Нанотек еу ЕООД
ул Синчец 10
1000 София - България
ДДС 207468719
Телефон +359 (2) 4910794

Determination of the equivalent thermal conductivity coefficient of a thermally insulating-reflective coating plaster InTek, OutTek and Stealth (λD)

Determination of the coefficient of equivalent thermal conductivity thermal insulating-reflective coating-plaster InTek, OutTek and Stealth (λD)

Investment consultancy and planning BIPLAN
Dr.ing Grzegorz Kaczmarzyk
UI. Paproci 11, 40-693 Katowice

Introduction

In line with the guidelines to be implemented in 2021, the Ministry of Transport, Construction and Maritime Economy has prepared a draft regulation on the technical conditions that buildings and their location must comply with.

This document contains requirements for, among other things, insulating properties of partitions, structures and requirements to be met by new and modernized buildings. One of the requirements is to reduce the maximum heat transfer value of the walls (U sign).

The requirements expected for 2014 raise the bar to U_{maks} = 0.25 W/(m²K).
However, in 2021, the walls will meet the U_{maks} criterion. = 0.20 W/(m²K).

In terms of physical changes to projects, the required thickness of thermal insulation will increase on average by approximately 2 cm in 2014, 4 cm in 2017 and 5 cm in 2021.

The same applies to roofs (about 15 cm - today, 18 cm in 2014, 20 cm in 2017, 25 cm in 2021) and floors (6 cm today and 10 cm in other years). Of course, this will affect the cost of the investment, but the expense will pay for itself after a few years of use, and the maintenance costs of the building will significantly decrease.

In investor activities, attention is currently focused on increasing thermal insulation by adding additional partitions to the walls of buildings made of materials with very low coefficients of thermal conductivity, such as e.g. polystyrene panels, slag or glass wool mats and, to a small extent, other more advanced thermal protection technologies. These technologies are mainly thin layers of heat-insulating and reflective plasters.

Heat-insulating-reflective protection technology takes into account the limitation or even elimination of an important component of heat movement, which is the transport of heat between media of different temperatures by means of infrared radiation.

In this category, one of the most modern technical solutions is the use of reflective heat-insulating coatings or masses with a high reflectivity of infrared radiation of up to 98%.

The reflection of infrared radiation towards a heat source at a higher temperature creates a "thermal barrier" on the reflecting surface, much more effective than classic thermal insulation materials.

The family of reflective thermal insulating plasters includes, first of all:

- **InTek** heat-reflective coatings for interiors, **OutTek** heat-reflective coatings for external walls, **MetalTop/TilesTop** heat-reflective coatings for roofs, **Stealth** for walls and roofs**;**

- Heat-insulating and reflective masses for **SkimPlaster** plasters or **IndustrialTek** high-temperature thermal pipe coatings.

Heat transfer between fluids of different temperatures, whether by heat conduction or infrared radiation, can be captured by the equivalent heat conduction mechanism, on condition that the equivalent thermal conductivity coefficient for the heat-insulating-reflective plaster is measured.

The specificity of the movement of heat by simultaneous thermal conduction and radiation allows the balance of heat fluxes on the surfaces of partition walls and flows penetrating through a partition wall covered with a heat-insulating-reflective coating defining the mode - called "Equivalent thermal conduction for reflective thermal insulation coatings" - referred to the traditional thermal conduction (heat transfer) coefficient U for comparative purposes.

Determination of the equivalent thermal conductivity coefficient for a thermally insulating-reflective coating - plaster

The measure for determining the equivalent heat conduction coefficient for reflective heat-insulating coatings was made with a closed cube with dimensions of 1.0 mx 1.0 mx 1.0 m, in which the heat source is positioned centrally, a resistance bulb with a power of 150W, and on each wall in its geometric center there are resistance thermometers at a distance of 2 cm from the wall surface. An additional thermometer was installed outside the cube to measure the ambient temperature. After turning on the heat source, measurements of the temperature distribution were made by measuring it in the microprocessor data collection system, taking measurements at 1 sec intervals with recording every 1 min. The temperature trends obtained in the individual experiments made it possible to estimate the movement of heat through the dividing walls for the various external plasterboard coverings used.

The measurement was carried out until uniform temperature trends were achieved (from 1.5 to 2 h). With a uniform pattern of internal temperature profiles and a constant external temperature, the total heat passing through the partitions to the outside was equal to the thermal efficiency of the heat source. The value of the heat transfer coefficient U was determined from the measured temperature difference between the average ambient temperature and the average interior temperature, the surface of the cube exposed to the environment and the power of the heat source.

The value of the replacement thermal conductivity coefficient was determined from the obtained values of the heat transfer coefficient and the thickness of the coating - heat- insulating-reflective plaster, calculated from the amount of coating used to paint the surface and the composition of the coating. Please remember that the thickness thus determined refers to the wet state. After drying, the thickness is reduced to approximately 2/3 of the original value.

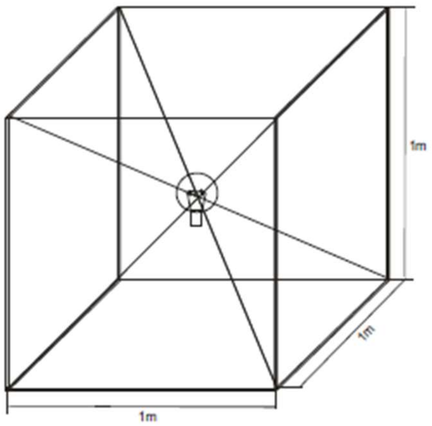


Figure 1: dimensions of the experimental stand

Partition parameters

Material	drywall	
Thermal Conductivity	0,23	W/m/deg
Thickness	0,01	m
Specific heat	1	kJ/kg/deg
Density	1000	Kg/m^3

The experiments were performed in three phases:

Phase 1	Description
 **EXPERIMENT 1** wall without covering	The walls were left for measurement as raw panels without application of heat-insulating-reflective coatings. In measurement, the basic value: $U_{\text{partition of the building},1} = \frac{1}{\left(\frac{1}{\alpha_w}+\frac{d}{\lambda_d}+\frac{1}{\alpha_z}\right)}$

Phase 2

Dry internal lining layer with thickness of 0,312 mm

EXPERIMENT 2
wall with InTek covering

Description

	Internal wall	Unit
Surface	1	m²
Wear of the covering material	240	g/wall
Coating density	0,8	kg/l
Dry matter content	100%	
Wall coverings	312	ml s.m.
	0,312	l
	0,000312	m³
	0,000312	m³ dry weight
Layer Thickness	0,000312	
	0,3120	

A value was determined in the measurement:

$$U_{\text{partition of the building},2} = \frac{1}{\left(\frac{1}{\alpha_w}+\frac{d}{\lambda_d}+\frac{d_1}{\lambda_{rw}}+\frac{1}{\alpha_z}\right)}$$

From which, for the thickness of the internal paint d_1, the value of the equivalent thermal conductivity coefficient was estimated for the internal thermal insulation and the reflective plaster λ_{rw} using the values I determined in the previous experiment a_w and a_z.

Phase 3	Description

Dry layer of OutTek coating with a thickness of 0,286mm

Dry layer of InTek coating with a thicknes s of 0,312m

EXPERIMENT 3
Wall with internal and external NANOTEK covering

An additional external application with the following parameters was used:

	External wall	Unit
Surface	1	m^2
Wear of the covering material	240	g/wall
Coating density	0,836	kg/l
Wall coverings	286	ml s.m.
	0,286	l
	0,000286496	m^3
Layer thickness	0,000286496	m
	0,286	mm

A value was determined in the measurement:

$$U_{\text{partition of the building,3}} = \frac{1}{\left(\frac{1}{\alpha_w} + \frac{d}{\lambda_d} + \frac{d_1}{\lambda_{rw}} + \frac{d_2}{\lambda_{rz}} + \frac{1}{\alpha_z}\right)}$$

From which, for the thickness of the external application d_2, the value of the equivalent thermal conductivity coefficient for the external thermal insulating-reflective plaster coating λ_{rz} was estimated using the values of a_w and a_z determined in the previous experiment 1 and in experiment 2 λ_{rw}

nanotek.eu®

Нанотек еу ЕООД
ул Синчец 10
1000 София - България
ДДС 207468719
Телефон +359 (2) 4910794

Basic relations used in the interpretation of measurement results

$Q_{\text{listed with surroundings}} = U_{\text{building partition}} * F_{\text{building partition}} * \Delta T_{\text{media}}$

Where:

$Q_{\text{listed with surroundings}}$ = heat output of 150W bulb for a fixed temperature profile
$U_{\text{building partition}}$ = general heat transfer coefficient for the partition, determined by the relationship[1]

$$U_{\text{building partition},1} = \frac{1}{\left(\frac{1}{\alpha_w} + \Sigma \frac{d}{\lambda_d} + \frac{1}{\alpha_z}\right)}$$

aw-; az- respectively, the heat exchange coefficients from the interior to the wall and from the wall to the environment

d - thickness of the thermal barrier elements in the wall (according to table 1)

λs - coefficient of thermal conductivity for elements of the wall (partition) material (according to table 1)

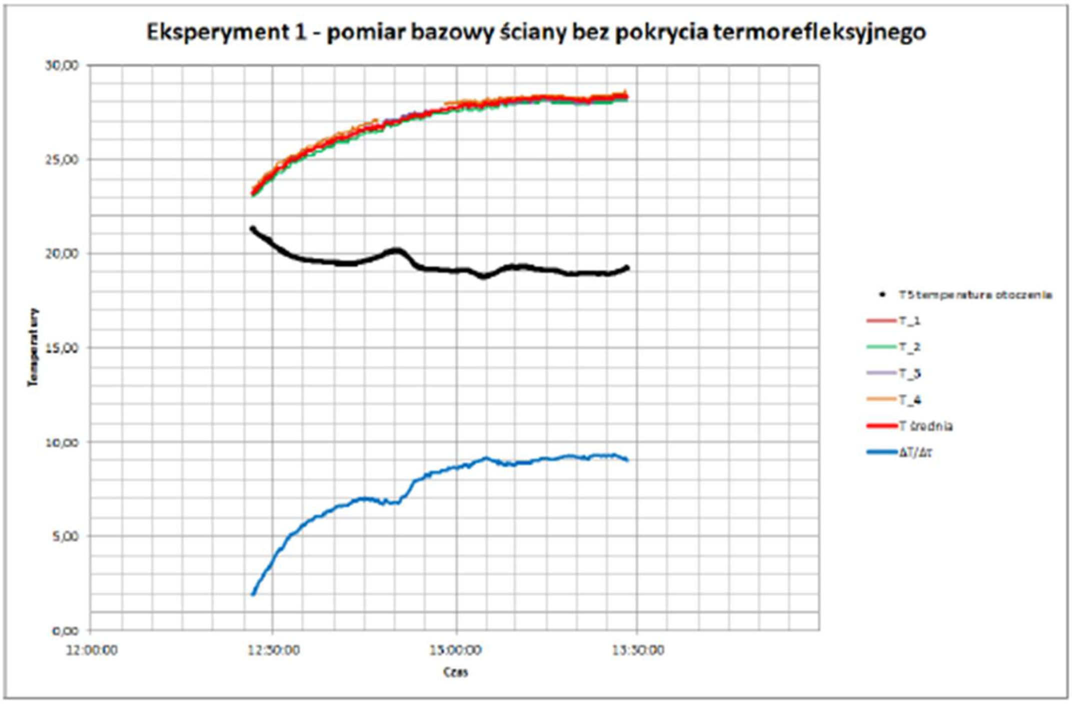
$F_{\text{building partition}}$ - the area of all walls exposed to the environment (6 m²)

$$\Delta T_{\text{media}} = \Delta T_{\text{media}} = \left(\frac{T_1 + T_2 + T_3 + T_4}{4} - T_{\text{dintorni}} \right)$$

Measurements and their interpretation

Phase 1 - without applying the NANOTEK coating

The temperature profile obtained for baseline measurement without applying a heat-insulating reflective coating is shown in fig. 2 below and the results of the thermal resistance calculations are presented in Table 2



The temperature trends clearly show a stable increase in the internal temperatures in the measuring cube, with the individual temperature trends T1, T2, T3, T4 being practically identical. Temperatures stabilized after about 40 minutes. The average temperature difference obtained between the surrounding environment and the interior of the measuring cube was 9.15 °C. The converted measurement results are shown in Table 2 below. The purpose of the measurement was to determine the values of the convective heat transfer coefficients a_1 and a_2

Table 2 Calculation results for the basic experiment - determination of convective heat transfer coefficients a1 i a2

Table 2

Power	150	W
Heat exchange surface	5	m^2
Media ΔT	8,00	deg
Average heat transfer coefficient	3,125	$W/m^2/deg$
Average thermal resistance U/1	0,32	$[m^2*deg]$ /W
Plasterboard wall thickness	0,0125	m
Plasterboard conductivity coefficient	0,23	W/m/deg
Thermal resistance of the wall $d_{plaster} / \lambda_{plaster}$	0,054	$[m^2*deg]$ /W
$1/k'=1a_1+1/a_2$	0,266	$[m^2*deg]$ /W
$a_1 = a_2 = a$	7,529	$W/m^2/deg$

The determined values of the coefficients 7.529 [$W/m^2/deg$] are consistent with the values reported in the case 1 of heat exchange between the heated surface and the stationary air layer in the surrounding environment.

Phase 2 – internal application

The temperature profile obtained for baseline measurement with the application of an internal heat-insulating reflective coating is shown in fig. 3 below and the thermal resistance calculation results are in Table 3

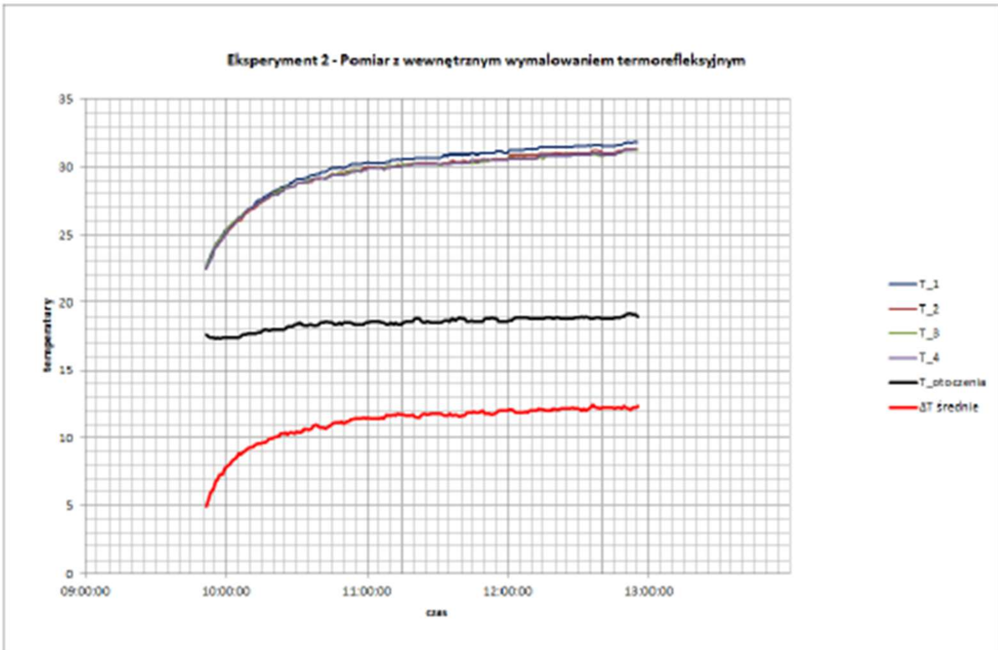


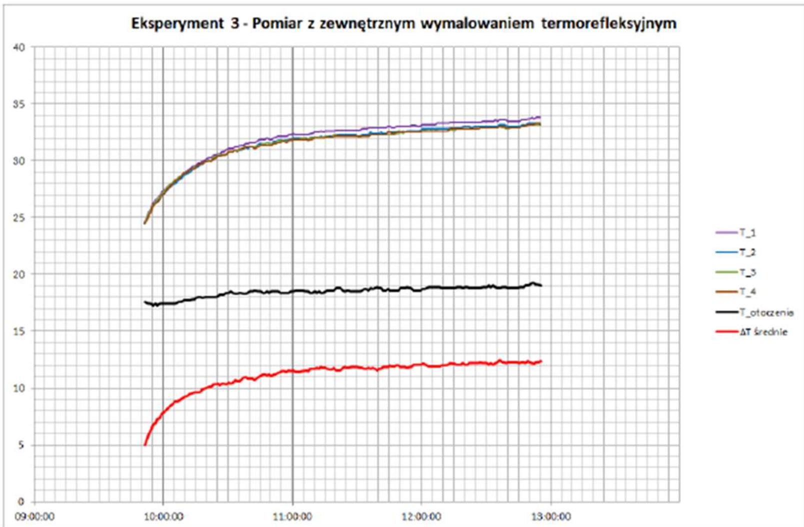
Table 3

Power	150	W
Heat exchange surface	6	m^2
Media ΔT	12,50	deg
Average heat transfer coefficient	**2,000**	$W/m^2/deg$
Average thermal resistance U/1	0,500	[m^2*deg] /W
Plasterboard wall thickness	0,0125	m
Plasterboard conductivity coefficient	0,230	W/m/deg
Thermal resistance of the wall $d_{plaster} / \lambda_{plaster}$	0,054	[m^2*deg] /W
$1/k'=1a_1+1/a_2$	0,266	[m^2*deg] /W
$a_1 = a_2 = a$	7,529	$W/m^2/deg$
Thermal resistance 1/k'' of the heat insulating reflective coating	0,180	[m^2*deg] /W
Thickness of the heat insulating reflective coating	0,312	mm
Equivalent conductivity coefficient of the heat insulating reflective coating	0,000079	W/m/deg
Thermal resistance distribution		
Total resistance	0,500	100%
Heat entry inside	0,133	27%
Internal application	0,180	36%
Plasterboard wall	0,054	11%
Heat entry towards the outside	0,133	27%

The value of the equivalent thermal conductivity coefficient for the internal reflective thermal insulating plaster is according to the measurements 5,62*10^{-5} [W/m/deg].

Phase 3-external application

The temperature profile obtained for the basic measurement with the application of the reflective heat-insulating internal and external coating is shown in fig. 4 below and the thermal resistance calculation results are presented in Table 4.



The temperature trends once again clearly show a stable increase of internal temperatures in the measurement cube, with individual temperature trends T_1; T2;T3; T4 are practically identical. Temperatures stabilized after about 60 minutes. The average temperature difference obtained between the surrounding environment and the interior of the measuring cube was 16.5 °C. The converted measurement results are shown in Table 4 below. The purpose of the measurement was to determine the value of the equivalent thermal conductivity coefficient for the external application using the convective heat transfer coefficients a_1 and a_2 determined from Experiment 1 and the value of the equivalent thermal conductivity coefficient for the internal application determined in 'experiment 2.

Нанотек еу ЕООД

ул Синчец 10
1000 София - България
ДДС 207468719
Телефон +359 (2) 4910794

Table 4

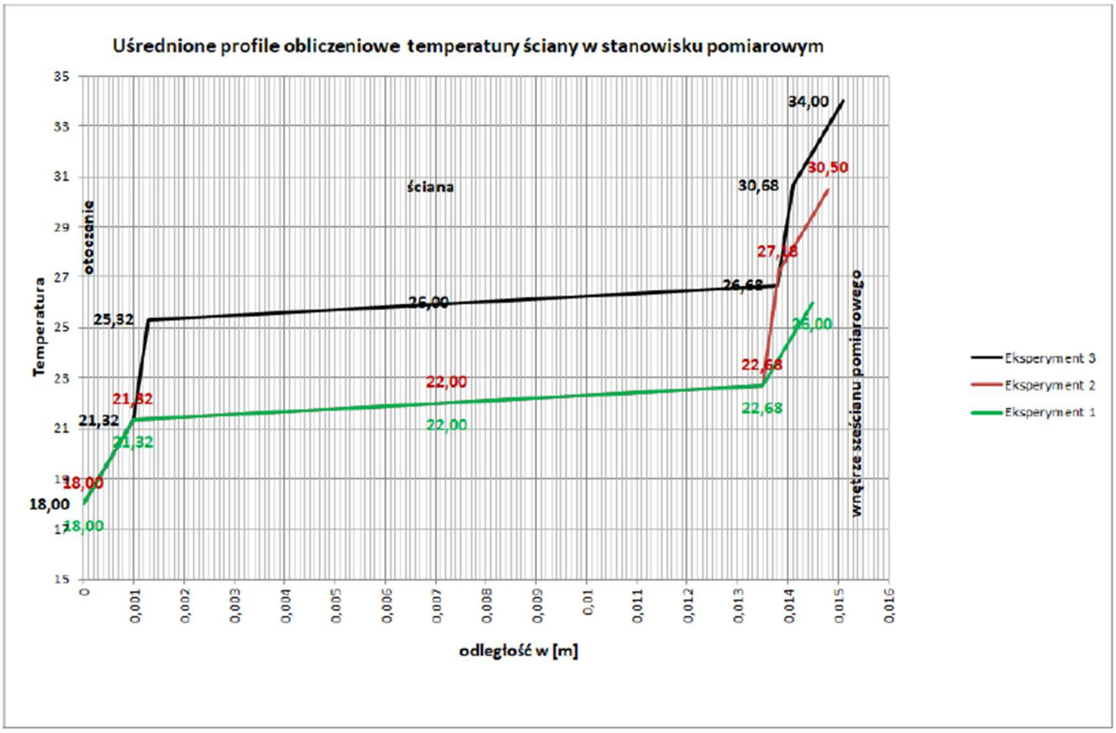
Power	150	W
Heat exchange surface	6	m^2
Media ΔT	16,50	deg
Average heat transfer coefficient	**1,515**	$W/m^2/deg$
Average thermal resistance U/1	0,660	$[m^2*deg]$ /W
Plasterboard wall thickness	0,013	m
Plasterboard conductivity coefficient	0,230	W/m/deg
Thermal resistance of the wall $d_{plaster}$ / $\lambda_{plaster}$	0,054	$[m^2*deg]$ /W
$1/k'=1a_1+1/a_2$	0,266	$[m^2*deg]$ /W
$a_1 = a_2 = a$	7,529	$W/m^2/deg$
Thermal resistance 1/k'' of the internal heat insulating and reflective coating	0,180	$[m^2*deg]$ /W
Thermal resistance 1/k'' of the external heat insulating and reflective coating	0,160	$[m^2*deg]$ /W
Thickness of the heat insulating reflective coating	0,286	mm
	0,000286	m
Equivalent conductivity coefficient of the heat insulating reflective coating	0,000088	W/m/deg
Thermal resistance distribution		
Total resistance	0,6600	100%
Heat entry inside	0,1328	20%
Internal application	0,1800	27%
Plasterboard wall	0,0543	8%
External aplication	0,1600	24%
Heat entry towards the outside	0,1328	20%

The value of the equivalent thermal conductivity coefficient for the external reflective thermal insulating plaster OutTek is 4.58*10-5 [W/m/ deg] according to the measurements carried out.

nanotek.eu ®

Нанотек еу ЕООД
ул Синчец 10
1000 София - България
ДДС 207468719
Телефон +359 (2) 4910794

Figure 5 presents an overview of the average temperature distribution in the wall for each of the experiments described above



The diagram above clearly shows the effect of the "thermal barrier" created by the heat-insulating- reflective coating, both on the external and internal surface of the wall.

Нанотек еу ЕООД
ул Синчец 10
1000 София - България
ДДС 207468719
Телефон +359 (2) 4910794

Comments on the measurements carried out

1. The measurements carried out confirmed the reflection effect of the thermal radiation from the surface covered with heat-insulating-reflective coatings, which translates into extremely low values of the so-called "Equivalent Thermal Conductivity Coefficients" for heat-insulating-reflective coatings. Are the following:

- For inner shell $5.62*10^{-5}$ [W/m/deg]
- For outer shell $4.58*10^{-5}$ [W/m/deg]

2. Such low values of the so-called heat conduction substitution coefficients derive from mechanisms other than the classic heat transport mechanism. For ordinary insulating materials, this mechanism is heat transfer by changing the frequency of vibrations of material molecules, for heat-insulating-reflective coatings, this mechanism is also thermal radiation. The greater the reflectivity of infrared radiation (non-visible radiation), the greater the insulating capacity of the protective coating. Thus, we use the term "equivalent thermal conductivity