

## REAGENT FOR CHEMICAL CLEANING OF MINERAL DEPOSITS COLLECTED IN STEAM BOILERS

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### ABSTRACT

The correct selection of “water-chemical reagent” standards for the water treatment system of thermal power stations, the main - turbine, condensers and secondary -compressors, pumps ensures efficient operation of the devices - prevents the accumulation of mineral salts, eliminates corrosion. For each type of circulating cooling systems, an individual approach to the selection of “water-chemical reagents” is required, and this is primarily related to the material of the components in the system and the type of reagents. Adding concentrated hydrochloric acid, sulfoamines, and phosphates to the environment is considered a traditional method and does not allow complete elimination of accumulated mineral salts and corrosion. Mineral salts collected on the surface of heat exchange devices affect vacuum weakening in technological systems, including heat exchange processes, which are considered the main economic indicator of energy devices. At the same time, special attention is being paid to the determination of effective components for “water-chemical reagent” correction-circulation cooling systems, production of competitive products based on organic synthesis from available raw materials, and determination of their properties.

**KEYWORDS:** Technological systems, including heat exchange processes, correction-circulation cooling systems.

### INTRODUCTION

In practice, periodic cleaning of steam boilers is carried out on average once in 1-2 seasons. Boilers with a service life of 20 years [1, 2] are cleaned approximately 10-15 times before decommissioning.

The formation of salts is different due to the difference in mineral salts in the water, the method of its purification and the operating modes of the boilers. According to their chemical composition, salts can be divided into four main groups: 1) salts of alkaline earth metals -  $\text{CaSO}_3$ ,  $\text{CaSO}_4$ ,  $\text{CaSiO}_3$ ,  $5\text{CaO} \cdot 5\text{SiO}_2 \cdot \text{H}_2\text{O}$ ,  $\text{Mg}(\text{OH})_2$ , etc.; 2) iron oxide and iron phosphate -  $\text{FeO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{Fe}_3\text{O}_4$ ,  $\text{NaFePO}_4$ ,  $\text{Fe}_3(\text{PO}_4)_2$ ; 3) brass and 4) aluminum [3, 4].

To clean boiler heating surfaces from salt deposits, reagent-based and reagent-free cleaning methods are applied depending on the structure of the contaminating layer, the degree of contamination of the heat exchange surface, and the type of boiler. The choice of the method

depends on the duration of the shutdown of the boiler, the availability of special equipment, chemical reagents, the flexibility of the technological scheme, and the availability of specialists and trained personnel. For example, as a result of mechanical cleaning, the roughness of the surface increases and the oxide protective layer is destroyed, during chemical cleaning, partial melting of the oxide film and metal, hydromechanical wear of the surface, etc. may occur. The problem of effective cleaning of heating surfaces and increasing the wear resistance of the equipment is closely related to each other [5].

The main advantage of the chemical cleaning method is that it does not require complete disassembly of the equipment being cleaned, and in some cases this salt is the only possible way to break up the sets.

Currently, chemical cleaning methods widely use organic acids (citric, adipic, maleic, oxalic, formic, acetic, and sulfamic), mineral acids (hydrochloric, sulfuric, sulfamic, and phosphoric), and chelating agents (such as disodium salt of ethylenediaminetetraacetic acid (Trilon B), hydroxyethane diphosphonic acid, and others) as well as compositions based on them. These methods are applied in open or closed cycles using forced circulation techniques or natural circulation of the solution.

The purpose of this article is to improve the efficiency of water supply systems by eliminating existing scale deposits and to develop affordable and effective compositions of reagents for removing accumulated mineral salts.

To achieve the goal, the process of sulfomethylation of aniline was studied to produce reagents for removing accumulated mineral salts. A three-neck flask with a volume of 250 ml, equipped with a mechanical stirrer and a reflux condenser, was used. Into the flask, 10 ml of H<sub>2</sub>O and 85 g of sodium metabisulfite (Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>) were added. 80 mL of 37% formaldehyde solution was added with vigorous stirring. 5 ml of 50% caustic soda solution was poured there. After the formaldehyde odor dissipates, 47.5 ml of aniline is gradually added to the mixture while stirring intensively. The mixture is then heated at a temperature of 60-70°C for 3 hours. After appropriate treatment and subsequent drying in a drying oven at a temperature of 100±5°C for 5 hours, 80% of the final product is obtained in powder form. The authenticity of the substance was proven using IR spectroscopy and GC-MS methods and confirmed by elemental analysis.

The effect of the rate of dissolution of mineral salts accumulated on the inner surface of steam boilers ( $W$ ) was calculated by the gravimetric method [6] according to the following formula.

$$W = \frac{\Delta m_{mt}}{S_t \cdot t} \quad (1)$$

Where:

- ✓  $W$  is the rate of removal of mineral salts (g/m<sup>2</sup>·h),
- ✓  $m_{mt}$  is the mass of the dissolved accumulated mineral salts (g),
- ✓  $S_t$  is the surface area being cleaned (m<sup>2</sup>),
- ✓  $t$  is the time for the removal of the accumulated mineral salts (hours).



The effect of the reagents on metal corrosion during the washing process (Mk) was determined using the following formula:

$$K_M = \frac{\Delta m_{mt}}{S_t \cdot t} \quad (2)$$

where –  $\Delta m_M = (m_0 - m_m)$  mass of the metal initially and after the washing process, g;  $S_t$  - metal surface area,  $m^2$ ;  $t$  - washing time, hours.

Studies of the composition and structure of mineral salts accumulated in the steam boilers of the Syrdaryo thermal power plant, as well as numerous experiments, show that the washing process consists of two main stages: the first stage is fast (covers a quarter of the total washing time) and dissolves up to 75-85% of the mineral salts, and the second stage is the dissolution of the hard-to-dissolve part of the accumulated mineral salts on the metal surface (this stage takes a long time and takes 75% of the reaction time) - covers 80%, at the same time it is the stage that determines the quality efficiency of the washing process).

The upper part of the accumulated mineral salts consists of relatively soft, mainly carbonate compounds, and iron oxides are observed more in the part close to the metal surface.

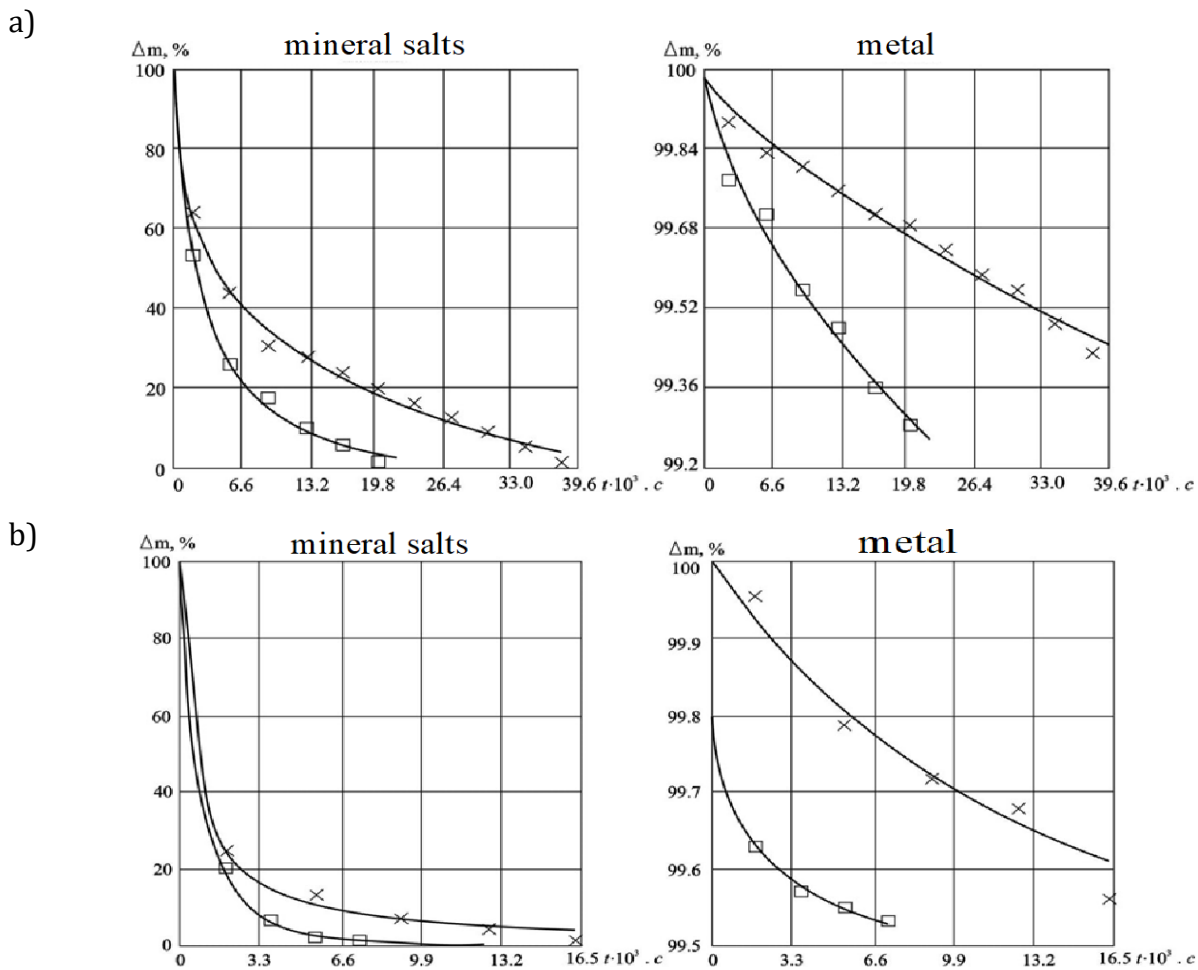


Figure 1. Concentration dependence of the dissolution process in washing (solution flow rate  $U=1$  m/s): -x- washing reagent concentration 5%; □- washing reagent concentration 8%; a) temperature  $t = 24$  °C; b) temperature  $t = 30$  °C

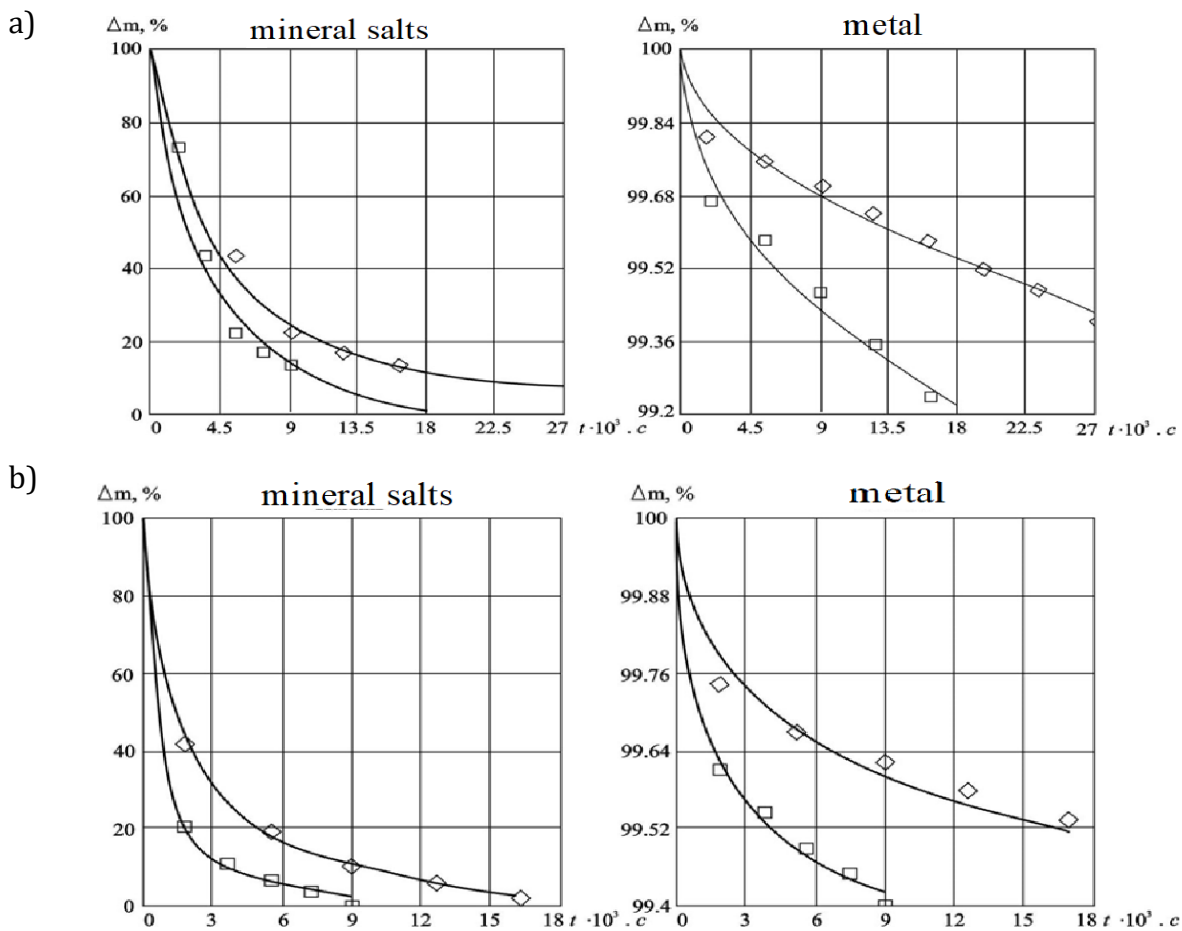


Figure 2. Dependence of the dissolution process in washing on the speed of solution movement (temperature  $t = 30 \text{ }^\circ\text{C}$ ):  $\diamond$ -washing reagent flow rate 0.1 m/s;  $\square$ - washing reagent flow rate 1.0 m/s; a) washing reagent concentration 5%; b) washing reagent concentration 8%.

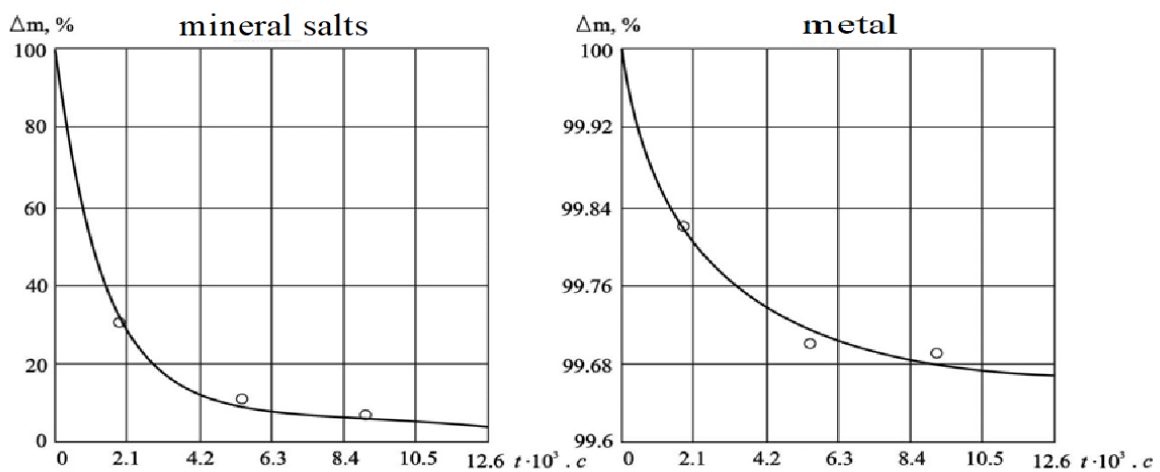


Figure 3. Variation of the washing process when the amount of washing reagent is 8%, the solution movement speed is 1 m/s, and the washing temperature is  $30 \text{ }^\circ\text{C}$

From the comparative graphs of washing temperature and washing solution dosage, it is evident that temperature increase has a greater impact on cleaning duration than dosage increase. For instance: At a 5% dosage and a temperature of  $20 \text{ }^\circ\text{C}$ , the cleaning duration for metal surfaces is  $39.6 \times 10^3$  seconds. Gradually increasing the temperature to  $70 \text{ }^\circ\text{C}$  at the same concentration reduces the cleaning duration to  $16.5 \times 10^3$  seconds, shortening it by up to 2.4



times. Increasing the washing solution dosage to 10% at 20°C results in a cleaning duration of  $19.8 \times 10^3$  seconds, reducing it by 2.1 times. This clearly demonstrates the aforementioned point.

Thus, the condensation products of aniline, formaldehyde, and sodium bisulfite in weakly acidic environments were studied using IR spectroscopy, elemental composition analysis, and PMR (proton magnetic resonance) spectroscopy. The synthesis of sulfomethyl aniline products aligns with the principles of organic chemistry theory, where it is based on the observation that with increased reaction time, sulfomethyl aniline produced in aqueous solutions undergoes hydrolysis, converting back to the initial products, which leads to a decrease in the reaction yield. The geometry and electronic structure of the obtained substances were studied using the semi-empirical quantum chemical method with PMZ (probabilistic molecular zone) analysis.

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