International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

TuEngr Group

PAPER ID: 10A16M

AN ANALYTICAL REVIEW OF METHODS FOR DETERMINING HEAT LOSS OF A BUILDING OBJECT

Panfilov Stepan Aleksandrovich [a], **Lomshin Mikhail Ivanovich** [a], **Sergushina Elena Sergeevna** [a], **Kabanov Oleg Vladimirovich** [a*]

[a] *Ogarev Mordovia State University, 68 Bolshevitskaya Street, Republic of Mordovia, Saransk, 430005, RUSSIA*

ARTICLEINFO

Article history:
Received 24 April 2019
Received in revised form 20 August 2019
Accepted 04 September 2019
Available online 20 September 2019

Keywords:
Heat transfer, Heat transfer coefficient, Heat transfer resistance, Energy efficiency; Thermophysical properties (TPP).

ABSTRACT

This article discusses the important role of experimental research in determining the thermophysical properties (TPP) of the object under study. The classification of existing methods is given, and also the analysis of restrictions, existing ways of definition of thermophysical properties of building objects is made. The existing methods and devices for determining the TPP of the investigated building objects, in most cases, require the reproduction of special conditions for the experiment, placement of special sensors in the thickness of the material under study, etc. Therefore, for the existing devices, the problem of obtaining reliable research results in industrial, civil and commercial use objects is actual; consequently, innovative methods for establishing the thermophysical properties of fences and various types of structures are required.

1. INTRODUCTION

Up to date one of the most pressing problems in improving energy efficiency is to use easy and reliable methods to check up on external heat loss through the enclosing structures of the facility and to assess thermophysical properties (TPP) massively affecting the thermal behavior. A decrease in external heat loss of a construction project has a great impact on its energy performance. To reduce the external heat loss of any construction project requires knowing its TPP. The properties of materials are known to change over time. More accurate information on external heat loss makes it possible to assess with greater reliability the required capacity of the heat supply system. The key source of information for the definition of the TPP enclosing structures is provided by an experiment. The methods to assess the TPP of construction projects and (or) materials are divided into three main types: non-stationary, stationary and complex (Ametistov, 2000; Batalov, 1982; Belov et al., 1986; Bogoslovsky, 2013; Fokin et al., 2004; Budadin, 2001; Vavilov, 2009; Vidin et al., 2018; Kulakov &

*Corresponding author (Panfilov S. Aleksandrovich) Email: panphilovsa@gmail.com

Makarov, 1979; Ivanova et al., 2007; Fokin & Chernyshov, 2004; Kudinov2015; Fokin & Kovylin, 2009; Rudzit, & Plutalov, 1991; Thermal Protection of Buildings, 2004; Tabunshchikov & Borodach, 2002; Barilovich & Smirnov, 2014; Klimenko & Zorin, 1999; Kabanov et al., 2014; Yureniev & Lebedev, 1975; Kabanov et al., 2015; Kabanov et al., 2016). Non-stationary TPP determination methods are the most challenging owing to its simplicity and short experiment time etc (Ametistov, 2000; Batalov, 1982; Belov et al., 1986; Bogoslovsky, 2013; Fokin et al., 2004; Budadin, 2001; Vavilov, 2009; Vidin et al., 2018; Kulakov & Makarov, 1979; Ivanova et al., 2007; Fokin & Chernyshov, 2004; Kudinov2015; Fokin & Kovylin, 2009; Rudzit, & Plutalov, 1991; Thermal Protection of Buildings, 2004; Tabunshchikov & Borodach, 2002; Barilovich & Smirnov, 2014; Klimenko & Zorin, 1999; Kabanov et al., 2014; Yureniev & Lebedev, 1975; Kabanov & Panfilov, 2016a; Kabanov & Panfilov, 2016b). Stationary methods are based on creating special boundary conditions on both sides of the structure (walls) under the study during the experiment (Ivanova et al., 2007; Fokin & Chernyshov, 2004; Kudinov, 2015; Fokin & Kovylin, 2009; Rudzit & Plutalov, 1991; Thermal Protection of Buildings, 2004). Compared to stationary methods, non-stationary methods are the most promising since less time and heat is spent in determining the TPP. The major constraints of stationary methods are complex equations for calculating the TPP as well as difficulties in determining the mutual conformity of real boundary conditions with theory. More authentic information about TPP as a result of one experiment can be provided by complex methods. Furthermore the research methods used in the study of the TPP materials are split into absolute and relative methods. The most promising methods of TPP research are absolute. For the analysis of TPP material they also adopt methods of temperature waves (Batalov, 1982; Budadin, 2001; Vavilov, 2009; Vidin et al., 2018; Kulakov & Makarov, 1979). TNDTM (temperature nondestructive testing methods) from the listed above rank the top when determining TPP. According to (Fokin & Chernyshov, 2004; Kudinov2015; Fokin & Kovylin, 2009; Rudzit, & Plutalov, 1991; Thermal Protection of Buildings, 2004; Tabunshchikov & Borodach, 2002; Barilovich & Smirnov, 2014; Klimenko & Zorin, 1999; Kabanov et al., 2014; Yureniev & Lebedev, 1975; Tabunshchikov, 1986), TNDTM have a diverse functionality, high performance, authenticity and the required efficiency. The methods and measurement instruments (MI) applied therein are split into groups. The first group refers to contact methods and measurement instruments, the second group refers to non-contact methods and measurement instruments. Compared to non-contact methods, the contact method applies to direct contact of measurement instruments with the surface of the sample section under study. Thermal sensors used for this purpose are submersible and non-submersible (Belov et al., 1986; Bogoslovsky, 2013; Vavilov, 2009; Vidin et al., 2018; Kulakov & Makarov, 1979; Ivanova et al., 2007; Fokin & Chernyshov, 2004; Kudinov 2015; Fokin & Kovylin, 2009; Rudzit, & Plutalov, 1991). The temperature nondestructive testing methods are mainly based on instant and (or) impulse temperature action on the material under analysis. TNDTM are widely represented in Ametistov (2000), Batalov (1982), Belov et al., (1986); Bogoslovsky (2013), Fokin et al. (2004). Budadin (2001), Vavilov (2009), Vidin et al. (2018), Kulakov & Makarov (1979), Ivanova et al. (2007); Fokin & Chernyshov (2004), Kudinov (2015), Fokin & Kovylin (2009), Rudzit, & Plutalov (1991), Thermal Protection of Buildings (2004), Tabunshchikov & Borodach (2002), Barilovich & Smirnov (2014), Klimenko & Zorin, (1999), Kabanov et al. (2014), Tabunshchikov (1986) and have broad functional properties. An impulse heat supply is placed on the tested material surface, and the operational ends of the thermocouple are placed at the fixed distance from the source. Afterwards the thermal impulse with the preset power comes from the heat supply and then the time span at which the required limit is set is also defined. Once the set value is reached, the power of the heat supply is recorded and the temperature at the specified point is controlled. The determination of the TPP of the analyzed projects can also be performed by the non-contact method (Batalov, 1982; Klimenko & Zorin, 1999; Kabanov et al., 2014). To identify the TPP of the construction project under study its surface is subject to heating by a steady thermal stream coming from a movable heat supply. A number of heat receivers follow the moving heat source at the same speed and serve to record temperature data coming from the heating surface. External heat loss to the environment results from this method. The given methods are also being used in regular mode methods, in quasistationary and stationary thermal modes (Vavilov, 2009) and temperature wave method. Due to the ever-increasing pressure on residential and non-residential environments, it is necessary to estimate the right amount of heat energy to maintain the required temperature in different climatic conditions. Due to a long operating cycle, infringements of the integrity of the enclosing structures, missing information about the design features, there are difficulties in determining the thermophysical properties (Yureniev & Lebedev, 1975). Let's consider in more detail the methods and devices to identify the TPP of the construction project under study by defining the external heat loss through the enclosing structures. Currently there are various methods and devices to determine the TPP of the research subject.

The nondestructive testing method (NDTM) has been applied to design a device to identify the TPP of the surfaces of enclosing structures (Batalov, 1982; Kovylin, 2011; Vavilov et al., 2012; Golovnev, 2014).

2. MAIN PART

The general view of the device implementation is shown in Figure 1 Figure 2 shows the appearance and mounting of the device to the wall of the research subject. Figure 1 shows the structure of this study, and Figure 2 shows the heating element.

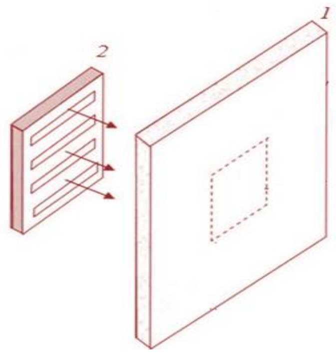

Figure 1: General view of the implementation method.

Figure 2: Layout and mounting of the unit to the wall of the object of study

The device is cube-shaped with a heating element within it (Batalov, 1982; Vavilov et al., 2013). By means of a heater installed inside the enclosure that creates a uniform heating zone as shown in Figure 2, and heat flux density sensors mounted on the examined enclosing structure, the temperatures of the heated and opposite surface of the enclosing structure (at the center of the heating zone) and the heat flux density on the surface of the enclosing structure (at the center of the heating zone) are measured. Moreover, the temperature and heat flux density are measured on the surface of the opposite heating surface of the enclosure structure within a distance of at least two maximum linear dimensions of the heating zone away from the center. Temperature and heat flux density measurements on the heated and opposite surfaces of the enclosing structure in the center of the heating zone are made simultaneously when the temperature difference between the temperature in the center of the heating zone and the temperature measured additionally, as well as the density difference between the heat flux in the center of the heating zone and the density measured additionally, exceed the limit of the appropriate measuring devices sensitivity (Vavilov et al., 2013). According to the data obtained during the study, TPP is determined by the formulas presented by Vavilov et al. (2013).

Pokhodun et al. (2013) have developed a device for the determination of the TPP. Figure 3 shows the drawing which illustrates the schematic view of the device design version.

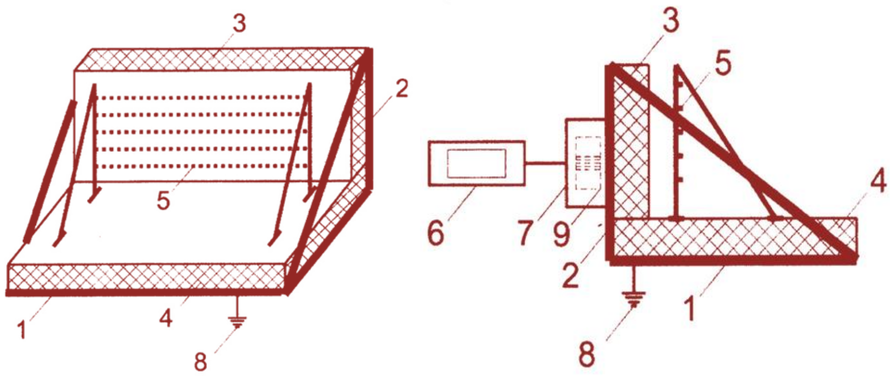

Figure 3: Design diagram of the device (after Pokhodun et al. (2013)).

This device is equipped with a frame made of heat-resistant material in the shape of a rectangular frame 1 with two vertical columns 2 between the vertical columns, a vertical heat-insulating element 3 is placed and a horizontal thermo-isolating element 4 is placed on frame 1. The heating element 5 is fixed on the insulating element 4, its surface is in parallel with that of the vertical insulating element

3. The heating element 5 is connected to the thermoregulator 6. The device also features a metal box 7 for fixing electronic units and a heat flux meter 9 as well as a ground wire 8.

The frame of the device for determining TPP is made of heat-resistant material. As the heating element 5 is used tubular electric heaters (TEH) with a capacity of no less than 5 kW. It operates as follows: the rectangular frame 1 is installed within the object of study including the external enclosing structure under study, horizontal heat-insulating element 4 is installed, then vertical racks 2 and heat-insulating element 3 are installed, then the grounding 8 is carried out, heating element 5 is plugged in, the set temperature of the air in the room is set on the thermoregulator 6, sensors of the measuring device are installed densely on the external enclosing structure under study, the sensors of the heat flux density meter 9, located in the metal case 7, are to be mounted on the examined external enclosing structure. As soon as the heating time has been determined, the temperature values of the inner and outer surface of the controlled structure, the air temperatures on both sides of the structure, and the density of the heat flux on the heated surface of the structure are measured after a while. Based on the data provided, the thermal transfer resistance of the structure to be tested is determined (Pokhodun et al., 2013).

Also based on NDTM, a system has been developed to measure TPP of building envelopes (Budadin & Abramova, 2011). It creates given temperature conditions on the inner and outer sides of the tested object, monitors the thermal flow passing through the object under stationary conditions.

There is a known procedure for defining NDTM building structure TPP (Budadin & Abramova, 2011). Figure 4 shows a drawing of the device design to determine the TPP of the building structure.

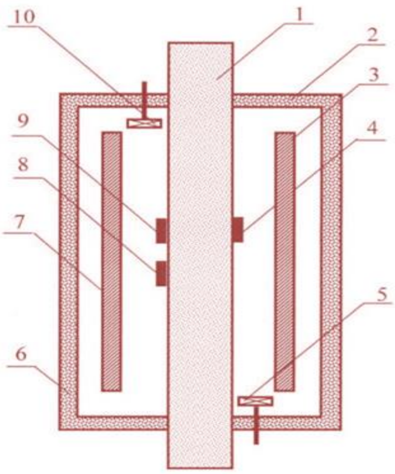

Figure 4. Device design drawing for TPP defining.

Figure 1 - construction, 2 and 6 - insulated box, 3 and 7 - flat thermostat, 4 and 9 - thermometer, 5 and 10 - adjustable fan, 8 - heat meter.

A thermo-insulated box with flat thermostats, a thermometer, and an adjustable fan, as well as a thermometer, are installed on the opposite sides of the construction project. The thermostat keeps the $T_{окр}$ - environment temperature unchanged, the thermostat in the opposite case keeps the temperature $T_{в}$ - internal temperature, not equal to the $T_{окр}$. Within a certain time interval the temperatures of the construction surfaces are determined by thermometers mounted in a thermally insulated box, and the density of heat flow through the construction is measured. An adjustable fan in the outer and inner insulated duct changes the intensity of the airflow rate to enable a change in the heat transfer of the structure under study according to the conditions described in (Budadin & Abramova, 2011). Upon setting the specified heat transfer (q) the heat transfer resistances are calculated using

$$R_0 = \frac{T_в - T_{окр}}{q}. \quad (1)$$

The restriction on the use of the unit is the length of the research procedure and the inability to determine the TPP of the whole object.

We know the NDTM of the object TPP definition (Budadin et al., 2002). The application algorithm of this method is based on measuring the time interval from the start of heating the internal surface area to the start of temperature rise at a fixed point on the external (or lateral) surface of the tested object. Afterward, an experiment is performed to determine the time dependence of the external (or lateral) surface overheating of the tested object. They determine the correlation between the first heating stage duration and the value of overheating of the external (or lateral) surface of the object under study. They calculate the value of heat transfer resistance through the object for various times. They define TPP values over the object, calculate its average value.

In (Sergeev, 2013; GOST R 56623-2015) we describe the method based on NDTM and consisting of installing the first and second flat insulated heating elements onto the building structure (e.g. the building wall). They are mounted on opposite sides - the outer and inner walls. Therewith, the linear sizes of heating elements make up from 3 to 5 values of the building structure thickness measured in the middle part of the installed heating elements, for example, on their axes. At that, the second heating element ensures the structure is heated to a temperature which differs from the one to which the first heating element heats the concerned side of the structure. Due to the heating actuators, the corresponding temperatures are set inside the elements. The given temperatures can be controlled using systems for the thermal stabilization of the actuating heating elements for a certain period of time Δt from 1 day (GOST R 56623-2015). Sergeev (2013) describes the way which includes thermal imaging testing of one of the surfaces, compared theoretical and measured results and the choice of thermal conductivity values from among the given ones for further calculations, which can provide comparison conditions. Figure 5 shows the schematic of experimental studies.

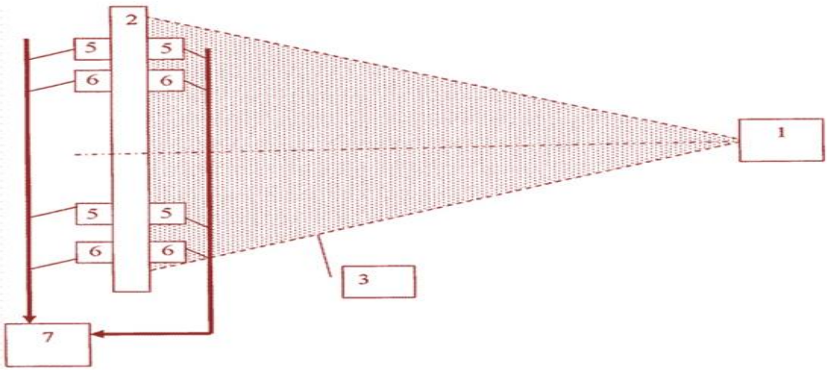

Figure 5: Scheme of experimental research

Figure represents: 1 - Thermal imaging system, 2 - Object of control - multilayer construction, 3 - Thermal imaging system overview field, 4 - Instant linear field (geometric resolution) of the thermal imaging system, 5 - Contact microprocessor temperature converters (temperature sensors), 6 -

Contact microprocessor heat flux converters (heat flux sensors), 7 - Electronic block of information collection and processing.

Prior to the thermal imaging inspection of the structure, the time of thermal inertia and discreteness of the thermal imaging camera resolution are determined. Thermal imaging inspection is held by measuring the temperature field of the surface with a spatial period specified by the size of the minimum design defect. They measure temperature values on opposite sides of the structure with time intervals and heat flow on the inside of the structure (Sergeev, 2013; GOST R 56623-2015).

There is a device for measuring the heat transfer resistance of a building structure (GOST 31166-2003). Figure 6 shows a drawing of the device design to determine the heat transfer resistance of the building structure.

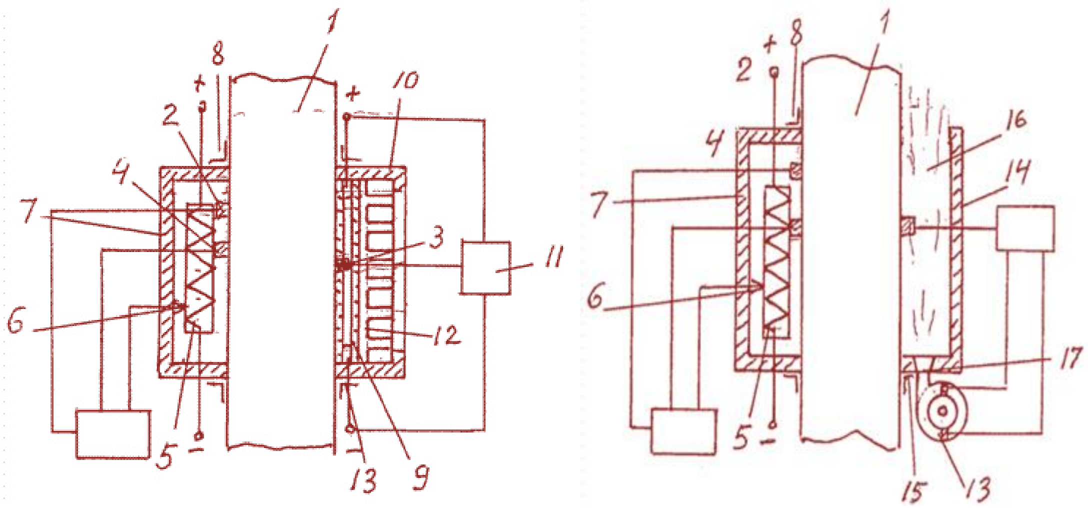

Figure 6: Drawing of the device design on determining the heat transfer resistance

Figure represents: 1 - wall of the object of study, 2 and 3 - thermometer, 4 - heat flow registration sensor, 5 - heating element, 6 - heating element regulator, 7 - insulated prefix chamber, 9 - thermoelectric module Peltier, 8 and 10 - clips, 11 - control panel, 12 - radiator, 13 and 15 - fixing elements, 14 - sun protection box, 16 - expansion chamber, 17 - nozzle.

For example, an attachment chamber with a heating element in it is mounted on a building structure, such as a wall of a building. A cage with an integrated thermoelectric module is mounted on the other side of the building, respectively, to the attachment chamber. The attachment chamber and the cage can be either boxed or round, and their size is chosen to be 3÷5 times the thickness of the building structure (GOST 31166-2003). The building structure is heated up to the temperature exceeding the ambient temperature by 5-10 °C by the heating element. Heating is combined with a thermoelectric module, which cools the surface of the building structure to negative temperatures. After a while we register the value of heat flow (q) passing through the building structure, then we calculate the TPP.

The method of measuring heat transfer resistance and the device for its implementation have been developed on the basis of NDTM (Datsyuk et al., 2007). This method consists of the thermal action on the outer surface. It is carried out by cooling down with a mobile coolant, at the same time measuring the stationary value of the temperature of the inner surface of the object under the study in the heating area, measuring the stationary value of the temperature of the outer surface of the object under investigation in the cooling area, measuring the stationary value of the temperature of the mobile coolant. The device contains a heat source, a temperature meter, an electronic processing unit and an external heat exchanger.

The method (Lavrov et al., 2006; Chernyshov & Slonova, 2006; Larioshina, 2015) can also be applied to NDTM thermal protection properties of the enclosing structure. In-situ temperatures measurements and heat fluxes density are taken at the reference point, in real environmental conditions of the building maintenance within at least two days. Heat transmission resistance at the reference point is calculated by processing the results, full-scale measurements and rejection of partial heat transmission resistance values. They calculate the heat transfer resistance at random points according to the temperature fields resulting from thermal imaging and the results of calculating the heat transfer resistance at the reference point. They measure and record the outdoor and indoor air temperature of the room, including the temperature and heat flux density on the indoor and outdoor surface of the enclosing structure within at least two days. Estimating heat transfer resistance in the reference point is being performed by measuring temperatures and heat flux densities for each i-measure.

We know a way to define the thermophysical properties of multilayer building structures without breaking their integrity (Varfolomeev et al., 1999). The method involves providing active thermal action on the surface of each outer layer adiabatically, starting from the disk heaters located in the cavity of probes, bordered by security (thermal insulation) rings, as well as recording the correlation between the surface temperature of the object under study and time. The TPP design is measured using a special approximation, obtained as a time-dependent function of temperature.

It is well known that NDTMs for determining TPP materials were developed in Khodayari Bavil, A., & Razavi, S. E. The method includes thermal exposure of the tested surface area. The data on the temperature field distribution of the object is transmitted both for analysis to the thermographic control device and then to the display device, which indicates changes in the temperature field distribution. This method enables us to determine the condition of the structure and its TPP, but it is not applicable for studying non-stationary processes taking place in real operational conditions of buildings and structures (Khodayari Bavil & Razavi, 2017).

The Russian Federation in practice mainly adopts the method of assessment of thermal properties of building envelope structures, consisting of measuring the density of heat flux passing through the structure under study, measuring temperatures on the external and internal surfaces, calculating the value of heat transfer resistance of the structure, as well as the method of determining the TPP objects by analyzing their heat transfer resistance (Larioshina, 2015; Malyavina, 2007; Thermal protection of buildings, 2012). After a preset time period, both the heat flow through the building structure and the temperature on both surfaces of the building structure are measured.

3. CONCLUSION

The analysis of the discussed sources revealed the following drawbacks:

- A long study duration, from 1 to 15 days;
- A complex structure of the installations;

- Inability to determine the TPP of the entire facility on the whole;

- Usage only in a certain period of time of year;

- The determination of the outer layers of the structure using the contact method resulting in a high error of temperature-temporal measurements due to the impact and randomness of contact thermal resistances, depends on the surface condition of the contacting bodies, the degree of their contact with one another, which does not allow to determine the value of the heat transfer resistance without correction or measurement results correction (Chernyshov & Slonova, 2006);

- Low TPP detection functionality triggered by the device dimensions allowing to determine TPP only for the local area of the enclosing structure (Pokhodun et al., 2013);

- The high prime cost of the equipment required to determine the TPP of the object, as well as the complexity of calculations.

The above methods and devices for determining the TPP of the studied materials in most cases necessitate reproducing special conditions for the experiment, placement of special sensors inside the examined material, etc. For this reason, the problem in obtaining reliable research results in industrial, civil and commercial applications is relevant for the current devices. Innovative methods are required to establish the thermal and physical properties of fences and various types of structures.

4. DATA AVAILABILITY AND MATERIAL

Data involved in this study can be requested to the corresponding author.

5. REFERENCES

Ametistov, E. B. (2000). Fundamentals of heat exchange theory. Method of the non-destructive control of the thermal-physical properties of the materials. *Publishing house: Moscow Energy Institute*, 242 c.

Barilovich, V. A., & Smirnov, Yu. A. (2014). Fundamentals of the technical thermodynamics and the theory of heat and mass transfer: Teaching guide. Moscow: INFRA-M Research and Publishing Center, 432 p.

Batalov, V. S. (1982). Simultaneous determination of the thermophysical parameters of the solid-phase substances. *Engineering and Physical Journal, 42*(6), 1026-1027.

Batalov, V. S. (1982). Simultaneous determination of the thermophysical parameters of the solid-phase substances. *Engineering and Physical Journal, 42*(6), 1026-1027.

Belov, E. A., Sokolov, G. J., & Platunov, E. S. (1986). Digital express meter of heat protection structures with direct reading. *Promyshlennaja teplotehnika*, 756-760.

Bogoslovsky, V. N. (2013). Construction Thermophysics (Thermophysical Basics of Heating, Ventilation and Air Conditioning): Textbook for Higher Education Institutions. *Publishing house: Book on Requirement*, 416 p.

Budadin, O. N. (2001). Thermal and non-destructive control and diagnostics of the technical condition of materials, products and structures. Doctor of Technical Sciences dissertation: 05.02.11. - Saint-Petersburg, 564 p.

Budadin, O. N., & Abramova, E. V. (2011). Patent No. 2420730. Russian Federation. IPC G01N 25/18. Method of the thermal control of the heat transfer resistance of the multilayer construction under the non-stationary heat transfer conditions.

Budadin, O. N., & Abramova, E. V. (2011). Patent No. 2478938. Russian Federation. IPC G01N 25/18. Method of the thermal control of the heat transfer resistance of the multilayer construction under the non-stationary heat transfer conditions.

Budadin, O. N., Potapov, A. I., & Kolganov, V. I., (2002). Thermal Nondestructive Examination of Products. Moscow, Nauka, p.476.

Chernyshov, A. V., & Slonova, A. S. (2006). Patent No. 2287807. Russian Federation. IPC G01N 25/00.Method for determination of the thermal-physical properties of the multilayer building structures and products [Text].Application submission date: 09.03.2005; Published on: 20.11.2006. Bul. No. 32.

Datsyuk, T. A., Isakov, P. G., Lapovok, E. V., Platonov, S. A., Sokolov, N. A., & Khankov, S. I. (2007). Patent No. 2308710. Russian Federation. IPC G01N 25/18.Method of the thermal resistance measurement (variants) and the device for its implementation [Text]; Application submission date: 27.05.2005; Published on: 20.10.2007. Bul. No. 29.

Fokin, V. M., & Chernyshov, V. N. (2004). Non-destructive control of the thermal-physical characteristics of the building materials. Moscow: Publishing house: Machine-building-1, 211 p.

Fokin, V. M., & Kovylin, A. V. (2009). Theoretical bases for the determination of the thermal conductivity, volume heat capacity and thermal conductivity of the materials on the thermal measurements on the surface by the nondestructive control method (in Russian). Vestnik Volgograd State University of Architecture and Civil Engineering. Edition "Construction and architecture", 14(33), 123-127.

Fokin, V. M., Boykov, G. P., & Vidin, Yu. V. (2004). Fundamentals of the technical thermophysics: Monograph. *Publishing house: Mechanical Engineering-1*, 172 p.

Golovnev, S. G. (2014). Patent No. 146590. Russian Federation. IPC G01N 25/28. Device for determination of the reduced heat transfer resistance of external enclosing structures in summer [Text]; Application submission date: 16.06.2014; Published on: 10.10.2014. Bul. No. 28.

GOST 31166-2003. National standard of the Russian Federation. Structures, fencing buildings and structures. Method of calorimetric determination of heat transfer coefficient.

GOST R 56623-2015. National standard of the Russian Federation. Non-destructive control, Method for determination of heat transfer resistance of fencing structures.

Ivanova, G. I., Kuznetsov, N. D., & Chistyakov, V. S. (2007). Thermotechnical measurements and devices: book for the students of the universities, studying in the specialization "Thermal power engineering". - 3rd Ed., Moscow. : Moscow Energy Institute, 458 p.

Kabanov, O. V., & Panfilov, S. A. (2016a). Modern methods of the objects thermal-physical properties determination (in Russian). XLIV Ogarevskie readings. Proceedings of the scientific conference: in 3 hours. *Saransk: Mordovian State Unitary Enterprise*, 156–160.

Kabanov, O. V., & Panfilov, S. A. (2016b). Modern methods of assessment of the thermal-physical properties of the object. Proceedings of the XX scientific and practical conference of young scientists, postgraduates and students of N.P. Ogaryov Moscow State University. *Saransk*, 169–174.

Kabanov, O. V., Panfilov, S. A., & Andronova, O. A. (2016). Analytical review of the methods of assessment (measurement) of the thermophysical characteristics of the investigated object. Topical issues of science and technology: Collection of scientific papers on the results of the III international scientific-practical conference. *Samara: Innovation Center for Education and Science Development*, 107–111.

Kabanov, O. V., Panfilov, S. A., & Barychev, V. I. (2015). Review of the modern methods for determination of the thermal-physical properties of the materials and objects with the use of the electrical devices (in Russian). *Collection of scientific papers "Development of technical sciences in the modern world". Voronezh, 2*, 178–180

Kabanov, O. V., Panfilov, S. A., Khremkin, A. S., & Bobrov, M. A. (2014). Development of the method for determination of the thermal physical properties of the object. *Journal of Science and Technology Vestnik of the Volga Region, 5*, 253–256.

Khodayari Bavil,. A., & Razavi, S. E. (2017). On the thermoflow behavior in a rectangular channel with skewed circular ribs. *Mechanics & Industry, 18*(2), 170-187

Klimenko, A. V., & Zorin, V. M. (1999). Thermal Power Engineering and Heat Engineering. *General Questions. Handbook [in Russian], MÉI, Moscow.*

Kovylin A. V. (2011). Development of the method for determination of the heat exchange and thermophysical properties of the fencing of buildings on the basis of the thermal measurements on the surfaces: dissertation ... Candidate of Technical Sciences: 05.23.03; [Location: Volgograd State University of Architecture and Civil Engineering] - Volgograd, 184 p.

Kudinov, A. A. (2015). Heat and mass exchange: Training guide. Moscow: INFRA-M Research and Publishing Center, 375 p.

Kulakov, M. V., Makarov, B. I. (1979). Measurement of the solid surface temperature. Moscow: Energy, 96p.

Larioshina, I. A. (2015). Thermal imaging control methods of thermal protection of building structures: dissertation of the candidate of technical sciences: 05.11.13.[Location: Tomsk Polytechnic University]. - Tomsk, 155 p.

Lavrov, V. N., Titaev, V. A., & Sosin, Yu. D. (2006). Patent No. 2285915. Russian Federation. IPC G01N 25/00.Method of the heat protection properties of the fencing construction [Text]; Application submission date: 20.10.2004; Published on: 20.10.2006. Bul. No. 29.

Malyavina, E. G. (2007). Heat Loss of the Building: A Reference Book.

Pokhodun, A. I., Sokolov, A. N., & Sokolov, N. A. (2013). Patent No. 2480739. Russian Federation. IPC G01N 25/72. Method of the thermal nondestructive control of the heat transfer resistance of the building structure [Text]; Application submission date: 23.08.2011; Published on: 27.04.2013. Bul. No. 12.

Rudzit, Ya. A., & Plutalov, V. N. (1991). Fundamentals of metrology, accuracy and reliability in instrumentation. Moscow: Mechanical Engineering, 302 p.

Sergeev, S. S. (2013). Patent No. 2476866. Russian Federation. IPC G01N 25/18.Device for measuring the heat transfer resistance of the building structure [Text]. Application submission date: 20.04.2011; Published on: 27.02.2013. Bul. No. 6.

Tabunshchikov, Yu. A. (1986). Thermal protection of the enclosing structures of buildings and structures. Moscow: Stroyizdat, 381p.

Tabunshchikov, Yu. A., & Borodach, M. M. (2002). Mathematical modeling and optimization of the thermal efficiency of the buildings. Moscow: AVOK-PRESS, 194 p.

Thermal Protection of Buildings, (2004). Construction Directives and Rules 23-02-2003[Text]. Moscow: State Committee of the Russian Federation for Construction and the Housing and Utilities Complex. p.2316.

Thermal protection of buildings, (2012). Construction Directives and Rules 50.13330.2012 apdated version instead of Thermal protection of buildings. Construction Directives and Rules (23-02-2003).

Varfolomeev, B. G., Orlova, L. P., Muromtsev, Yu. L., & Potapov, V. M. (1999). Patent No. 2140070. Russian Federation. IPC G01N 25/18.Method for determination of the thermal-physical characteristics of the multilayer building materials without breaking their integrity.

Vavilov, V. P. (2009). Infrared thermography and thermal control. Moscow: Spectrum, 544 p.

Vavilov, V. P., Grigoriev, A. V., Ivanov, A. I., & Nesterukov, D. A. (2012). Patent No. 2468359. Russian Federation. IPC 01N 25/18. Method for determination of the heat transfer resistance of the building structures.

Vavilov, V. P., Grigoriev, A. V., Ivanov, A. I., & Nesterukov, D. A. (2013). Patent No. 105998. Russian Federation. IPC H01L 23/34.Method for determination of the heat transfer resistance of the fencing constructions.

Vidin, Yu. V., Ivanov, V. V., & Kazakov, R. V. (2018). Engineering methods of calculation of heat exchange problems [Text]: monograph. Moscow: INFRA-M Research and Publishing Center; Krasnoyarsk: Siberian Federal University, 166 p.

Yureniev, V. I., & Lebedev, P. D. (1975). Thermal Engineering Reference Book under the general edition of V. I. Yurenieva and P. D. Lebedeva. Moscow: Energy, 2, 896 p.

Professor Dr.Panfilov Stepan Aleksandrovich is Professor of Ogarev Mordovia State University, Republic of Mordovia, Saransk, Russia. He has a Doctor of Technical Sciences degree. His research interests include Process Automation, Quality Management.

Professor Dr. Lomshin Mikhail Ivanovich is Professor of Ogarev Mordovia State University, Republic of Mordovia, Saransk, Russia. He graduated with a Ph.D. degree in Philology and a Doctor of Pedagogical Sciences degree from the Faculty of Philology of Mordovia University. His research encompasses Scientific and Methodological Foundations for Improving Modern Literary Education in National Groups of Higher Education.

Sergushina Elena Sergeevna is Chairman of the All-Russian Center for Higher Education and Research (Department) of General Professional and Special (economic) Disciplines, and Deputy Dean for Research, Ogarev Mordovia State University, Republic of Mordovia, Saransk, Russia. Her research is related to Basic Economic Sciences.

Kabanov Oleg Vladimirovich is an Engineer at Ogarev Mordovia State University, Republic of Mordovia, Saransk, Russia. His research is Energy-Saving Systems, Automated Control Systems.