Heat exchange on the outside of the pipe when heat is distributed by heat networks

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Abstract

The article deals with the exchange of heat on the outside of the pipe when distributing heat through heat networks. This is a combined heat exchange, i.e. free convection and radiation. The calculations and outputs analysed in the article are mainly applicable to thermal networks run aboveground. In the calculation, an ambient temperature of 15 °C was measured, ranging from the temperatures corresponding to the air temperatures in the channel. The results are interpreted in the form of diagrams and tables. The calculation was performed on the secondary DN 125 pipe with PIPO_ALS insulation and the calculation was extended to all nominal diameters used in the secondary wiring for determining the influence of heat transfer, depending on the change in pipe diameter.

Keywords: thermal network, heat transfer coefficient, convection, radiation

1. Introduction

In the supply of heat through heat networks, there are signs of thermal losses affecting the operation of the heat network and the overall economy of the heat supply. Analytical methods are currently being used to determine heat losses, in which it is necessary to perform a detailed analysis of all measured and calculated variables occurring in individual relationships. The determination of the external heat transfer coefficient consists of the determination of its part, connected to the convection (free or forced) and also to the radiation.

2. The Effect of Free Convection on the Heat Transfer Coefficient

To determine the coefficient of external heat exchange according to free convection αk, the following equations were used for free flow in an unlimited space:

$$\overline{\alpha}_{\mathrm{k}} = \frac{\overline{Nu}\,.\,d}{\lambda} \quad (1) \qquad (1)$$

where: $\overline{Nu}$ is Nusselt's number ($\overline{Nu} == C\cdot(Gr\cdot Pr)^n \cdot \varepsilon$) (1),

λ - thermal conductivity coefficient ($\mathrm{W\cdot m^{-1}\cdot K^{-1}}$),

d - the characteristic dimension (m)

Pr - Prandtl's criterion (1),

Gr - Grashoff's criterion (1).

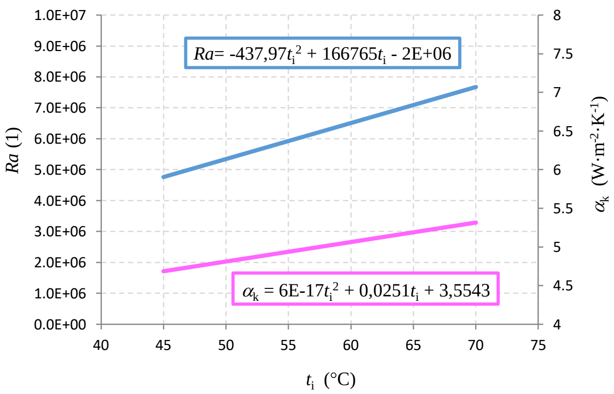
For the storage conditions and the character of the pipe, the constants C = 0.5, n = ¼, ε = 1 were chosen.

The process of the heat transfer coefficient on the outside of the pipe was analysed for the measured water flow $Q_{V1} = 2.68\ \mathrm{m^3\cdot h^{-1}}$ ($Q_{m1} = 0.73\ \mathrm{kg\cdot s^{-1}}$). In the calculations and graphical solutions the PIPO_ALS insulation with the prescribed insulation thickness was considered.

The progress of the Rayleigh number and heat transfer coefficient through free convection on the outside of the pipe, for the analysed heat network (DN 125) at the constant volume flow $Q_{V1} = 2.68\ \mathrm{m^3\cdot h^{-1}}$, depending on the change in temperature of the transferred water, is in Fig. 1 and from the change in the surface temperature of the insulation is in Fig. 2.

Changing the water temperature in the pipe at a constant velocity ($\upsilon = 0.19\ \mathrm{m.s^{-1}}$) causes a change in the surface temperature of the insulation, thereby changing Grashoff's number and thus the external heat exchange coefficient α_{k}.

The physical properties of air for air temperature t_{e} = 15 °C are in Table 1. The table also shows calculated values for α_{k} for different water temperatures, i.e. and a different temperature for insulation on its surface (DN 125).



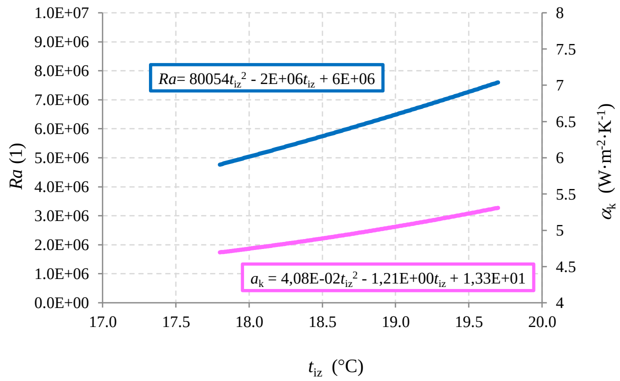


Figure 1. The progress of Rayleigh's number and the heat transfer coefficient on the outer side of the pipe depends on the change in water temperature for DN125

Figure. 2 The progress of Rayleigh's number and the heat transfer coefficient on the outer side of the pipe depends on the change in water temperature for DN125

Table 1. Table of physical quantities and calculated values of the heat transfer coefficient from insulation to air

t_i (°C)	t_{iz} (°C)	ρ (kg·m^{-3})	c_p (J·kg^{-1}·K^{-1})	λ (W·m^{-1}·K^{-1})	η 10^5(Pa·s)	ν 10^5(m^2·s^{-1})
45	17.8	1.227	0.9875	0.025	1.80	1.46
50	18.2	1.227	0.9875	0.025	1.80	1.46
55	18.6	1.227	0.9875	0.025	1.80	1.46
60	19.1	1.227	0.9875	0.025	1.80	1.46
65	19.4	1.227	0.9875	0.025	1.80	1.46
70	19.7	1.227	0.9875	0.025	1.80	1.46

Cont. Table 1

Pr (1)	Gr (1)	$Gr \cdot Pr$ (1)	Nu (1)	α_k (W·m^{-2}·K^{-1})
0.715	6.62E+06	4733992	23.3	**4.7**
0.715	7.48E + 06	5347156	24.4	**4.8**
0.715	8.32E + 06	5951304	24.7	**4.9**
0.715	9.17E + 06	6555451	25.3	**5.1**
0.715	9.93E + 06	7096479	25.8	**5.2**
0.715	1.07E + 07	7637507	26.3	**5.3**

In Fig. 3, the progress of the external heat transfer coefficient is recorded, depending on the change in the pipe diameter, while maintaining the same operating conditions of the network as the water temperature, the used insulation, ambient temperature and volume flow Q_{V1} = 2,68 m^3.h^{-1}. Tab. 2 shows the values of the heat transfer coefficient α_k for different DN pipes.

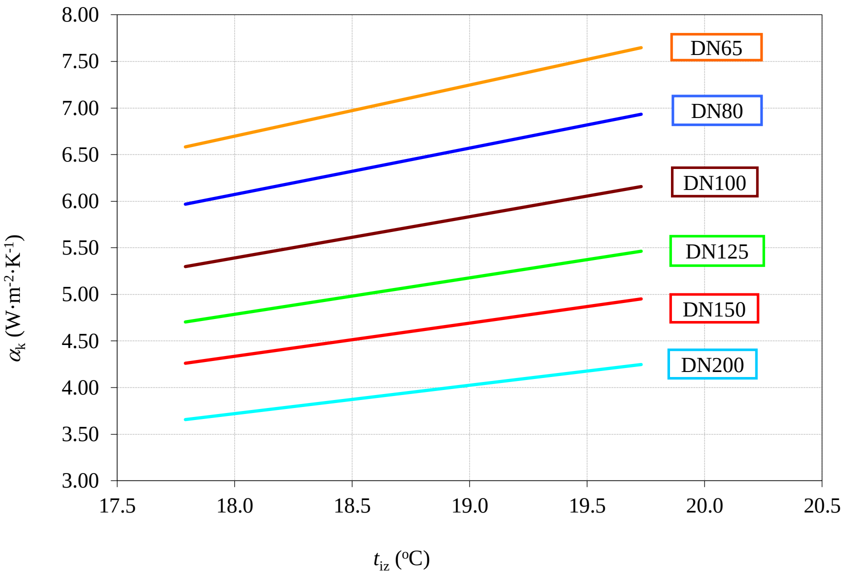


Figure. 3 The flow rate of the heat transfer coefficient on the outside of the pipe in dependence on the change of the pipe diameter at a constant flow rate

Decreasing the nominal pipe diameter means a slight increase in the heat transfer coefficient through convection at the same temperature of the transferred water. By reducing the DN, the rate increases (at a constant volume flow rate) and the temperature gradient decreases from 1 m of pipe length. At the same ambient temperature and the same temperatures of the water being transported, the heat dissipation is more intense with smaller DN.

Table 2 The heat transfer coefficient on the outside of the pipe, depending on changes in the pipe diameter at flow rate Q_{V1} = 2.68 $m^3.h^{-1}$

DN	t_i (°C)					
	45	50	55	60	65	70
	α_k ($W \cdot m^{-2} \cdot K^{-1}$)					
DN65	6.6	6.8	7.1	7.2	7.5	7.7
DN80	5.9	6.2	6.4	6.6	6.8	6.9
DN100	5.3	5.5	5.7	5.8	5.9	6.2
DN125	4.7	4.9	5.0	5.2	5.3	5.5
DN150	4.3	4.4	4.6	4.7	4.8	4.9
DN200	3.7	3.8	3.9	4.0	4.1	4.3

The external heat exchange represented by α_k is practically not dependent on the amount of the medium transferred or its pipe speed. The influence of the surface temperature of the insulation (which is, at the given quality of the insulation function, only at the temperature of the transferred water), the ambient air temperature, the size of the transport network, its diameter and the type of insulation used and its thickness are predominant.

2.1 The Effect of Free Convection on the Heat Transfer Coefficient

For the heat transfer coefficient by radiating α_s, there applies the relationship [5]:

$$\alpha_s = \varepsilon_{12}.C_0 \cdot \left[T_1^2 + T_2^2 \right] \cdot \left[T_1 + T_2 \right] \qquad (W \cdot m^{-2} \cdot K^{-1})$$

where T_1 - tube temperature (K),

T_2 -the temperature of the basement walls (K)

ε_{12} - relative emissivity (1),

C_0 - Stefan-Boltzman constant, C0 = $C_0 = 5.67 \cdot 10^{-8}$ ($W \cdot m^{-2} \cdot K^{-4}$).

Values of the heat transfer coefficient by radiating α_s depending on the insulation temperature for the measured network (DN 125) are elaborated in Tab 3.

Table 3 Value of α_s depending on the temperature of the insulation (DN 125)

t_i (°C)	t_{iz} (°C)	t_{ss} (°C)	ε_{12} (1)	C_0 ($W \cdot m^{-2} \cdot K^{-4}$)	**α_s ($W \cdot m^{-2} \cdot K^{-1}$)**
45	17.8	15	0.9	5.67	**4.95**

50	18.2	15	0.9	5.67	**4.96**
55	18.6	15	0.9	5.67	**4.97**
60	19.0	15	0.9	5.67	**4.98**
65	19.4	15	0.9	5.67	**4.99**
70	19.7	15	0.9	5.67	**5.00**

Legend: t_{ss} - basement wall temperature (°C), t_{iz} - tube temperature (°C)

2.2 The Overall Heat Transfer Coefficient

The total coefficient of external heat exchange $\alpha_{c,2}$ is a function of the heat transfer coefficient through free convection and radiation. We identify it with respect [4]:

$$\alpha_{c,2} = \alpha_k + \alpha_s \qquad (\mathrm{W \cdot m^{-2} \cdot K^{-1}})$$

Fig. 4 shows the overall coefficient of the external heat exchange at the surface temperature of the insulation for DN 125.

The progress of the total heat transfer coefficient on the outside of the pipe at constant volume flow rate Q_{V1} = 2.68 m^3.h^{-1}, depending on the change in the pipe diameter and the changed surface temperature of the insulation is shown in Fig. 5.

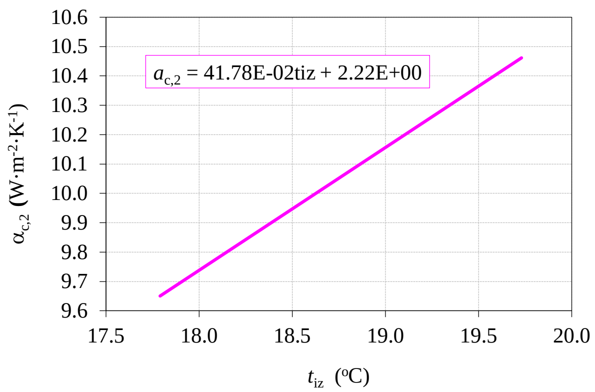


Figure. 4 Progress of $\alpha_{c,2}$ depending on surface temperature insulation for DN 125

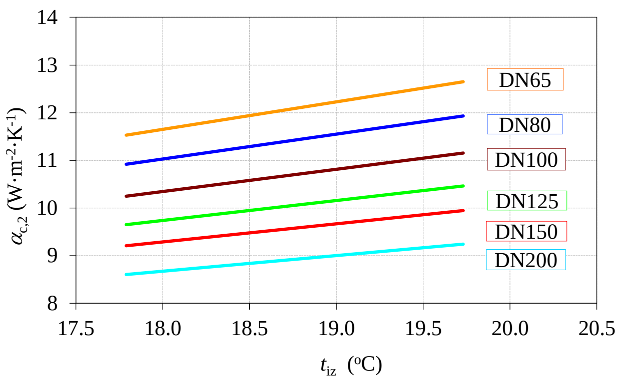


Figure. 5 The progress of the total heat transfer coefficient on the outer side of the tube , depending on the change in the pipe diameter at the constant flow

Within the temperature range of the transferred water the value of the total coefficient of the heat transfer on the outside shifts from 8.5 W.m^{-2}.K^{-1} (at t_i = 40 °C) to 12.8 W.m^{-2}.K^{-1} (at t_i = 70 °C).

3. Conclusion

The analytical procedures described in the professional literature can be used to determine thermal losses of heat distribution. Based on the analysis of thermal loss, there applies that the application of the procedure according to the mentioned methodology is mainly accompanied by the complication of the expression of the linear thermal resistance of the network. This depends on the nominal pipe diameter, the temperature of the water to be transported, the ambient temperature, the quality and the thickness of the insulation and the material used for conveyance. The most complicated is the expression of the heat transfer coefficient on the side of the flowing water and the side of the environment in which the conveyance is conducted. The determination of the external heat transfer coefficient consists of the determination of its part, connected to the convection (free or forced) and also to the radiation.

4. Acknowledgement

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