Boiler water regime

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Abstract. Active development of autonomous heating the past 25 years has led to the widespread use of hot-water boilers of small capacity up to 2.5 MW. Rational use of the design of autonomous sources of heating boilers design features significantly improve their technical, economic and operational performance. This publication reviewed and analyzed a number of features of the design, operation and exploitation of boilers of small capacity, significantly affecting the efficiency and reliability of their application.

1. Introduction
Domestic hot water heat generators and boilers of low power constructively grouped into three types:
- Cast iron sectional;
- steel fire-tube boilers;
- Flowing water tube.

The main difference is due to the organization of the hydraulic regime of the boiler. For the first two types of boilers natural gravitational movement of the coolant to a limited extent with speeds not exceeding $w \leq 0.03-0.05$ m / s. It is therefore unacceptable to swap the input and output of heat carrier in the boiler, the boiler breaking hydraulics, as well as to reduce water flow through the boiler limiting or refusing coolant recirculation. The flow structures water-tube boilers with forced motivation movement organized flow of coolant, having, as a rule, velocity $w \leq 3-6$ m / s and more limited to the upper limit hydraulic resistance of the boiler. This factor creates a metal-compact design flow boiler with a maximum of speeding up the processes of heat and a small amount of coolant that causes extremely high dynamic performance of the boiler.

Steel Boilers fire tube boilers have the greatest amount of water, although it allows a more compact design (less metal content) than cast iron sectional boilers.

Using low-carbon steels in boilers ensures their resistance to thermal stress \cite{1, 2}, increase low-cycle reliability, but they become less resistant than iron acidic galvanic corrosion.

2. Method
Physical and chemical processes of combustion and heat transfer in low power due to reduction of the geometric dimensions of boilers are characterized by 2-3 times greater volume of fuel thermal stresses and heat flux on heat transfer surfaces in the combustion chamber \cite{3, 4}. At the same time, the convective heat transfer surfaces for intensification by the combustion products often use different kinds of baffles, fins, studding and others. The compact design of the boilers cause considerable unevenness of heat transfer processes with zonal heat flow is 3-4 times higher than the average values. This is particularly evident in the boilers with flame reversal in the flare reversal zone, as well as in violation of the
conditions for the traction and the boiler with vacuum output of more than 30 Pa (at the required vacuum 0 Pa) and at low loads, in this case there is an early reversal of the torch in near the furnace burners and overheating badly turbulized flow tube sheet products and the initial pipe sections of convective package. Sometimes these processes are provided for the removal of boiler vortex design.

When you start-up and commissioning works of the customer often exhibit high performance boiler, even in the case of serious violations of the technological regime and working conditions [5]. Violation to the boiler equipment work will be shown in a relatively short period of time, and they are connected mainly with the violation of thermal conditions and water-chemical conditions of work.

In more detail, within the framework of the publication, will focus on the second question. to the water chemistry boilers Requirements [6] a little bit softer than for steam boilers, due to the imperative not boiling coolant, which significantly reduces the requirements for the formation of mineral deposits and corrosion activity of the boiler (mains) water. Considering the previously listed features of different designs boilers should focus on fire-tube boilers of steel, as the most vulnerable to negative processes related to the water-chemical mode of operation.

The deposits on the outside of the heat exchange surface [7], as well as on the inside, increases the thermal resistance of the heat, reduce the efficiency of the boiler. [8] However, the outer metal deposits decrease the temperature, and its interior is very important to increase as the thickness of the deposits at less than 1 mm, a wall surface temperature can rise to 120 °C and at a thickness of 3–4 mm deposits, the surface temperature can rise to 550 °C and higher superheat tubes such low carbon steels leads to loss of strength, plastic deformation and breakage.

Low speed and low turbulence flow [9, 10] of water in fire-tube hot water boilers [11], combined with a high density of local heat fluxes intensify the formation of mineral deposits of different density of the boiler water in the heating surface.

To illustrate these provisions shows photographs (Figure 1, Figure 2, Figure 3), sections of the fire-tube boiler, operation which was carried out with violations of water-chemical mode of operation in the area of pipe products of combustion input board in a convective part, the maximum heat flow and overheating.

![Figure 1. Pellet Boiler Cutting.](image)

The main components of the mineral deposits are sulfates, carbonates, silicates, phosphates, and others. Calcium and magnesium salts, causing the total water hardness.

Water Quality Requirements circulating in the boiler circuit is set RD 24.031.120-91 (updated in 2016), "Quality standards network and make-up water boilers, the organization of water chemistry and
chemical control." These requirements for all types of boilers determine the permissible total hardness less than mEq / L. Note that the specified value for more than 50 years with no changes from one transition to other regulations.

![Image of boiler deposits](image1.png)

**Figure 2.** Deposits in the boiler in the cut zone.

The specified value of the total hardness in magnitude can be relatively estimated from the mean conditional equilibrium total hardness water long circulating in the boiler circuit, or acquired total hardness of demineralized water (condensate zero total hardness, 0 mEq/l) after prolonged contact with scale [12] is operated in the operating circuit of the boiler.

![Image of tube plate with deposits](image2.png)

**Figure 3.** Detail of the tube plate with deposits

Conditionally equilibrium value total hardness of the water for the operating temperature in the boiler of 115 °C ~ 0.01 mEq/l.
In this regard, it is revealing that the requirements of the foreign producers from the EU countries in the formation of the warranty is based on the requirements of the standard EN 12953-10. Fire-tube boilers. to feed water quality requirements, excerpts of which are shown in the table.

| Table 1. Requirements for feed water quality |
|---------------------------------------------|
| Characteristics | Units | Pressure ≤ 20 |
| Direct conductivity | uS/cm | < 6000 |
| Total hardness | mmol/l | < 0.01 |
| Ph at 25 °C | °dH | < 0.05 |
| Oxygen (O₂) | mg/l | < 9.2 |
| Iron (Fe) | mg/l | < 0.05 |

Table 1. Requirements for feed water quality

Perhaps in Table 1 requirements for total hardness of water network are represented too high, however, has repeatedly pointed out that the level of total water hardness of 0.7 mEq/L does not allow the safe, trouble-free to operate the hot water fire-tube boiler for a long time (25-30 years) [13].

The most dense sediments form sulfates and silicates of calcium and magnesium, and most friable and porous bicarbonates and carbonates of calcium and magnesium (temporary hardness salts). Mostly past together with oxides, iron hydroxide, and organic form of suspension in the water network, forming sludge deposits in the boiler.

The slurry is deposited in the areas of coolant stagnation [14]. They are not only superheat tubes, but also lead to corrosion of the active sludge. Therefore, the requirements for water quality in the domestic regulations (RD 24.031.120-91), and in foreign EN 12953-10 regulated almost identical values of ph, oxygen content O₂, Fe iron water.

3. Conclusions

Water treatment plant capacity is determined not only by the power of the boiler system, but also a complex solution of heat supply systems: open or closed, respectively, dependent or independent connection of the heating system, as well as the quality and condition of thermal networks, amounts of compensation and coolant leakage losses. The higher these costs, the greater the risks objectively significant mineral deposits in the boiler and lower operational reliability.

Ways and methods of water treatment are largely determined by the characteristics of the source of water [15], among them the easiest and most common method - the use of ion exchange resin in the processes or sodium hydrogen-sodium ionization with strongly acidic cation exchangers, often sulfonated coal, KU-1; KU-2; KU-2-8, characterized by stable properties and high exchange capacity. Conditions of application of cation and anion exchange methods can be found in [16].

For low-power boilers can be carried out a comprehensive water treatment in which the water is dispensed into the power supply chelating forming stable chemical compounds with cations of calcium and magnesium hardness salts are converted into a soluble state. However, such processing often does not provide the desired water quality.

Deep softened, desalinated water is practically possible to obtain a reverse osmosis system, but the high cost of equipment, large amounts of drain risers and frequent need for water pretreatment process greatly complicates and expensive installation.

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