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DETERMINATION OF HEAT EXCHANGE ON THE INTERNAL SIDE OF PIPELINES IN DISTRICT HEATING SYSTEMS

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ABSTRACT

The present article deals with the heat exchange on the internal side of the pipelines during the distribution of heat through heat networks as the heat exchange parameters must be known for the purpose of calculating the heat loss within the distribution of heat through heat networks. The calculations and outcomes published in the article were carried out for above-ground heat networks, for the nominal diameter DN125 at the temperature of the environment of -15 °C which represents, according to STN EN 12831 - 1 standard, the design outdoor temperature in the town of Košice. The calculation was also extended to all nominal diameters used in secondary pipelines of the distribution network.

KEYWORDS: heat losses, Nusselt number, flow rate, Reynolds criterion.

INTRODUCTION

The determination of heat losses within the distribution of heat may be carried out applying the analytical approach which is accompanied with certain complications regarding the expression of the linear specific thermal resistance of the network. This depends on the nominal diameter of the pipeline, temperature of the conveyed water, temperature of the environment, quality and thickness of the insulation, and the pipeline material. The most complicated task is to express the heat transfer coefficient for the flowing water and for the environment in which the pipelines are located. In the case that the pipelines are located in open space (unrestrained), certain criterial equations may be used to identify such coefficient.

DETERMINATION OF THE HEAT TRANSFER COEFFICIENT ON THE INTERNAL SIDE OF THE PIPELINE

The calculation of the coefficient on the internal side of the pipeline depends on changes in individual physical parameters, mainly on the temperature of water and on the nature of the flow of the conveyed water.

The nature of the water flow inside the pipeline was analysed for two flow rate limits:
$Q_{V1} = 2.68\ \mathrm{m^3 \cdot h^{-1}}$ ($Q_{m1} = 0.73\ \mathrm{kg \cdot s^{-1}}$) - minimum flow rate for the system during the non-heating period.
$Q_{V2} = 8.25\ \mathrm{m^3 \cdot h^{-1}}$ ($Q_{m1} = 2.29\ \mathrm{kg \cdot s^{-1}}$) - maximum flow rate for the system during the heating period.

The calculation of the nature of the flow was made applying the Reynolds criterion:

$$Re = \frac{\upsilon \cdot d}{\nu} \quad (1) \tag{1}$$

where υ is the flow velocity ($\mathrm{m \cdot s^{-1}}$);
d - the internal diameter of the pipe (m);
ν - thekinematic viscosity of the fluid $\nu = \eta / \rho$ ($\mathrm{m^2 \cdot s^{-1}}$).

At the flow rate Q_{V1}, water flew in the pipeline turbulently at the constant velocity of water flowing in the pipeline $\upsilon = 0.06\ \mathrm{m \cdot s^{-1}}$, depending on the temperature of water, the Reynolds number ranged between approximately 12,500 and 18,400 (**Error! Reference source not found.**).

At the flow rate Q_{V2}, water flew in the pipeline turbulently again and at the constant velocity of water flowing in the pipeline $\upsilon = 0.19\ \mathrm{m \cdot s^{-1}}$, depending on the temperature of water, the Reynolds number ranged between approximately 38,500 and 57,000 (Fig. 2).

The calculation of the heat transfer coefficient was made using the following formula:

$$\alpha_k = \frac{Nu \cdot d}{\lambda} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \qquad (2)$$

where Nu is the Nusselt number ($Nu = f(Re, Pr)$) (1);
λ - the thermal conductivity coefficient ($\mathrm{W \cdot m^{-1} \cdot K^{-1}}$);
d - the characteristic dimension (m);
Pr - the Prandtl criterion (1).

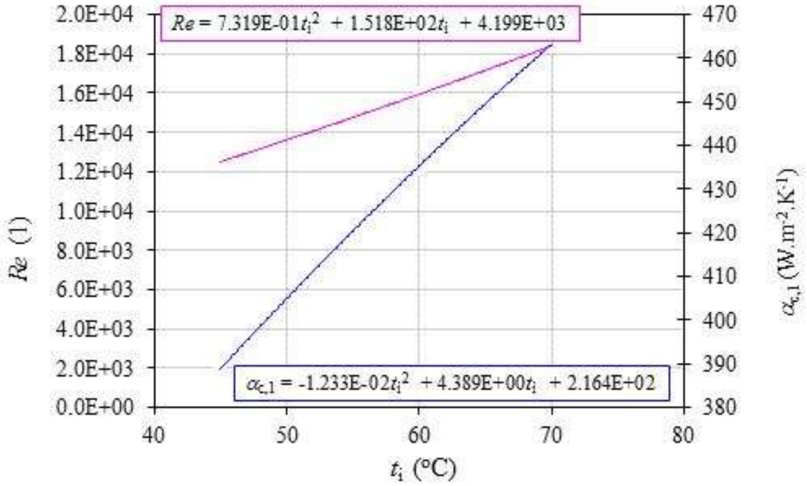

Figure 1.Curve of the Reynolds number and the heat transfer coefficient on the internal side of the pipe, depending on changes in the temperature of water, at $\upsilon = 0.06\ \mathrm{m \cdot s^{-1}}$

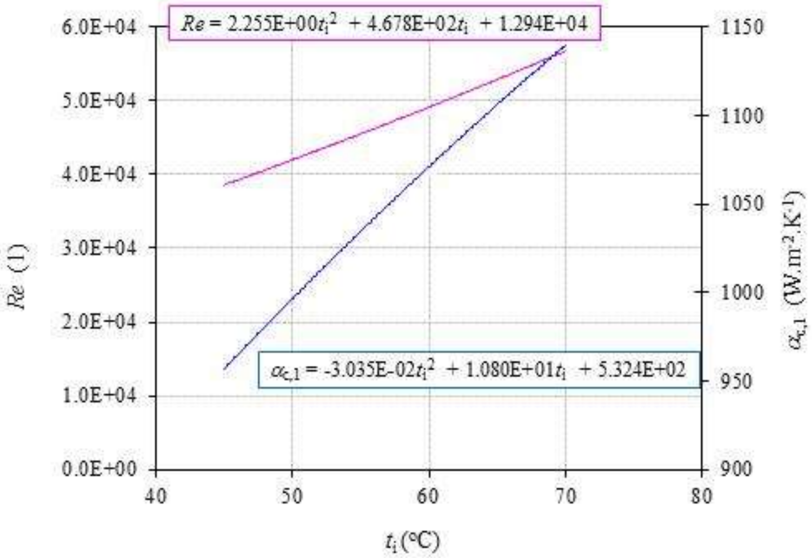

Figure2.Curve of the Reynolds number and the heat transfer coefficient on the internal side of the pipe, depending on changes in the temperature of water, at $\upsilon = 0.19\mathrm{m \cdot s^{-1}}$

Changes in the heat transfer coefficient on the internal side $\alpha_{c,1}$ were related to value of the Reynolds number due to kinematic viscosity v that is affected by the temperature. With a rising temperature of the conveyed water, Re as well as $\alpha_{c,1}$ are also increasing. (Fig.1 and 2). As a result of changes in the water flow rate at the given diameter DN125 and at the constant temperature of water, its velocity changes too, and so does the Reynolds number as well as $\alpha_{c,1}$.

The following table contains the data on the values of individual physical properties required for the calculation of *Re* and $\alpha_{c,1}$ at velocities corresponding to both flow rate limits.

Table 1.Table of physical properties of water and calculated values of criteria required for the calculation of $\alpha_{c,1}$ [2]

t_i (°C)	ρ (kg·m^{-3})	c_p (J·kg^{-1}·K^{-1})	λ (W·m^{-1}·K^{-1})	η 10^4 (Pa·s)	ν 10^7 (m^2·s^{-1})	*Pr* (1)
45	989.8	4181	0.633	6.05	6.08	3.97
50	988.0	4183	0.639	5.49	5.56	3.60
55	985.3	4179	0.645	5.09	5.17	3.31
60	983.0	4183	0.651	4.70	4.78	3.02
65	980.3	4187	0.656	4.38	4.46	2.79
70	977.5	4191	0.661	4.06	4.15	2.57

Table 1.(Continued). Velocity of water in the pipeline υ= 0.06 m·s^{-1}

υ (m·s^{-1})	$Re^{0,8}$ (1)	$Pr^{0,4}$ (1)	*Nu* (1)	$\alpha_{c,1}$ (W·m^{-2}·K^{-1})	*Re* (1)
0.062	1904	1,73	76	388	12578
0.062	2044	1,67	78	404	13745
0.062	2165	1,61	80	418	14769
0.062	2305	1,56	83	434	15978
0.062	2438	1,51	85	447	17135
0.062	2580	1,46	87	462	18393

Table 1.(Continued). Velocity of water in the pipeline υ= 0.19 m·s^{-1}

υ (m.s^{-1})	$Re^{0,8}$ (1)	$Pr^{0,4}$ (1)	*Nu* (1)	$\alpha_{c,1}$ (W·m^{-2}·K^{-1})	*Re* (1)
0.19	4685	1.73	187	956	38761
0.19	5029	1.66	193	995	42359
0.19	5327	1.61	197	1029	45514
0.19	5674	1.56	203	1067	49240
0.19	5999	1.51	208	1100	52806
0.19	6349	1.46	213	1136	56682

Fig. 3 represents the impact of changes in the DN of the pipe at the constant flow rate (Q_{V1}) on the heat transfer coefficient on the internal side of the pipe, and Fig. 4 represents the impact of changes in the DN of the pipe on the Reynolds number.

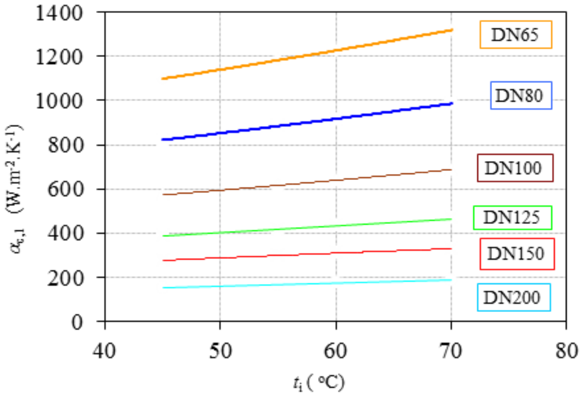

Figure3.Curve of the values of the heat transfer coefficient on the internal side of the pipe affected by changes in the pipe diameter at the constant flow rate.

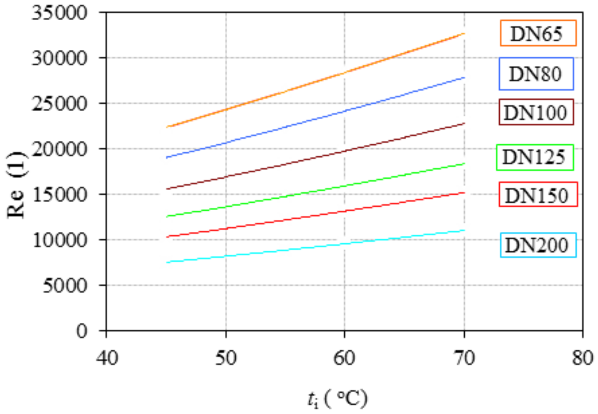

Figure4.Curve of the Reynolds number values affected by changes in the pipe diameter at the constant flow rate.

The values of the heat transfer coefficient $\alpha_{c,1}$ at various nominal diameters of the pipe, affected by the temperature of the conveyed water, are listed in Table 2; all the data apply to the minimum measured flow rate in the system $Q_{V1} = 2.68\ m^3 \cdot h^{-1}$.

Table 2.Values of the heat transfer coefficient on the internal side of the pipe affected by changes in the pipe diameter, at the constant flow rate Q_{V1}.

	υ (m·s^{-1})	t_i (°C)					
		45	50	55	60	65	70
		$\alpha_{c,1}$(W·m^{-2}·K^{-1})					
DN 65	0.195	1,098	1,143	1,182	1,226	1,264	1,319
DN 80	0.142	821	860	884	916	945	986
DN 100	0.094	572	595	616	638	658	687
DN 125	0.062	388	404	418	433	447	466
DN 150	0,042	276	287	298	308	317	328
DN 200	0.022	155	161	167	173	178	186

The internal heat exchange, represented by the coefficient $\alpha_{c,1}$, only depends on the velocity of flowing water if there is a change in the velocity of water flowing in the pipeline as a result of a change in the nominal diameter but at the constant water flow rate. As the nominal diameter decreases, the velocity of water increases, and hence there is an increase in the value of the Reynolds number and an increase in the intensity of heat exchange through an increase in the coefficient of internal heat exchange $\alpha_{c,1}$.

CONCLUSION

The determination of heat losses in heat distribution systems may be carried out applying the analytical procedures described in the technical literature. As indicated by the extent of the calculations of individual physical parameters, the analytical methods for expressing the heat loss are rather complicated and even impracticable without the knowledge of particular values of physical parameters, for example the coefficient of heat transfer on the internal and external sides of the pipeline, etc.

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