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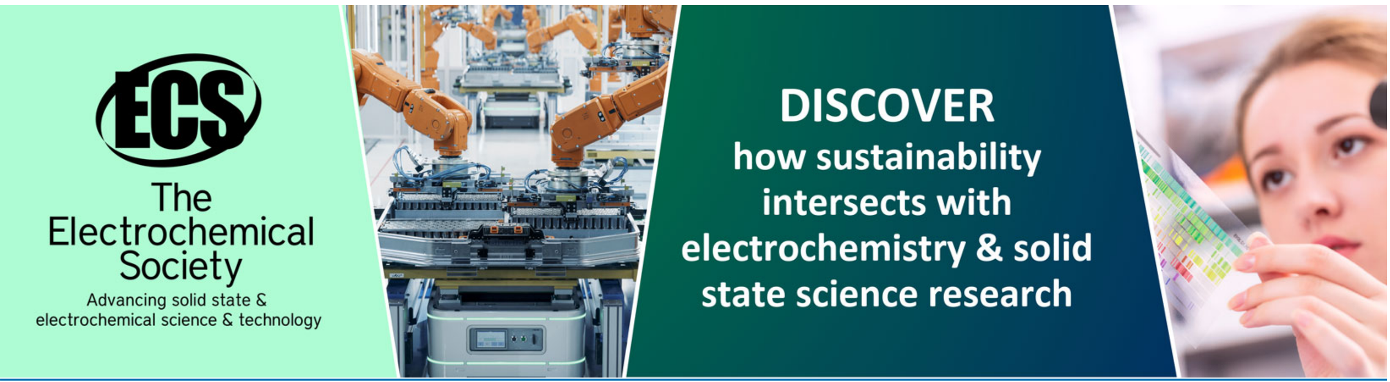

The Influence of Heat Gains on the Heating System Design

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Abstract. The article deals with the influence of heat loss of the distribution piping system and the related cooling of the heating water on the design of two-pipe counter-current heating system. The heat loss of the heating water distribution system to the heated room were observed on a reference family house. Consideration of heat gains is particularly important for low energy houses. Moreover, the consequences of heat gains to the room and its effect to the required radiator power output design were solved for case when the piping distribution system is placed visible on the wall and without thermal insulation. The effect is also evident with thermal insulation or embedded pipelines. Furthermore, mass flows and temperature gradients at the same mean temperature were observed on all radiators. This calculation was compared to the results of classic calculation design.

1. Introduction

This article deals with the influence of heat loss of the distribution piping system (further HLD) in the vicinity depending on thermal insulation (further TI) and the related cooling of the heating water in the piping to dimension the two-pipe counter-current heating system (further HS). It also deals with heat gains from HLD to heated areas and their influences on the design of the required radiator output.

The conventional design of heating systems with HLD is not considered and thus is proposed with constant temperatures throughout the HS, which is not physically accurate [1, 2, 3]. In fact, the HLD occurs and due to their neglect in the calculations can occur wrong states. These are manifested especially in larger HS with pipes without TI and with higher initial water temperatures. The deviations may not be negligible even in low temperature HS with quality thermally insulated distributions. [1].

One of the faulty states is for example the insufficient heating of the furthest radiators from the heat source. It is because the projected heat production from the classical design is insufficient and the heat passed in the form of HLD to the surrounding area is then missing at the target areas.

The overheating of rooms is another effect in the erroneous design due to neglect of HLD as gains to the given heated area, especially if the piping runs visibly on the wall and without TI. Radiators are designed for 100% heat loss of the room and heat gains from the HLD are in practice neglected. This causes rooms overheating. If the heat gains from pipeline were considered in a room thermal balance, the room overheating will not occur. The smaller radiators installation will also save money.

There is a discomfort of the inhabitants due to these problems in individual spaces. Moreover, an inefficient design and operation in point of both view economic and energy demands [4].

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2. Reference Heating System

Heating system in two-story family house was used as reference HS. HS runs visible on the wall and without TI, which is typical for buildings where pipes cannot be built in a floor due to the construction or technological issue e.g. reconstruction. This HS can be seen in figure 1. and 2.

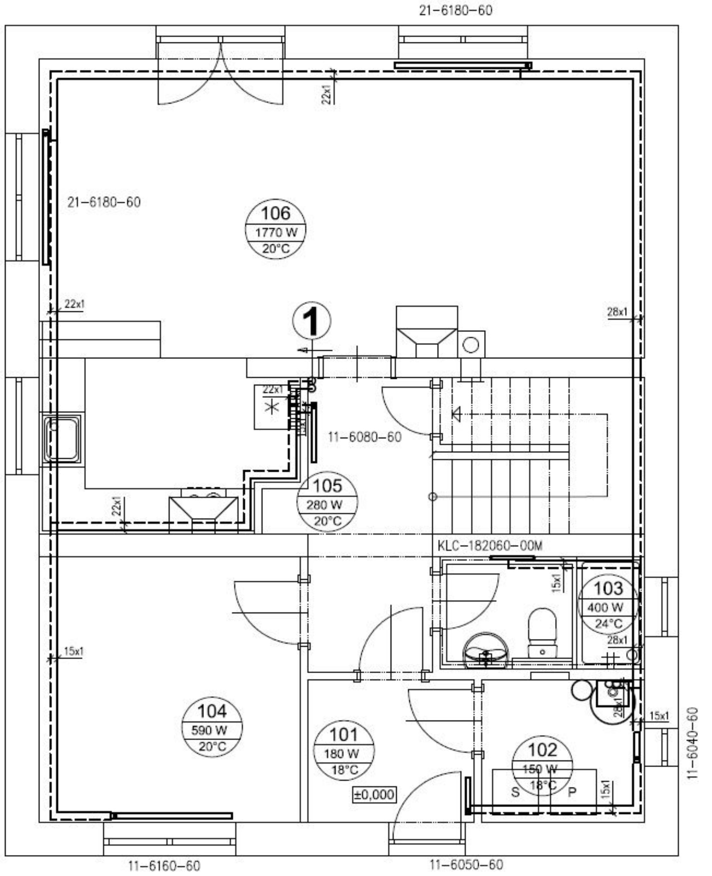

Figure 1. Floor plan ground floor – Pipes visibly on the wall

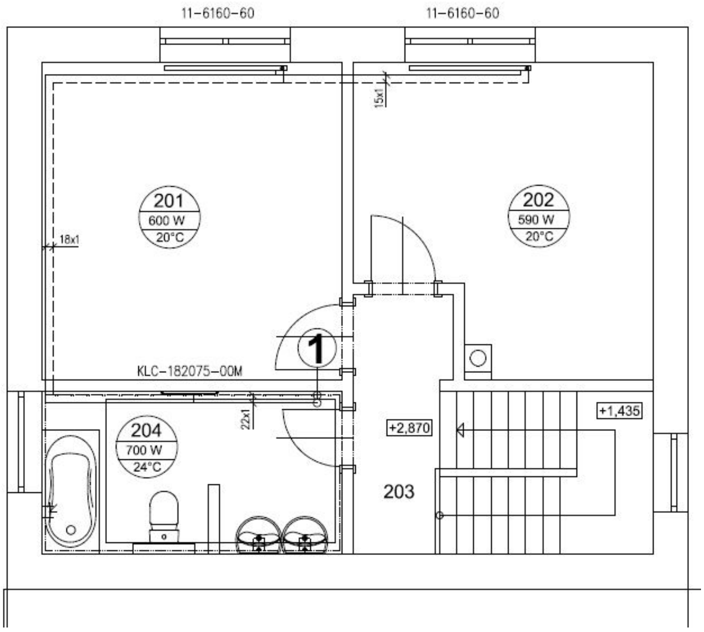

Figure 2. Ground plan of the attic – Pipes visibly on the wall

3. Mathematical modelling of HS

As already mentioned in the introduction, the HLD occurs in the HS and it has effect firstly on cooling of heating water in the pipeline and secondly on overall thermal balance of the area. Therefore, a computational model has been created that considers the effects of HLD and actual temperature at individual points in the HS [1, 5]. The model is based on the selected heating water temperature at the beginning of the HS and the selected mean heating water temperature, which is the same for all radiators. Other temperatures are calculated from the cooling of heating water along the pipeline due to the HLD and mass flow rates in the given sections. The actual mass flow rates correspond to the decreasing of the temperature gradient with the distance from the heat source [2]. For this reason, the calculation must be performed for the entire HS at an iterative way. At each point, the HS generally apply:

$$dQ = m.c.dt = U.dx.(t(x) - t_i) \text{ [W]} \tag{1}$$

each section is then described by the equation for the supply or the return pipe

$$Q = m.c.(t_1 - t_2) = U.L_{(1-2)}.\left(\frac{(t_1 - t_2)}{ln\left(\frac{t_1 - t_i}{t_2 - t_i}\right)}\right) \text{ [W]} \tag{2}$$

Where Q is Thermal loss of section [W]
m Mass flow rate [kg/h]
c Specific heat capacity [W.h/(kg.K)]
t_1 Water temperature at the beginning of section [°C]
t_2 Water temperature at the end of section [°C]
t_i Ambient temperature [°C]
U Heat transfer coefficient for circular piping [W/(m.K)]
L Section length [m]

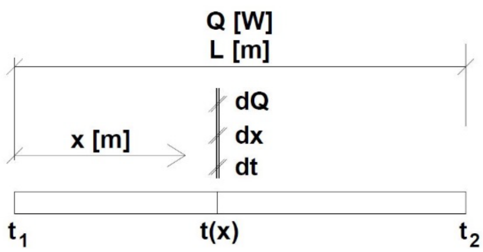

Figure 3. Diagram for equation heat loss of a section

4. Variants of heating system solutions

- **Var. 1** –Heat gains from HLD are considered, pipeline visibly on the wall without TI
  - In this variant, HLD and the related cooling of the heating water are considered in the calculation.
  - Heat gains from HLD are considered in the overall thermal balance of heated rooms and their effect on reduced required power output of radiators are counted.
- **Var. 2** – Classic dimensioning calculation
  - This variant is considered neither a cooling of the heating water nor the heat gains from the HLD in the radiators design.

The outlet temperature of the heating water was chosen as 50 ° C at the heat source for computational outdoor conditions. The average heating water temperature for all radiators was chosen as 44 °C.

5. Result analysis

The required radiator output is the first compared value for this type of HS. As can be seen in Fig. 4, the need of radiator performance can be reduced for Var. 1 if compared to Var. 2. Design of radiators with heat output reduced by heat gains from HLD will positively affect the operational cost and the thermal comfort of people. In the case of room 102, the heat gains will heat room up by itself.

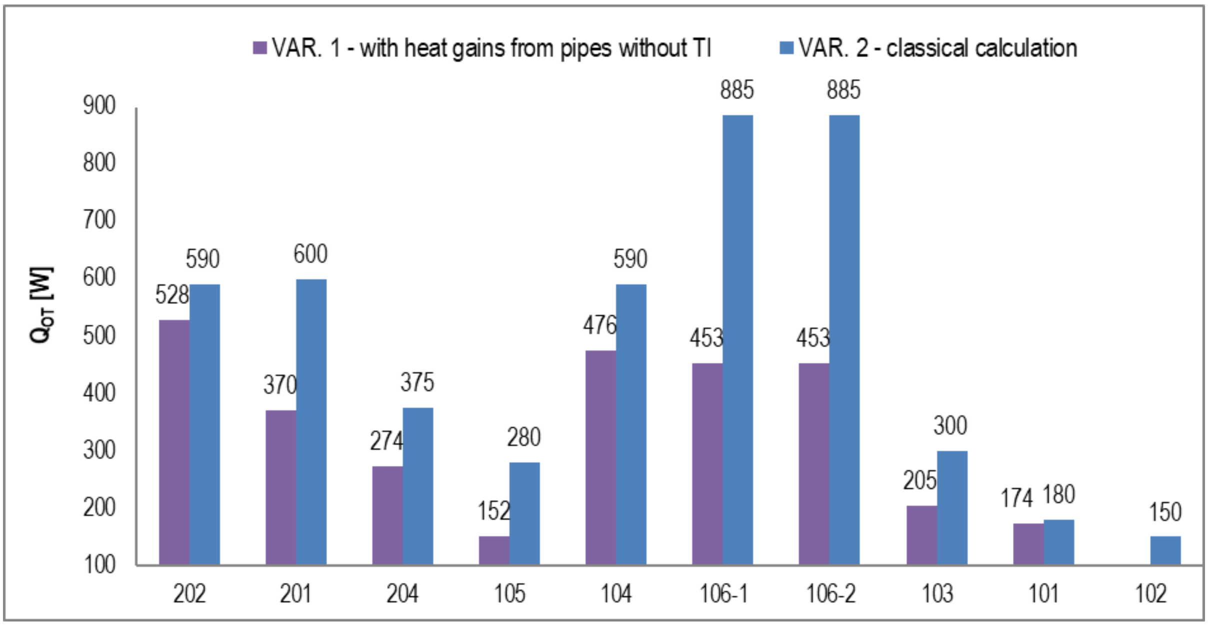

Figure 4. Required heat output of radiators

The temperature gradients of heating water in radiators was the second comparative parameter and can be seen in Figure 5. Temperature gradients was calculated for mean temperature 44 °C. Here we can see deviations from the classical calculation at Var. 1. Decreasing of the temperature gradient is depended on the distance from the source, the transmitted mass flow rate and the HLD size. These deviations from the assumed temperature gradients from the classical calculation will be reflected in the mass flows discussed in the next part of the text.

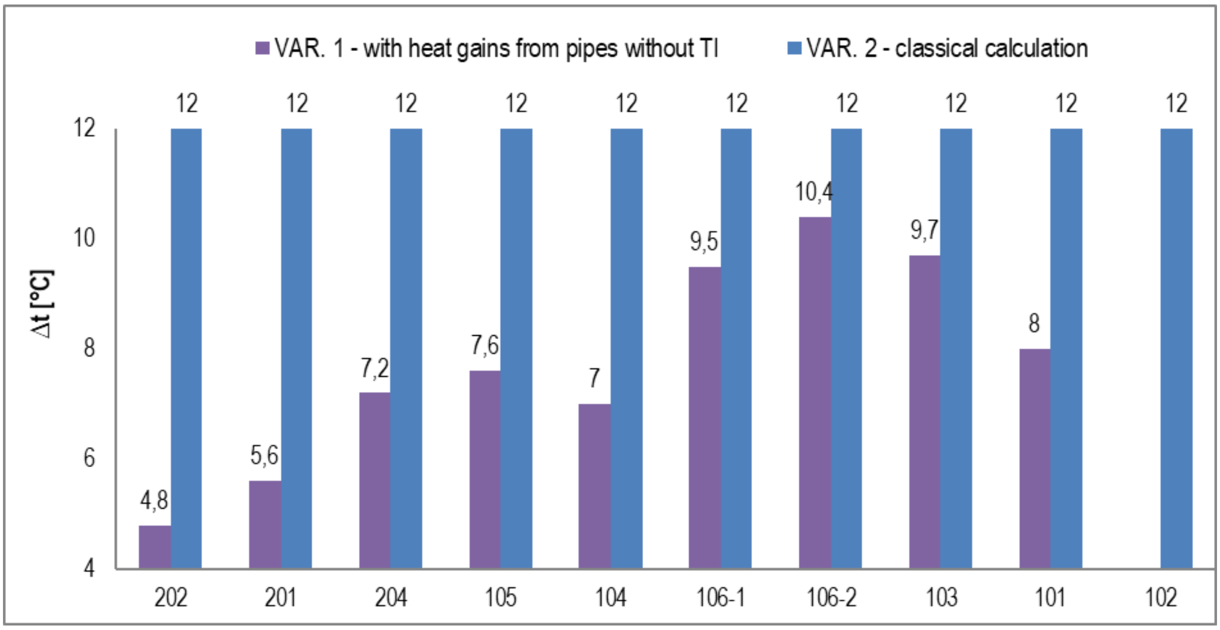

Figure 5. Temperature gradients on radiators

The mass flow rate was the last observed parameter. These influence firstly the pressure conditions of the HS, which are reflected in the adjustment of the balancing valves, control valves and circulating pumps. Secondly, they also influence the thermal effect of the OS, see equation (2). It follows from this equation that temperature decrease is indirectly proportional to the mass flow for case with the same HLD in the section. The results are illustrated in Figure 6, where can be seen the percentage deviation from the Var. 2 classical calculation taken as 100%. It can be seen that in Var. 1 is mass flow rate higher and smaller than the standard calculation from Var. 2. This is given on one hand by decrease with temperature gradient depending on the cooling of the heating water, but on the other hand by the effect of the required heat output radiators, which can lead up to 0 in rooms with large heat gains from the piping.

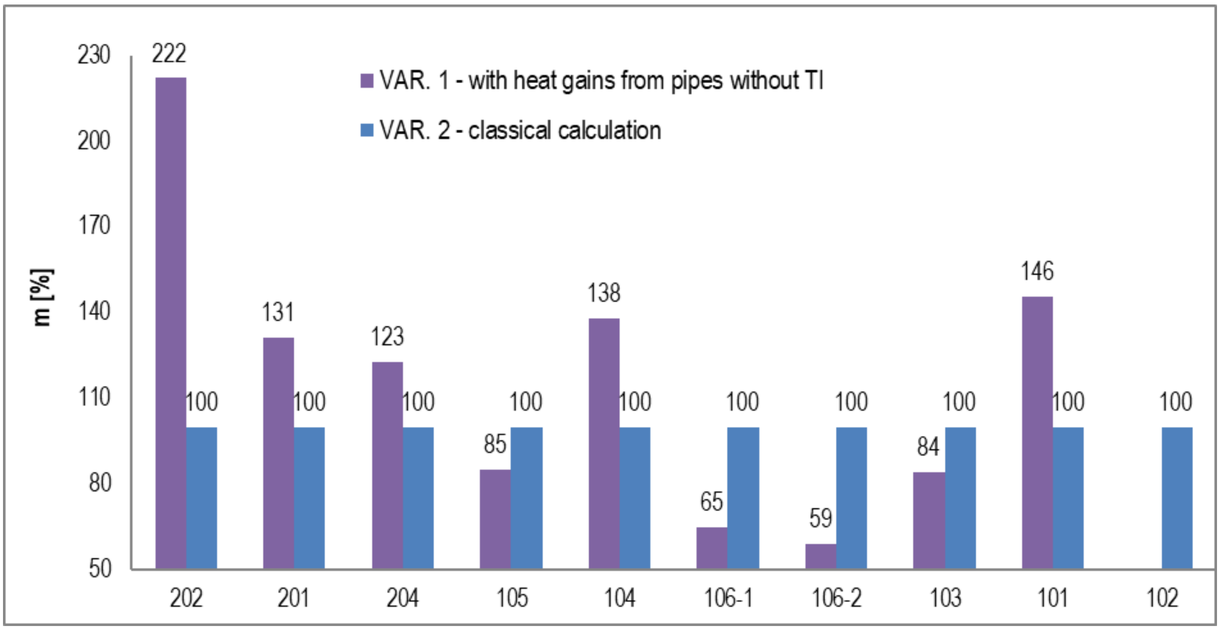

Figure 6. Mass flows to radiators

The circulating pump should be set for each variant according to values listed in Table 1. The values are further percentage compared to Var. 2.

Table 1. The required values for circulation pump

	m (kg/h)	m (%)	P_{dis} (Pa)	P_{dis} (%)
Var. 1	375	108	6100	277
Var. 2	347	100	2200	100

6. Conclusion

In the article, shortcomings caused by the neglect of the heat gains from HLD and associated with this cooling of the heating water in the design of two-pipe counter-flow of the HS were pointed out at the reference detached house.

It was shown the influence of heat gains from HLD and their consequence on the design of the required heat output of radiators and mass flow rates on selected parameters. The classical calculation does not work with these aspects, although it has been proved that the results of each variant differ from each other.

It is necessary to work with the influence of HLD and cooling of the heating water for more precise adjustment of heating system and for increasing indoor environment quality especially in low energy buildings.

The outputs are well suited for upgrading professional computing program for heating systems. The most widely used Czech commercial computing program for heating system design has already been modified for these outputs.

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References

[1] Spurny J 2016 Effect of cooling of heating water on design of heating system (Vliv ochlazování topné vody při návrhu otopné soustavy – Czech Language) *Prague CTU Diploma Work* (Prague)

[2] Raz J V 2016 http://www.usporyteplaets.cz/

[3] Spurny J and Kabrhel M Effect of heat distribution losses and cooling of heating water on design of heating system (Vliv tepelných ztrát rozvodů a ochlazování otopné vody na návrh otopné soustavy – Czech Language *Vytápění, větrání, instalace* **26, 1** 2–5

[4] Raftery P, Geronazzo A, Hwakong Ch and Paliaga G 2018 Quantifying energy losses in hot water reheat systems *Energy Build.* https://doi.org/10.1016/J.ENBUILD.2018.09.020

[5] Cihelka J kol. 1985 Vytápění, větrání a klimatizace (Prague: STNL)