data

Stream	Medium	Flow rate (m^3/day)	Operating P (bar)	Operating T(C^0)
1	Seawater	475.7	1	28
2	Distilled	50	3	36.2
3	Brine	393.2	1.8	37.5
4	Steam inlet	7.3	10	180
5	Outlet Seawater from Evaporator 7-6	443.2	-	62
6	Distilled pipe from stage 6-7	27.3	-	70.5
7	Outlet Seawater from Evaporator 1	443.2	-	98.6
8	Inlet water to stage 1	443.2	-	108
9	Brian pipe from stage 6-7	415.9	-	71.4

B. Multi Effect Distillation (MED) plant

MED plant in NRC has the main equipment's [3]:

1- Evaporator cells: The evaporator shell consists of one or two cylindrical bodies closed at each end by flanges, including the cells separated by tube plates.

2- Main condenser: The condenser consists in a cylindrical shell in which part of the vapor produced in cell (2) is condensed outside the tubes.

3- Thermo compressor: The thermo compressor is made of stainless steel.

4- Vacuum system condensers: A vacuum two stage steam ejector/condenser system cooled by the raw water feed to cell (1).

5- Pumps: Two pumps are required to operate the unit. They are horizontal type centrifugal pumps with tropicalized IP 55 motor. 6- Piping and Valves.

Table 3: Process Data Of MSF Plant

MSF- Once-Through 12 flash	
➢ Nominal capacity	1200 m^3/day
➢ Brine Top Temperature 108 °C	108 °C
Type of chemical dosing	
➢ Antiscale approx.	0.93 kg/hr
➢ Antifoam approx.	0.14 kg/hr
Sea Water inlet:	
➢ Flow	475.7 m^3/hr
➢ Temperature	14 - 28°C
➢ Pressure	1 bar
Heating steam inlet:	
➢ Flow	7.30 m^3/hr
➢ Temperature	180°C
➢ Pressure.	8 - 9 bar
Distillate outlet :	
➢ Flow	50 m^3/hr
➢ Temperature	36,2 °C
➢ Pressure	3 bar
➢ TDS	50 ppm
Blow Down (Brine)	
➢ Flow	393.2 m^3/hr
➢ Pressure	1.8 bar
➢ Temperature	37.5 °C
Electricity:	
➢ Power consumption	245 kW

Process description: MED plant consists of evaporator includes two successive cells at decreasing temperature from cell (1) to cell (2) as in shown Fig. 3 and table 4.

The vapor introduced at 0.31 bar. In cell (1) is condensed at 70°C in a tube bundle externally sprayed by raw water. The vapor condensation heat allows part of this raw water to evaporate at a lower temperature / pressure (66°C/0.26 bar). The vapor produced then goes through cell (2) where it is condensed, thus evaporating part of cell (2) raw water at a temperature / pressure of (62°C/0.22 bar).

Part of the vapor produced in cell (2) is drawn up by the thermo compressor, in order to feed cell (1) with vapor. The remaining goes to the raw water cooled condenser where it is condensed.

The water condensed in the first cell goes through a U-shape tube to the second cell and finally to the condenser. The water is extracted from cell (2) by means of the distilled water pump. In a similar way, the part of the sprayed raw water which has not been evaporated in cell (1) goes through a U-shape tube to the cell (2) to be finally blown down by means of the brine pump.

The thermo compressor, by action of the high pressure steam (19 bars) coming from the steam generator, draws up the low pressure vapor (62°C/0.22 bar) of cell (2) and compresses it by mixture with the HP steam to the higher pressure (0.31 bar) required for the introduction in cell (1) and the Process data of MED plant shown in Table 5.

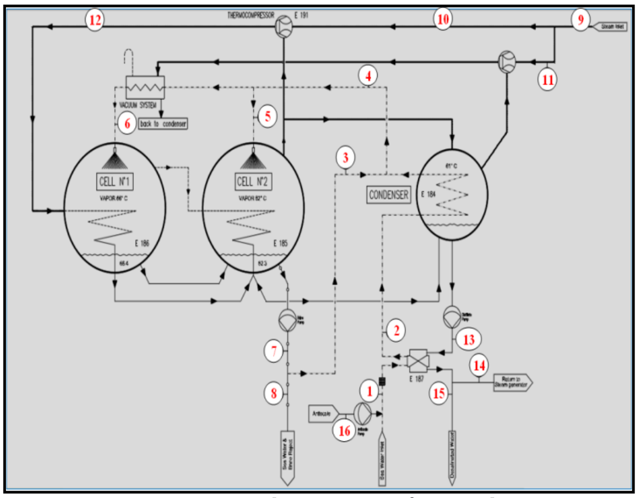


Figure 3. Process Flow Diagram of MED Plant

Table 4. Stream Data

Stream	Medium	Flow rate (m^3/day)	Operating P (bar)	Operating T (C^0)
1	Seawater(summer)	200	3.5	28
	Seawater (winter)	160	3.5	16
2	Seawater (summer)	200	3	38
	Seawater (winter)	160	3	31
3	Seawater	40	0.5	62.3
4	Seawater	200	0.3	58
5	Seawater	100	0.2	58
6	Seawater	100	0.1	60
7	Brine	140	0.7	62.3
8	Brine	150	0.1	62.3
9	Steam inlet	7.5	20	214.8
10	Steam	7.3	19	212
11	steam	0.2	19	212
12	steam	-	0.69	70
13	Distilled	57.5	2.7	61
14	Distilled	7.5	1.8	38
15	Distilled	50	1.8	38
16	Antiscalent	0.002	3.5	-

Table 5. Process Data of MED Plant

Number of units	1
Number of cells	2
Distillate output	
➢ Flow (daily)	1200 m^3/day
➢ Distillate output pressure	1.8 bars
➢ Temperature Less than	38°C
➢ TDS	50 ppm
Steam inlet	
➢ Flow	7.5 m^3/hr
➢ Pressure	20 bars
➢ Temperature	215°C
Sea water inlet/unit	
➢ Required flow	200 m^3/hr
➢ Temperature	28°C or less
➢ Piping design pressure	3.5 bar
Antiscale approx.	2.7 kg/hr
Power consumption	50 kW

C. Design of seawater reverse osmosis plant (SWRO)

Reverse osmosis is most commonly known for its use in drinking water purification from seawater, removing the salt and other substances from the water molecules.

One of the reasons for this is that reverse osmosis is commercially available in a range of sizes and is one of the most efficient technologies having much lower specific energy consumption SEC (about 3-10 kWh of electric energy per m^3 of fresh water produced from seawater) than the average of desalination technologies compared to MED and VC [4].

As the Fig. 4, SWRO plant design scheme of Single Stage System with capacity of 1200 m^3/day consists of the following components: 1- Feed water unit ((Intake)). 2 - Pretreatment system. 3 - High pressure pump. 4 - Membrane element assembly unit.5 - Permeate treatment and storage unit.

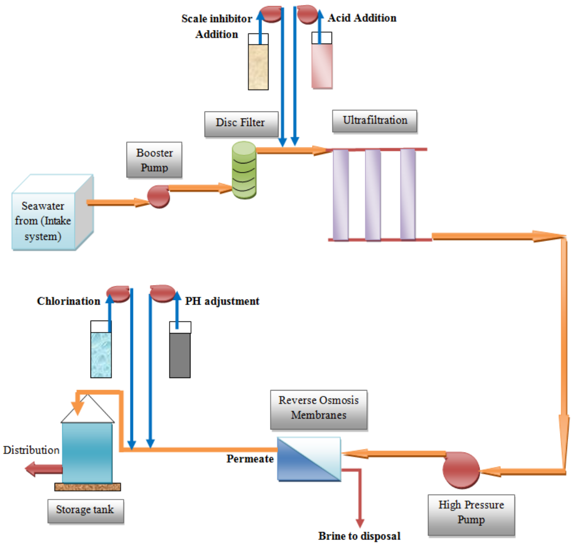


Figure 4. SWRO plant design scheme with capacity of 1200 m^3/day

For design scheme of seawater Reverse osmosis plant spiral wound membrane by the Dow chemical Company for Filmtec elements 8" were selected in the design, and used ((FilmTec ROSA Software, Version 8.3)) to select of Membrane elements unit [5].

The elements types with FILMTEC elements define as following:

- SW30 – SeaWater RO membrane, typically used for low salinity or cold seawater RO and high salinity brackish water RO.
- SW30HR – SeaWater RO membrane with High salt Rejection, typically used for single pass seawater desalination.
- SW30HRLE - SeaWater RO membrane with High salt Rejection, typically used for Low Energy seawater desalination.
- SW30XLE – membrane for SeaWater desalination with eXtremely Low Energy consumption.

III. THE RESULTS

The average fluxes of 8 inch element seawater desalination for Open intake = 14 $\frac{l}{hr.m^2}$

The number of elements needed:

The total membrane area

$$A_m = \frac{1000 \times M_h}{\varphi} \quad (1)$$

Where: φ= the average fluxes, 1000 convert from m³ to liter.

The total membrane area $= 3571.45\ m^2$

Number of elements:

$$(NE) = \frac{\text{The total membrane area } A_m}{\text{Active area } (m^2)} \quad (2)$$

Number of pressure vessels needed:

Divide the number of elements NE by the number of elements per pressure vessel, NEPV, to obtain the number of pressure vessels.

$$(NEPV) = \frac{\text{Number of elements}}{\text{Number of element in eash vessel (6,7 or 8)}} \quad (3)$$

TABLE 6. Number of Elements Per Pressure Vessel 6, 7 & 8

	membrane element type	Active area (m²)	number of elements	number of pressure vessel		
				6	7	8
1	SW30HR-380	35	128	21	18	16
2	SW30XLE-400i	37	102	17	15	13
3	SW30XLE-440i	41	96	16	14	12
4	SW30HRLE-370-34i	34.4	87	15	13	11
5	SW30HRLE-400	37	104	18	15	13
6	SW30HRLE-400i	37	97	16	14	12
7	SW30HRLE-440i	41	97	16	14	12
8	SW30XHR-400i	37	87	15	13	11
9	SW30XHR-440i	41	97	16	14	12
10	SW30ULE-400i	37	87	15	13	11
11	SW30ULE-440i	41	97	16	14	12

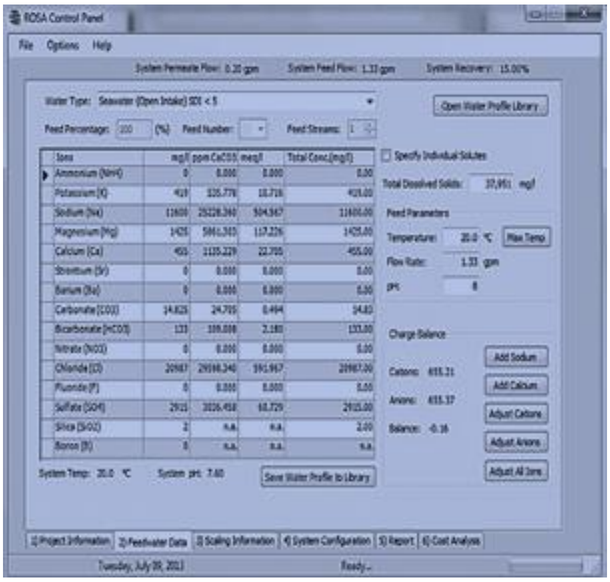
All this data given to ROSA Software for Dow Membranes Company as the Fig. 5. To calculate feed pressure and TDS for product water when the recovery (R) 35%, 40% and 45% and Selection of the best membrane element [5,6].

SW30XLE-440i was selected the best membrane element at 8 elements per pressure vessel, so the total elements 96 element on 12 pressure vessel, R = 45%, the feed pressure was 55.5bar & TDS was 190 ppm. This selection based on low feed pressure at high recovery.

The feed flow rate of the membranes unit (M_f):

$$\% R = \frac{M_h}{M_f} \times 100 \quad (4)$$

$$M_f = 111.11 \frac{m^3}{hr}$$



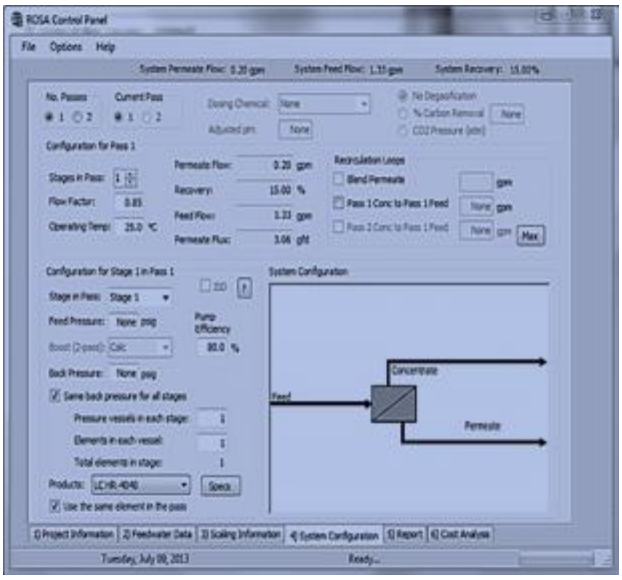


Figure 5. ROSA Software of Dow Membranes Company

Table 7. The Results for Permeate and Brain Analysis

Name	Feed	Adjusted Feed	Concentrate	distilled
K	419.19	419.19	759.87	2.81
Na	11605.28	11605.47	21045.57	68.02
Mg	1427.65	1427.65	2594.23	1.89
Ca	455.21	455.21	827.18	0.6
CO3	18.17	0	0.02	0
HCO3	162.93	27.97	50.37	2.02
Cl	20977.49	20977.5	38049.37	112.7
SO4	2913.68	3049.32	5542.99	1.62
SiO2	2	2	3.62	0.02
CO2	0.9	111.53	111.7	110.26
TDS	37981.61	37964.31	68873.24	190
pH	8	5.14	5.47	4.45
P(bar)	55.5	-	53.5	2

The pretreatment system is the most important part of the plant. This system allows the membranes to perform according to the design .The pretreatment system designed as following:

1. Disc filters.
2. Ultrafiltration.
3. Chemical Dosing for Feed water.

Disk filter is used for the micro filtration of solids, a very robust, mono block piece of machinery, with a minimum mesh of 20 microns and maximum 200 microns.

The seawater flow needed from the intake [7]:

$$M_{f,(intake)} = \frac{M_f}{R(1-\beta)} \quad (5)$$

Where:

β is the fraction feed water lost at the pre-treatment plant (typically between 3% and 15%, depending on the process), in this process the water lost from pre-treatment almost 3 % at recovery (R) 98%.

$$M_{f,(intake)} = 116.5 \frac{m^3}{hr}$$

At average water resource and filtration degree 100μ, 2 filters (P2S4 type) [8] was selected of 60m^3/hr for each one.

Ultrafiltration (UF) involves pressure-driven separation of materials from a feed solution. The technology is used to remove particulate and microbial contaminants, but it does not remove ions and small molecules:

The number of Ultrafiltration elements its same calculation of the membranes elements [5, 9]:

Membrane recovery ratio for Ultrafiltration is 98%, and the feed flow rate to Ultrafiltration ($M_{f,U}$):

$$\% R = \frac{M_f}{M_{f,U}} \times 100 \quad (6)$$

$$M_{f,U} = 113.3 = 114 \frac{m^3}{hr}$$

The total Ultrafiltration area in Equation (1)

$$A_m = \frac{1000 \times M_{f,U}}{\varphi}$$

Where: φ= *the average fluxes* = $70 \frac{l}{hr.m^2}$

The total membrane area $A_m = \frac{1000 \times 114}{100} = 1140\ m^2$

Number of elements (NE) = $\frac{The\ total\ membrane\ area\ A_m}{Active\ area\ (m^2)}$

The active area = 51 m^2

Number of Ultrafiltration elements is 23 elements.

Chemical dosing for feed water is two processes Antiscalent and Acid Addition (Sulfuric acid).

Scaling of SWRO membranes may occur when sparingly soluble salts are concentrated within the element beyond their solubility limit. The tendency for $CaCO_3$ scaling has been traditionally predicted by the Langelier Saturation Index (LSI) method (Langelier, 1936) [5].

$$LSI = pH\ (actual) - pH_s \quad (7)$$

Where: pH_s = pH of solution if it were in equilibrium with $CaCO_3$, i.e.:

$$pH_s = p_{Ca} + p_{Alk} + C_{(T,TDS)} \quad (8)$$

Where:

p_{ca} = log of Ca^{++} concentration

p_{Alk} = log of HCO_3 alkalinity

$C_{(T,TDS)}$ = constant to include temperature and TDS

At higher ionic strengths (seawater), the Stiff and Davis Index is a more accurate predictor of scaling tendency.

$$SD = pH\ (actual) - pH_{SD} \quad (9)$$

Where: SD = Stiff and Davis Index

$$pH_{SD} = p_{Ca} + p_{Alk} + K_{(T,IS)} \quad (10)$$

Where: K = constant to include temperature and ionic strength.

Table 8: Scaling Results (ROSA Software)

	Raw Water	Adjusted Feed	Concentrate
pH	8	5.14	5.47
Langelier Saturation Index (LSI)	1.06	-2.57	-1.74
Stiff & Davis Stability Index (SD)	0.06	-3.57	-2.93
Ionic Strength (Molal)	0.79	0.79	1.48
TDS (mg/l)	37981.61	37964.31	68873.24
HCO_3	162.93	27.97	50.37
CO_2	0.9	111.52	111.68
CO_3	18.17	0	0.02
$CaSO_4$ (% Saturation)	22.06	22.06	48.52
SiO_2 (% Saturation)	1.59	1.59	2.65
$Mg(OH)_2$ (% Saturation)	0.49	0.49	0

In this plant there are two important pumps, Booster pump and high pressure pump. The equation of design to find the power required as follows:-

$$bhp = \frac{(Q) \times (\Delta P)}{(1714) \times (\zeta)} \quad (11)$$

Where:
Q= rate of raw seawater flow, g/min.
ΔP = differential pressure, Psia.
ζ= efficiency of pump.

The Booster pump pumps the raw seawater from intake basin to the pretreatment stage with pressure drop 4 bar, 80% efficiency of the pump and Power 16.5 kW. The high pressure pump pumps to membranes unite with pressure drop 54 bar, 80% efficiency of the pump and power 217kW. So, the electrical consumption of SWRO plant was 235 kW.

Post treatment (treatment of Permeate) is two processes to treatment of Product Water by addition the chemicals materials pH Adjustment and Chlorination.

Table 9. Chemicals Additions for Feed and Permeate Water Treatment

The Chemicals additions	Dosing rate (Kg chemical/Kg H_2O)	Dosing rate (Kg chemical /hr)
Sulfuric acid	2.42E-05	2.7
Antiscalent	4.99E-06	0.55
Calcium Hydroxide (pH Adjustment)	1.4E-05	0. 7
Sodium hypochlorite (Chlorination)	4E-06	0.2

IV. DISCUSSIONS

Discussing the technical analysis for the design results of SWRO plant with two thermal desalination plants MSF and MED in the following points:

1- The seawater inlet flow rate for SWRO plant consume 111 m^3/hr which is lower than MSF plant which consume 475.7 m^3/hr and MED plant which consume 200m^3/hr. The reason of this various results is the different amounts of their operating efficiencies. This parameter can be considered as an advantage for SWRO plant because it saves the capital cost (using lower HP pumps) and the operating cost (kWh needs to operate the pumps).

2- The Brine outlet pressure for SWRO plant was 53.5bar which is higher than MSF plant which was 1.8 bar and MED plant which was 0.1 bar. This parameter can be considered as an advantage for SWRO because it can be used with an energy recovery system to support the high pressure pump. The clear reason for that, the SWRO plant uses high pressure pump to deliver the seawater into the membranes by 55.5 bar pressure.

3- The Product quality TDS for SWRO plant was 190 ppm which is higher than MSF and MED plants which was 50 ppm. So the Distillate product water from MSF and MED plants needs to add some minerals to become good drinking water which can be considered as disadvantage for these plants. The reason for this several TDS results of the three plants is the nature of the distilling processes.

4- SWRO plant uses 2 types of chemicals additions (Acid, Antiscalent) while MSF plant uses other 2 types of chemicals dosing (Antiscalent, Antifoam) and MED plant uses 1 type (Antiscalent). It is clear that SWRO and MED almost consume the same amount of chemicals while MSF needs about 50% of the amount.

5- MSF & MED plants uses heating steam at flow rate of 7.3m^3/hr while SWRO plant does not use heating steam. This contributes to operating cost saving and makes RO technology environmentally friendly.

6- The Electrical consumption of SWRO plant was 235 kW which is lower than Electrical consumption of MSF plant which was 245 kW and higher than Electrical consumption of MED plant which was 50 KW. For the two thermal plants, the use of fuel to produce the steam in the boilers is also added to the total plant power consumption. SWRO technology does not consume fuel because there is no need for steam.

7- The Efficiency of plants is Ratio between product water and inlet flow rate. SWRO plant efficiency is 43 % which is higher than MSF plant efficiency 10.5 % and MED plant efficiency 25 %.

V. CONCLUSION

This paper investigates the technical analysis of SWRO plant design with two thermal desalination plants MSF and MED with capacity of 1200 m³/day for each plant for the nuclear research center (NRC) located in Tajura. In general SWRO technology is definitely less complex to operate and more environment friendly than the other two. Also ROSA Software is a powerful tool to select between different designs. The main result items are the number of SWRO elements, percent recovery (R), and inlet feed pressure. As a result of the study, The SWRO plant for this capacity 1200 m^3/day has better technical parameters than the other two plants taking into account that MED plant ranking second.

REFERENCES

[1] Befesa Desalination Developments Ghana Limited, "proposed seawater reverse osmosis desalination plant at Nungua, Accra", March 2011, pp. 29-30.
[2] E. Massaoud and O. Abd Alazizi, "Design Criteria of 10,000 m^3/day SWRO Desalination Plant of Tajura - Libya", Tajura Nuclear Research Center.
[3] The National Association of Scientific Research "Official documents of Description of the Plant Process MSF and MED plants", Tripoli - Libya, 2004.
[4] E. Gkeredaki, "Autonomous photovoltaic powered seawater reverse osmosis for Remote coastal areas", Master of Science in Sustainable Energy Technology, Delft university of Technology, June 2011, pp.5.
[5] Reverse Osmosis Membranes Technical Manual, "FILMTEC Reverse Osmosis Membranes", Dow Chemical Company, pp. 80-93.
[6] Dow Chemical Company, "An Overview of Products, Applications, and Technical Resources", Dow Liquid Separations, December 1997, pp. 10.
[7] D. Plessis, A. Burger, C. Swartz and N. Musee, "A Desalination guide for South African municipal engineering", Water Research Commission, July2006, pp. 47-48.
[8] Miller-Leaman, Inc, USA. "Automatic TURBO-DISC filter".
[9] Dow Chemical Company, "Pretreatment with DOW™ Ultrafiltration Helps to Save Water at Jumeirah Beach Hotel", 2009.