Thermal Insulation of Distribution Pipelines

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Abstract— *In heat distribution systems, which are used to supply a heat-conveying medium to consumers, a certain amount of heat is always released to the surrounding environment. Such inevitable and undesired release of heat is referred to as heat loss. Heat loss causes that the medium flowing inside the distribution system cools down and its subsequent heating up is therefore more demanding. The consequences include higher costs of heat and hot water production not only for system operators but also for end consumers. Therefore, attention should be paid to thermal insulation when incorporated in heat distribution systems, primarily to its quality and thickness.*

Keywords— ***heat network, efficiency, heat loss, ambient temperature.***

I. INTRODUCTION

A heat network is a pipeline system used to transport thermal energy, carried by a heat-conveying medium, from a source to an appliance. Thus, it is a system of buildings and equipment facilitating heat transport from central sources to heat consumers, regardless of their performance, nature and method of heat utilisation. A basic component of a heat network is a pipeline, including accessories.

II. FUNCTION OF HEAT NETWORK INSULATION

The purpose of thermal insulations of heat networks within the central supply of heat is to reduce the heat escape from a heat-conveying medium to the surrounding environment and maintain the operating temperature of the heat-conveying medium in the pipeline or a facility. Pipelines are insulated not only to prevent heat loss or cold loss, but also to prevent undesired heating [1]. If the temperature of the transported medium is higher than the ambient temperature, insulation also protects against potential burn injuries; on the other hand, at temperatures lower than the ambient temperature, it prevents pipeline misting [1].

Selection of an insulation type should be based on the temperature of the heat-conveying medium and the ambient temperature of the environment in which the heat network is to be built.

A general rule is that the appropriate insulation should exhibit minimum thermal conductivity at comparable temperature parameters; that is to say, the insulation surface temperature should be minimal in the same heat transport conditions. This is also closely related to the minimum value of the heat transfer coefficient for the heat transfer from the insulation surface to the air.

III. THERMAL INSULATION STATE OF THE ART

Thermal insulations are made of inorganic as well as organic materials. The key requirements that should be met by thermal insulations include: low temperature conductivity and thermal conductivity, non-absorbency, resistance to mechanical and chemical effects, they must be not aggressive to the pipeline surface and they must be hygienically acceptable.

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Newly constructed or reconstructed pipelines are nowadays equipped with the pre-insulated METALNET system with the service life of as much as 30 years under stable thermal stress [3].

At the thermal stress of up to 150 °C, pre-insulated pipelines are produced as a complex system consisting of a heat pipe, insulation and a jacket pipe, together forming one compact unit. The outer surface of a heat pipe and the inner surface of the jacket pipe are connected by the insulation material which transfers forces to both pipes.

Pipelines are insulated by PUR foam consisting of freon-free polyurethane foam made of polyol and isocyanate. Pipelines may be laid underground channel-free in a HDPE jacket, or overhead in a SPIRO jacket. The HDPE jacket is made of high-density polyethylene (Fig. 1) and the SPIRO jacket is made of spiral-rolled zinc-coated steel (or aluminium) sheet (Fig. 2) [3].

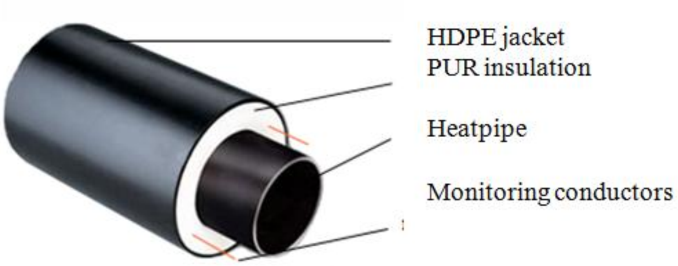

FIGURE 1: Pre-insulated system for underground channel-free applications[3]

FIGURE 2: Pre-insulated system for overhead applications [3]

Fig. 3 shows the curves of correlations between linear thermal resistance R_l and specific heat loss q_l with an insulation radius $r_3$for overhead application of the pre-insulated METALNET system which exhibits a very low heat transfer coefficient ($\lambda = 0.026$ W·m^{-1}·K^{-1}). The diagram relates to the nominal diameter DN125, and the heat transfer coefficient for the heat transfer from the insulation surface to the surrounding environment was $\alpha_2 = 3$ W·m^{-2}·K^{-1}.

The graphs indicate that as the insulation thickness increased, thermal resistance R_l increased and heat loss q_l continuously decreased.

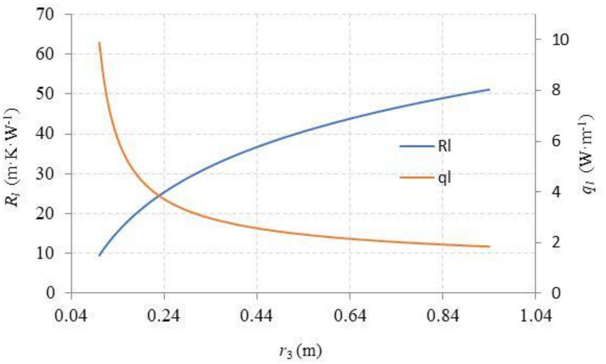

FIGURE 3: Correlation between specific heat loss q_l and linear resistance R_l with radius r_3

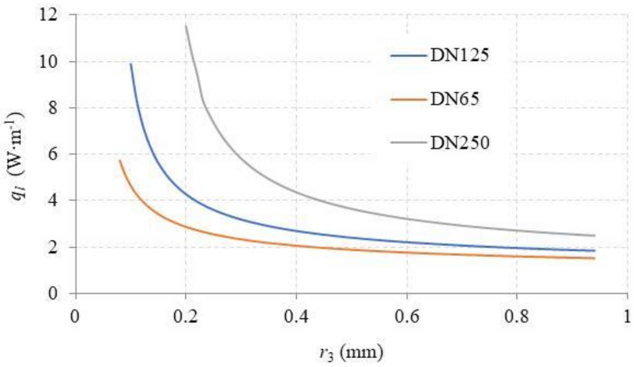

FIGURE 4: Correlation between specific heat loss q_l and radius r_3 for various pipe diameters (DN)

Fig. 4 shows the correlation between specific heat loss q_l and insulation radius $r_3$for three different pipe diameters. The curves clearly show that as the inner radius of the pipe increased, specific heat loss increased with the same insulation thickness.

IV. ECONOMIC INSULATION THICKNESS

An insulation thickness is usually designed with the aim to achieve the highest cost saving or ensure protection of persons moving around the insulated object.

A thickness of the insulation material s_{ins} is selected depending on a type of the insulation material, required temperature of the surface to be insulated, pipeline diameter, price of the insulation material, price of heat, annual operation hours, as well as other, less important factors. The thickness that meets all the requirements above is referred to as the economic insulation thickness.

The economic insulation thickness is the thickness at which the sum of the cost of heat loss reduction and the cost of the insulation system for a given period of time reaches the lowest value. A thicker insulation reduces the heat loss and therefore also related costs, but it increases the cost of the insulation system.

The cost of insulation is not a linear function of the insulation thickness. As the insulation thickness increase, such increase in the cost of the insulation system is more intensive than the reduction of the cost of heat loss. It is always necessary to search for a compromise with the lowest possible costs. Economic insulation thickness may be identified while applying several different methods, such as the method of minimum cost of insulation [4].

The annual costs of various insulation thicknesses (annual cost of material, annual cost of installation and maintenance cost) also includes the annual cost of heat loss. The annual cost of material may be calculated as the fraction of the total cost of insulation and the planned service life of the insulation system; the same applies to the annual cost of installation. The thickness which exhibits the lowest total cost is referred to as the economic insulation thickness. The above described method of identification of the economic thickness is depicted in Fig. 5.

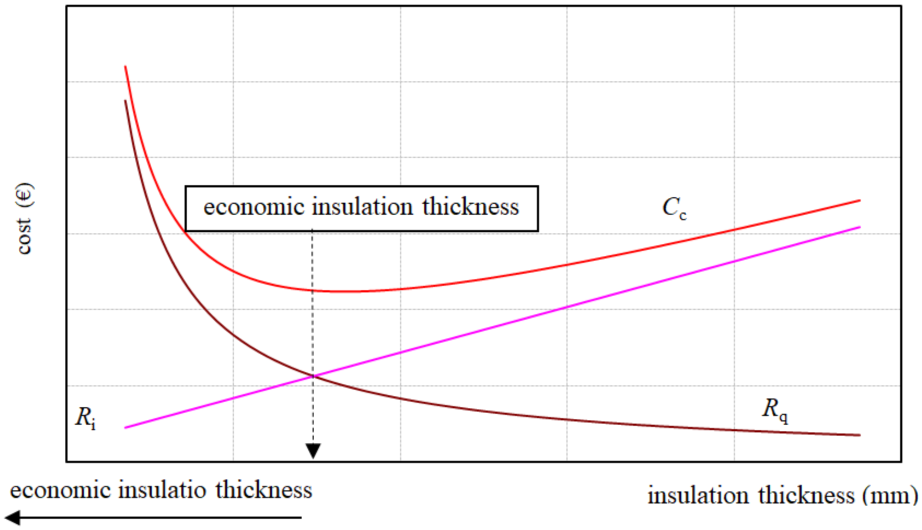

FIGURE 5: Identification of the economic insulation thickness

For a particular type of the insulation material and various thicknesses, the annual heat loss may be calculated using Formula (1); the relevant curve is the *Rq* Curve in the diagram.

4.1 The annual heat loss is calculated using Formula [5]:

$$R_q = 3.6 \cdot 10^{-6} \cdot q_l \cdot C_e \cdot h \ (€ \cdot m^{-1} \cdot year^{-1}) \quad (1)$$

Wherein q_l is the specific heat loss of the pipeline (linear heat flux density) ($W \cdot m^{-1}$), C_e is the cost of energy ($€ \cdot GJ^{-1}$) and h represents the operation hours per year ($hour \cdot year^{-1}$).

The cost of insulation is calculated using the values of the insulation service life per annual acquisition cost; these values represent line R_i in Fig. 5.

4.2 The cost of insulation calculated for one year:

$$R_i = \frac{C_i}{r} \ (€ \cdot m^{-1} \cdot year^{-1}) \quad (2)$$

Wherein C_i is the total cost of the installed insulation ($€ \cdot m^{-1}$) and r is the insulation service life (years).

The total cost, i.e. the annual procurement cost per1 m of insulation, represents the C_c Curve in Fig.5. This curve initially declines down to the minimum value, where the total cost is the lowest, and then inclines again.

4.3 The total cost is calculated using the following formula:

$$C_c = R_q + R_i \ (€ \cdot m^{-1} \cdot year^{-1}) \quad (3)$$

The insulation thickness on the horizontal axis, under the minimum point, determines the economic insulation thickness for the given insulation material.

V. CONCLUSION

Thermal insulation represents an integral part of heat distribution systems. Its role is to prevent heat escape to the surrounding environment and maintain the required temperature of the heat-conveying medium inside the pipeline. One of the tasks of insulation materials used in industrial applications is to reduce heat loss not only in the technological equipment but also in the heat distribution system. Cost-efficiency of the operation of pipeline systems, in terms of heat and technology, is most significantly affected by a proper choice of the insulation material and a correct calculation of the thickness of the selected insulation.

ACKNOWLEDGEMENTS

This paper was written with the financial support of the granting agency VEGA within the project solution No. 1/0108/19 and No. 1/0626/20 and of the granting agency KEGA within the project solution No. 005TUKE-4/2019.

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