P a r t 2

WATER PROTECTION FROM DISCHARGES

2.2. Contemporary water treatment technologies at power plants and their environmental impact assessment

2.2.4. Reverse osmosis demineralization of water

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An increased interest to reverse osmosis technology is observed in domestic water demineralization practice in recent years. A number of reverse osmosis units are constructed and are in a successful operation: Thermal power plant (TPP)-23 of JC "Mosenergo" (VNIIAM design, production 50 m^3/h, reverse osmosis membranes –Dow Chemical); Nizhnekamskaya TPP (design and supply of Hidronoutics company, production 166 m^3/h); Magnitogorsk metallurgical enterprise (VNIIAM design, production 90 m^3/h, reverse osmosis membranes of "Filmtec" company); Voronezh TPP and Kursk TPP-1 (production 50 and 250 m^3/h, design of "Voronezh-aqua" company, supplier of reverse osmosis membranes – Hidronoutics); Novomoskovskaya state district thermal power plant (SDTPP) two reverse osmosis units (production of 50 m^3/h each); Taganrog automobile works (TagAZ) two reverse osmosis units (production of each – 50 m^3/h); Sochi TPP two reverse osmosis units (production of each 7 m^3/h, manufacture, supply and commissioning of last six units are performed by JC "Energoservice"); Ufimskaya TPP (production of 50 m^3/h); Novosibirsk TPP-2 (production 100 m^3/h), Novocherkasskaya SDTPP (production 150 m^3/h, "Mediana-filtr" company design) and at some other facilities [1, 25, 35, 36].

It should be noted that the above mentioned reverse osmosis units operate on water passed different options of preliminary treatment. At Mosenegro TPP-23 water from water reservoir is treated in a clarifier by aluminum sulfate or its oxichloride and in mechanical filters with two layer loading (advanced clarification). Filtrate is demineralized at the second stage of H-OH ion-exchangers.

The following water pre-treatment was designed for Nizhnekamsk TPP [36]: lime-soda water treatment with coagulation with ferrous sulfate in clarifiers, treatment in two layer mechanical filters, H-cationic exchange of water with "Hungry" (without excess supply of reagent) regeneration of cationic exchange resin and final treatment in fine filters. Then H-"hungry" cationic exchange was substituted by acidation. Operation experience revealed low efficiency of such pre-treatment, first of all because of unpredictable quantity and quality of organic contaminants in river Kama. Then reverse osmosis unit was switched to feed water that passed lime coagulation and Na-cationic exchange softening. After this performance of reverse osmosis unit improved, sound removal of ion disperse organic admixtures from water was noted. Final treatment of the reverse osmosis unit filtrate was provided at the second stage of the chemical demineralization unit.

At Novomoskovskaya state district power plant water from a water storage pond is treated using the following scheme [36]: lime treatment with coagulation with ferrous sulfate in clarifies, filtration in clarifying (mechanic) filters, two stage Na-cationic exchange. Deeply softened water after the second stage of Na-exchangers in the amount of 30% of the total flow of the boiler make-up water is directed to the reverse osmosis unit (ROU). Besides, softened water is acidified up to pH≈9.5. Treated water after the reverse osmosis units is mixed with the rest part of softened water. Concentrate of the reverse osmosis unit in amount of 1-15 m^3/h together with softened water after the first stage of Na-cationic exchangers is directed to the heating system. Quality of the mixed flow satisfies the regulations for the heating system make-up water. The unit is equipped with "Filmtec" elements of "Dow Chemical" company.

Quality of initial softened water and water after reverse osmosis unit, obtained at water treatment of Novomoskovskaya state regional power plant and other enterprises is presented in table 2.3. Operation of reverse osmosis units is characterized by high selectivity on mineral components – 98.5-99.3% and on organic compounds -80-85%. Efficiency of removal of dissolved silicic acid made 99.3%, non-reactive silicic acid – 65-85%. Membranes were chemically washed with Roclin P 111 solution after a year of operation caused by fall of the efficiency at 10%. As a result operational characteristics of the reverse osmosis unit were fully restored.

At Taganrog automobile works two ROU of 50 m^3/h production operate using sea water from Taganrog bay. Raw feed water is heated up to 20…25 °C and is directed to the degasifier, then is treated with cationic flocculent solution in a pipeline and clarified in clarifies, filled with silica sand. Clarified water after disinfection at bactericide unit is treated with inhibitor solution and is sent to ROU. ROU is equipped with membrane elements SW30 HR-380. Filtrate is sent to the demineralized water tanks, concentrate is discharged through the special pipeline to the bay at a distance of 1500 m. from the shore. Filtrate of ROU is softened in Na-cationic exchangers and is sent for the boiler feeding and other technological needs of the plant.

Chemical washing of membranes is performed not more than once in 8 months. During the whole period of operation membrane elements were replaced only in 2003 at one of the units because of membrane selectivity reduction at 10% as a result of detachment of the upper selective layer of a composite membrane from the filtration bottom layer.

At Sochi TPP water treatment feed water is taken from a municipal water supply system. Such water is directed to ROU after inhibitor dosing without additional treatment [36]. Filtrate is collected in the tanks and directed to the following stage of chemical demineralization at H-OH exchangers, needed because of high requirement of boiler-utilizer manufacturer to the feed water in respect to salt-content (less than 0.3 mg/dm^3).

Thus the majority of water treatment units operating in our country have been designed and manufactured by domestic companies with implementation of imported membranes. Experience of operation of the first units is about 10 years. Rapid destruction of membranes expected by many specialists did not occur.

At the same time advantages of the above technology are vivid and are accepted by staff of all power plants that promotes their further implementation.

Operation experience allows the following conclu-

sions:
1. The basis for reliable operation of the units is high quality of feed water, i.e. effective pretreatment and prevention of depositions on membranes using various methods.
2. Design, manufacture and commissioning must be provided by a company experienced in dealing with high production units.
3. The most reliable units are units with previous deep softening of water at Na-cationic exchangers.
4. Direct filtrate feeding to low parameter boilers (instead of Na-cationic technology) without advances treatment should be implemented with precautions, because it is concentrated with sodium salts.
5. To feed high parameter boilers filtrate has to be additionally demineralized in H-OH filters of the second stage.
6. Na-cationic treatment of water before ROU and filtrate advanced treatment and also necessity of periodic membrane washing leads to mineralized waste water, requiring additional costs for their treatment and utilization.
7. Use of ROU concentrate produced from Na-cationic treated water for heating system make-up water may cause sufficient rise of mineralization of heating system water, its alkalinity and corrosivity, especially when volume of additional water is comparable with ROU production. Increased alkalinity of heating system water increases danger of scaling as a result of suction of water system water [37].

Table 2.3. **Quality of water and filtrate**

Indicator	Enterprises implemented									
	AO «Novomoskovskaya SRPP»		JSC «Tagaz»		JSC «Sochi TPP»		Ryazan oil works		OJSC «NGHK»	
	u	*n*	*u*	*n*	*u*	*n*	*u*	*n*	*u*	*n*
Temperature, °C	29	29	23	23	10	10	25	25	10	10
Water hardness, mg-eqv/dm^3	0,005	0,0	31,7	0,02	2,65	0,022	5,45	0,049	0,38	0,0
Ca-content , mg-eqv/dm^3	—	—	19,0	0,01	2,4	0,020	3,10	0,028	0,2	0,0
Mg-content, mg-eqv/dm^3	—	—	12,7	0,01	0,25	0,002	2,35	0,21	0,18	0,0
Alkalinity, mg-eqv/dm^3	0,5	0,01	8,0	0,19	2,6	0,09	3,55	0,27	0,28	0,0
pH	9,9	8,8	6,87	5,0	7,84	6,0	7,8	5,85	6,47	5,1
Na-content, mg/dm^3	86	0,9	715	14,4	12,0	1,2	27,1	0,69	2,4	0,02
Fe-content, mg/dm^3	0,01	0,0	0,05	0,0	< 0,1	0,0	0,1	< 0,05	0,1	0,0
SO_4-content, mg/dm^3	122	1,5	1641	10	18,11	0,18	48	0,43	6,45	0,0
Cl -content, mg/dm^3	24	0,2	1010	9	1,49	0,01	7,4	2,0	3,3	0,0
NO_3-content, mg/dm^3	—	—	—	—	0,37	0,0	—	—	—	—
SiO_3-content, mg/dm^3	2,8	0,025	—	—	6,0	0,09	7,6	0,14	41	0,04
Salt-content, mg/dm^3	316	4,5	4143	39,5	151	1,7	355	11,2	60	0,06
Unit electric conductivity χ, mcSm/sm	630	9,0	7687	84	312	3,5	715	23	129	0,14
Oxidizability, mg O/dm^3	3,2	0,5	—	—	0,44	0,0	—	—	—	—