Experimental study pipe insulation heat losses with moisture ingress

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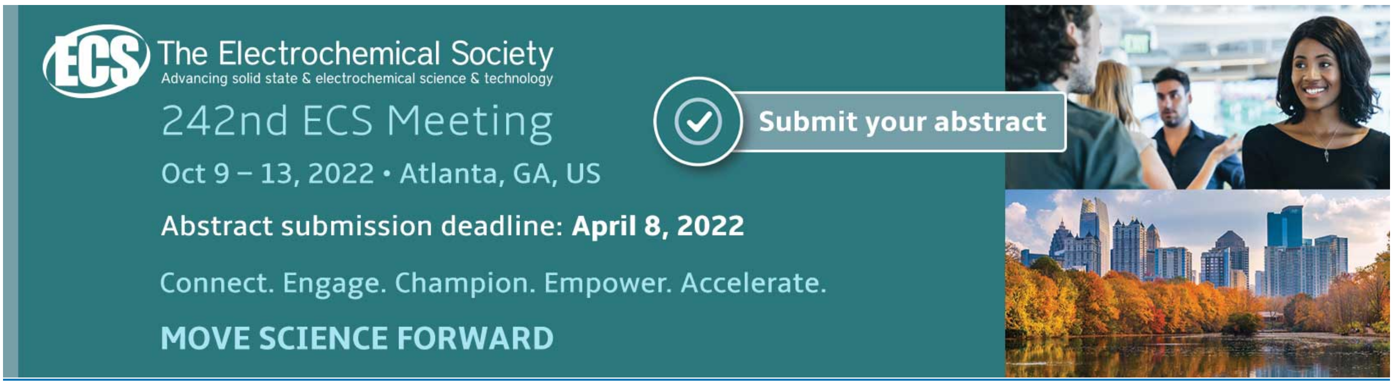

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Experimental study pipe insulation heat losses with moisture ingress

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Abstract. The article presents the experimental studies of the influence of moisture ingress on thermal performance pipe insulation. To determine heat losses of the insulating material under moisture ingress, the guarded heated pipe method was used. Rock wool was used as insulation material. Moistening of the insulating material was carried out according to the injecting method. The moisture content by weight was 2%, 4% and 6%, the temperature of the heated pipe was 45 °C, 65 °C and 90 °C. Heat losses of rock wool can increase from 1.3 to 1.9 times, depending on the temperature of the heated pipe and the moisture content.

1. Introduction

Energy saving in the transportation of thermal energy is one of the most important problems in reducing energy consumption. Heat losses through the insulation of pipelines in heating networks can be significant [1], therefore, there is potential for energy savings. In heat networks, various insulating materials are used [2]. Mineral wool based on rock wool has become widespread in heating networks due to its thermal performance and ability to withstand high temperatures. However, the characteristics of rock wool deteriorate with time [3]. The heat losses of the insulating material increases with the penetration of moisture [4]. Therefore, when choosing thermal insulation of heating networks, it is should be considered the effect of moisture on heat losses. In the literature, various methods have been proposed for choosing the optimal thermal insulation materials [5]. However, they do not consider the thermal performance of insulation materials with moisture ingress to the lack of experimental data. Thermal performance of insulation material under wet conditions are affected by temperature, density and degree of moisture content [6]. Also, heat losses can differ depending on the manufacturer of the insulation material [7], due to the differences in the manufacturing process. The thermal conductivity of insulating materials is mainly determined on flat slab samples according to the guarded hot plate method [8]. This method is used both for flat slab insulation systems and partially for pipeline insulation. Another method is the guarded hot pipe method [9]. This method is designed for determining the thermal conductivity of pipeline insulation. The available information on the thermal conductivity of heat-insulating materials was mainly obtained on flat slab samples [10-11], while studies with the guarded hot pipe method are limited. The results obtained on flat slab samples are not always applicable to pipeline insulation. This paper presents a study of the thermal performance of rock wool with different levels of moisture content and temperature using the guarded hot pipe.

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2. Methodology and measurement apparatus

Experimental studies were carried out based on the guarded hot pipe method [9]. The experimental equipment is shown in figure 1. The test section was 1440 mm long and 89 mm in diameter. The test section had three zones. The working area was located in the center of the test section. The guarded areas were on the left and right of the pipe. The length of all sections was the same 480 mm. The test section was heated by electric heating. The insulation temperature was measured on the surface of the heated test section and on the outer surface of the insulation. The temperature measurement scheme is shown in figure 2. To compensate for heat losses in the axial direction, the temperature of the pipe surface in the guarded areas was maintained the same as in the working area. For this, the heating of the guarded areas was regulated separately from the heating of the working area. The temperature of the test section was kept constant using control equipment. Heat losses of the insulation material were determined from the working area. The insulating material was wired rock wool intended for heating networks. The nominal insulation density of rock wool ρ was 80 kg/m^3, thickness δ 100 mm. Rock wool was installed on the test section according to the procedure used in heating networks (figure 3). When rock wool was installed, the thickness of the material decreased. The insulation density on the heated pipe was ρ^* 104 kg/m^3. The injection method was used to moisten the material [10]. Moisture was injected evenly into the work area until the desired moisture content was reached.

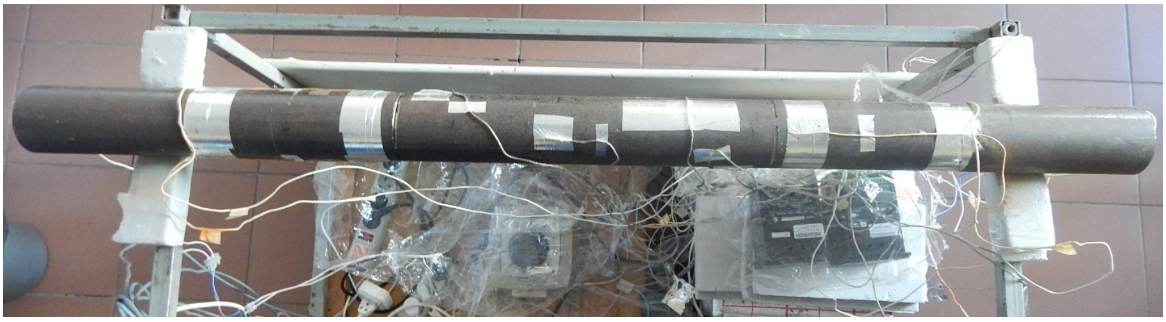

Figure 1. Experimental setup. Guarded hot pipe.

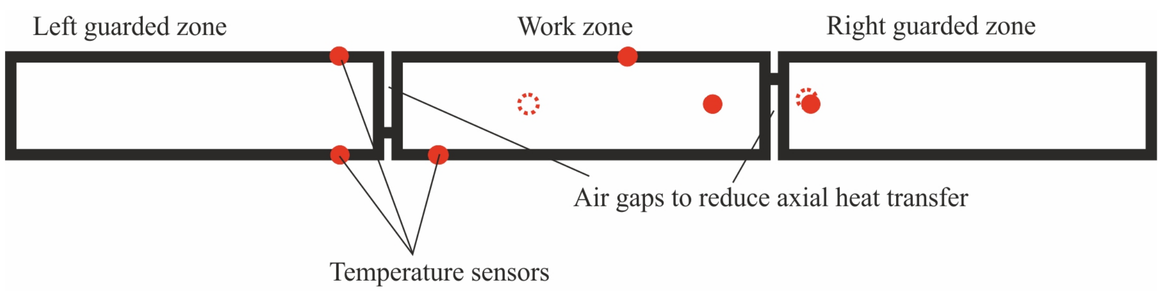

Figure 2. Temperature sensor layout.

3. Results

Studies were carried out at three test section temperatures of 45°C, 65°C, 90°C. The temperature of the outer surface of the insulation was 26.4±2.9°C. Moisture content (MC) by weight was calculated by the formula (1) and was 2%, 4%, 6%.

$$\mathrm{MC} = \frac{m_{\mathrm{MC}}}{m_{\mathrm{dry}} + m_{\mathrm{MC}}} \cdot 100\% , \tag{1}$$

where m_{MC} – mass of moisture content, m_{dry} – mass of dry insulation in work area. Heat losses of dry and wet insulation material were found according to formulas (2) and (3).

$$q_{\text{dry}} = \frac{N_{\text{dry}}}{L} \text{ W/m}, \quad (2)$$

$$q_{\text{wet}} = \frac{N_{\text{wet}}}{L} \text{ W/m}, \quad (3)$$

where N_{dry}, N_{wet} – average electric heating power in the working area at a constant temperature of the test section for dry and wet insulation material; L – working area length. Electric heating power for dry and wet insulation material was determined in the following order:

- The temperature of the test section was set;
- When a steady state is reached, the heating power of dry insulation was recorded (N_{dry} has been averaging over the last half hour);
- Water was injected into the material;
- After five hours of measurements, the power was averaged N_{wet}.

Figure 3. Measurement of heat losses of rock wool.

Figure 4 shows the variation of the heating power of wetted insulation over time. After the insulation is moistened, it gradually dries out. With increasing time, the averaging value of N_{wet} will tend to the value of dry insulation N_{dry}. For five hours, there is no significant decrease in heating power due to drying out of the insulation. Therefore, the averaging time was chosen to be five hours.

Table 1 and figures 5 and 6 show the results of measurements of heat losses of rock wool at different levels of moisture contents and temperature. With an increase in the levels of moisture and temperature, heat losses through rock wool increase. At higher temperatures, the effect of an increase in the levels of moisture content on the change in heat losses $q_{\text{wet}}/q_{\text{dry}}$ is generally less. At a temperature of 45 °C, heat losses increased from 1.3 to 1.9 times with a change in moisture content from 2% to 6%. At a temperature of 90 °C, heat losses increased from 1.6 to 1.7 times with a change in moisture content from 2% to 6%. This is possibly due to the fact that at higher temperatures the drying time is reduced.

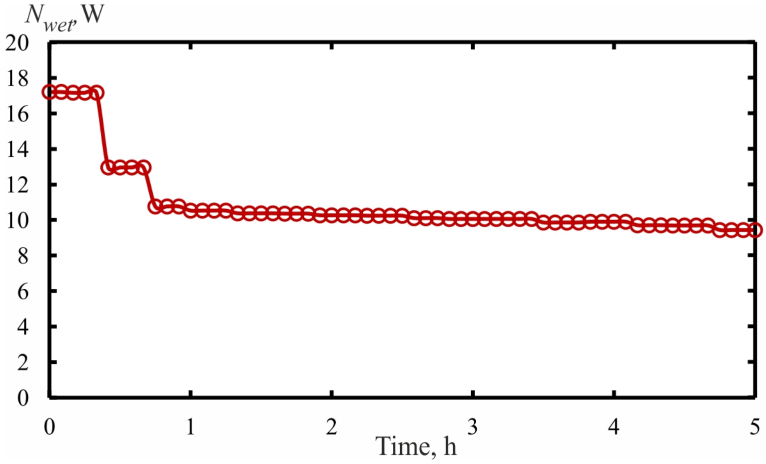

Figure 4. Heating power of wetted insulation over time.

Table 1. Measurement results of heat losses of rock wool.

Temperature °C	MC %	q W/m	q_{wet}/q_{dry}
45	0	4	-
	2	5.4	1.3
	4	5.9	1.5
	6	7.5	1.9
65	0	10.1	-
	2	12.9	1.3
	4	14.0	1.4
	6	16.6	1.7
90	0	14.2	-
	2	22.6	1.6
	4	25.3	1.8
	6	24.2	1.7

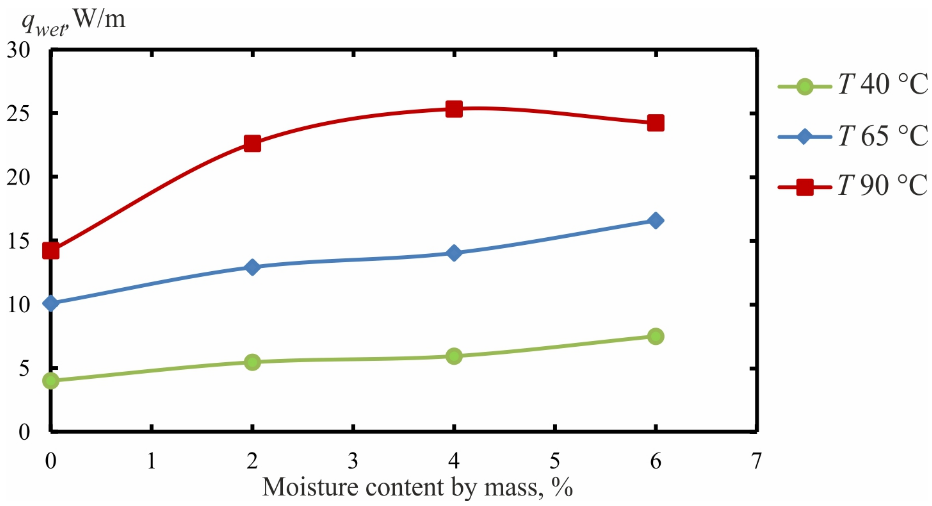

Figure 5. Heat losses of rock wool with moisture ingress.

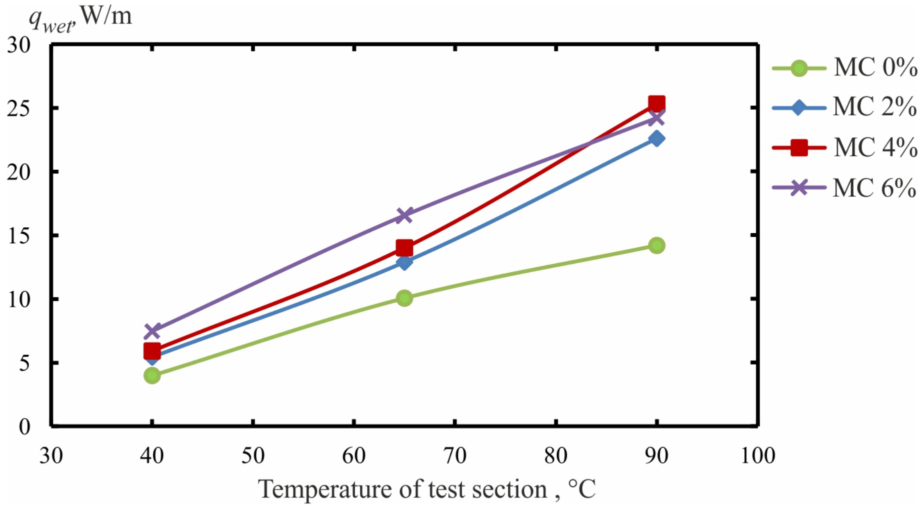

Figure 6. Heat losses of rock wool with test section temperature.

4. Conclusion

The influence of moisture content on the heat losses of rock wool was studied experimentally using a guarded heated pipe. It was found that the presence of moisture always leads to an increase in heat losses. In the investigated range, the maximum increase in heat losses was 1.9 times at the heated pipe temperature of 45 ° C and a moisture content of 6%. The minimum increase in heat losses was 1.3 times at the heated pipe temperature of 45 ° C, 65 ° C and a moisture content of 2%.

Acknowledgments

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