Physical modeling of stabilization water processes of reverse cooling system the thermal power plant

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Abstract. The system of reverse cooling is an integral part of combined heat and power plant and, respectively, demands constant control and regulation of structure and the number of deposits from circulating water for maintenance of the steady mode of equipment. Insufficient circulating water processing turns into a big internal problem for combined heat and power plant work and is a source of heat exchange, surfaces pollution sludge formation in device channels, equipment corrosion, biological fouling, biosludge formation, etc. Depending on the reverse cooling functioning at combined heat and power plant various problems demanding accurately differentiated approach to the decision are identified. Various criteria allowing to define existence and intensity of deposits and ways of fight against the formed deposits and equipment corrosion are offered. For each type of reverse cooling system the possible reasons of deposits formation on the heatpower equipment are analyzed and physical and chemical methods for circulating water stabilization are described. These methods safe water treatment installation modes in a case of the interfaced reverse cooling system and provide the minimum quantity of drains in a case with not interfaced system.

The Reverse Cooling System (RSC) with vaporizing coolers traditionally is most widely operated for turbine condenser cooling (CT) and the service equipment of the thermal power plants (TPP) in the territory of the Russian Federation. As additional water in RCS, mainly, the natural raw water is used. During the work of RCS, as a result of evaporation of water in coolers, natural mechanisms of grain formation with initial concentration and the next loss of almost insoluble substances in a deposit. Emergence on the CT heat exchange surfaces deposits of insoluble substances (scum) is result worsening a heat transfer processes. Overall performance of thermal power plant and an overconsumption of fuel, a condition of the equipment, his resource and accident rate directly depends on it.

On the mechanism of sewage utilization of RSC with vaporizing coolers are divided into two types. The first type is a interfaced RSC with selection of circulating water after heating in CT on water treatment installation (WTI). As circulating water stabilization processing at such scheme isn't carried out because of a possibility of violations in work of WTI, restrictions for water evaporation extent in RCS at the drainless scheme of this type are set. On different sources the evaporation coefficient (Ku) of circulating water in RSC shouldn't exceed 1.3 - 1.2 [1,2]. At the same time the initial (natural) water composition, its temperature, season, etc. isn't considered. However even in case of observance of this restriction it isn't possible to avoid formation of insoluble substance deposits in RSC, first of all on CT heat-exchanging surfaces and the cooling towers (CT) elements on which pollution power units
profitability of operation depends in general. Besides, in RSC also other negative processes are proceed. Equipment corrosion, a sludge formation in channels and devices, biofouling and a biosludge formation.

The researches conducted in 2014 on RSC of the Kazan CHPP-3 show [3] that the scale formation in RSC occurs, first, owing to phase instability of the initial Volga water, especially in winter time. In winter deposits in CT begin if Ku < 1.2. Secondly, it happens owing to concentration of circuitual water because of evaporation in cooling tower. The third reason is an increase pH value more than 8.3 because of volatilization of the free carbonic acid part in cooling tower. And at last, it occurs because of extremal conditions on some sections of RSC – the increased temperatures on heat exchange surfaces of CT and intensive transpiration process on the cooling tower elements. An acceleration of scale formation processes is promoted seasonal (summer) increase in Ku from time to time to 2.1, connected to switch-off of a heating net, and not stationarity of the main flows: additional water in RSC and the circuitual water consumption on WTI. Essential changes of mass of circuitual water in RSC (±40%) and Ku's values (±100%) are a consequence of these flows inconsistency. Therefore in RSC water concentrating or diluting take place periodically. Naturally, at the moments of circuitual water concentrating processes of scale formation are activated. This problem has different solutions. It is shown that use of technically simple and safe for the WTI methods of the synchronization, of the incoming and outgoing flows, cleaner water recycling (figure 1) arriving from WTI lead to deposit formation extinction, improvement of the conditioned water quality and corrosion lowering on RSC devices.

![Figure 1. The technological diagram of the recycling organization on the Kazan CHPP-3.](image)

The second RSC type with transpiration coolers is independent interfaced RSC without selection of reverse water on WTI, with a purge. If for RSC of the first type a set of methods of water stabilization processing is strongly limited by requirements to water quality on WTI, then on RSC of the second type various methods are applied: chemical, cationite, physical, electrochemical, mechanical and others. Among them, the chemical methods are more effective and economic, connected to introduction to reverse water of different reagents. In particular, for prevention of mineral deposits organic phosphonates and its compositions were widely adopted [4].

The first domestic experience of scale formation prevention by means of complexons in systems of reverse cooling with towers has been realized in the seventies on the Ufa CHPP-4 [5]. For stabilization of reverse water octaethylidendiphosphonic acid (OEDF) was used. One more example is the Ulan-Ude CHPP-2 where when using reverse water for evaporators the non-scale mode is reached by liming of reverse water, acidulation by sulfuric acid and dispensing of OEDF. At the same time the general salinity of reverse water doesn't exceed 1000 mg/l, and concentration of sulfates – to 270 mg/l. The CT cooling system of the Chelyabinsk CHPP-3 is operated without venting of purge water. The part of circulating...
water is pumped in clarifier where is exposed to liming. Clarifier works in the bicarbonate mode at pH =9.6. The softened water comes back to circulating system. As inhibitor of a scale formation N(CH2PO(OH)2)3 (IOMS) is used. Besides systems of reverse cooling with vaporizing coolers there are examples of complexons use and in systems with a cooling pond [6].

At Naberezhno-Chelninsky combined heat and power plant chemical reagents complex dispensing is made: the stabilizer of rigidity and a dispergator of the weighed substances – "Aktiphos" or "Aquaresult - 1010", a dispergator of organic substances and microorganisms "Turbodispin D 80", reagent against development of microorganisms – "Turbanion of M 101, 104" and inhibitor of non-ferrous metals corrosion – "Corrodex 900" or Aquaresult of B1.

In recommendations about use phosphonates producers point to the following advantages: a) of excess amount of fuel burnt reduction; b) reduction of a consumption of make-up water; c) sewage reduction; d) reagents costs reduction. At the same time it is known that such water quality indicators as the general rigidity, alkalinity significantly influence a necessary dose (concentration) of phosphonate. As opposed to the aforesaid data on inspection of RSC of really operating Naberezhno-Chelninsky combined heat and power plant with modern system of reagent stabilization processing of circulating water are submitted. The data analysis on streams and water composition shows that in RSC intensive processes of scale formation are periodically observed. Apparently, it is connected with lack of correction of the reagent dispensing mode at change of water carbonate and not carbonate hardness, or with instability of the dispensing reagents mode. Here still such important aspect as the price as modern multicomponent inhibitors are expensive reagents and there is a problem of their consumption minimization.

In 2015 the analysis of deposits structure in RSC of Naberezhno-Chelninsky TPP by the chemical analysis and IR-spectroscopy methods was carried out [7]. Deposits represent the multilayered structure including various corrosion products (α- and γ-forms) with layers of insoluble substances (carbonates, silicates) and inclusion of organic substances of allochthonous (humic substances) and autochthonous (biofouling products) origins (figure 2).

![Figure 2](image_url)

**Figure 2.** IR spectrums of deposits models from RSC of Naberezhno-Chelninsky TPP; a - deposits with a high content of lepidocrocite (FeO(OH)); b - deposits with a high content of silicates; c - deposits with a high content of carbonates.
In addition, a high content of heterotrophic bacteria is detected in circulation water of the Naberezhno-Chelninsky TPP, the presence of which leads to intensification the corrosion processes, scale formation and biofouling, a vacuum decrease in CT and to all system critical condition.

In general the obtained data show that the reagent processing mode realized at combined heat and power plant doesn't provide protection against scale formation, corrosion and biofouling.

As an alternative reagent antiscalant processing of water technological schemes of stabilization processing of thermal power plant circulating water are offered [7]. Due to the difficulties of carrying out pilot studies on the operating industrial installations of thermal power plant from the point of view of accident rate and safety measures the laboratory stand "Installation of Water Reverse Cooling-0,3" imitating really operating cooling tower with an irrigation area of 3200 sq. m. has been developed. At the laboratory stand an experiment number with water from the Volga River for physical modeling of processes of system of reverse water supply is conducted.

New technical solutions for rigidity decrease and others scale formation substances in initial and circulating water are developed. The best results are received at realization of technical solution with passing of initial water through preprocessing by alkalizaton with a simultaneous bypassing and circulating water part treatment. On the obtained experimental data there are developed the technological schemes of stabilization processing of initial and circulating water of thermal power plant including, the scheme of initial water treatment by the alkaline fulfilled regeneration solutions from anionite filters with a bypassing of circulating water without purge (figure 3). It is shown that specific reagents consumptions and residual rigidity at the organization of a bypassing decrease in comparison with traditional precleaning. Offered technological decisions ensure non-scale and not corrosion functioning of reverse water supply equipment and meet the relevant environmental requirements.

Finally, it is possible to note that irrespective of reverse cooling system type of thermal power plant the reliable and economic functioning of reverse cooling system is decisive factor which directly depends on equipment of deposits and corrosion. In this regard search of solutions and prevention of these problems are represented to us especially important. And the more possible options and technological approaches it will be developed in this direction by the world scientific community, the more opportunities will be for their embodiment in the conditions of real daily work of thermal power plant taking into account all technical requirements of the concrete functioning system.

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