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PREVENTION OF EXTERNAL FLOOD FORMATION ON THE SURFACE OF HEAT EXCHANGER PIPES

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Abstract: Purpose of the work. There are various methods for preventing scale formation on heating surfaces and cleaning surfaces from scale: chemical, mechanical, and methods related to the management of hydrodynamic modes. Since these methods require certain costs and time, their use in the processes of thermal treatment of food products is not always effective. For this reason, the transfer of water used as a coolant in heat exchange devices to the heating process by means of a magnetic field is one of the modern methods that allows reducing the slag layer. The scale layer is usually removed by acid washing of the internal heat exchange surfaces or mechanical washing. However, both methods involve the use of a substantial amount of chemicals and result in highly polluted wastewater. In addition, it significantly increases operating costs. The article uses statistical methods for processing experimental data, and generally accepted methods for conducting experiments to study the patterns of scale formation using control and measuring instruments and accurate methods for measuring technological parameters. The main purpose of the paper is to study the influence of a constant magnetic field on the formation of mineral salts deposits on the surface of walls of thermal appliances used in chemical, oil refining, and food processing industry.

Keywords: Ion, magnetic field, sediment, heat exchanger, scale mass, temperature, hydrodynamic regime, crystallization.

Introduction. In our country, significant attention is being given to scientific and practical research aimed at modernizing food industry enterprises. Comprehensive efforts are being undertaken to implement innovative technologies in enterprises to deeply process food raw materials, increase the volume of products that meet international standards, and expand their variety. The Development Strategy of New Uzbekistan outlines important tasks such as "raising the industry to a qualitatively new stage, deeply processing local raw materials, accelerating the production of finished products, and mastering new types of products and technologies.

In this regard, research aimed at enhancing the operational efficiency of pipeline heat exchangers holds particular importance.

During the thermal processing of liquids, the formation of scale on heat exchange surfaces is a common issue in technological processes. The increasing thickness (mass) of the scale layer, which has a low thermal conductivity coefficient, on the heat transfer surfaces leads to a reduction in the thermal efficiency of these devices.

In heat exchange equipment, scale formation generally occurs in three main forms [1]:

- **Primary scale** – forms directly on the heating surface through the mixture;
- **Sludge** – forms within the volume of the mixture via crystallization centers and settles;

- **Secondary scale** – forms on the heating surface through the adhesion of sludge.

The formation of crystals in the mixture is explained by the presence of crystallization centers and the saturation of the mixture with scale-forming components. Crystallization centers play a key role in the further thickening of pre-formed scale masses in the equipment, as they are influenced by suspended particles in the mixture that possess corrosive properties [2].The chemical composition of scale-forming salt deposits is primarily determined by the temperature of the heat exchange surfaces. Calcium carbonate ($CaCO_3$) deposits form at temperatures ranging between 60–70 °C, while magnesium hydroxide ($Mg(OH)_2$) deposits develop at temperatures between 70–100 °C. Salt deposits in the form of crystallohydrates or anhydrous calcium sulfate appear at temperatures above 100 °C. Calcium carbonate and magnesium hydroxide are formed as a result of the decomposition of calcium bicarbonate [$Ca(HCO_3)_2$], during which carbon dioxide (CO_2) and hydroxide ions (OH^-) are released.

Figure 1. Shell-and-tube heat exchanger and the appearance of the formed scale layer

Eliminating scale composed of calcium sulfate, which forms at various operating temperatures during the working cycle of evaporators used in food industry enterprises, is a rather difficult process.

Any type of scale that forms acts as a factor that stabilizes the heat exchange process and affects the efficiency of heat transfer on both the internal and external surfaces of the tubes.

In addition to chemical and physical methods for removing the scale layer that forms in heat exchange equipment, the use of magnetic field treatment on water has become a widely adopted method for preventing scale accumulation on the inner surfaces of pipes. Magnetic converters are installed on the pipes supplying liquid to the equipment, allowing the flow to pass directly through a magnetic field. Numerous scientific studies have been conducted in this area. In food industry enterprises, water and its steam are used as heat transfer agents. Therefore, special attention must be paid to the hardness of both drinking and technical water.

Methods. There are various methods for preventing the formation of scale layers on heating surfaces and for removing existing scale. These include chemical methods, mechanical methods, and methods based on controlling hydrodynamic regimes. However, since these approaches require certain costs and time, they do not always prove effective in thermal processing operations within the food industry. For this reason, transmitting heat-carrying water through a magnetic field before it enters the heat exchange process is considered one of the modern methods that enables the reduction of scale formation [3,9,10].

Studies have shown that one of the negative factors affecting scale formation on heat exchange surfaces is ensuring chaotic (turbulent) movement of the flow. However, in the present study, the main objective is to investigate the effect of the flow velocity of the technological fluid passing through a magnetic field on the formation of scale mass on the heat transfer surfaces. Specifically, the accumulation of scale mass was studied at different flow rates of the technological fluid exposed to a constant magnetic field. The experimental results showing the relationship between scale mass formation on the heating surface and temperature at various flow rates of the heat carrier are presented in table 1.

Table 1. Scale mass formed on the heating surface at different flow rates of the heat carrier

Method	**Heat carrier flow rate G, l/min**			
	3	5	7	9
	70 °C			
Heating without magnetic field	2,6	2,74	2,89	2,97
Heating under the influence of magnetic field	0,211	0,213	0,217	0,22
	100 °C			
Heating without magnetic field	2,93	3,05	3,22	3,41
Heating under the influence of magnetic field	0,231	0,238	0,241	0,247

In experiments conducted at a temperature of 70°C under the influence of a magnetic field, the scale formation was found to be 0.21 grams, whereas without the magnetic field, this value was 2.6 grams. In experiments studying the effect of magnetic field induction on the heat carrier flow rate ranging from 3 to 9 l/min, it was observed that with a threefold increase in flow rate under conventional heating methods, the scale mass increased by 14.2%. When water was passed through a magnetic field, the scale mass formed on the heating surface was found to increase by 4%. In experiments conducted at 100°C, it was observed that when the flow rate of water was varied from 3 to 9 l/min under conventional heating, the scale mass formed on the heating element increased by 16.3%. This value was 7% for water passed through the magnetic field.

Table 2. Scale mass formed on the heating surface at different flow rates of the heat carrier (120°C)

Method	Heat carrier flow rate G, l/min			
	3	5	7	9
Heating by conventional method	3,85	4,08	4,35	4,52
Heating under the influence of magnetic field	0,54	0,61	0,77	0,82

In the environment where the temperature was raised to 120°C, as the water flow rate increased from 3 to 9 l/min, the scale mass increased by 17.4% under the conventional heating method, while under the influence of the magnetic field, it increased by 51%. However, when heating under the influence of the magnetic field compared to conventional heating, the scale mass formed was found to increase 7.13 times at a flow rate of 3 l/min and 5.51 times at a flow rate of 9 l/min. This indicates that as the water flow rate increases, the magnetic field induction reduces the ordered movement of mineral salt ions in the water.

The effect of increasing the flow rate from 3 l/min to 9 l/min on scale mass formation at temperatures of 70°C and 100°C was not very significant, changing by about 14-16%, as shown in figure 1. However, when the temperature of the heated water reached 120°C, increasing the flow rate from 3 to 9 l/min resulted in a sharp increase in the scale mass. At flow rates of 3 l/min (0.54 g), 5 l/min (0.61 g), 7 l/min (0.77 g), and 9 l/min (0.82 g), the scale mass was 51.85% higher compared to the initial value.

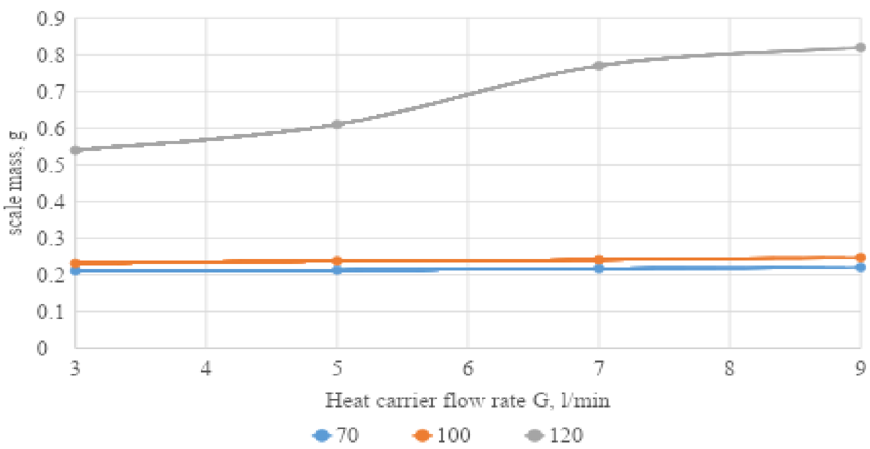

Figure 2. The effect of heat carrier flow rate on scale mass accumulation

Based on the results obtained, it can be concluded that an increase in the heating flow rate and temperature reduces the orderly movement of mineral salt ions in the water due to the influence of the magnetic field induction. As a result, the formation of microcrystallization centers in the water slows down, and the formation of scale mass on the heating surfaces accelerates.

In the heat exchangers used in the food industry, water is widely used as the main heat carrier. This leads to the accumulation of not only carbonate scale but also deposits formed as a result of corrosion on the internal walls of heat exchangers. One of the non-traditional methods to prevent these processes is treating water with magnets. As a result of magnetic treatment, calcium, silicon, and magnesium ions dissolved in the water lose their ability to form salts on sorption surfaces. Consequently, the dissolved salts remain in a colloidal state, and the scale layer formed on the surfaces gradually decreases [4,5].

Studying the effect of the power of the constant magnetic field induction on the volume of water moving through the pipe allows effective management of the processes described above [6,7,8,9].Therefore, the effect of changing the power of the constant magnetic field induction (Vum = 12700 ÷ 30480 milliTesla), the temperature of the water (100°C), and the volumetric flow rate of water (G = 3÷9 l/min) on the accumulation of scale mass on the heating surfaces was studied.

The constant magnetic field was generated by a ferromagnetic magnet with dimensions 20x10x3, and the maximum magnetic induction (V max = 1270 milliTesla) was used. The magnets were installed in the pipe carrying cold water, ranging from 10 to 24 magnets, and after each adjustment, the effect of magnetic induction on scale formation was studied. After each experiment, the results were recorded.

The experimental results, presented in the table below, show that with various power levels of the magnetic field induction (Vum = 12700 ÷ 30480) and temperatures ranging from 20°C to 100°C, changes in the temperature and flow rate of the heated water (G = 3÷5 l/min) affected the accumulation of scale mass on the heating surface in different ways. A decrease in the magnetic field induction resulted in a gradual reduction in the formation of microcrystallization centers in the water.

The results obtained in the laboratory conditions are summarized in table 3.

Table 3. The Effect of Magnetic Field Induction Power on Scale Accumulation at Various Flow Rates of Heat Transfer Fluid (100°C).

Magnetic field induction power V_{gen} in milliTesla.	Heat carrier flow rate G, l/min			
	3	5	7	9
12700	0,335	0,364	0,413	0,455
15240	0,298	0,331	0,362	0,407
17780	0,274	0,298	0,315	0,369
20320	0,256	0,266	0,287	0,320
22860	0,240	0,247	0,263	0,288
25400	0,231	0,238	0,241	0,247
27940	0,228	0,236	0,238	0,245
30480	0,227	0,233	0,236	0,242

Results. When the magnetic field induction power was 12,700 milliTesla, the accumulated scale mass over 30 working days was 0.335 grams. As the magnetic field induction power increased to 30,480 milliTesla, the accumulation of scale mass decreased by 46%, reaching 0.227 grams. At this point, the scale accumulation was 62% at a flow rate of 5 l/min, 78% at 7 l/min, and 92% at 9 l/min. However, changes in the magnetic field induction power within the range of 25,400 to 30,480 milliTesla resulted in a much smaller decrease in scale mass, about 1 to 6%. Therefore, when heating the heat carrier at 100°C with a flow rate of 3 to 7 l/min, a magnetic field induction power of 25,400 milliTesla is economically effective, as the scale accumulation does not increase significantly at these flow rates.

Discussion and conclusion. One of the major problems in heat exchange systems is the reduction in the heat transfer coefficient due to the scale layer that forms on the heat exchange surfaces. During the experiments, the effect of the magnetic field on the heat carrier flow and its influence on scale formation were studied. It was observed that when heating water at 100°C using the conventional method, the accumulation of scale mass increased by 16.3% as the flow rate changed between 3 and 9 l/min. However, with the use of the magnetic field, the scale accumulation was reduced to 7%. When the magnetic field induction power was 12,700 milliTesla, the accumulated scale mass over 30 working days was 0.335 g. As the magnetic field induction power increased to 30,480 milliTesla, the scale accumulation decreased by 46%, reaching 0.288 g.

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