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INFLUENCE OF TEMPERATURE ON THE THERMO-HUMIDITY CONDITIONS OF WALL MATERIALS

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The construction of energy efficient housing is a strategically important scientific, technical, economic, social and political trend. The goal of the work is to show the influence of temperature on the thermo-humidity conditions of various wall materials. To achieve this goal, a testing complex was developed at Polotsk State University. The testing complex consists of a laboratory installation with the ability to change samples of wall materials, temperature and humidity sensors, an information input-output interface, software. The experiment showed comparable heat retention results for mineral wool, expanded polystyrene, wood-concrete and foil sample. The results obtained indicate that the proposed technology can be used both in existing buildings and in buildings under construction.

Keywords: *temperature, thermo-humidity conditions, humidity, desired properties, energy efficiency, wood-concrete, sensors.*

Introduction. The construction of energy efficient housing is a strategically important scientific, technical, economic, social, and political trend. Those countries that have previously and further advanced along this path have received serious advantages already now since they have made a breakthrough in solving many painful problems of energy conservation.

Energy efficient materials are gaining popularity all over the world. Analysis of publications allows us to conclude that wood-concrete is one of these materials [1–18].

The increase in the energy efficiency of residential buildings, dictated by the energy crisis, required a significant increase in regulatory requirements for the resistance to heat transfer of the building envelopes and the development of a set of energy-saving measures. One of these activities is the use of smart systems to control and regulate the parameters of enclosing structures.

Cold air, especially highly saturated with moisture, takes heat from the outer structures of the facade. As a result, energy efficiency decreases and the thermal stability of the enclosing structures decreases [19].

The goal of the work is to show the influence of temperature on the thermo-humidity conditions of various wall materials.

Main part. To achieve this goal, a testing complex was developed at Polotsk State University. The testing complex consists of a laboratory installation with the ability to change samples of wall materials, temperature and humidity sensors, an information input-output interface, and software.

The software and the information input-output interface are implemented on the arduino platform.

A sensor is a device that detects and measures a physical quantity from the environment and converts it into an electronic signal. The physical quantity could be moisture, temperature, motion, light or any other physical phenomenon. Examples of sensors include: oxygen sensors, temperature sensors, infra red sensors, humidly sensors, soil moisture sensors and motion detection sensors. The output of the sensors is usually charge, current or voltage[1].

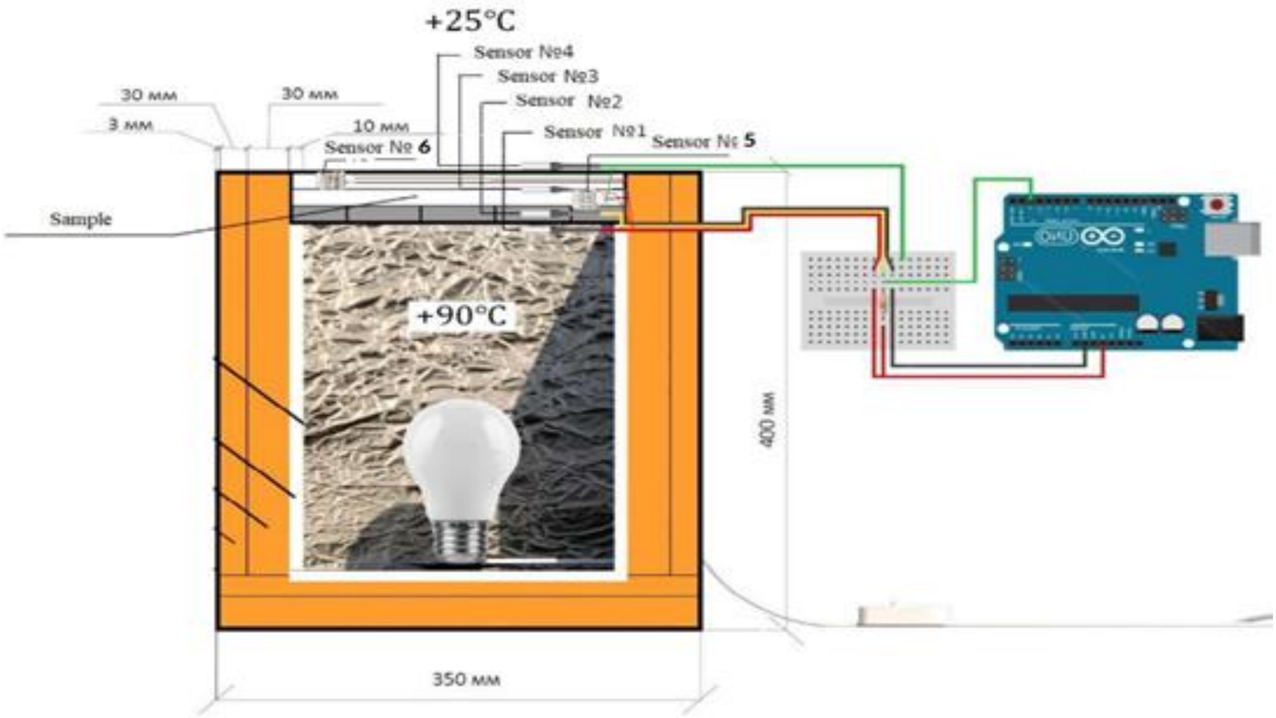
To carry out the experiment, an installation and a model of a three-layer wall structure were created (figure 1). The structural system of its four side walls is as follows: 3 mm cardboard; penoplex 20 mm (density 35 kg/m^3); expanded polystyrene 30 mm (density 35 kg/m^3); PVC panel 10 mm (in which air channels are directed vertically); foil. Installation base: cardboard 3 mm; penoplex 20 mm (density 35 kg/m^3); expanded polystyrene 30 mm (density 35 kg/m^3); foil. In the middle of the base the unit is equipped with a heat source (lamp).

A sample (with sensors inside) was placed on the setup, a lamp inside the sample was turned on and heated the space. The temperature and humidity readings were recorded by sensors and provided information to the specialized program Arduino Uno. The automated processing of the obtained experimental data was carried out using the Microsoft Office Excel software package.

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. DHT22 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements is connected with 8-bit single-chip computer. Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient

[1]URL: https://amperka.ru/page/kak-vybrat-datchik-dlya-arduino.

is saved in type of program in OTP memory, when the sensor is detecting, it will cite coefficient from memory. Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or outdated boards see the Arduino index of boards. The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection[2].



Sensors 1-4 – DS18B20[3]; sensors 5-6 – DHT22[4]

Figure 1. − Sectional view of the pilot plant

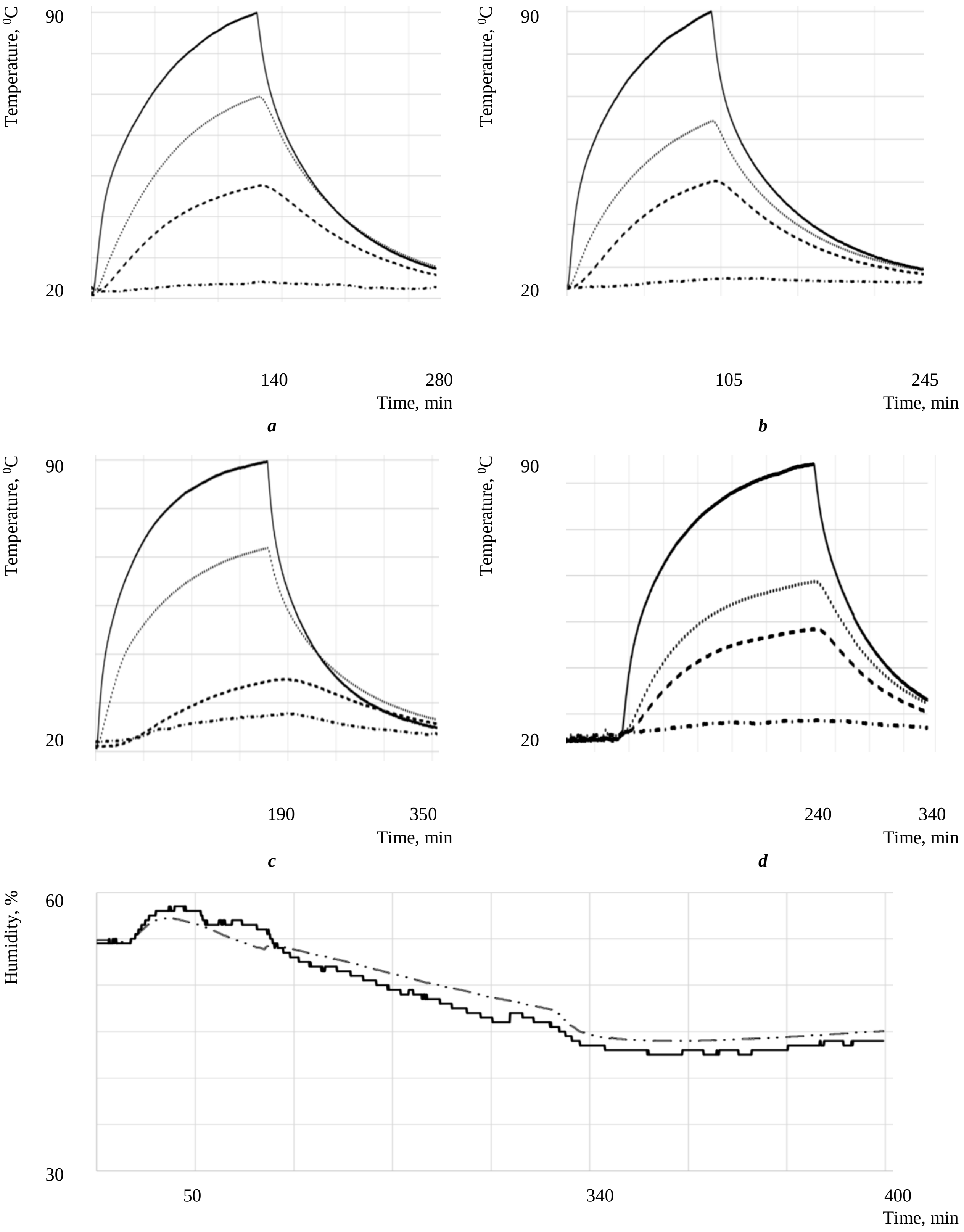
A prototype was placed on the top of the pilot plant. The pilot plant was heated to create a temperature difference of +90^{0}C and +25^{0}C, after heating the incandescent lamp was turned off and the temperature readings as well as the rate at which the heat from the pilot plant went outside were monitored.

The experiment showed comparable heat retention results for mineral wool, expanded polystyrene, wood-concrete and foil sample [19]. The test results are shown in figure 2. Mineral wool heats up in the installation to the maximum temperature in 140 minutes, cools down in about the same time (figure 2, *a*). Expanded polystyrene heats up to a maximum temperature in 105 minutes, cools down in 130 minutes (figure 2, *b*). Wood-concrete heats up to a maximum temperature in 190 minutes, cools down in 160 minutes (figure 2, c). Foil sample heats up to a maximum temperature in 240 minutes, cools down in 100 minutes (figure 2, *d*). The leader in heating is expanded polystyrene, which is ahead of mineral wool by 35 minutes, wood concrete by 85 minutes, foil sample by 135 minutes. The leader in cooling (heat accumulation) is wood concrete, which cools down longer than expanded polystyrene by 30 minutes, than mineral wool by 20 minutes, foil sample by 60 minutes.

The humidity content in different parts of the foil sample (figure 2, *e*) first had some growth of 5–7% (due to humidity migration due to heating of the inner space of the experimental setup), and then decreased by 25–30% (due to heating of the material).

The advantages of the developed testing complex are the speed of data acquisition, mobility, cross-platform.

[2] URL: https://store.arduino.cc/products/arduino-uno-rev3/.
[3] URL: https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf.
[4] URL: https://www.sparkfun.com/datasheets/Sensors/Temperature/DHT22.pdf.



—— – sensor 1; ········· – sensor 2; – – – – – sensor 3; – · – · – sensor 4; —·—· – sensor 5; ⎯⎾⎯ – sensor 6

***a* – mineral wool test; *b* – expanded polystyrene test; *c* – wood-concrete test; *d* – foil sample test; *e* – humidity test**

Figure 2. − Test results

Conclusion. The goal of the work was fully achieved. Developed testing complex consists of a laboratory installation with the ability to change samples of wall materials, temperature and humidity sensors, an information input-output interface, and software has shown its worth.

The experiment showed comparable heat retention results for mineral wool, expanded polystyrene, wood-concrete and foil sample. The results obtained indicate that the proposed technology can be used both in existing buildings and in buildings under construction. Having finished laboratory tests the authors are going to carry out full-scale tests in existing buildings, what will allow to continuously monitor the temperature and maintain an optimal thermal regime as well as save energy for heating.

It is also planned to use strain sensors (for the control of mechanical characteristics) and ph-sensors (to control carbonation and durability of concrete).

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ВЛИЯНИЕ ТЕМПЕРАТУРЫ НА ТЕРМО-ВЛАЖНОСТНОЕ СОСТОЯНИЕ СТЕНОВЫХ МАТЕРИАЛОВ

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Строительство энергоэффективного жилья – стратегически важное научное, техническое, экономическое, социальное и политическое направление. Цель работы – показать влияние температуры на термо-влажностное состояние различных стеновых материалов. Для достижения этой цели в Полоцком государственном университете разработан испытательный комплекс. В состав испытательного комплекса входят лабораторная установка с возможностью замены образцов стеновых материалов, датчики температуры и влажности, интерфейс ввода-вывода информации, программное обеспечение. Эксперимент показал сопоставимые результаты по сохранению тепла для минеральной ваты, пенополистирола, деревобетона и образца из фольги. Полученные результаты свидетельствуют о том, что предложенная технология может быть использована как в существующих зданиях, так и в строящихся зданиях.

Ключевые слова: *температура, термо-влажностное состояние, влажность, заданные свойства, энергетическая эффективность, деревобетон, датчики.*