Make-up Water Treatment within the Water Circuit of the Thermal Power Plants

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The water is one of the most important fluids used especially for different industrial processes. In order to be utilized, the water has to be treated. The most used technologies for water treatment are the technology using ion exchangers and the technology using reverse osmosis. The article presents a critical comparative study of the two mentioned technologies, based on the main features and steps recommended, and their application for the water circuit within a thermal power plant.

Keywords: water treatment, chemical process, ion exchangers, reverse osmosis

The main characteristic of water is its capacity to be a remarkable solvent, so that in its natural status contains dissolved matter, as well as suspended or colloidal matter (resulting from the environment it crosses).

In order to use water for different purposes, that needs specific treatments. More than 80% of the water requested is from industrial processes. The great part of this water quantity is used for cooling and only 10% is used as process water.

There are no essential differences between the physico-chemical processes of the natural water treatment technologies for obtaining drinking water or high purity water for different industrial requirements and the physico-chemical processes of the waste water treatment technologies. The differences consist in the nature of the treated water and the quality of the final effluent that must be obtained. The unwanted substances are removed from the water in both cases.

The product of a water treatment station is superior quality water that corresponds to the requirements of usage, and the product of a water purifying station is an effluent that does not affect the quality of the natural water resources [1].

The modern make-up water treatment technologies in the thermal circuit that are used on a global scale, depending on the quality of the input fresh feed water and the quality of the water required for power boilers, are based on:
- treatment of the water through ion exchangers,
- treatment of the water through reverse osmosis.

Water treatment using ion exchangers

The water treatment systems using ion exchangers have evolved in two main directions:
- the improvement of ion exchangers
- the improvement of the treatment technologies and the equipment.

The back current regeneration technologies have evolved from operating in fixed layers (“classic back current”) to systems operating in a compact or floating layer.

The total water deionization is carried out through a double ion exchange that takes places in the ionic filters fitted with ion exchangers in a compact layer. These systems have high regeneration efficiency, materialized through a substantial reduction of the regenerating substances and washing water consumption. The compact layer systems have ionic filters with one or more compartments (chambers) with inert layer or overlapping layer.

The ion exchangers occupy the entire space of each chamber, while the systems maintains the compact characteristic of the layers, in depletion state (operation), as well as during the restoration of the resin work capacity (regeneration).

An inert resin layer with a smaller density than the ion exchangers is foreseen besides the active resins. The inert resin allows avoiding the clogging of the nipples from the superior part of the chamber with fine particles of active resin.

The operating scheme of the demineralization line is based on a simple process [1]:

\[ H –D –OH, \] (1)

where:
- \( H \) = cationic filter with weak acid/ strong acid overlapped layers,
- \( D \) = CO₂ de-aerator,
- \( OH \) = anionic filter with weak basic/ strong basic overlapped layers.

The operation of the \( H \) cationic filter

During operation, following the ion exchange reactions, the cations of the dissolved salts are retained in the filter and the effluent is left with their connecting anions.

During operation, the cations are retained on a weak acid ionic mass following this reaction:
The principle of reverse osmosis

The reversed osmosis process eliminates dissolved salts, inorganic molecules and organic molecules with a molecular weight higher than 100, measuring less than 10 Angstrom, from water. The elimination ration of dissolved salts is 95% - 97%, by mass.

Reversed osmosis is one of the non-polluting systems for de-ionizing water because the content does not comprise other salts besides the ones existing in the water at the inlet of the installation [2].

Osmosis is a physical phenomenon that balances the concentration of two solutions existing in a container with two compartments, separated by a permeable membrane only for water molecules. The water passes through the membrane from the low salinity compartment to the high salinity compartment, reducing its salinity [3]. As the water infiltrates in the saline compartment, the water height increases in this compartment and the level in the low salinity compartment is reduced. The height of the liquid column from the saline compartment increases until its pressure on the permeable membrane stops the infiltration of water molecules in this compartment (fig. 1).

The height balance point, respectively the height difference between the two compartments, that defines the water pressure on the membrane, is called osmotic pressure.

By applying a pressure on the surface of the liquid from the saline compartment that is equal or higher than the osmotic pressure, the reversed phenomenon occurs when the water molecules from the high salinity compartment.
pass through the permeable membrane into the low salinity compartment. This physical phenomenon is called reversed osmosis.

In an industrial application, the reversed osmosis principle is carried out by introducing water with a high pressure pump, in a continuous way into the filtration module.

In the module, a part of the water without salts passes through the filtering membrane into the pure water compartment, from where it is evacuated through the pure water pipe, and the concentrated solution that comprises salts that do not pass through the membrane is evacuated through the concentrate pipe (fig. 2). An adjusting cock mounted on the concentrate evacuation pipe controls the supply water flow for obtaining the pre-established de-ionized water flow.

The membrane is designed in order to allow only water to pass through the dense layer, stopping the particles, the dissolved compounds, bacteria and viruses, directing them towards the drain. This process requires an inlet water pressure of at least 2.7 bar [3].

The operation of the reverse osmosis installations

The scheme of the reverse osmosis installation is presented in figure 3.

The operation yield and duration of the reverse osmosis systems depends on the supply water penetration system, respectively its quality.

During operation, in the saline stage, the solubility limit of CaCO₃, CaSO₄ and SiO₂ is exceeded for most water supply sources due to the salt concentration.

In order to eliminate the salt precipitation risk on the permeable membranes, which can cause their degradation, the supply water of the reversed osmosis installation shall be dosed with substances for maintaining the solid matter in suspension.

Another factor that can cause the degradation of the membranes is free chlorine. Activated carbon filtering or sodium pyrosulphite dosage is applied in order to retain the chlorine. Cellulose triacetate membranes, which are not sensitive to chlorine, can also be used. The complete reversed osmosis systems comprise a pH adjustment module in order to obtain a pH in the range of 5.5 - 6.5, for preventing the deterioration of the membranes.

Another factor that leads to the deterioration of the membranes is the existence of bacteria in the supply water, for which an UV disinfection system is foreseen.

The pretreatment system is designed with maximum efficiency in order to avoid the following processes to which the permeable membrane is sensitive: (i) Impurities with substances in suspension; (ii) Precipitation accumulation, such as CaCO₃, CaSO₄ and BaSO₄; (iii) Biological impurities.

For the case of impurities with substances in suspension, in order to avoid the contamination of the filtering membranes, an additional filtering is required for the pre-treated water and the water filtered through sand filters, with a spark plug filter stage for retaining the suspensions higher than 5 microns, having the porosity of the filtering layer smaller or equal to 5 microns.

In the case of precipitate accumulation, during operation, the solubility limit of the calcium carbonate, calcium sulfate and silica is exceeding for most water supply sources due to the salt concentration in the saline stage.

In very rare cases, there is a danger of other salt precipitations, such as calcium fluoride, barium sulfate, strontium sulfate.

In order to eliminate the danger of salt precipitations on the permeable membrane, the following water treatment systems are required, depending on the water salinity:

- correct the pH by dosing sulfuric or chlorhydric acid; respectively acidulate water in order to avoid the precipitation of the calcium carbonate. The calcium carbonate precipitation tendency is controlled through the Langelier saturation index.
- when the pH saturation is \( \text{pH}_8 \), the water is balanced with the calcium carbonate. The Langelier saturation index is expressed through:

\[
L_{\text{Si}} = \text{pH} - \text{pH}_8
\]

where:

- \( \text{pH} \) is the water \( \text{pH} \),
- \( \text{pH}_8 \) - saturation \( \text{pH} \).

In order to avoid calcium carbonate accumulations, the acid dosage are applied to maintain \( L_{\text{Si}} \) negative, according to the following possibilities:

- dosage of inhibitors, organic polymers that avoid the precipitation of calcium carbonate and calcium sulfate. If the dosage of inhibitors is used, a \( L_{\text{Si}} < 1 \) index is maintained at approx. 20 mg/L in the concentrate.
- Na-cationic softening, because this process entirely eliminates the precipitation danger, the reversed osmosis yield increases up to 99.5%.
- decarbonization through weak acid cationite, followed by the carbon dioxide gas purging applied with a high content of calcium bicarbonates.

The reversed osmosis system is easy to install and is formed of a series of tubes that contain membranes, a high pressure pump for the water passage through the system.

The purity of the treated water depends on the membrane retention percentage (92.0 - 99.5 %) and the salt solution type. The membranes retain the components with great molecular mass and multi-value ions. The single-value ions, such as Na and Cl, are harder to retain. While the retention percentage of the membrane decreases up to 90 %, or less.

Once a month or after any installation stop, the membranes are washed with high pressurized water and a cleaning agent for an hour. If the pre-treatment system is adequate, the life span of the membranes from the reversed osmosis system can reach 20 years without interventions. The reversed osmosis installation is completely controlled, this being carried out through a PLC.

Conclusions

Based on the description of the two technologies one can conclude the following:

- both technologies ensure the quality of water needed for thermal circuit of the thermal power plant;
- technologies based on ion exchanges are used for treatment of low salt water;
- technologies based on reverse osmosis are used for treatment of very salt water (ex. see water). Reverse osmosis could be used also for low salt water, but the use of this technologies for this kind of water is a matter of cost;
- from environmental point of view the waste water resulted from the reverse osmosis process is not contaminated by other chemical reagents;
- in terms of occupied area, the reverse osmosis technology uses less area than the ion exchanges technology.

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References


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