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Efficiency evaluation of Sodium-cationic resins for water softening in heat producing plants operation

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ABSTRACT

The paper presents the efficiency evaluation results of hardness salts removal in water purification using ion exchange,including various sodium-cationic resins to produce softened water for heat producing plants feeding. The research was carried out at the pilot ion exchange plant using a single-stage sodium-cation scheme under laminar operation. The experiments consisted in determining the softening efficiency dependence on water flow rate until the resins capacity exhaust, followed by their regeneration and repeated studies of the efficiency at different flow rates. Sodium-cationic resinswere found to provide high purification degree of hardness salts removal. Herewithbetter results of softening efficiency and regeneration degree were obtainedforthe resins PuroliteC100E and Tokem-150. Basing on the research results, these resins were recommended to be used for water softening as a part of multi-stage water treatment plants at thermal power plants and boilers.

Key words: Heat producing plants, water softening, ion exchange, sodium-cationic resins, hardness salts, regeneration

1. INTRODUCTION

Water is one of the key resources used in industry, agriculture, for household purposes and drinking needs. Depending on water application, it has certain requirements to be met which the source water does not always correspond to. Certain requirements also apply to the used water. To meet the requirements for source and waste water, it is treatedapplying various methods, their choice depends on the initial water composition and the Standards requirements [1-5].

The production of thermal energy at thermal power plants and boilers are known to use turbines of various capacity and steam-gas. These heat generating plants are constant consumers of softened water in significant amount [6]. The quality of feed and make-up water for steam boilers and turbines of various operating pressures depends on the power equipment reliability of heat generating plants, so the water quality is subject to strict regulatory requirements. Thusthe softened water production for the operation of heat generating plants is an urgent task as the share of electric power industry in the total amount of fresh water industrial consumption in Russia ranks about 70%.

To produce feed and make-up water of the required quality, multi-stage treatment of source water is used at water pre-treatment plants (WPP). The technologies traditionally used in WPP at heat power facilities comprise two principle units [7, 8]:

- physical and chemical water treatment unit, including chemical treatment (coagulation, liming, soda-liming), clarification (settling, mechanical filtration at pressure clarification filters, ultrafiltration);
- water softening unit aimed at preparing and maintaining the salt (ionic) composition of pre-treated water to achieve the make-up water quality for turbines of various capacity, according to the established standards.

Such methods as Na-cationic softening, nanofiltration and reverse osmosis, decarbonization and finishing deep desalination (H-cation, OH-anionation) can be usedfor water softening [9-11].

The research objective is to determine the efficiency of various Na-cationic resins application in the process of water softeningfor the heat-producing plants operation.

2. RESEARCH OBJECTS AND METHODS

In this research the source water from the central water supply inOktyabrsky district of Vladimir was used. The experiments were performed using sodium-cationic resins - PuroliteC100E (Germany), Tokem-150 (Russia), and KU-2-8 (Russia).NaCl aqueous solution was used in compliance with GOST 4233-77 of 8 % concentration, fed at the volume ratio of resin: solution = 1 : 5 for the waste resins recovery. The resin was washed after regeneration with distilled water according to GOST R 58144-2018.

Experimental studies were carried out at the pilot plant for single-stage ion exchange, developed and manufactured by BMT Ltd (Vladimir), with the laminar flow ensuring the particles immobility of the ion exchange resin layer. This plant provides the resin loading in the volume of 0.6 liters.

The plant technological diagram, shown in Fig. 1, provided the source solution feeding into the filter element from top, and NaClregenerating solution was fedcounter-flow to the direction of water supply. The feed rate of the source water ranging from 1.77 to 15.92 m/h (from 5 to 45 l / h) was regulated using the metering pump DME 48-3 Grundfos, and the regenerating solution was supplied by gravity and regulated by the valve. To suppress the pulsation associated with the pumps reciprocating movement, a pulsation damper was mounted after the pump.

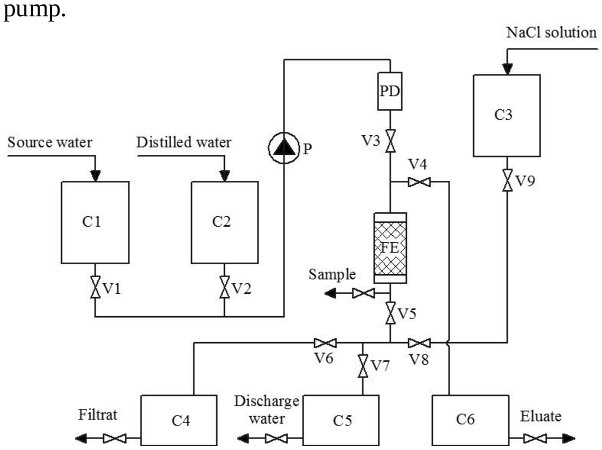

Figure 1: Flow diagram of sodium-cation process at the ion exchange plant:
C1 – initial tank; C2 –tank for distilled water; C3 – tank for NaCl solution;C4 –tank for filtrate; C5 –tank for discharge water; C6 –tank for the eluate;P – pump; PD – pulsation dampener; FE –filter element; V1-V9 – valve

After ionite recovery with NaCl solution, it was washed with distilled water, which was supplied by the metering pump. The filtrate, which is softened water, the eluate, which is a spent regenerating solution, and the spent washing water were collected in separate tanks.

To assess the softening process efficiency, the source water hardness and water hardness at the filter element outlet were determined in compliance with GOST 31954-2012. The water purification efficiency (E, %) by resin for removing hardness salts in relation to the source water and the recovery rate regarding treatment efficiency before and after regeneration have been determined basing the obtained data concerning hardness.

3. RESEARCH RESULTS AND DISCUSSION

The experimental studies revealed that the source water hardness supplied to the pilot plant ranged from 5.35 to 5.84 mg-EQ/l, and the water temperature was 22-23 ^{o}C. The Reynolds criterion varied from 31.26 to 187.43 during the testing, and, consequently, the flow mode was laminar and provided particles immobility of the ion-exchange resin layer.

The research results dealing with water softening efficiency using the studied resins at different water flow rates are shown in Fig. 2. The obtained data demonstrates that the studied flow rate range have similar dependencies, consistingofthe increase of the softening efficiency ranging from 93.46 to 99.76% alongsidethe flow rate increase. Such type of dependence can be explained by the fact that the flow rate increase causesfaster change of the water layer contacting the surface of the ionite particles. In this layer, which is the interphase contact surface of the water-ionite system, the ion exchange reaction of mobile Na^+ resin ions to Ca^{2+} and Mg^{2+} ions in softened water occurs. As a result of the rapid change of the layer, Na ions concentration in it is constantly decreasing,and Ca^{2+} and Mg^{2+} ions concentration is increasing, thus causinga constant shift in the ion exchange equilibrium towards Ca^{2+} and Mg^{2+} ions absorption, and this, in turn, causes softening efficiency increase.

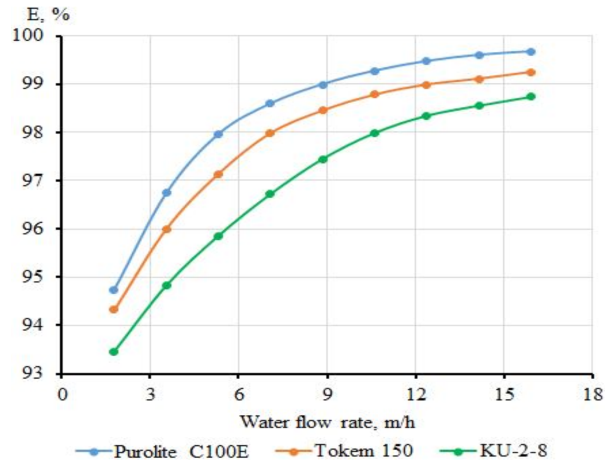

Figure 2: Dependence of water softening efficiency on flow rate and resin brand

Besides the received datademonstrate that Purolite C100E and Tokem-150 (99.76 and 99.23 %) are the most effective having similar results, but KU-2-8 resin was least effective (98.66 %) of all the studied Na - cationic resins. The performance difference depends on the fact that resins PuroliteC100E and Tokem-150 exhibit higher activity in ion exchange reactions.

When increasing the water hardness, passed through the ion exchange resin layer up to the values twice the average for the stable plant operation, each resinwas regenerated with 8% NaCl solution. After recovery and washing of each resin, the experiments for determining the dependence of the treatment efficiency on the flow rate were repeated.

The softening efficiency results after resin regeneration shown in Fig. 3 demonstrate that Purolite C100E and Tokem-150 resins insignificantly decrease in efficiency in relation to studies conducted before recovery, and for KU -2-8 resin– the decrease is more considerable.

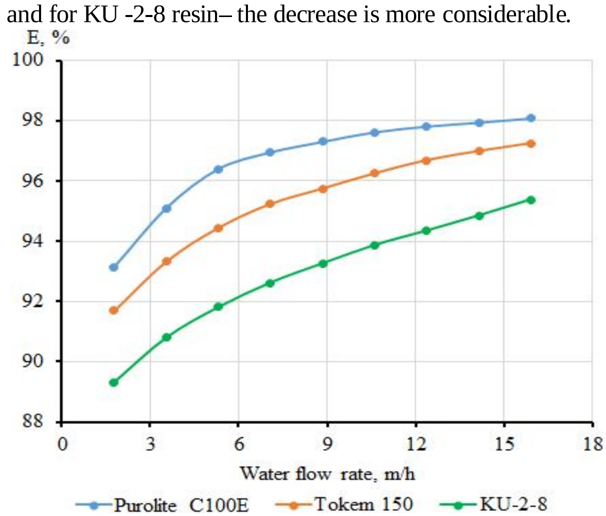

Figure 3: Dependence of water softening efficiency on flow rate and resin brand after its recovery

The comparison of capacity, cleaning efficiency, and recovery rate for the studied resins at the maximum flow rate of 15.92 m/h for the applied plant (corresponds to the source water flow rate of 45 l/h) is presented in the table.

Table: Efficiency indicators of sodium-cationic resins application for water softening

Resin	Capacity, l		Purification efficiency , %		Recovery rate, %
	Before regeneration	After regeneration	Before regeneration	After regeneration	
Purolite C100E	182.5	155	99.67	98.08	98.40
Tokem 150	177.5	155	99.25	97.24	97.97
KU-2-8	172.5	132.5	98.74	95.38	96.60

The resulted data reveals that softening process efficiency for Purolite C100E and Tokem-150 resins is higher than for KU-2-8, with insignificant advantage of Purolite C100E.

4. CONCLUSIONS

The research results revealed that sodium-cationic resins of Purolite C100E, Tokem-150 and KU-2-8 allow water softening of the initial hardness of 5.35 to 5.84 mg-EQ/l at the flow rate of 15.92 m/h with sufficiently high efficiency.

The resin Purolite C100E appeared to be the most effective during two cycle operation among the considered sodium-cationic resins. It allows water softening with the treatment efficiency of 98.08-99.76 % and performance capacity of 155-182.5 liters of softened water per 0.3 liters of resin for the specified values of the initial water hardness and flow rate.

Basing on the research results, this resin can be recommended for water softening atthe multi-stage water treatment plants at thermal power plants and boilers.

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