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Destruction of thermal insulation and effectiveness of the thermal energy transfer system

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Abstract. The work is devoted to improving the efficiency of the system of thermal energy transportation. The results of determining the thermophysical properties, such as the coefficient of thermal conductivity, water absorption, vapor permeability, the percentage of structural changes in the fibers during heating and exposure to vibration, basalt super thin fiber and other thermal insulation materials are presented. The results of thermal imaging testing control of basalt super-thin fiber mats are presented. The effect of the degree of thermal insulation aging on the increase in the heat flow density is shown.

1 Introduction

Reducing heat losses during transportation of the coolant is one of the key aspects of improving the efficiency of the thermal energy transportation system. The rise in prices for fuel and energy resources in the context of commercial relationships between energy supplying organizations and consumers makes the problems of more accurate determination of heat and coolant losses urgent.

High-energy-intensive industries, where high-temperature heat-transfer agents (steam) are used in large volumes, have a high potential for energy saving, which is not fully realized.

In many ways, a high level of transport losses of thermal energy is caused by the long-term operation of pipelines in abnormal conditions [1-2].

The effectiveness of the coolant transportation system is influenced by a combination of such factors as the change in the operating mode of the system, as well as the change in the thermophysical properties of the insulation during operation [3-4].

The actual state of thermal insulation, especially in certain areas, may differ significantly from the initial one provided for by the project [5-9].

The durability of thermal insulation depends on the temperature of the insulated surface. So the use of high-temperature coolants (steam) can lead to thermal destruction of thermal insulation. It is known that the materials used in Russia can lead to an increase in the coefficient of thermal conductivity by 20-30% for the first time already 5 years of operation. For example, manufacturers guarantee that polyurethane foam operates at a temperature of 150 ° C. However, in fact, at a temperature of 120 ° C, its destruction occurs [10-13].

In connection with the foregoing, an important criterion in the selection of thermal insulation materials is an indicator of the durability of thermal insulation properties, as well as the conservation of the design thermophysical properties of an insulating material throughout the entire service life.

2 Determination of thermal properties of thermal insulation materials

The results of the comparison of various heat-insulating materials with one-sided heating, as well as under vibration exposure are presented in table 1. According to the presented results, basalt super-thin fiber is subject to the least structural changes [14].

Determining the sintering temperature of basalt super-thin fiber revealed maximum temperature indexes for densities of 30 kg/ m^3; 40 kg/ m^3; 60 kg/ m^3 (Figure 1). Average index is 1144 ˚C.

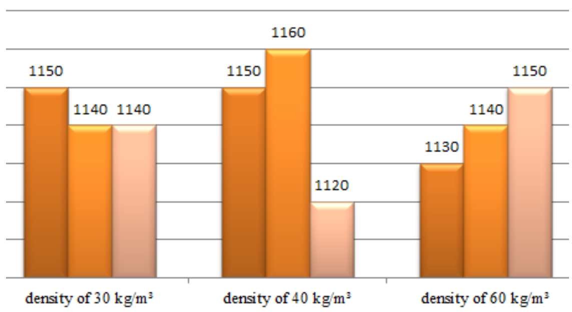

Fig. 1. BSTF sintering temperature.

The determination of such thermal insulation properties as water absorption (see Table 2) and vapor permeability was also conducted (Figure 2).

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Table 1. The percentage of structural changes in various fibers with one-sided heating for three hours with vibration frequency ν = 50 Hz and amplitude A = 1 mm.

Fibername	Initial thickness of the test sample, mm	Heating temperature, degrees C				
		400	600	700	800	900
BTF	40	2.0	2.0	5.0	9.0	12.0
Fiberglass	40	95	100	100	100	100
BSTF	40	0.01	0.15	0.23	0.03	0.35
Mineral fiber	40	75	95	100	100	100
Slag fiber	40	100	100	100	100	100

Table 2. Water absorption of various heat-insulating materials.

Water absorption, %	Polyethylene foam	Reinforced foamconcrete	Improved reinforced foam concrete	Polyurethane foam	Phenolic porous plastics	BSTF
	1	20	15	10	40	1

Table 3. Thermal conductivity of basalt fibers of different density depending on temperature.

Average temperature, ˚C	Fiber thermal conductivity, W/(m˚C), by density kg/m^3					
	60		80		100	
	BTF	BSTF	BTF	BSTF	BTF	BSTF
50	0.06	0.0475	0.057	0.044	0.054	0.046
100	0.072	0.0495	0.068	0.049	0.062	0.051
150	0.085	0.055	0.081	0.055	0.073	0.056
200	0.105	0.062	0.097	0.0605	0.086	0.061
250	0.129	0.0695	0.117	0.0665	0.091	0.0765
300	0.166	0.077	0.141	0.072	0.118	0.0715

Thus, when choosing a heat-insulating material, an important indicator is not only a low coefficient of thermal conductivity (see table 3), but also such properties as water absorption, vapor permeability, sintering temperature, the amount of structural changes during heating, which allow to maintain the thermal properties stated in the design from the operating conditions of pipelines for a long time.

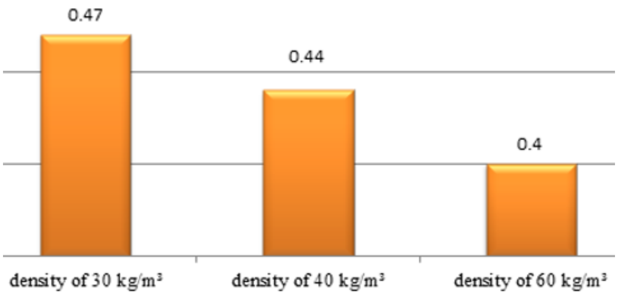

Fig. 2. Determination of BSTF vapor permeability, mg/(m·h·Pa).

3 Results

According to the results of a seven-day test of BSTF mats (60 mm thick, density 70) at the Zelenodolsk plywood factory (gas supply pipeline) the following indexes were achieved: The temperature at the surface of the gas supply pipeline is 235 ° C. The temperature on the surface of the material is 35 ° C. The results of thermal imaging control are presented in Figure 3.

According to the methodology described in Building codes and regulations 41-03-2003 "Thermal insulation of equipment and pipelines" (updated version of Set of rules 61.13330.2012) [15-16], the specific heat losses of the steam pipeline above-ground gasket d-159 mm were calculated, through which steam with temperature of 194 ° C, thermal insulation basalt + polyurethane foam (the initial state of thermal insulation and with destruction was taken into account). It was also considered the option of using as insulating material BSTF. The calculation results are presented in the diagram (Figure 4).

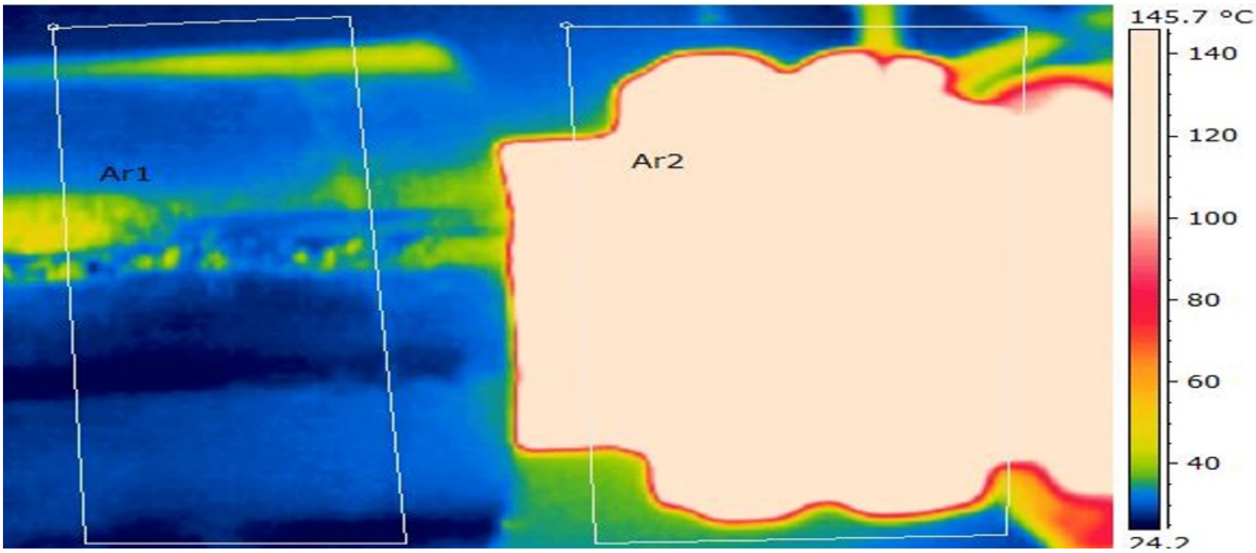

Fig. 3. The results of the thermal imaging control test of BSTF mats: Ar 1 - installation zone with cylinders, Ar 2 - installation zone without cylinders.

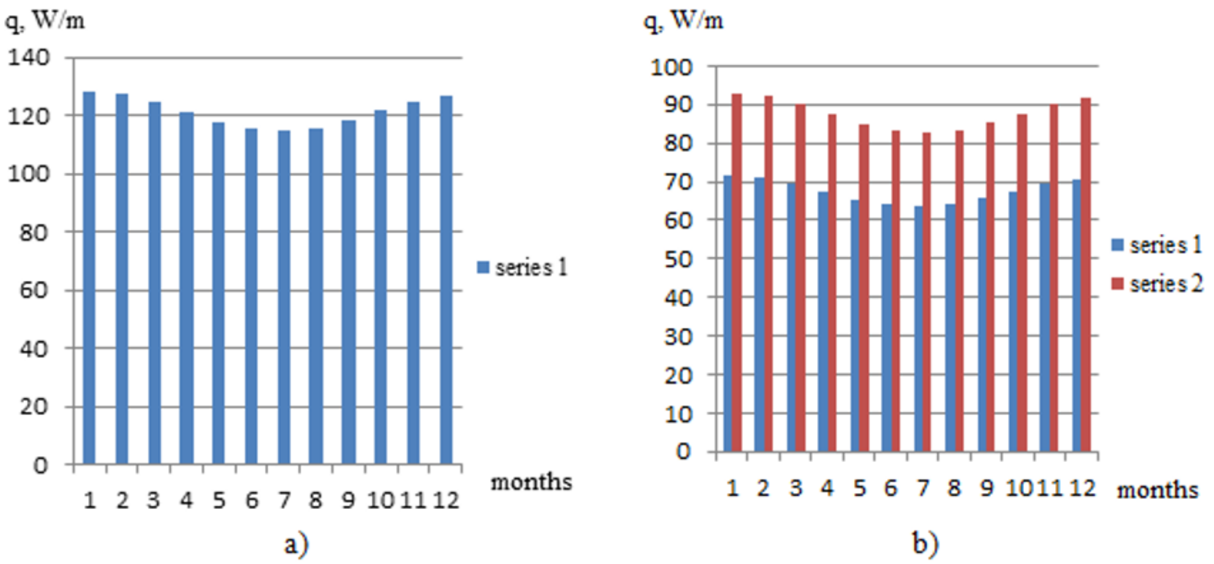

Fig. 4. The results of the calculation of the specific heat losses of the steam line d-159 mm. a) thermal insulation BSTF, b) thermal insulation basalt + PU foam, series 1 - specific heat losses without taking into account the temperature destruction of PU foam insulation, series 2 - specific heat losses with an increase in the coefficient of thermal conductivity due to temperature destruction on 20%.

4 Conclusions

The results indicate the need to take into account the actual operating conditions when assessing heat losses.

Also, when designing thermal insulation, it is necessary to take into account the amount of structural changes, sintering temperature, water absorption and vapor permeability of heat-insulating materials, which affects the amount of heat losses during long-term operation in various working conditions.

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