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HEAT LOSSES EVALUATION FOR DOMESTIC HOT WATER DISTRIBUTION SYSTEMS

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In sanitary systems assembly, domestic hot water distribution/supply networks represent an important weight for energetically balance.

This paper presents, in an analytical and graphical manner, the computational tools needed for domestic hot water piping system behavior characterization in different functional and structural assumptions.

1. Introduction

For the evaluation of domestic hot water distribution systems behavior, the next indicators must be determined:

a) the quantity of stored heat in pipes (water and pipe material);

b) the hot water temperature evolution, in pipes, for periods of no circulation;

c) the heat losses from the hot water to surrounding environment, during periods of no circulation, until the minimum comfort temperature is reached;

d) the specific heat losses in domestic hot water distribution pipes;

e) the minimum insulation thickness, depending on thermal conductivity and quality classes of thermal insulating materials.

The assessment of mentioned indicators is made by the implementation of thermal balance equations, adapted to specific functional conditions, considering the physical and geometric parameters for the pipe material and working hypothesis.

For temperatures, the European Norms and National Standards normalized values are used, respectively 60°C for hot water, 10°C for cold water, 20°C for surrounding environment and 40°C for minimum comfort temperature of domestic hot water.

This analysis is applied for the insulated pipes and also for pipes without insulation, during circulation and stagnation periods.

2. The Quantity of Stored Heat in Pipes

Represents the heat retained in pipe materials, corresponding to the temperature difference $(\theta_{ac} - \theta_{\text{amb}})$, the same as in the water volume stored inside pipes, for temperature difference $\theta_{ac} - \theta_{ar}$.

The stored heat has the expression

$$Q = \rho_{\text{water}} v_{\text{water}} c_{\text{water}} (\theta_{ac} - \theta_{ar}) + \rho_m v_m c_m (\theta_{ac} - \theta_m), \tag{1}$$

where: $\rho_{\text{water}} = 983.2\ \text{kg/m}^3$, $c_{\text{water}} = 4,185\ \text{J/kg}\cdot{}^\circ\text{C}$, and ρ_m, [kg/m^3], c_m, [J/kg·°C] represent pipe material characteristics.

3. The Hot Water Temperature Evolution, in Pipes, for Periods of no Circulation

During the stagnation intervals between two utilizations, the heat is transferred from the inside pipe water volumes to the surrounding environment. Depending on stagnation periods duration and the level of thermal insulation, a temperature decrease, under the comfort limit (40°C), is possible.

In these situations, from the energetically point of view, additional losses appear with the evacuation of unusable water volumes, until the accepted hot water temperature is acquired.

This time dependent temperature is given by

$$\theta_f = \theta_{\text{amb}} + (\theta_{ac} - \theta_{\text{amb}}) e^{-\frac{KS}{mc}\tau}, \tag{2}$$

where: θ_f is the domestic hot water instantaneous temperature; θ_{amb} – surrounding environment temperature; θ_{ac} – domestic hot water nominal temperature; K – overall heat transfer coefficient; S – thermal transfer surface; m – stored water mass; c – specific heat capacity of pipe materials; τ – stagnation period between two utilizations.

4. The Heat Losses from the Hot Water to Surrounding Environment, During Periods of no Circulation, until the Minimum Comfort Temperature is Reached

Depending on the stagnation period, the transferred heat is

$$Q = m_{\text{water}} c_{\text{water}} (\theta_{ac} - \theta_f), \tag{3}$$

where θ_f represents the hot water temperature after a time period, τ, determined with relation (2).

5. The Specific Heat Losses in Domestic Hot Water Distribution Pipes

The specific heat losses, on unit of length, is expressed by

$$q = K \Delta T, \tag{4}$$

where

(5) $$K = \frac{1}{R} = \frac{1}{\frac{1}{\pi D_i h_i} + \sum_1^j \frac{1}{2\pi\lambda_i}\ln\frac{D_e}{D_i} + \frac{1}{\pi D_e h_e}},$$

for pipes without insulation, respectively

(6) $$K = \frac{1}{R} = \frac{1}{\frac{1}{\pi D_i h_i} + \sum_1^j \frac{1}{2\pi\lambda_i}\ln\frac{D_e}{D_i} + \frac{1}{2\pi\lambda_{iz}}\ln\frac{D_{iz}}{D_e} + \frac{1}{\pi D_{iz} h_e}},$$

for insulated pipes. Here h_i represents the internal coefficient of superficial thermal convection

$$h_i = 2,538\frac{v^{0.8}}{D_i^{0.2}}, [\mathrm{W/m^2.{}^\circ C}],$$

with: $v = 0,6$ m/s – fluid velocity in pipes, D_i – interior diameter, [m]; external coefficient of superficial thermal convection is given by

$$h_e = 9.4 + 0.052(\theta_{ac} - \theta_{\mathrm{amb}}), [\mathrm{W/m^2.{}^\circ C}].$$

For insulated pipes $h_e = 10$ W/m^2.°C. The utilized notations are: θ_{ac} – domestic hot water temperature, [°C]; θ_{amb} – surrounding environment temperature, [°C]; D_e – exterior diameter of pipe, [m]; D_{iz} – interior diameter for the insulated pipe, [m]; λ_i – heat conductivity for pipe materials, [W/m.°C]; λ_{iz} – heat conductivity of thermal insulation materials, [W/m.°C].

6. The Minimum Insulation Thickness, Depending on Thermal Conductivity and Quality Classes of Thermal Insulating Materials

According to EN 12828 – *Heating Systems in Buildings*, the thermal insulation level for hot water pipes (heating and/or domestic hot water installations) is differentially structured in six classes with minimum values in direct correlation with the overall heat loss coefficient as follows:

a) insulation class 1: $K = 3.3D_e + 0.22$ W/m.°C,
b) insulation class 2: $K = 2.6D_e + 0.20$ W/m.°C,
c) insulation class 3: $K = 2.0D_e + 0.18$ W/m.°C,
d) insulation class 4: $K = 1.5D_e + 0.16$ W/m.°C,
e) insulation class 5: $K = 1.1D_e + 0.14$ W/m.°C,
f) insulation class 6: $K = 0.8D_e + 0.12$ W/m.°C,

where D_e is the exterior diameter of pipe, [m].

For domestic hot water piping systems, EN 12828 demands at least the first insulation class.

With the implementation of mentioned equations, for the usual series of standardized pipe diameters and for the usually used materials – steel, cooper, polyethylene, polypropylene, polymerized vinyl chloride – a set of diagrams were established for the evaluation of the energetically behavior of installations in different functional and structural hypothesis (Figs. 1,...,6).

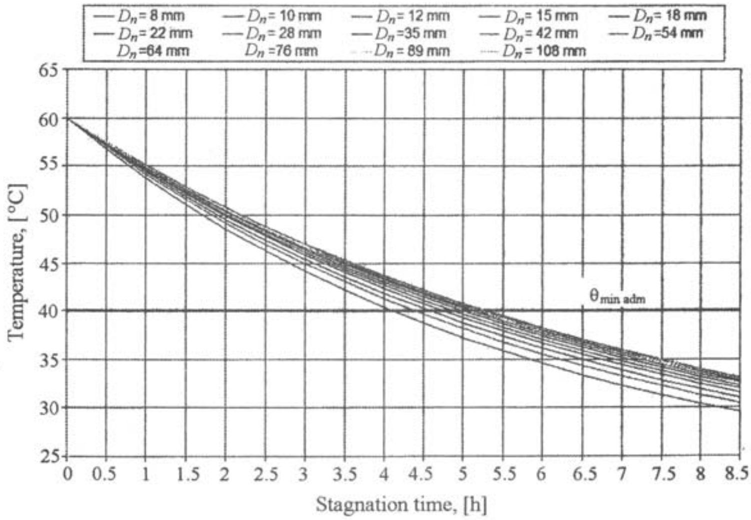

Fig. 1.– Hot water temperature evolution for uninsulated cooper pipes.

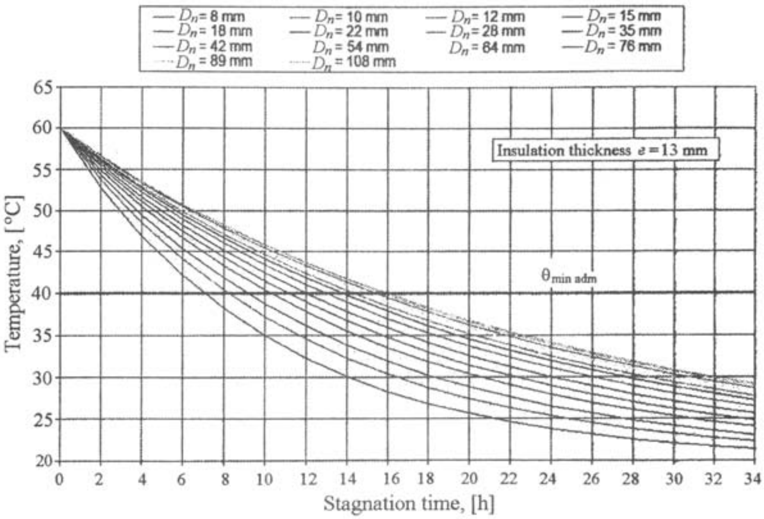

Fig. 2.– Hot water temperature evolution for insulated cooper pipes.

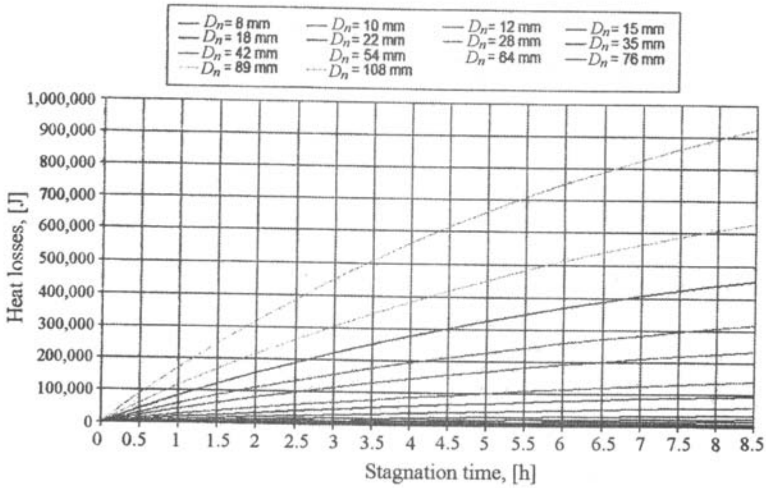

Fig. 3.- Heat losses for uninsulated cooper pipes.

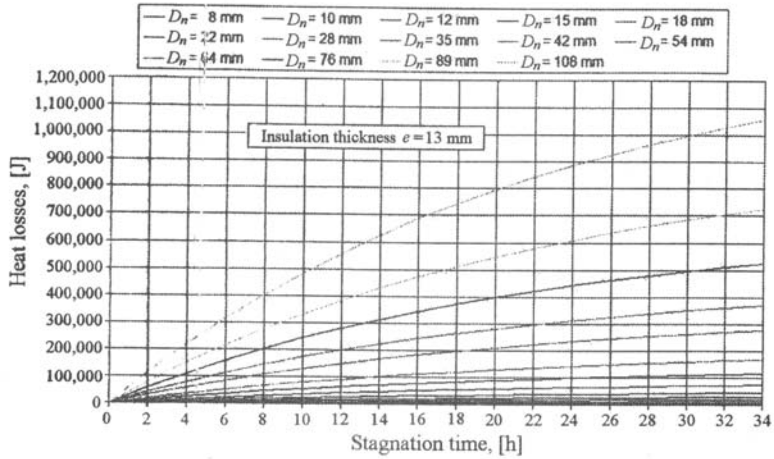

Fig. 4.- Heat losses for insulated cooper pipes.

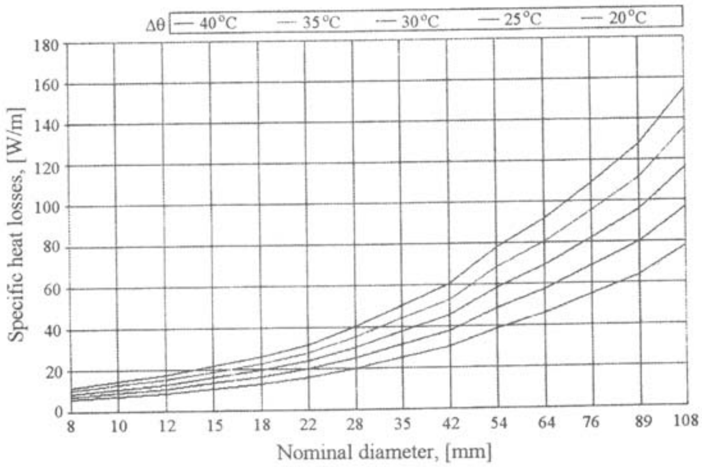

Fig. 5.– Specific heat losses for uninsulated cooper pipes.

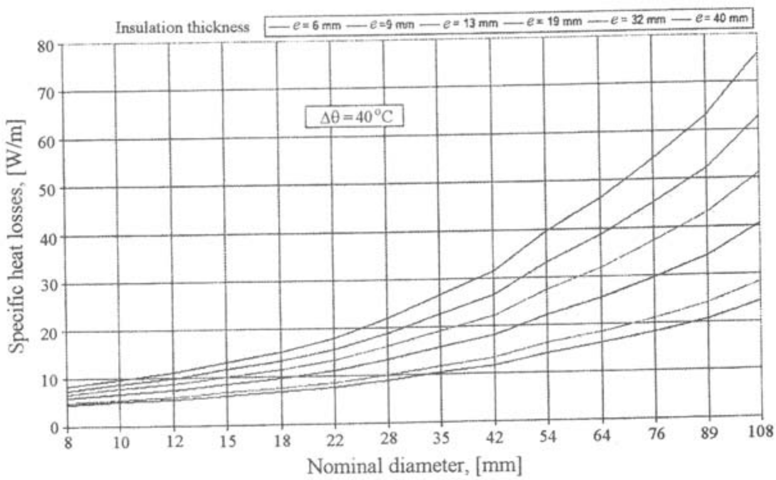

Fig. 6.– Specific heat losses for insulated cooper pipes.

As an exemplification, the indicated parameters variation diagrams are presented for cooper pipes.

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EVALUAREA PIERDERILOR DE CĂLDURĂ DIN REŢELELE INTERIOARE DE DISTRIBUŢIE A APEI CALDE DE CONSUM

(Rezumat)

În ansamblul sistemelor de instalaţii, reţelele de alimentare/distribuţie a apei calde de consum intervin cu o pondere importantă în bilanţul energetic.

Se prezintă, analitic şi grafic, instrumente de lucru pentru caracterizarea comportării energetice a conductelor în diferite ipoteze de alcătuire şi funcţionare.