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Chapter 8. Examination of the temperature dependence between the measuring points of the heat cost allocator

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Streszczenie. Przedstawiono budowę i zasadę działania elektrycznych podzielników kosztów ciepła. Skupiono się na poprawnej interpretacji temperatury sond pomiarowych podzielnika oraz odpowiadających im temperatur grzejnika i otoczenia. Przeprowadzono badania, a także opracowano własne analizy i wnioski w celu udoskonalenia metody obliczania ciepła oddanego z grzejnika.

Abstract. The structure and operating principle of electric heat cost allocators are presented. The focus is on correctly interpreting the temperature of the allocator temperature sensors, as well as the corresponding heater and ambient temperatures. Research was conducted and analyses and conclusions were developed to improve the method of calculating the heat emitted from the radiator.

Słowa kluczowe: podzielnik kosztów ciepła, czujnik temperatury, moc cieplna grzejnika, centralne ogrzewanie

Keywords: heat cost allocator, temperature sensor, thermal output of radiator, central heating

Introduction

Heat cost allocators with electrical power supply [1, 2] are used for establishing the heat consumption value of room heating radiators. This standard specifies that heat cost allocators shall not be used for heating systems where the temperature of the heating system falls below or exceeds the temperature limits of the heat cost allocators, where the rating factor for the thermal output, K_Q, cannot be clearly specified or where the heating surface is inaccessible. This applies usually to the following heating systems:

- floor heating,
- radiant ceiling heating,
- flap-controlled radiators,
- radiators with ventilators,

- fan-assisted air heaters,
- heating systems with steam-operated radiators.

Paper [3] presents the results of analyses of convection radiators from various manufacturers that can be used with cost allocators. The analyses focused on the volume, mass and length of the convection radiators, using the appropriate indicators Q_M, Q_V and Q_L. The papers [4, 5] present the evaluation criteria for heat cost allocator recordings based on the 2009 VDI 2077 guidelines, which align well with the realities of multi-family residential buildings for housing associations in eastern Poland. The purpose of article [6] is to provide a brief overview of the requirements set out in the PN EN 834 standard. It also provides the values of the EB coefficients necessary for analysing the accuracy of heat consumption recording. The standard defines the basic condition of the radiator, and the control diagrams should be constructed in such a way that the radiators on which the cost allocators are mounted release heat to the room in ambient conditions.

The temperatures supplied to the radiators in the flats were compared with the requirements for electronic heat cost allocators set out in PN-EN 834. Due to the requirements of electronic heat cost allocators, new design temperatures for central heating systems were proposed [7]. If cost allocators operate outside the baseline state, the readings of heat consumption are nonlinear. Paper [8] identified three cases of radiator operation. In the first case, the allocator registered too many heat units; in the third case, it failed to register the heat delivered to the room. The second case was unstable, meaning the allocator initially registered too much heat, but then failed to register the heat transferred by the radiator to the room when the flow through the radiator was minimally reduced. In work [9], the amount of heat Q_{obl} theoretical transferred by the radiator to the room was calculated using equation

$$Q_{obl} = Q_n \left(\frac{\Delta t}{\Delta t_{ln}} \right)^n dt \tag{1}$$

where Q_n – catalogue heater power [W], Δt_{ln} – logarithmic temperature difference according to the manufacturer's assumptions, for catalogue heater power of radiator, Δt – logarithmic temperature difference during measurements, $n = 1.33$ – coefficient characteristic for a given type of heater. The total power of the heater during the measurement was multiplied by the test time *dt* of individual periods (24 hours) and was expressed in kWh.

The value Q_{obl} was then compared with the values Q_r read from the cost allocator and with the values Q_{Wobl} determined using equation [8]

$$Q_{Wobl} = K \int \left(\frac{t_H - t_L}{60} \right)^{1.33} dt \tag{2}$$

where t_H – measured radiator surface temperature at the sensor location, t_L – ambient temperature, $K = K_Q K_C K_T$ – conversion factor [1].

The results of heat consumption analyses were conducted on a building [10], housing estate [11] and city scale [12].

This article aims to present the relationship between the measurement sites t_H, t_{HS}, t_{RS} and t_L (Fig. 1).

Electronic heating cost allocators

Electronic heating cost allocators are devices that account for the costs of central heating in multi-family buildings. They are used in calculations to allocate the overall heating costs to individual users of the premises, depending on their heat consumption. Mounted on radiators in apartments, they work by measuring the temperature difference between the radiator and the air in the room. As they are indicators rather than measures, their readings may be misinterpreted; however, they encourage heat conservation and enable fairer settlements. They do not measure thermal energy in physical units (GJ or kWh); they only indicate consumption units, which are used for heating cost accounting. Two temperature sensors ensure their operation, and heat consumption units are calculated based on the difference in their values.

One t_{HS} sensor measures the temperature of the heater t_H.

The second t_{RS} sensor measures the air temperature in the room t_L.

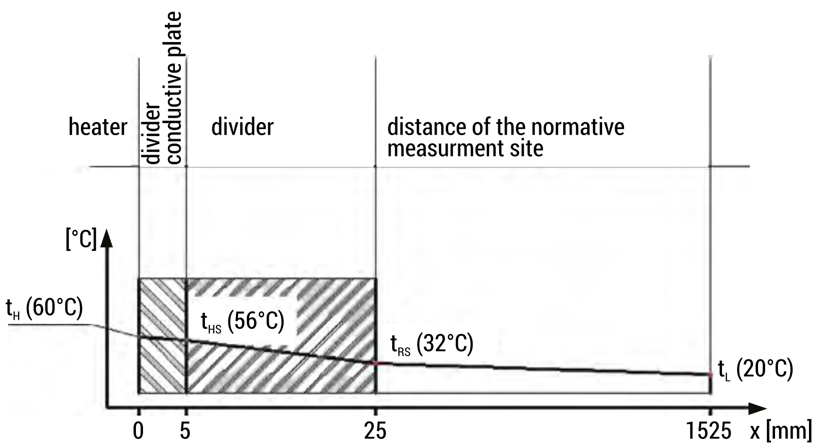

FIGURE 1. An example of a temperature drop between the heater (t_H), the divider sensors (t_{HS} and t_{RS}) and the ambient temperature (t_L)

Measurement stand

The test was performed on a heater with a power output of Q_n = 2310 W at an inflow temperature of 90°C and an outflow temperature of 70°C and a room temperature of 20°C. Fig. 2 below shows the diagram for mounting the measuring probes. In place of the original NTC thermistor sensors in the divider, temperature sensors have been installed that are connected to an electronic recorder which collects data in a text file.

The measurements were carried out in the actual operating conditions of the radiator.

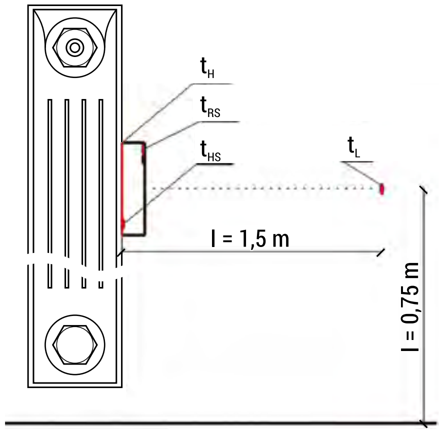

FIGURE 2. Diagram showing the arrangement of the tested measurement points

Measurement results

Fig. 3 shows the measurement data that has been analysed and archived. More than 34,000 measurement cycles were recorded.

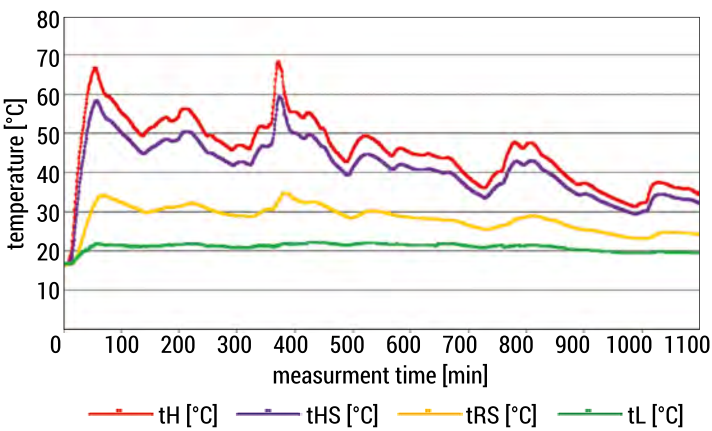

FIGURE 3. Graph showing the results of temperature measurements (t_H, t_{HS}, t_{RS} and t_L)

Analysis of measurement results

The analysis results are presented in Figs. 4 and 5.

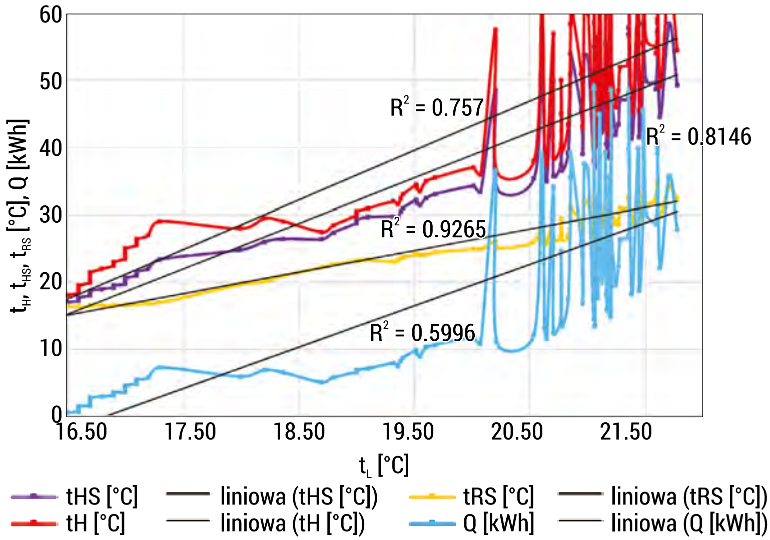

FIGURE 4. Data obtained versus room temperature t_L

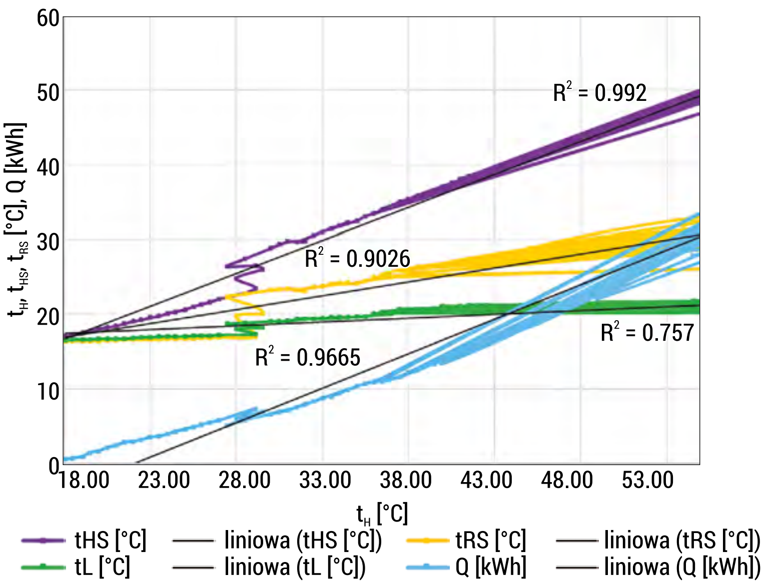

FIGURE 5. Data obtained versus radiator temperature at the location of the allocator t_H

Room temperatures t_L (Fig. 4) fluctuate around 20°C. Temperatures below 18°C are not included in the definition of the radiator's normal operating conditions. Such temperatures may occur in unoccupied rooms. Significant temperature fluctuations are possible for room temperatures above 20°C.

The graph (Fig. 5) shows that the measured temperatures versus the radiator temperature at the allocator location t_H vary linearly, and the actual values of temperatures (t_{HS}, t_{RS} and t_L) can be approximated quite well by linear functions. The correlation coefficient R between the presented data and the temperature t_H is as follows:
$t_H \rightarrow t_{HS} = 0.996$,
$t_H \rightarrow t_{RS} = 0.950$,
$t_H \rightarrow t_L = 0.870$,
$t_H \rightarrow Q$ [kWh] = 0.983.

Conclusions

The above study examined the relationship between the temperatures t_H, t_{HS}, t_{RS}, t_L. The correlations between these temperatures and the heater temperature t_H at the point of installation of the cost allocator, as well as the ambient temperature t_L were determined.

The temperature t_H has the greatest correlation to the temperature t_{HS} = 0,996; however, the coefficient of determination R2 of the linear trend line for t_{HS} is 0.992. This indicates a high degree of convergence in the data, but the temperatures t_H and t_{HS} are different.

The greatest correlation with the ambient temperature (t_L) is with the external sensor temperature (t_{RS}), with a coefficient of determination (R^2) of 0.962. However, the temperatures (t_L and t_{RS}) are different.

The temperature measured by the electronic divider's sensors (t_{HS} and t_{RS}) is primarily dependent on the surface temperature (t_H) of the heater at the installation site. By contrast, the ambient temperature (t_L) varies over a relatively small range and has a smaller impact on the values recorded by the allocator.

Temperatures follow the inequalities $t_H > t_{HS} > t_{RS} > t_H$, and no anomalies caused by disruptive factors have been identified.

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