ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

RESEARCHES REGARDING USE OF TEXTILE MATERIALS FOR THERMAL INSULATION AT NEGATIVE TEMPERATURES

IOSUB Andrei[1], AVRAM Dorin[2], VERDES Marina[1], HORGA Mihaela[2]

[1] *University of Iasi, Romania, Building Services, Faculty of Civil Engineering and Building Services, 700050, 123456 Iasi, Romania, E-Mail1: decanat@tex.tuiasi.ro*

[2] *University of Iasi, Romania, Industrial Engineering, Faculty of Textiles & Leather Engineering and Industrial Management, Postal address1, 123456 Iasi, Romania*

Corresponding author: Iosub Andrei, E-mail: iosubandrei84@yahoo.com

Abstract: *Using thermal insulation in negative temperature acts to reduce heat flow to the cooled space or to objects that have a temperature below ambient temperature. To achieve economic operation of the space to be cooled insulation thickness and quality is an important factor. In this article we want to compare three products used in thermal insulation at negative temperatures: expanded polystyrene, non-woven and wool coats. The materials will be tested with a mechanical vapor compression refrigerator capable of producing temperatures in the range +4 .. -35 ° C, managed by a programmer Dixel capable of recording values between +40. .. -60 °C. Refrigeration insulation enclosure was made with 100 mm expanded polystyrene. On one side of the enclosure will be a cut of 250 * 250 mm, chosen in a central position where the material will be introduced to be tested. The dimensions of the samples are 250 * 250 * 60 mm.*
To check the insulation properties of materials it will be used a temperature logger capable of recording with two probes temperatures between +125...-40° C. One of the probes will be inserted inside the refrigerator and the second probe will be positioned to the outside of the test material adhered to an aluminum plate, in order to read a average temperature. The difference in thickness of the insulation shall be filled with non-woven material. Hardening the assembly will be made using a 6 mm thick OSB board. The materials will be tested in an identical ambient temperature and humidity.

Key words: *refrigeration cycle, heat flux, air, vapor barrier, thermal conductivity coefficient*

1. INTRODUCTION

According with the the second principle of thermodynamics, heat pass by itself from the body with higher temperature towards the body with lower temperature. Thermal insulation is intended to minimize this process, as a result the insulation does not reduce the total passage but only decreases it.

In practice, two situations may occur:

- thermal insulation, where temperature of the thermodynamic system is higher than the outside ambient temperature, for thermal machinery and equipment;
- refrigeration insulation, where the temperature of the thermodynamic system is smaller than the outside ambient temperature, for refrigeration system; [1]

This paper treats the second situation, refrigeration insulation. The heat can propagate in three distinct ways: conduction, convection and radiation [2].

Heat transfer through insulating materials occurs by conduction, while losing or gaining heat from the environment to insulating material occurs by convection and radiation.

Insulating materials that have a low coefficient of thermal conductivity are those materials having in the composition a large proportion of small air gaps or a certain gas. These gaps must be small enough not to may occur convection and radiation and thus reduce heat transfer [3].

Insulating materials are divided into two categories:

- Natural, such as asbestos, mica, earth;

- Industrial, obtained from industrial processes such as glass wool, rock wool, polystyrene, polyurethane foam, cork tiles, wood fiber plates [4].

Some of the conditions that must fulfill insulating materials that are used in refrigeration technology are:

- Low thermal conductivity;
- Reduced hygroscopicity;
- Reduced vapor permeability;
- High resistance to frost;
- Have no smell;
- Have no nutritive value for insects and rodents;
- Mechanical resistance;
- Long life [5].

The most representative materials used in refrigeration technique are cork, polystyrene, polyurethane foam, R13. Refrigeration insulation also involves using other materials such as: support for attaching the insulation, vapor barrier foil, mechanical shock protection, paint applied with corrosion and aesthetic role.

Whatever the purpose of using cold insulation, a vapor barrier should be installed having the role to limit the entry of water vapor. The phenomenon of migration of water vapor from the environment occurs due to the temperature or humidity difference between the cold surface and environment temperature. Not to be confused condensation with water vapor in the air, there are materials that are water resistant, but not resistant in the passage of water vapor from air. All insulation materials used in refrigeration have some degree of penetration of the water vapor from air, if penetration it is not prevented then this vapors will enter the material, where they condense when dew point temperature is reached or will form ice crystals which will lead, in time, the destruction of insulation. Therefore, vapor barrier plays an important role in the cold insulations. It is applied on the warm side of the insulation and must have a great attention at installation, for not being damaged. For choosing the vapor barrier will keep in mind data provided by producer about permeability of the material used, fire resistance performance of vapor barrier not to affect the entire assembly of refrigeration insulation and a possible scenario for its replacement if it is damage. A possible deterioration of the vapor barrier will lead to poor performance of cold insulation or even the destruction over time.

Condensation can occur when warm insulation surface drops below the dew point temperature of the environment. Condensation on the warm side of the refrigeration insulation, which has installed vapor barrier, does not affect the quality of insulation, but is a phenomenon that should be avoided by a proper calculation of the thickness of the insulation. When sizing the thickness of insulating material must consider the relative humidity of the environment or its approximation as accurately as possible. For selection of insulating material must consider its destination, and it is recommended to consult even the producers [3].

2. GENERAL INFORMATION

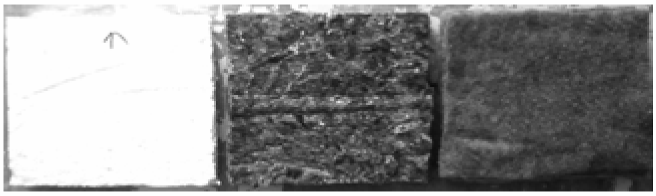
2.1 Experimental aspects

Testing of insulating materials used in this paper will be done with a mechanical vapor compression refrigerator, capable of producing temperatures in the range of +4 ..-35 °C.

This instalation is controlled by a Dixel programmer equipped with PTC 1000 probe, capable of recording temperature values between +40 .. -60 °C. Refrigeration insulation enclosure is made of 100 mm thick polystyrene.

Fig. 1: *Refrigerator used for experiments*

Materials used for experimentation are expanded polystyrene, non-woven material (made of recycling) and layers of wool (turcana).



a) b) c)

Fig. 2: *Insulating materials used in the experiments (a- polystyrene, b-nonwoven material, c-layers of wool)*

Apparent density for each material is 15 kg/m³ for expanded polystyrene, 68 kg/m³ for nonwoven and 33.5 kg/m³ for wool. Samples will measure 250 x 250 x 60 mm.

To conduct the experiments on a side wall, in the central area of the enclosure there is a cutout of the insulation refrigerator with the dimensions 250 * 250 mm.

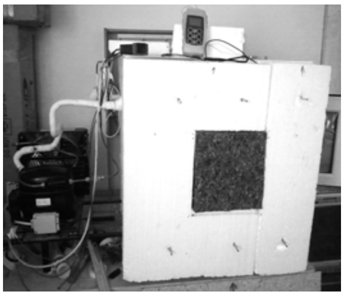
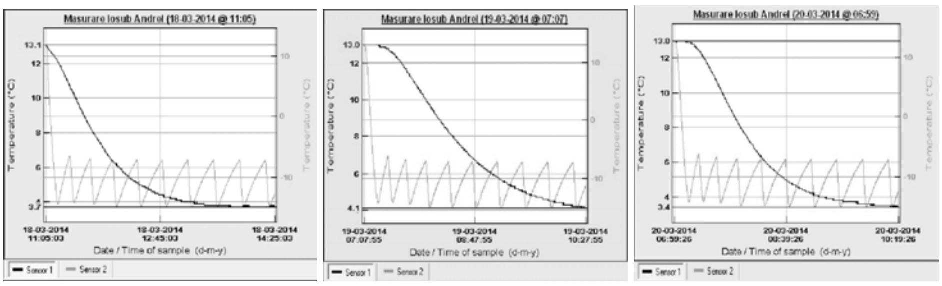


Fig. 3: *Refrigerator used for experiments (test wall)*

Samples of the materials will be inserted into the decoupage. Tracking the temperature fluctuation will be done using a temperature logger equipped with two temperature probes, capable of recording temperatures between +125..-40 °C. One of the probes will be inserted inside the refrigerator bonded to the interior wall, and the second probe will be positioned on the warm side of the insulation materials used in experiments. In order to read a average temperature, the second probe will be bonded to an aluminum plate with the size 150 * 150 mm. On the outside of the tested material will be applied a polyethylene vapor barrier.

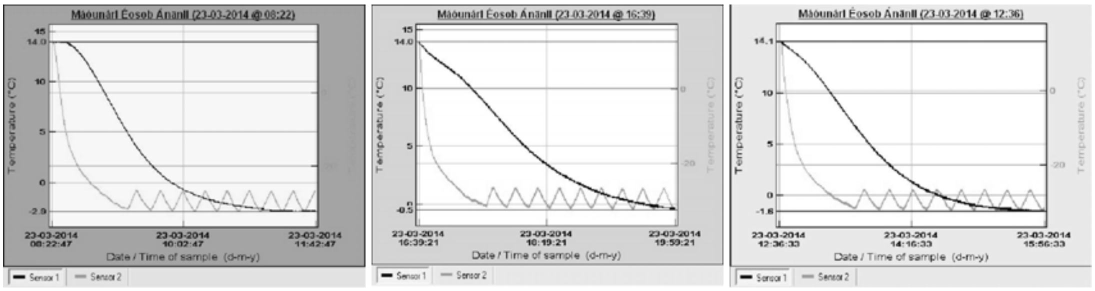
Filling up insulation enclosure to the thick of 100 mm, is made with layers of non-woven material. Hardening the ensemble will be made using a 6 mm thick OSB board, with a 6-bolt mounting system with butterfly nuts for a quickly assembly/disassembly. Experiments will be done at ambient temperature and humidity in order to not apear errors. Test temperatures are -10 and -30 °C, and the duration of the test will be 3 hours and 20 minutes, with recording of the temperature values at 6 sec.

After the tests where finished the data from the Logger was copied and processed by the Logger program in a graphical representation,



a) b) c)

Fig. 4: *Graphical representation of ThermaData Logger t = -10 ° C (a-polystyrene, b-nonwoven material, c-layers of wool)*



a) b) c)

Fig. 5: *Graphical representation of ThermaData Logger t = -30 ° C (a-polystyrene, b-nonwoven material, c-layers of wool)*

and centralized the important data from the graphical representation in Tab.1.

Tab. 1: *Insulating materials testing results*

Ambient temperature 13 ° C			Ambient temperature 14 ° C		
Test temperature -10 ° C			Test temperature -30 ° C		
expanded polystyrene	nonwoven	layers of wool	expanded polystyrene	nonwoven	layers of wool
3.7 °C	4.1°C	3.4°C	-2.9°C	-0.5°C	-1.6°C

3. CONCLUSIONS

According to Fourier, heat flux density is equal to the amount of heat transferred per unit time per unit area [6], resulting that the thermal conductivity is equal to the heat flux crossing unit area of a plate of uniform thickness, when the difference in temperature between the outer surfaces is equal to unit. Following the results obtained at the temperature of -10 °C Fig. 4, and -30 °C Fig. 5 it can be seen in the left values recorded by temperature sensor positioned outside the insulating material and in the right side it can be seen the values recorded by temperature sensor placed in the refrigerated enclosure. In the upper left it can be seen the common temperature that the two sensors start. This value represents the ambient temperature.

In the lower left and right it can be observed the values recorded at the end of the experiment. For the first experiment it can be observed that the recorded temperature of the sensor aplied to the outside of the insulating material of the nonwoven material and the expanded polystyren have a superior temperature than the material made from layers of wool, but in the second experiment the nonwoven material and the wool layers material have a superior temperature than the expanded polystyren meaning that at -10 °C the nonwoven material and the expanded polystyren are better thermo-insulating than the wool layers material and at -30 °C the nonwoven material and wool layers material are better thermo-insulating than the expanded polystyren.

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