

Study of the thermal characteristics of the aluminum radiator ROYAL Thermo Evolution

Z G Mar'ina¹, A Y Vereshchagin¹, A V Novozhilova¹, M A Komarevtsev¹ and K O Isaeva¹

¹ Northern Arctic federal university named after M. V. Lomonosov , 17, Northern Dvina Emb., Arkhangel'sk, Russia

Abstract. The use of aluminum radiators in heating systems began with the foreign companies products such as Fondital Group, Global Radiatori, Ferroli, etc. There are now Russian aluminum radiators companies that adhere to European standards, for example ROYAL Thermo, Rifar. The thermal characteristics of radiators are usually specified by the manufacturer. However, they are not always confirmed in practice. This is due to the fact that radiator connecting method is not taken into account. In some technical data sheets, the power reduction factors are given depending on the difference between the average coolant temperature and the air temperature in the room. Therefore, the study of the influence of aluminium heating appliances connecting on its thermal characteristics is an actual task. The article presents the results of research of radiator of the ROYAL Thermo Evolution type, it was made on request from company specialising in heating systems design. It was found that the actual thermal power of one section varies in the range of 135 ... 225 W, depending on the connection method of the radiator, the thermal power of the section declared by the manufacturer corresponds only to the diagonal «top-bottom» connection, the thermal power of the eight-section radiator with one-sided «top-bottom» connection is 12% higher than with a diagonal one. Studies show, when designing heating systems, it is necessary to take into account the connection method and the number of device sections.

1. Introduction

A large variety of heating equipment nowadays has led to the fact that the thermal performance of radiators is usually specified by the manufacturer. However, it is not always confirmed in practice. The review of numerous sources on this issue allows us to conclude that heating studies confirm data only for certain types of radiators [1–10].

There are a large number of modern heating devices on the Russian market nowadays and a large proportion is accounted for by aluminum radiators. Their undoubted advantage is high heat transfer, which stands at 200÷210 W, while the volume of each radiator section is only 450 ml. They have an aesthetic appearance, what allows to “introduce” such radiators into the interior design of any style. The low inertia of aluminum heating devices allows to regulate the temperature regime precisely with the help of thermostatic devices. These advantages, as well as a long service life and a large variety of design possibilities and size types of aluminum radiators led to their widespread use in Russia and abroad.

An eight-section aluminum radiator of the ROYAL Thermo Evolution type intended for heating systems in residential, public and industrial buildings was presented for the research. The technical specifications of the device are presented in table.

Table. The technical specifications of the ROYAL Thermo Evolution type radiator.

Working pressure, MPa	Heat transfer of one section, W	Maximum temperature of the coolant, °C	Capacity of one section, l	Centre-to-centre dimension, mm	Weight, kg	Life cycle, years
1.6	203	110	0.35	500	1.3	25

To date, the Government of the Russian Federation has adopted the Resolution No. 717 of June 17, 2017 on the introduction of an obligatory certification system of all types of heating devices [11], their accordance with State standard [12]. Thus, the deviations of the nominal heat flux claimed by the manufacturer from the indicators established by the test results, should not exceed the maximum permissible tolerances (from – 4 % to + 5 %) [12]. It is of interest to determine the actual heat flux of a heating device, therefore the aim of the work is to study the thermal characteristics of the heating device of the ROYAL Thermo Evolution type [13].

At present, when designing heating systems, the manufacturer does not give recommendations about the influence of the device connecting method on the change in heat output, therefore, the influence of the device connecting method on its heat transfer was also determined.

2. The Scheme of the Experimental Installation

The studies were conducted in the laboratory of the training-scientific center of energy innovations of the Heat Technology and Heat Power Engineering Department NArFU.

The company presented an eight-section aluminum radiator of the ROYAL Thermo Evolution type for the research, (figure 1).

The increased thermal power of the radiator is provided not only by using aluminum as a high thermal conductive material, but also by the design of the fins. The fins form vertical rectangular channels in which air moves freely from bottom to top, increasing the heat transfer of the device during natural convection. Smooth transition of the heat flux from the fin spacing provides direct air flow into the room.



Figure 1. The appearance of the radiator.

The scheme of the experimental installation is shown in figure 2. The water heater 2 made it possible to obtain a coolant temperature up to 80 °C. The circulation of the coolant was provided by the pump 3. The heat load of the device was determined by the indications of the flow meter (4) and two Chromel-Copel thermocouples (9, 10). Thermocouples are caulked in metal inlets to the device at the inlet and outlet from it and connected via a multi-position switch 7 to a millivoltmeter 8. The cold

junctions of the thermocouple are immersed in the Dewar vessel 6 with melting ice. A screen filter 5 [14–15] is installed in front of the flow meter for the pollution capture.

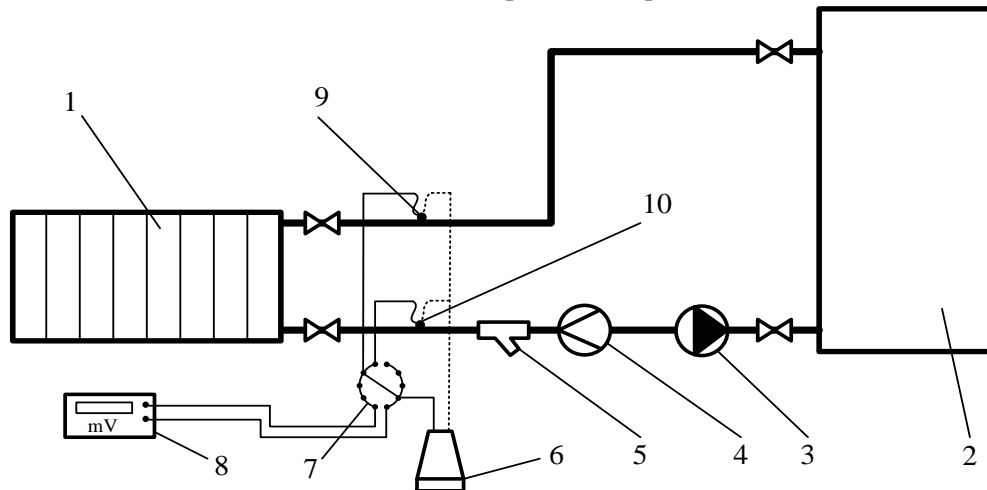


Figure 2. The scheme of the experimental installation.

By the stationary thermal mode, there were made measurements of the coolant flow rate, the emf. of the thermocouples installed at the inlet and outlet of the radiator, and the air temperature in the room. The experiments were carried out in the range of temperatures of the heating coolant 40...80 °C at flow rates of 0.13...0.22 m³/h. The thermal load of the heater was determined by the flow rate and temperature difference of the coolant. The uniformity of the temperature field on the outer surface of the fins and the direction of the coolant's movement in the device was determined using a TESTO-350 thermal imager.

3. The study of the heating characteristics of aluminum radiator

Let us determine the thermal power of a radiator ROYAL Thermo Evolution with different methods of connection.

In the equipment certificate the thermal power of the section, claimed by the manufacturer, is $q_n = 203$ W with the calculated difference between the average coolant temperature and the air temperature in the room $\Delta t_{av} = 70$ °C, obtained at coolant temperature 110/70 °C and air temperature 20 °C [4]. In Russia, two-pipe heating systems are designed at coolant temperatures before and after the heating device of 95 °C and 70 °C respectively, and the air temperature in the room is 20 °C, which corresponds to the calculated temperature difference $\Delta t_{av} = 62.5$ °C.

In other design conditions, manufacturers offer to use the correction factor $k = f(\Delta t_{av})$ and determine the density of the heat flux section by the formula:

$$q = q_n \cdot k. \quad (1)$$

The thermal power of the radiator at different coolant temperatures and methods of connection is shown in figure 3.

The change in consumption does not affect the heat transfer of the radiator with one-sided and diagonal «top-bottom» connections (lines 1, 2). Impact of costs should be taken into account with «bottom-bottom» connection (lines 3).

The heat flux density of the eight-section radiator declared by the manufacturer, taking into account the influence of Δt_{av} , calculated by formula 1, is shown by line 4.

Comparison of the declared and experimental data shows that with «top-bottom» connection there is a stock of thermal power, and with «bottom-bottom» connection, the number of sections should be

determined with caution, because the device power will be lower than declared by the manufacturer and significantly depend on the coolant flow rate.

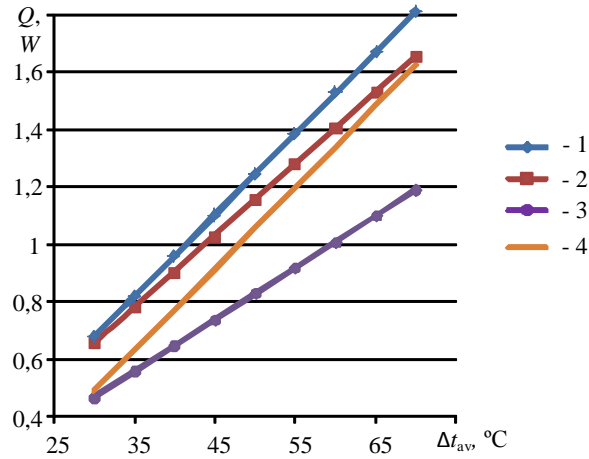


Figure 3. Thermal power of radiator.

To study the direction of the coolant in the device with a one-sided «top-bottom» connection, a TESO-350 instrument was used for thermal imaging from the beginning of the coolant supply until the radiator was fully heated. Thermal imaging was performed at intervals of 20 seconds. The 75 °C coolant enters the cooled radiator from the top, heats the upper collector, and then the vertical columns (figure 4).

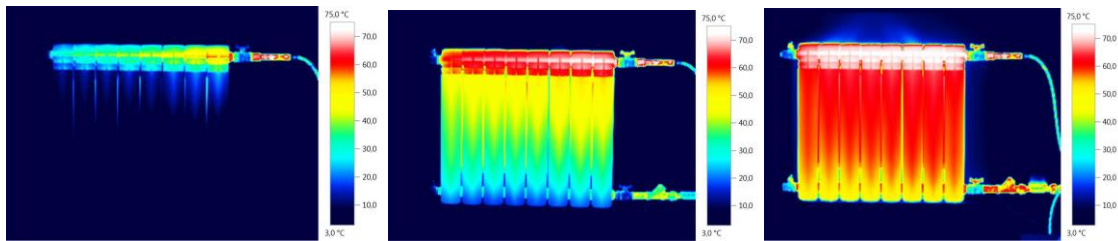


Figure 4. Thermograms of the aluminum radiator heating: after 40 seconds, 1 minute 40 seconds and 3 minutes 20 seconds respectively.

Full heating of the radiator, when the fins temperature becomes constant, occurs in 5 minutes. After processing the thermal imaging data, there was prepared a height graph of the temperature change on the surface of the radiator fins (figure 5). All radiator sections heat evenly. The surface temperature differed only in height for the extreme and central sections: at the initial moment – by 20 °C and by 8 °C after heating.

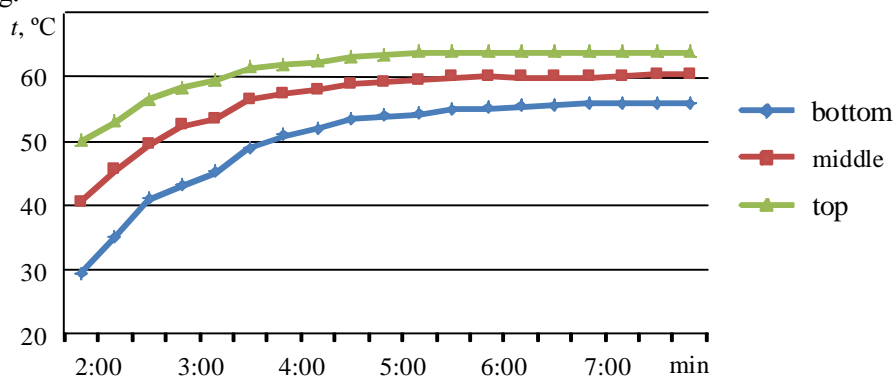


Figure 5. Fins surface temperature of the sections during the radiator heating.

The temperature difference between the coolant and the fins surface after heating was on average 13 °C.

It can be seen that with diagonal «top-bottom» connection of the radiator, the coolant fills the heating device through the furthest (eighth) section with a gradually heating from the last section to the first (figure 6).

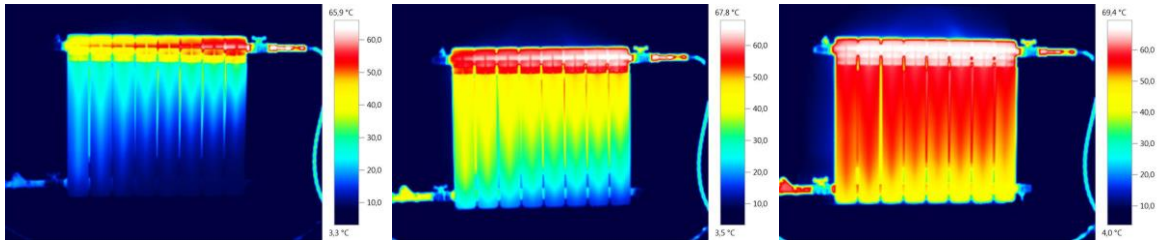


Figure 6. Thermograms of the aluminum radiator heating: after 1 minute, 2 minutes and 5 minutes, respectively.

Based on the analysis of thermograms (figure 7), it can be seen that the heating of the eighth section proceeds more evenly, as the coolant circulation begins to flow through it. The temperature difference between the top and bottom of the fin is on average 5 °C. The first section starts to heat with a delay. The difference between the upper and lower points of the fin decreases from 20 °C at the beginning of heating to 10 °C. This difference can be explained by a different amount of coolant flow through each section, as evidenced by the lower thermal power of the radiator (by 12%) compared to a one-way connection.

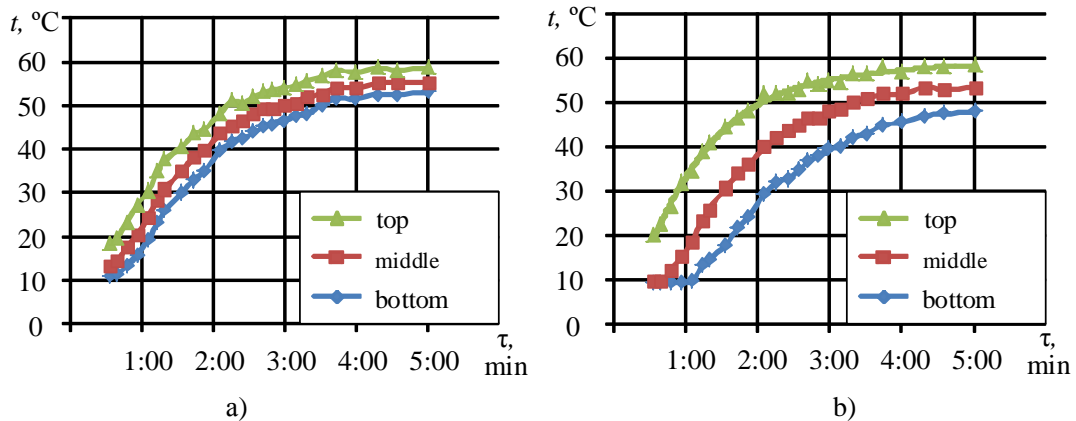


Figure 7. The temperature of the fins' surface of the aluminum radiator sections: eighth section (a) and first (b).

Figure 8 shows the thermogram of the radiator heating with «bottom-bottom» connection. In this case, the radiator heating is as follows. The coolant rises through the first section to the upper collector and then moves through the other sections from top to bottom.

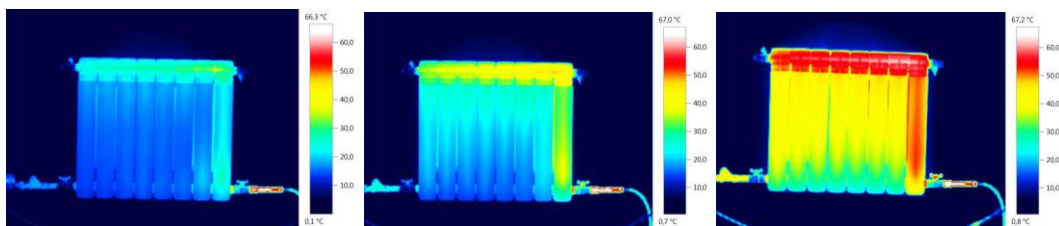


Figure 8. Thermograms of the aluminum radiator heating: after 1 minute, 2 minutes and 5 minutes, respectively, with «bottom-bottom» connection.

4. Conclusions

- 1) The thermal power of the section declared by the manufacturer is 203 W, it corresponds only to the diagonal «top-bottom» connection.
- 2) The thermal power of the device in the design conditions with one-sided connection is 12% higher than with a diagonal one.
- 3) The actual thermal power of the section varies in the range of 135 ... 225 W at 70 °C, depending on the connection method of the radiator. The discrepancy is -33...+11%.
- 4) With «bottom-bottom» connection method it is necessary to consider the effect of coolant flow.

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