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Gas-filled thermal insulation use in heat supply

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Gas-filled thermal insulation use in heat supply

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Abstract. The possibility of applying a new type of thermal insulation, which will significantly reduce heat losses during transportation of heat, increase the service life of the pipeline, and reduce the cost of heat insulation work considered. Using multi-layer thermal insulation, which is a system of closed, sealed microvolumes (pores), which are filled with carbon dioxide proposed. As a shell, high-density polyethylene is used. Such a film can be used as a ready-made material for insulation of pipelines. Depending on the temperature of the pipeline, the required number of layers of thermal insulation is applied to the pipeline.

Introduction

Reduction of thermal losses of buildings and structures, transport of coolant in pipelines of heating networks and process plants is an actual technical and economic task, especially in the Russian Federation, as most of the territory of the country belongs to climatic conditions to the northern territories. This condition requires increased expenditures of heat energy for heat supply to consumers in the residential sector and is accompanied by significant heat losses during transportation of the coolant to ensure the life of production and settlements. In both cases, a significant reduction in heat losses can be achieved by applying modern thermal insulation: for residential, industrial and administrative buildings - in the form of elements of building structures (thermal panels); for heat networks and process pipelines - in the form of a roll thermal insulation coating.

The materials used for thermal insulation are characterized primarily by the properties of thermal conductivity[1]. The lower the thermal conductivity of the material, the better it retains heat. Therefore, thermal conductivity is their passport characteristic, and the need for its measurement is relevant.

The choice of the most effective gas for the development of gas-filled insulation

As is known, gases possess the lowest coefficients of thermal conductivity. For use in gas-filled insulation, several types of gases can be used. The most common and effective are: air, carbon dioxide, oxygen and flue gases of combustion products of organic fuel[2].

The summary data of the thermal conductivity coefficient as a function of the temperature of the above gases is shown in Fig. 2.

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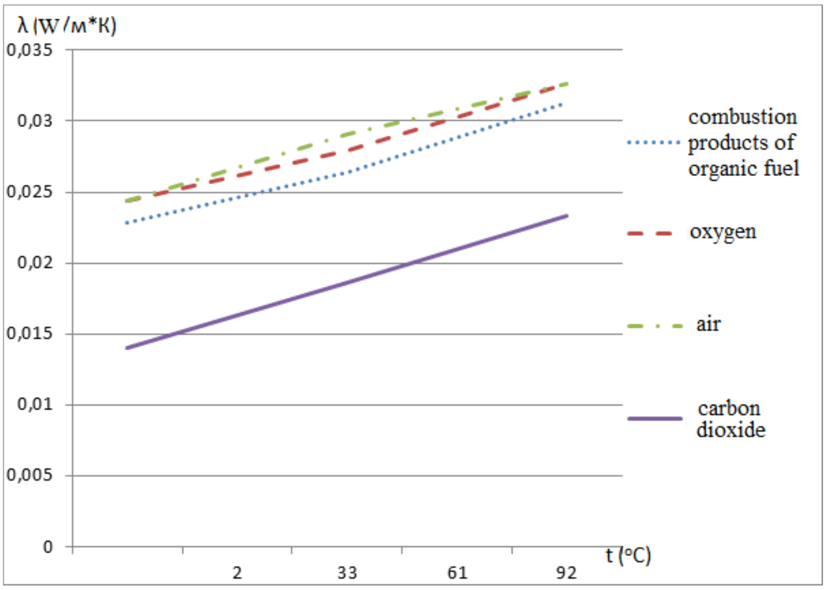

Figure 1. Dependence of the coefficient of thermal conductivity on the temperature of gaseous media.

As can be seen from Fig. 1, carbon dioxide is the lowest value of the thermal conductivity coefficient. Carbon dioxide is released in liquid form at low temperature, in liquid form at high pressure and in gaseous form. The gaseous form of carbon dioxide is obtained from waste gases in the production of alcohols, ammonia, and fuel combustion. Gaseous carbon dioxide by its properties is a non-toxic and non-explosive gas, odorless and colorless. It is proposed to use it as a gaseous medium for thermal insulation[3].

Justification of the choice of polyethylene as a shell for gas-filled insulation

As a coating for carbon dioxide, a film based on polyethylene is considered. Polyethylene is a thermoplastic polymer with a relatively low hardness, odorless and tasteless. Various research methods (microscopic, X-ray and electron diffraction, etc.) show that polyethylene has a crystal structure similar to that of normal paraffins (for example, C60H122, etc.). The degree of crystallinity of the polymer obtained by polymerization of ethylene does not reach 100%: along with the crystalline phase, amorphous is always contained. The ratio of these phases depends on the method of polymer preparation and temperature. Like high-melting waxes and paraffins, it slowly lights up and burns with a weak flame without soot. In the absence of oxygen, polyethylene is resistant to 290 ° C. Within 290-350 ° C, it decomposes into low-molecular-weight polymers of the wax type, and above 350 ° C, decomposition products are low molecular weight liquid substances and gaseous compounds - butylene, hydrogen, carbon monoxide, carbon dioxide, ethylene, ethane, etc. As can be seen from Figure 1, carbon dioxide is the lowest value of the thermal conductivity coefficient. Carbon dioxide is released in liquid form at low temperature, in liquid form at high pressure and in gaseous form. The gaseous form of carbon dioxide is obtained from waste gases in the production of alcohols, ammonia, and fuel combustion. Gaseous carbon dioxide by its properties is a non-toxic and non-explosive gas, odorless and colorless. It is proposed to use it as a gaseous medium for thermal insulation.

The mechanical properties of polyethylene depend on its molecular weight and the degree of crystallinity. With an increase in molecular weight, they improve. Crystallinity also enhances mechanical strength. In thin films, polyethylene (especially low-density polyethylene) has great flexibility and elasticity, and in thick sheets it acquires rigidity [2]. At present, polyethylene can be of high, medium and low density.

High-density polyethylene (HDPE) - PE with a linear macromolecule and relatively high density (0.960 g / cm³). This polyethylene, also called low-density polyethylene (HDPE), it is obtained by polymerization with special catalyst systems. Linear polyethylenes form crystalline regions, which strongly affect the physical properties of the samples. This type of polyethylene is commonly referred to as high density polyethylene; it is a very solid, strong and rigid thermoplastic, widely used for injection molding and blow molding of containers used in the household and industry. High density polyethylene is stronger than low density polyethylene. The softening temperature of HDPE (121 ° C) is higher than that of LDPE, so it can withstand steam sterilization. The tensile and compressive strength is higher than that of LDPE, and the resistance to impact and tear is lower. Due to the linear structure, HDPE molecules tend to orient in the direction of the flow, and the tear resistance in the longitudinal direction of the films is much lower. The differences in tear resistance in the longitudinal and transverse directions can be increased with orientation, and the properties of ribbons working on tearing will be inherent in the film. The permeability of HDPE is lower than that of LDPE, about 5-6 times, and it is an excellent barrier to moisture. Among ordinary HDPE films, in terms of moisture permeability, it is second only to films based on copolymers of vinyl chloride and vinylidene chloride.

The chemical resistance of HDPE is also superior to LDPE, especially in resistance to oils and fats. With increasing density, the solubility in organic solvents decreases, as does the permeability to solvents. HDPE is prone to environmental cracking, like LDPE, but this effect can be reduced by using high molecular weight PE grades that do not have this deficiency. Areas of application of high- density polyethylene, as a rule, coincide with the areas consuming low-density material, but the changed properties of the first, undoubtedly, improve the quality of the products produced. Thus, a film of high-density polyethylene will be stronger and more transparent, molded parts may have a smaller cross-section, and pipes and fibers will have greater strength. Increasing the melting point of new polyethylenes allows sterilization with steam. These factors, combined with the ability to regulate the properties of the products, will promote the growth of the use of polyethylenes produced on surface catalysts. Thus, the most suitable material for gas-filled insulation is a film based on high density polyethylene (low pressure). Advantages over other types of polyethylene are higher softening temperature, high tensile and compressive strength, low moisture permeability, very good weldability.

Gas-filled insulation description

The modern thermal insulation material is a complex multilayer structure and includes high density polyethylene (HDPE), the interlayer space of which is made in the form of cells filled with carbon dioxide. The process of preparing the material is the filling of the polymer hose (in this case it is high density polyethylene of high density HDPE) with carbon dioxide, after which the sleeve is welded to form hemispheres[4]. After receiving the so-called "air-bubble" film, it can be used as a ready-made material for insulation of walls of buildings and structures, as well as technological pipelines. Depending on the normalized heat flow, the required number of layers of thermal insulation is applied to the pipeline (Figure 2).

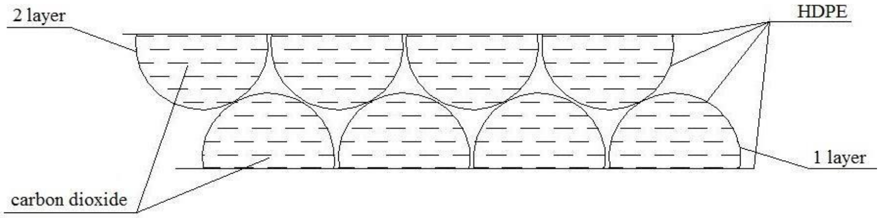

Figure 2. The scheme of gas-filled thermal insulation

Since the volume of carbon dioxide in each pore is small, the free motion that occurs in particles located in this volume can affect in the current under consideration. The motion and heat transfer depend in this case on the nature of the gas, its temperature and the dimensions of space. In this ball layer, the entire volume of gas is covered with motion. In practical calculations, it is required to determine the heat flux that passes through the gas-filled cell. The average density of the heat flux is determined by the formula:

$$q = \frac{\lambda_{eq}}{\delta} * (t_1 - t_2),$$

where λeq is the equivalent coefficient of thermal conductivity, taking into account the heat transfer as heat conductivity, and convection.

The ratio ε_eq = λ_eq / λ, where λ is the thermal conductivity of the gas, characterizes the effect of convection on heat transfer. The quantity ε_eq is a function of the complex Gr * Pr. The dependence ε_eq = f (Gr * Pr) is presented in for vertical and horizontal plane slits, annular and spherical layers filled with a gas or a dropping liquid.

In determining the similarity numbers, regardless of the shape of the interlayer, its thickness is taken as the determining dimension, and the average temperature of the gas is determined as the determining temperature.

Since the represented gas-filled insulation is multilayered, it is required to determine the overall thermal conductivity for the two layers of the HDPE film and the carbon dioxide layer. The total coefficient is determined by the formula:

$$\lambda_{ins} = \frac{\delta_{\mathrm{HDPE}} + \delta_{\mathrm{co2}} + \delta_{\mathrm{HDPE}}}{\frac{\delta_{\mathrm{HDPE}}}{\lambda_{\mathrm{HDPE}}} + \frac{\delta_{\mathrm{co2}}}{\lambda_{\mathrm{co2}}} + \frac{\delta_{\mathrm{HDPE}}}{\lambda_{\mathrm{HDPE}}}} = \frac{0{,}0005 + 0{,}009 + 0{,}0005}{\frac{0{,}0005}{0{,}28} + \frac{0{,}009}{0{,}014} + \frac{0{,}0005}{0{,}28}} = 0{,}0155 \frac{W}{m * \mathrm{K}}.$$

This type of thermal insulation has a number of advantages: low thermal conductivity, and, as a consequence, high thermal resistance, increased moisture resistance, corrosion protection, ease of installation, durability, low cost and safety of use.

In this case, this thermal insulation material has one significant minus - the temperature range on the surface should not exceed 126°C (softening temperature of HDPE). The maximum temperature of the coolant for residential, public and administrative buildings should not be more than 95 degrees for two-pipe systems, and not more than 105 degrees for single-pipe systems.

For thermal insulation of pipelines whose temperature exceeds the softening point of HDPE, it is proposed to use gas-filled insulation over a thin layer of a known heat-insulating coating, which may be either a heat-resistant paint or a fiberglass. This layer is laid on the pipeline first and reduces the surface temperature of the pipeline to the range of application of gas-filled insulation. The next layers are laid gas-filled insulation. The number of layers of insulation depends on the surface temperature. Therefore, this thermal insulation material is perfect for thermal insulation of heating pipelines, hot and cold water supply, sewage pipelines, etc.

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