REVERSE OSMOSIS AND ION-EXCHANGE WATER TREATMENT FOR BOILERS- A BRIEF REVIEW

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ABSTRACT: *Strong treatment of feed water for boilers solve the high need on a demineralized water chemistry/quality in the process involve open evaporating system/ closed system/ hot water/ Chilled water/ boiler waters. There are several demand of water chemistry/quality parameters such as- pH, Conductivity, Cationic Conductivity, Chloride, Hardness, Alkalinity, Sulfite, Phosphate, Silica, Iron, Ammonia, Carbohydrazide, Dissolve oxygen content, etc. according to Working Pressure and the kind of boiler, capacity of the cooling tower(open evaporative system) and the closed system. Communally efficient softening and/or demineralization are always predictable. All water desalination process consist of its standard pre-treatment stages and post-treatment stages (deionization/demineralization stages). A combination of pre-treatment steps depends on the type of water origion (sea, Bore/well, surface, or tap water) and its specific analysis. All these water treatment steps are essential for the safety protection of the plant. The Post-treatment (deionization/demineralization stage) stage of the water treatment Plant is selected and designed on the basis of requirement of the Water Chemistry/quality which if defined by manufactured of the plant(boiler, HRSG/Steam turbine). There are two basic method of desalination, first is Wet Method and second is Dry Method. Reverse Osmosis is the example of wet method. RO is the latest technique in the wet method. Examples of dry method are Multi-Effect Distillation MED and Multi-stage Flash MSF. Currently for brackish water Reverse Osmosis along with Ion-Exchanger/ Electro-deionization becomes more popular. The project is presented by Mega Company's consist of Ultrafiltration, Reverse Osmosis(BWRO) and Ion-Exchanger (for demineralization) at the segment of water treatment for boilers feed water. It defines some installation and their characteristic-source and water quality/chemistry, pre-treatment technique and product quality. A detailed review of brackish water reverse osmosis process and demineralization process is furthermore discussed.*

Key words: Ultrafiltration, Reverse Osmosis and Ion-Exchanger, Boiler, Demineralize water, Bore water.

1. INTRODUCTION

The Water treatment plant work as a complementary automation in almost all industrialized process. The chemistry of process water and wastewater acting an actual important role in industrial application and process and even in environmental. So, a demand of proper treatment of water with respect to economic and environmentally friendly features is discussed. The use of advanced and latest filtration technology open a new industrial chapter. Water recovery from BWRO is around 75%, while the rest of brine goes to drain. The situation in SWRO is 40 to 50% recovery and the rest of the brine goes to drain so this brine has much contamination that produced a bed impact on environment of sea[1,2]. This can open the research chapter for ecofriendly SWRO reject stream option [3]. Recovery of rejected water from SWRO is achieved by the process called Membrane distillation and their excess heat is utilize in other nearest electricity generation plant[4, 5]. Other techniques of treatment of water like Crystalization combination with Membrane distillation produced zera percent discharge brine[6.7]. Mericq reported that sea water recovery achieved 89% via SWRO with vaccume Membrane distillation[8]. The process involve in Membrane distillation is vapour-liquid equilibrium for separation of molecules[9]. The benefit of Membrane distillation are moderate temperature, rejection of solute 100% and low operating pressure and high purity product [10]. Its another benefit is more compact than other thermal techniques[11]. Scale deposition on surface of membrane create operational difficult and performance and life time of the plant [12]. Supersaturation of salt via water vapor flux on surface of membrane enhance the salt precipitation [13]. $CaCO_3$ scale on the polypropylene membrane can be dissolved by Hydrochloric Acid of concentration 3%, this can be reported by Gryta in 2008 [14]. $CaSO_4$ scale on the polypropylene membrane can be dissolved by Hydrochloric Acid of concentration 3% rinsing, this can be studied by He *et al* [15]. Nghiem and Cath stated about cleaning and flushing regime of Polytetrafluoroethylene membrane[16]. In order to control the scale in the reverse osmosis system antiscalant chemical used and antiscalant consist of organophosphate, polyphosphates [17]. Organophosphate based antisacalnt effective for potential scaling in Membrane Distillation at 74^0 C under supersaturated solution reported by He *et al* [18]. In order to inhibit the $CaCO_3$ prepicipetation from hard water, Ketrane et al studied five different types commercial antiscalant along with cartridge filters [19,20]. Sea water desalination with Reverse Osmosis started in 1950 with high permeable membrane, the use of efficient pump and with ERD energy recovery device price decreasing from 2.2 to 0.6 USD per cubic meter and decrease in energy consumption from 14-18 KWh/m^3 to 1.4-2.5 KWh/m^3 [21-25].

This paper explains the use of brackish water reverse osmosis (BWRO) and demineralization in the regional treatment of water for HRSG's, boilers, Cooling system (Open-evaporative, Open, Closed system). Selected models of BWRO water treatment unit manufactured by means of "Mega Company" are shown. Detailed information of the BWRO plant process and the demineralization+ exchange of ion method is also specified.

The requirement for boiler feed water chemistry are dissimilar for the different kinds and different operational pressure of the boilers. Here also a problem that the consumption of water in the boiler circuits: as water is used as a circulation water or the feed water in order to accommodate the bottom blow down water, header blow down water and continuous/surface blow down water. Normally, pure and colorless water must be verified, deprived of colloidal solid, suspended solids, oils and destructive chemicals. The other control parameters of boiler feed water are less content of chloride, Total Hardness, total alkalinity, Silica, Phosphate, Oxygen and the value of pH above 8.8.[26] This document deals only with the treatment of water for brackish or well water. In the current situation advanced applications of Sea Water Reverse Osmosis (SWRO) technology for treatment of seawater in the world [27, 28], which effectively conflicting with desalination by thermal process [29, 30]. Treatment of river water by Reverse Osmosis technology is joined with Clarification and ultrafiltration or Clarification joined with multimedia/sand filtration process [31, 32]. Additionally, the uses of pretreatment membrane/filtration process and the reverse osmosis process for desalination sanitization then use in the process and this process contaminated water again used as a waste water so for this requirement of effluent treatment plant installed in order to cover the losses of the fresh water requirement of power plant locations in Europe [33] and middle-east.

2. WATER TREATMENT

Water treatment plant or unit along with salinity removal can be distributed as three segments, initial/pre-treatment, desalination stage and the (deionization) post treatment. The feed water pre-treatment plays a significant role in the efficiency of the plant, economical cost of producing water and shelf-life of a reverse osmosis system (salinity removal). If the capital cost of a new reverse osmosis water treatment plant is quantified, the amount of initial treatment is approximately same regardless the application salinity removal method. The installation of the initial treatment(pre-treatment) steps based on the type of water origin/source and its contamination. In large volume scale river water can be treated; in small volume scale normally treated water is tap water or well water.

The objective of the salinity removal and the final-stages of the water treatment are to come with a chemistry/quality of water as per manufacturer recommendations for the kind of HRSG and its operational pressure. The above techniques can be used to yield the feed water of typical parameter for the boiler/HRSG from brackish water in the Czech Republic:

- Multi-media screens
- Ion-Exchange Filters
- Single-pass Reverse Osmosis followed by Ion-Exchange demineralization,
- Single-pass Reverse Osmosis followed by electri-deionization EDI
- double-pass Reverse Osmosis
- Single-pass Reverse Osmosis followed by Ion-Exchange demineralization.

Ion-Exchange procedure are the old procedure for deionization/demineralization. Now a days it appears as disadvantage due to high consumption of chemicals for regeneration along with generation of salty wastewater, but its advantage (e.g., low investment cost) hardness removal so the load on reverse osmosis also minimize. Reverse Osmosis is the best process for water demineralization. By using multiple-stage RO or by using combination of reverse osmosis with different-pass desalination unit along with Ion-Exchange demineralization or electro-deionization EDI, it is possible we get water having a conductivity around 0.08 us/cm.

3. COMPARISON OF DESALINATION METHOD

An assessment between the desalination methods is connected with different aspects. The factors which have greatest importence are as follows:

- Capital cost,
- Operational cost, which included cost of electrical energy, chemical consumption and operators,
- Environmental effect of planned technology.

The mention above, capital budget of initial/pre-treatment are almost same irrespective of salinity removal (reverse osmosis) method, and for this we assumed that its operating cost. Therefore, the assessment of desalination method is of attention. If the criteria for selecting the best desalination technology are volume based means permeate water volume and with his conductivity/salinity, So:

- Reverse Osmosis is the best method for high volume and water with higher levels of conductivity/salinity treatment.
- Ion-Exchangers are the best when small volume of water and water with low conductivity.
- Conventional method used for seawater desalination are dry method, MED Multi-Effect Distillation and MSF Multi-stage Flash, but due to high operation and maintenance cost, reverse osmosis replaced all these methods with the name seawater reverse osmosis (SWRO).

These arguments are on the basis of experience and on calculation cost [33]. It will be appreciated that from the above case here the price of chemicals have been almost calculated for reverse osmosis and ion-exchange (deionization and or hardness removal) that the installation of dual technologies in salinity removel are significant. Reverse Osmosis are yet more costly for the the both treatment either small or large volume of water production, but cost of complete total operation are lower than the cost of chemicals of Ion-Exchanger, but reverse osmosis is environment friendly. The cost and consumption of different chemicals in the Country Czech are matched for the small capacity in table:1. The example is a scatch of potential client which has old facility of water treatment plant with ion-exchanger plant in order to produce boiler feed water. Due to the requirement of high quality permeate water, they need a reverse osmosis plant unit as a next step to Ion-Exchange unit (shown in Fig. 1a). The chemical price were calculated as per request and compared with the chemical price where the order of desalination method is reversed (see Fig. 1 b). On the environment aspect this point of view is much better that first to decrease the Total Dissolve Solid TDS and other contamination of tap water or well water on the reverse osmosis plant with moderately high cost of electrical energy and then remove the remaining total hardness , chloride and alkalinity content with an Ion-Exchange

Table 1: Assessment of chemical cost for Ion-Exchange-Desalination RO technology (Surface water dissolve solid 750 ppm; water production for boiler feed water with 10 m^3/hr capacity)

Process	RO to Ion-Exchange			Ion-Exchange to RO		
	Quantity Kg/m^3	Unit Price $/Kg	Cost $/m^3$	Quantity Kg/m^3	Unit Price $/Kg	Cost $/m^3$
36 % HCl for RO	1.060	0.113	0.120	0.093	0.113	0.011
100 % NaCl for I.E.	0.008	0.267	0.002	1.564	0.267	0.417
Quantity on 1 m^3 of product			0.122	Quantity on 1 m^3 of product		0.428

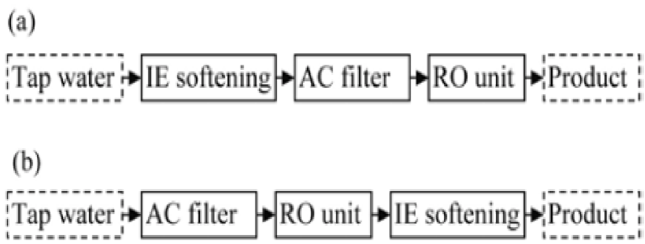

Fig 1: Technology set-up: (a) demanded by costomer, (b) proposed by Mega

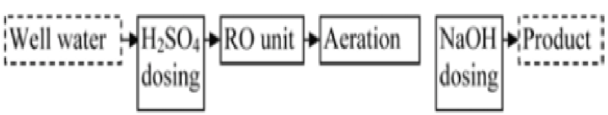

Fig. 2: Technology set-up at Saint-Gobain Vertex.

softening plant with small capacity and with little usage of regeneration chemicals. However, the capital cost takes more importance in the above situation than the operational cost with a harmful environmental effect of hardness removal through Ion-Exchange, therefore, the technology designed giving to the actual need of the customer as compared to other competitor.

The benefit of operation presented in fig 1(b) compare with fig 1(a) :

- Lesser the feed water osmotic pressure of reverse osmosis gives a smaller pressure of pump so that little cost of operation.
- Lesser chloride and alkalinity of the permeate.
- Lesser concentration of dissolved solid in the permeate.
- Lesser the dissolve solid concentration in the reverse osmosis retentate, and ion-exchange process gives a little volume of wastewater.

Fig. 3: RO unit in Perla, Usti nad Orlici

4. APPLICATION OF REVERSE OSMOSIS

Salinity removal application with ion-exchange process of water treatment process for boiler, HRSG'S are widely used in Czech Republic. Low dissolve solid/conductivity wells and surface water mostly treated with ion-exchange process and such process are very cost-effective [34]. The Environmental effect of Ion-Exchange is controlled by the capital cost of new installed plant of reverse osmosis, while they are not more costly. The cost of operation of a new desalination plant is lesser compared with a new type of low-pressure membrane (in case of reverse osmosis) and small electrical resistance membrane (e.g. is electro dialysis and electro deionization process) announced to the marketplace.

If the new boiler house is assembled or certain older are reassembled, it is detected that reverse osmosis is the best alternative. After the reverse osmosis Ion-Exchange demineralization is also sometimes used as a additional next stage depends upon the feed water quality requirement.

The Mega Water Company has deliberate two parallel reverse osmosis unit for the request of Water treatment for the HRSG's/ Boilers in current years [30]. Both parallel reverse osmosis units serve as a sub-ordinate of Ion-Exchange demineralization/desalination unit for treating well water. Initial application of production of deionized water having capacity 2.5 m3/h; after that its application was increased and production going to 62 m3/hr of deionized water. Above application was used first time at Saint-Gobin Vertex (Czech Republic) designed in June 1999. The simplest setup of this desalination unit is shown in Fig. 2, that provide pictorial representation of this type of unit. In the treatment plant well water go into from the ball valve with a bypass and pass through the cartridge filter which is the safety of the reverse osmosis unit and also the pH of the feed water maintained through sulfuric or hydrochloric acid as per manufactured recommendation and pH of the feed water is analyzed by pH sensor which installed in the feed water system. In Fig. 3 the reverse osmosis unit distributed the feed water into two streams, one is permeate and the second is concentrate. Concentrate stream(reject water) go to drainage and the product water(permeate stream) go to the forced draft aerator where carbon dioxide remove from the permeate stream and then the addition of sodium hydroxide to maintain the product water pH and then this water go to the Ion-Exchange unit for demineralization [30].

The reverse osmosis unit pressure vessel filled with 12 Hydranautics ESPA2-4040 membrane modules in 3*2 + 3*2 configuration and with an operational pressure of 15 bar [33].

Outline of this technology in Saint-Gobin Vertex (Czech Republic) is as follows:

- Water source : Well water having dissolve solid = 550 ppm
- Pre-treatment: Cartridge filter with acid addition.
- Reverse osmosis unit: Product flow = 2.5 m3/h with recovery 68%.
- Post-treatment: Aeration, alkalization and ion-exchange demineralization.

The chemistry/composition of well water is presented in Table 2, Column A. In Bore/well water bicarbonate and calcium ions have large proportions as compared to other ions.

Table 2: Comparison of water composition

Test	Well Water (Column:A)	RO + IE (Column:B)
Ca^{2+} (ppm)	150	0.41
Mg^{2+}(ppm)	20	0.06
Na^{+}(ppm)	8	2.3
K^{+}(ppm)	4	0.05
NH_4^{+}(ppm)	<0.05	<0.05
HCO_3^{-}(ppm)	280	7.2
SO_4^{2-}(ppm)	78	0.7
Cl^{-}(ppm)	55	<0.3
NO_3^{-}(ppm)	46	<2
SiO_2(ppm)	4	<.1
pH	7.53	7.02
TDS(ppm)	610	8.5

With this latest technology rate of continuous blow down decreased and due to this energy losses minimized. The HRSG/Boiler water chemistry is shown in Column B [33].

Another application of Mega Water Company RO plant for production of boiler feed water is installed on Perla Usti Czech Republic in 2005 [34]. The process steps of this technology presented in Fig. 4 that gives the pictorial demonstration of the system. The process is same as previous explain that Well water come from the inlet line to cartridge filter, then addition of acid to maintain the pH and check through pH detector which installed in the feed water sampling line. The Reverse Osmosis unit (Fig. 5) shown, it divided the feed water streams into two streams , permeate and concentrate streams. Concentrate stream go to drain line while the permeate stream is our product go to aeration unit for the removal of carbon dioxide and addition of Sodium Hydroxide to maintain the pH for product water.

Reverse Osmosis unit pressure vessels consist of 30 Hydranautics ESPA2-7 membrane module in 4*5+2*5 configuration.

Overviews of technology are as follows:

- Water Source = Well water having dissolve solid 610 ppm.
- Pretreatment = Acid injection.
- Two Pass RO unit = 2*30 m^3/h permeate flow with recovery 76 %.
- Post-treatment = Aeration, Alkalization, thermal de-aeration.

5. CONCLUSION

Reverse Osmosis in combination with Ion-Exchange is the most popular technology for the boiler feed water production. Its use permit the reduction of operation cost, high maintenance cost and avoid the high degree of automation like other water treatment units. Reverse Osmosis system also the ecofriendly unit due to it generate a low degree of dissolved solid/ salinity compare to other units. Reverse Osmosis combination with Ion-Exchange give the complete free mineral free water.

Reverse Osmosis unit has no boundary that it have no necessity to high capacity plant. In this type of unit only capacity and water chemistry required to installed new plant. In case of river water, tap water reverse osmosis (TWRO) units for this purpose. In case of Well or Bore water, Brackish water reverse osmosis units (BWRO) for this purpose. In case of sea water, sea water reverse osmosis units (SWRO) used for this purpose. Water demineralization with Ion-Exchange (Cat-ion and Anion) unit give good quality mineral free water, but its disadvantage is high consumption of regeneration chemicals. Electro-deionization in combination with Reverse Osmosis give the environmentally friendly demineralization system that produced of very high quality water for steam generation.

6. REFERENCES

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