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COMPARATIVE ANALYSIS OF CURRENT STANDARDS FOR TESTING THERMAL PROTECTION OF FACADE CARPENTRY

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Abstract: *The low level of energy efficiency in buildings results in increased energy consumption for heating and cooling and high carbon dioxide emissions. Insufficient thermal protection of the exterior of a building contributes to a high value of thermal transmittance of external walls and facade carpentry.*
Regulations and standards in the field of energy efficiency in Serbia are going to be harmonized with European documents, which is an integral part of the EU accession process. Before placing construction products on the market, it is necessary to examine product performances of products so that the thermal transmittance of facade carpentry can be tested according two valid Serbian standards: SRPS U.J5. 060 from 1984 and SRPS EN ISO 12567-1, which were adopted in 2012. These types of testing can only be performed in accredited laboratories.
The paper presents a comparative analysis of those two standards for testing thermal transmittance of external carpentry, the testing method, measuring equipment, the obtaining of results that prove the performance of the product.
Keywords*: thermal transmittance, exterior carpentry, energy efficiency, SRPS U.J5.060, SRPS EN ISO 12567-1*

1. INTRODUCTION

Over the past few years, more and more attention is being paid to improving the energy efficiency of buildings. People have become more aware of the problems that our planet is facing and for that reason they are trying in every way to reduce harmful impacts. For this reason, special attention is paid to proving the best possible performance of products that are installed in new or existing buildings.

Because to their large surface area, windows considerably contribute to the heat loss of buildings in connection with requirements for cooling and heating. Therefore, countries have introduced laws and bylaws to regulate construction of energy efficientbuildings.

The JUS U.J5.060 standard was used, with mandatory application, from January 21, 1984, until July 28, 2015, when it was withdrawn. The standard is still in use when obtaining laboratory values for the thermal transmittance coefficient, due to the fact that the Rulebook on Energy Efficiency of Buildings ("Official Gazette of RS", No. 61/2021 of 19 August 2011) calls it a support standard for key standards, a list of which is contained in Table 2.3 of the Rulebook. In order to meet the values prescribed by the Rulebook during the construction of buildings, the contractor must submit the necessary certificates that can only be issued by a laboratory accredited by the Accreditation Body of Serbia.

The SRPS U.J5.060 standard has been replaced by the ISO 12567 standard, which consists of two parts: SRPS EN ISO 12567-1, which states the principle of measuring the thermal transmittancecoefficient for windows and doors and which will be presented in this paper, and SRPS EN ISO 12567-2 which deals with the measurement of the thermal transmittance coefficientof skylights and protruding windows. In addition to the withdrawn standard, the Rulebook on Energy Efficiency also cites SRPS EN ISO 12567-1 as a standard that can be used when determining the thermal transmittance coefficient of construction carpentry.

Tests according to these standards can be performed only in the Laboratory for Thermal Engineering and Fire Protection, which is located within the IMS Institute in Belgrade.

2. THERMAL ENGINEERING IN HIGH-RISES - LABORATORY METHODS FOR TESTING THERMAL TRANSMITTANCEFOR BUILDING CONSTRUCTIONS (SRPS U.J5.060)

The principle of measuring the thermal transmittance coefficient according to standard SRPS U.J5.060 is based on the hot-box method. The principle of this method consists of installing a sample between a hot and a cold chamber in which different temperatures are maintained with the help of a heating and cooling source. Creating a temperature difference between the two chambers leads to the process of heat passing through the sample. Using experimentally obtained values, as well as measured dimensions of the sample and data on sample composition, the value for the thermal transmittance coefficientis obtained by calculation.

2.1. Application of standards

This standard established the definitions of measured quantities, general measurement conditions, laboratory methods of measurement using chambers with regulated temperature conditions and the method of data processing for determining the resistance to heat flow "R", i.e. the thermal transmittance coefficient "k" (also labeled as "U") of building constructions.[1] The standard refers to the measurement on samples that cannot be tested by the hot plate method (JUS U.A2.020, current SRPS U.J1.020), sample of structures of buildings (walls, ceilings, windows, doors, etc.) in the laboratory.[1]Testing is mandatory in the design phase for all building structures whose resistance to heat flow "R" cannot be calculated according to standard JUS U.J5.510, current SRPS U.J5. 510.[1]

2.2. Device for measuring the thermal transmittance coefficient

According to the standard, the device used to acquire the value for thermal transmittance coefficient consists of two chambers ("hot" and "cold") in which different temperatures are maintained with the help of a heating and a cooling device. It is also necessary to install fans in order to create the most uniform temperature image that must prevail in all parts of the chambers. In addition, it is necessary to have protection to protect the sample from the heating device. Figure 1 shows the device used in the Laboratory for Thermal Engineering and Fire Protection, IMS Institute.

Figure 1: Test chamber according to SRPS U.J5.060

2.3. Measuring devices

Temperature ismeasured using temperaturesensors - thermocouples (Cu-const, Fe-const, etc.), resistance thermometers, etc., which measure the temperature at the sample surface, as well as air temperature in the “hot” and “cold” chamber. Measurementaccuracy of must not be under 0.2ºC, while the thickness of the wire must not exceed 0.3 mm.[1] Heat flux density is measured using heat fluxmeters whose measurement accuracy must be 2%.[1] Heat fluxmeters must be as thin as possible, not exceeding a thickness of 8 mm, or a surface area of 40 cm^2. In order to control the prescribed constant heat fluxmeters must be calibrated annually.

2.4. Sample preparation for measurement

The sample can be placed in the chamber in a dried or non-dried state. If the sample is conditioned (dried), it is necessary to record its mass before and after conditioning in the dryer, after which the sample can be installed in the chamber in the position in which it will be installed in the building (this especially goes for samples with an air layer, windows and doors). The sample is installed between the "hot" and the "cold" chamber, after which the measuring elements are placed on the sample. Thermal fluxmeters and temperature sensors (thermocouples) are used as measuring elements. The number of installed fluxmeters depends on the area of heat fluxes that must be covered. After that, thermocouples are placed inside the measuring field of heat flux meters.

2.5. Measurement principle

After installing the sample and installing the measuring elements, the cooling and heating device are turned on. The heater provides continuous heating of the air in the "hot" chamber, while the cooler cools the air in the "cold" chamber, which mimics the actual conditions to which the sample is exposed after installation in the building. The process of constant heating and cooling of the chambers is performed until a steady state is reached. Steady state is established after at minimum of 8 hours. After 8 hours, or two series of measurements of 4 hours each, the largest differences in resistance toheat flow "R" must be obtained, and must not exceed 1%. When this condition is met, the equipment can be shut down and data processing can begin.

2.6. Measurement results

The maintaining of temperatures in the "hot" and "cold" chamber, achieves a temperature difference that causes the process of heat passing through the sample, as well as through the wall that separates the two chambers. In addition to the temperature difference, with the help of a measuring fluxmeter, values for heat flux density are obtained. By knowing these two informations, the formula for heat flow resistance is obtained as a quotient of the mean temperature difference between the boundary surfaces of the sample and the value for heat flow density through the sample in the steady state. By obtaining the value for resistance to heat flow, using its reciprocal value, we arrive at the result for the thermal transmittance coefficient through the sample.

$$k = 1/(R_i + R + R_o) \quad (1)$$

where: k [W/m^{2}K] thermal transmittance coefficient; R_i [m^{2}K/W]and R_o[m^{2}K/W] resistance to heat flow due to thermal transmittance; R [m2K/W] resistance to heat flow of the sample.

3. THERMAL PERFORMANCE OF WINDOWS AND DOORS - DETERMINATION OF THE THERMAL TRANSMITTANCE COEFFICIENT BY THE HEATING BOX METHOD - PART 1: COMPLETE WINDOWS AND DOORS (SRPS EN ISO 12567-1: 2010)

Standard SRPS EN ISO 12567-1 is based on the principle of the hot-box method. The principle of obtaining the thermal transmittance coefficient is divided into two phases. The first phase is the calibration phase, and the second phase is the phase of measuring the temperature and air flow of the test sample. By calibration values of the thermal transmittance coefficient are obtained from the hot and cold side of the hot-box device.

A sample of the calibration sample, as well as the sample subject to testing, are installed in the same way. The sample is placed in the middle of the chamber, between the hot and cold chambers in which different temperatures prevail. Due to the temperature difference, heat passes through the sample. The thermal transmittance coefficient is calculated using experimental values and dimensions and sample composition.

3.1. Application of standards

Standard SRPS EN ISO 12567-1 refers to the methodology for measuring the thermal transmittance coefficient for windows and doors using the hot-box method. The hot-box method is a standardized method used in thermal engineering in which the thermal transmittance coefficient of construction carpentry is established in conditioned chambers between which the test sample is located. The value of the total thermal transmittance coefficient for the whole sample is obtained as the output.

The standard is applicable to all effects of frames, window sashes, shutters, blinds, partitions, panels, doors and openings. It does not apply to edge effects that occur outside the sample boundaries, transmission of energy due to solar radiation on the sample, effects of air leakage through the sample, skylights and products designed so that the outer cladding is outside the cold side of the roof surface.[6]

3.2. Thermal transmittance coefficient measuring device

The thermal transmittance coefficient measuring device consists of a test chamber which has two parts. The first part ("cold" chamber) simulates external influences on the built-in sample, while the second part ("hot" chamber) simulates the conditions prevailing inside the room. The "hot" chamber contains a part that is a measuring box. The measuring box is positioned so that there is as little heat loss as possible through the walls of the measuring box. For that reason, the second part of the "hot" chamber, contains two fans and two heaters, while the "cold" chamber contains a fan and a cooling element.


Figure 2: Test chamber according to SRPS EN ISO 12567-1

The sample is installed in the middle of the measuring box, between the two chambers. It is mounted into the partition wall made of partition panels. Partition panels must be thicker than 100 mm, with a thermal conductivity value that must be 0.04 W/mK. The sample, must be surrounded by partition panels on all sides in order to eliminate the edge effects that occur between the frame and the partition panel. For this reason, panels with a low thermal conductivity value are chosen. According to the standard, another condition that panels must meet, is that the value of their emissivity must not exceed 0.8.[2]

3.3. Measuring devices

The temperature on the sample, is measured using measuring devices - type T thermocouples (copper constant) made of wire with a diameter of 0.3 mm. These are attached to the test sample by straps whose emissivity must exceed the value of 0.8.

One air flow meter eachare placed in the "hot" and in the "cold" chamber. The meter must record air flow of 0.3 m/s in the hot chamber, and 1.5 m/sin the cold chamber.

3.4. Sample preparation for measurement

The thermal transmittance coefficient is measured in two phases. The first phase involves the use of calibration panels, which are placed in the place where the sample will later be installed and whose thermal performances must be known. In the second phase of measurement, the test sample is installed in the chamber.

During the first phase, a calibration sample is used, which consists of two pieces of glass 4 mm thick each, as well as an insulating material (EPS - expanding polystyrene) which has a known value for thermal resistance or thermal conductivity. Calibration panels should be of similar dimensions as the test sample. The purpose of this first phase is to establish surface resistances of the calibration panels, as well as to establish the appropriate thermal transmittance coefficient of the partition panels themselves. The material used in the calibration consists of two calibration panels which must be made of a homogeneous material with known thermal conductivity or thermal resistance. Panel thicknesses used for calibration must be approximately 20 mm and 60 mm. The thermal resistance of the insulating materials used should have mean temperature values ranging from 0ºC to 15ºC. After installing the sample, it is necessary to attach the measuring equipment. Then, three measurements of the calibration panel are recorded, which determines the repeatability of results and the quality of measurements.

It is then possible to move on to the second phase when a door/window test sample is installed. Samples installed in the chamber must have prescribed dimensions. Table 1 contains allowable dimensions of window and door samples that can be installed in the chamber.

Table 1. Recommended sample dimensions

Sample	Height [mm]	Width [mm]
Window	1480 (with a tolerance of -25%)	1230 (with a tolerance of ±25%)
Window	2180 (with a tolerance of ±25%)	1480 (with a tolerance of +25%)
Door	2180 (with a tolerance of ±25%)	1230 (with a tolerance of ±25%)
Door	2180 (with a tolerance of ±25%)	2000 (with a tolerance of ±25%)

The test specimen is installed between the "hot" and the "cold" chamber and positioned so that there are partition panels around it. There are 4 ways of installation: a window is located inside the opening of the partition panel, a door is located inside the opening of the partition panel, a door is installed on the hot side of the chambers, the door is internally mounted, when the door profile is additionally thermally protected.

After installation, measuring equipment is placed on the test sample. A minimum of 9 thermocouples must be placed, evenly distributed, on the sample, so that each thermocouple covers one ninth of the sample. It is also necessary to install 8 thermocouples to measure the temperature of the partition panel. The temperature of the "hot" and of the "cold" chamber must be measured.

Air flow meters should be located in the space between the partition and the partition wall, at a height corresponding to half the height of the sample to enable parallel flow.

In order to achieve natural convection in the hot chamber, the distance between the partition and the partition panel in the hot chamber must be over 150 mm, and in the cold chamber not less than 100 mm.

3.5. Measurement principle

The calibration sample is measured in order to set appropriate conditions for testing the actualsample. It also serves to obtain the values of heat flow (flux) and surface heat transfer of partition panels. Measuring is done with a minimum of three different measurements of the average air temperature in steps of ±5 K by changing the temperature in the "cold" chamber, without changing the conditions of air movement in the "cold" chamber, or the temperature and natural convection in the "hot" chamber. Using this procedure, surface resistances can be established, as well as the heat transfercoefficient over the function of heat flux through the calibration sample.

The first calibration test should be performed with a thinner panel, about 20 mm thick, with a mean temperature (between "hot" and "cold" chambers) that should be about 10ºC. Before the start of the measurement, air speed is adjusted via the fan, and remains constant during all measurements (calibration panels and door/window samples).

After completing the first phase and obtaining the values of surface resistance, as well as knowing the emissivity that should be similar to the emissivity of the window/door sample, one can move on to the second phase. After the installation of the sample and the placement of the measuring equipment, the same conditions are created in the chamber as were during the measurement of the calibration sample. Since the presence of condensation on the sample can have an impact on the measurement of thermal conductivity, it is necessary to maintain the relative humidity in the chambers at a sufficiently low level to avoid measurement error.

3.6. Measurement results

The thermal transmittance coefficientU (W/m^{2}K) is obtained based on following measured values:

$\Delta U = \Delta U\ (\Theta ci\ ,\ \Theta ce\ ,\ \Theta si,b\ ,\ \Theta se,b\ ,\ \Theta si,sur\ ,\ \Theta se,sur\ ,\ \Phi in,\ vi\ ,\ ve\ ),$

where:

U – thermal transmittance coefficient (W/m^{2}K); Θ_{ci}– air temperature in the hotchamber (ºC); Θ_{ce} – air temperature in thecoldchamber (ºC); $\Theta_{si,b}$ – temperature of the partition in the hotchamber (ºC); $\Theta_{se,b}$ – temperature of the partition in thecoldchamber (ºC); $\Theta_{si,sur}$ – temperature of the partition panel in the hotchamber (ºC); $\Theta_{se,sur}$– temperature of the partition panel in thecoldchamber (ºC); Φ_{in} – input power to the hot box (W); v_i – air flow in thehotchamber (m/s); v_e– air flow in thecoldchamber (m/s);

It is also necessary to measure the dimensions of the sample and write down the values for: frame width (w), partition panel thickness (d_{sur}), sample surface area (A_{sp}), partition panel surface area (A_{sur}), sample length (L).

Based on all the above data, the total thermal transmittance coefficient of the sample, U_m [W/(m^{2}K)] is obtained using the following equation:

$Um = qsp/\Delta\Theta n$,

where q_{sp} [K] is the heat flux calculated via the test sample, and $\Delta\Theta_n$ represents the difference in air temperature between the two chambers. Then the value for the measured thermal transmittance coefficient is corrected for the effect of q due to total surface resistance $R_{s,tot}$ to obtain the standardized thermal transmittance coefficient U_{st} [W/(m^{2}K):]

$Ust = [Um\text{-}1 – Rs,tot + R(s,tot),st]\text{-}1$,

where the value R $_{(s,tot),st}$ is taken as the European, prescribed value which is 0.17 m^{2}K/W, while the value for $R_{s,tot}$ is obtained during the calibration of the calibration sample.

4. COMPARISON OF TWO STANDARDS SRPS U.J5.060 AND SRPS EN ISO 12567-1

Table 2 contains differences between SRPS U.J5.060 and SRPS EN ISO 12567-1.

Table 2. Comparison of two Serbian standards

Parameters	SRPS U.J5.060	SRPS EN ISO 12567-1
Year of issue	**1984**	**2010**
Samples that can be tested	Building structures (windows, doors, walls, ceilings, etc.).	Windows and doors.
Sample dimensions	No restrictions for dimensions.	Windows and doors must have prescribed dimensions.
Composition of measuring devices	Hot and cold chamber,partition panel heating andcooling element, radiation protection, fans.	Hot and cold chamber, measuring box as part of the hot chamber, partition wall, fans, heating and cooling elements.

Parameters	SRPS U.J5.060	SRPS EN ISO 12567-1
Year of issue	**1984**	**2010**
Measuring devices	Temperature sensors - thermocouples (Cu-const, Fe-const, etc.), resistive thermometers etc., thermal flux meters.	Type T (Cu-const) thermocouples, air flow meters.
Sample preparation	Some samples need to be conditioned before testing.	No need for conditioning.
Calibration	Not needed.	Performed before each test.
Sample placement	The sample is placed inside the opening of the partition panel.	The sample can be placed in several ways: inside the opening of the partition panel, on the hot side of the chambers, whilea door is internally mounted, with the door profile additionally thermally protected.
Installation of measuring equipment	The number of measuring points depends on the area of heat flows and they are placed only on the tested sample. Thermocouples are also placed in the chambers to measure ambient temperature.	At least 9 thermocouples are placed on the sample, and 8 are placed on the partition panel.Air flow velocity meters are placed between the partition and the partition panel. Thermocouples are also placed in the chambers to measure ambient temperature.
Measurement principle	Data obtained by measuring devices only for the test sample are collected.	Measurement is performed in two phases: first the calibration sample is measured, and then the test sample.
Measurement results	The "U" value is obtained for each part separately (e.g. with a single-sash window a separate value for the frame, and for the glass), as well as the total value.	Only a "U" value that applies to the whole sample is obtained.
Correction of results	No result correction.	The obtained "U" value is corrected for the effect of q.

5. CONCLUSION

Heat losses and gains of buildings largely depend on the thermophysical characteristics of building elements and structures from which the buildings are built.[4] In order to reach these characteristics, it is necessary to perform all required measurements to prove the performance of the products. Therefore, the paper presents a comparative analysis of standards SRPS U.J5.060 and SRPS EN ISO 12567-1 which refer to the measurement of the thermal transmittance coefficient for construction carpentry.

One of the biggest shortcomings of the SRPS EN ISO 12567-1 standard is that the value of thermal transmittance coefficient is obtained as a unique value for the whole sample, while SRPS U.J5.060, in addition to the total value for the thermal transmittance coefficient of the whole sample, prescribes obtaining values for the transparent and non-transparent part of the sample separately. In addition to this shortcoming, the disadvantage compared to the old standard is reflected in the fact that samples of only strictly prescribed dimensions contained in the standard are installed in the chamber. SRPS EN ISO 12567-1 prescribes only the possibility of measuring doors and windows, while the former JUS standard provides the possibility of measuring construction structures of buildings (walls, ceilings, windows, doors, etc.).

The advantage of the SRPS EN ISO 12567-1 standard in relation to SRPS U.J5.060 is reflected in the fact that the testing of samples of the same dimensions can facilitate comparison of results which significantly contributes to science and improves sample production. Also, another advantage that can be mentioned is the larger number of measuring points and a more complex way of measuring, which provide more accurate results.

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