**Calculation of Energy-Efficient Pipe Parameters for a Water Heating Boiler**

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**Abstract.** This article presents a methodology for calculating the main parameters of heat supply pipes used in energy-efficient water heating boilers. The study analyzes and examines heat flow, pipe diameter, heat losses, thermal insulation efficiency, and hydraulic properties of the working medium. During the calculation process, optimal design solutions aimed at reducing energy consumption and ensuring continuous heat transfer were identified. The possibilities of increasing the overall efficiency of the boiler system based on modern energy-saving technologies were analyzed. Based on the obtained results, an economically efficient design for local heating systems has been recommended, which allows for the selection of reliable and effective pipe diameters and suitable thermal insulation parameters.

**Keywords:** boiler unit, heat, heat exchange, pipe, energy, temperature.

**INTRODUCTION**

Today, optimizing heating systems in residential and industrial buildings is one of the most urgent tasks due to efficient use of energy resources. The implementation of energy-saving technologies allows for reducing heat losses and saving fuel consumption. Currently, studying the technical and operational parameters of energy-efficient heating boilers and their associated pipeline systems adapted to local conditions is of great importance. This process requires determining the thermal efficiency, pipe diameter, heat conductivity, and hydrodynamic parameters of the heating system [1].

Calculating the parameters of energy-efficient boiler pipes not only ensures stable operation of the system but also reduces the overall process costs by minimizing energy losses. This process takes into account numerous factors such as heat load, water consumption, pressure drop, and the effectiveness of thermal insulation. Furthermore, it emphasizes the necessity of selecting optimal design solutions based on local climatic conditions and building codes. This article presents the results of work aimed at determining the most suitable parameters for pipes used in locally produced energy-efficient heating boilers and improving their overall efficiency.

**METHODS**

One of the key processes in water heating boilers is the flow of water inside the boiler. The movement of water within the boiler and the distribution of heat directly affect its efficiency [2]. Hydrodynamic processes determine the characteristics of water flow and heat transfer at the boiler walls.

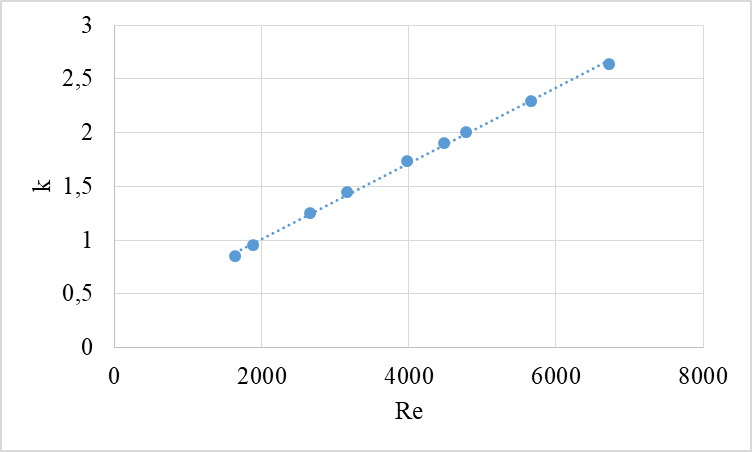
In order to increase the heat transfer efficiency of these water heating boiler installations and conserve fuel resources, the parameters of energy-efficient heating boiler pipes were determined and improved based on theoretical and laboratory studies. As a result, an upgraded heating boiler design was recommended. To increase the efficiency of the heat-supply pipeline, a laboratory setup was developed [3]. During the preparation of the experimental apparatus, two identical steel pipes with a diameter of 50 mm and a length of 0.7 m were used. One of the pipes remained in its original state, while external fins were installed on the other to increase its outer surface area. In the laboratory setup, the heat transfer efficiency of a regular pipe and a finned pipe was investigated. In these heating boilers, steel plate fins were installed on the heat-transfer pipes, ranging from 32 to 64 units. As a result, the heat-exchange surface area increased.

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**FIGURE 1.** External view of the heating boiler (UVK-150):1-boiler body; 2-fuel furnace; 3-steel pipe inside the boiler d = 50 mm; 4-steel pipe fin; 5-manometer; 6-supply heat carrier to the heating system; 7-return heat carrier; 8-thermometer.

The relationships observed in the research can be expressed using the following criteria::

-Nuselt number; -Reynоlds number; -Prаndtl number:



**FIGURE 2.** Heat transfer coefficient of the heating boiler

Based on analyses conducted using the theory of measurement units, the following relationship for k can be written:

(1)



where: A, x₁, x₂ – coefficients determined experimentally.

In the particular case of turbulent flow regime the following expression can be written for k:



(2)



The heat transfer coefficient k in the local water heating boiler was determined (see Figure 2). According to it, the heat transfer coefficient was recorded in the range of 0.85–2.63 [4-6].

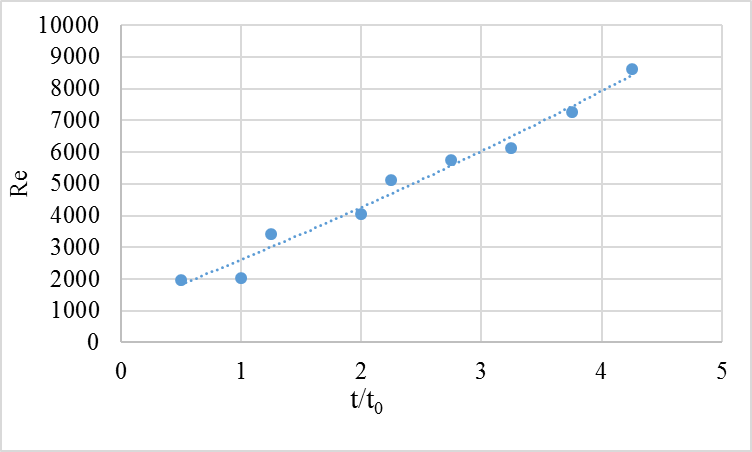
**RESULTS AND DISCUSSION**

Analysis of the research results showed that the heat transfer efficiency of a pipe with ribs installed on its outer surface increased by 15–20% compared to a regular pipe. Based on these conclusions, theoretical studies were conducted to determine the optimal parameters of water heating boiler systems. For existing cylindrical pipes, a new expression was proposed, based on the use of two formulas, to calculate the amount of heat transfer:

 (3)

here: Re- Reynоlds number; α- heat transfer coefficient;  - Prаndtl number; *S*- heat exchange surface area of the cylindrical pipes; - temperature difference.

Based on the theoretical and laboratory studies conducted, the flow regime and the variation of the Reynolds number in the heat supply boiler systems were determined (see Figure 3).



**FIGURE 3.** Flow regime in the heat supply boiler systems

Based on the analysis of the results obtained above, the variation of the hydraulic friction coefficient in the pipes of local water heating boiler systems was determined as follows [4].

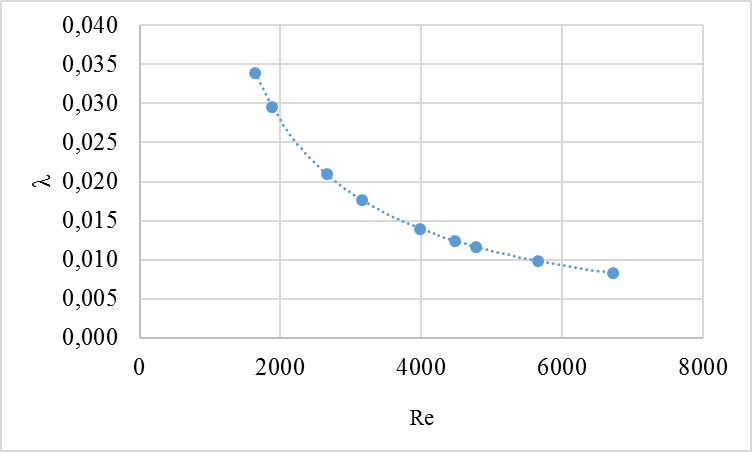
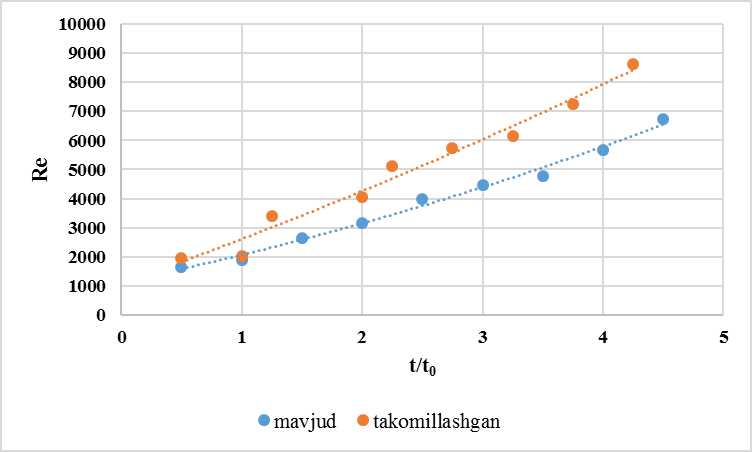


FIGURE 4. Graph of the hydraulic friction coefficient of the heating boiler pipe depending on the flow regime

The Reynolds numbers in water heating boilers constructed using conventional and improved methods were compared. The comparison results showed that the Reynolds number of the water flow in the heating boiler built with the improved method was 20–22% higher than that of the existing heat supply water boiler.



**FIGURE 5.** Graph of the flow regime dependence on relative temperature

The theoretical research conducted, the methods used in the studies, the data collected, the selected and compared data, and the following formulas were used to determine the energy efficiency of finned pipes relative to non-finned pipes [5].

 (4)

here:  efficiency of an improved heating boiler,  heat output of an existing hot water boiler, kVt;  volume of liquid in an existing hot water boiler, m3;  heat output of an improved hot water boiler, kVt;  volume of liquid in an improved hot water boiler, m3;

 (5)

here: S₁ – heat exchange surface designed by the conventional (simple cylindrical pipe) method; k₁ – heat transfer coefficient of the existing boiler;  temperature difference; χ – applied perimeter; l – pipe length; N – number of pipes [6].





here:  heat exchange surface of the improved design;  heat transfer coefficient of a boiler with improved hydraulic parameters;  temperature difference.

The water volume in the existing heating boiler was determined using the following formula.

 (6)

here:  volume of liquid in an existing hot water boiler, m3;  surface area of the heating boiler base, m2;  surface area of the heating boiler pipes m3;  working height of the heating boiler, m.

The base surface area of the local water heating boiler is determined using the following formula:

 (7)

here:  diameter of the heating boiler

The surface area of the heating boiler pipes was determined using the following formula:

 (8)

here: d- diameter of the heating boiler pipes, N- number of pipes. The water volume in the improved heating boiler was determined using the following formula:

 (9)

here: volume of liquid in an improved hot water boiler, m3;  base surface area of the improved heating boiler, m2;  surface area of the pipes and fins of the improved heating boiler, m2;  working height of the heating boiler, m.

The surface area of the pipes and fins of the improved heating boiler was determined using the following formula:

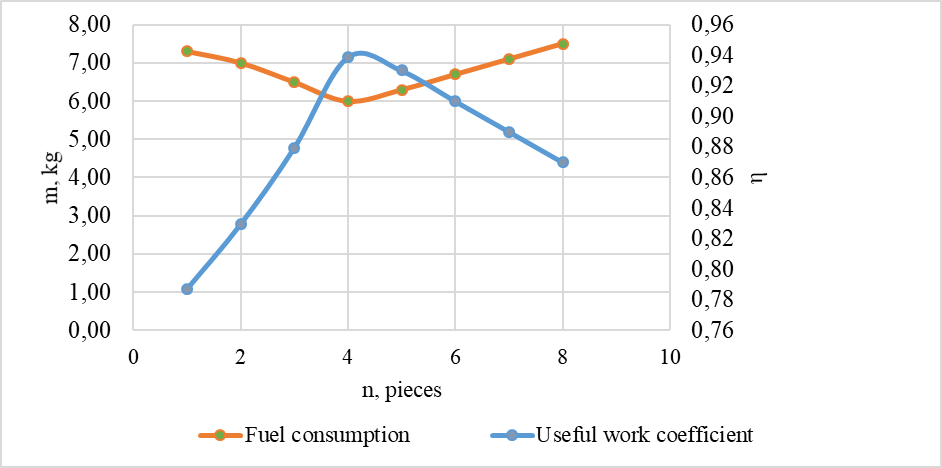
 (10)

here: а and b - dimensions of the used as a rib; d – diameter of the heating boiler pipes; N - number of pipes; n - number of fins (ribs). The results obtained are presented in the following table (Tab 1).

**TABLE 1.** Table for evaluating the efficiency of the improved heating boiler

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **№** | **n, dоnа** | **Q1, kVt** | **Q2, kVt** | **W1, m3** | **W2, m3** | **η, %** | **m, kg/sоаt** |
| **1** | 0 | 150 | 150 | 0,291 | 0,291 | 0,75 | 7,60 |
| **2** | 1 | 150 | 153 | 0,291 | 0,272 | 0,79 | 7,30 |
| **3** | 2 | 150 | 156 | 0,291 | 0,253 | 0,83 | 7,00 |
| **4** | 3 | 150 | 159 | 0,291 | 0,234 | 0,88 | 6,50 |
| **5** | 4 | 150 | 162 | 0,291 | 0,215 | 0,94 | 6 |
| **6** | 5 | 150 | 159 | 0,291 | 0,196 | 0,93 | 6,3 |
| **7** | 6 | 150 | 156 | 0,291 | 0,177 | 0,91 | 6,7 |
| **8** | 7 | 150 | 153 | 0,291 | 0,159 | 0,89 | 7,1 |
| **9** | 8 | 150 | 152 | 0,291 | 0,140 | 0,87 | 7,5 |

Based on laboratory research, the effect of the ribs installed on the water heating boiler pipes on the efficiency and coal savings was evaluated:



**FIGURE 6.** Efficiency evaluation graph of the device

The analysis of the research showed that when four ribs were installed on the boiler pipes, the highest FIK was achieved. Fuel consumption (coal) was also at its minimum value (6 kg) when the number of ribs was four. Utilizing the proposed improved water heating boilers allows for achieving high economic efficiency.

**CONCLUSION**

This article analyzes the methodology for calculating the main parameters of local energy-efficient water heating boiler pipelines and the possibilities for improving their efficiency. According to the research results, the hydraulic parameters, including the diameter and length of the water heating boiler pipes, the thermal conductivity of the material, and the temperature regime, directly affect the boiler's energy efficiency. The calculated pipe parameters reduce heat loss and significantly decrease energy consumption. Additionally, the article demonstrates effective methods for determining the optimal structure of pipeline systems through the application of hydraulic calculations. Improving the hydraulic performance of water heating boiler units contributes to the efficient utilization of local resources and enhances energy efficiency.

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