GAS FILLING IN GLASS SYSTEM

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The filler structure is one of the most critical parts of the building´s envelope so great emphasis should be placed on its proper design. In addition to the number of panes in the glass system, material of the spacer, the type and the concentration of the filler gas in the cavity between glasses of the insulated system as well as the size of the cavity are also important. The paper focuses on the assessment of the influence of filler gas in the glass system cavity to the energy features of the glass structure. The reason for the assessment is the key influence of the inert gas and the glass cavity dimension on the energy properties of the glass system and the fact that its gradually decreasing concentration greatly affects the properties of the glass system.

Keywords: filler gas, gas space width, energy features, heat transfer

1. Introduction

The paper deals with the effect of the type and concentration of the filler gas between the glass panes on the deformation of thermal field. The transparent structure consists of a frame and glass system. The glass system accounts for up to 80% of the total area of the transparent structure, indicating that it has a key effect on the energy properties of the entire structure. The number of glass panes, the type and concentration of fill gas in the gap between the glasses, the use of selective layers and coatings, and the spacer bar material, enter the notional formula.

At present, the most commonly used triple insulating glass systems compared to insulating double glass systems have significantly improved energy properties due to the addition of additional pane and gas-filled gap. An important role in this case is also replacement of air as a gap filling with inert gas. In particular, the inert gas provides mentioned properties. However, the glass system filled with inert gas as a result of the degradation of sealing materials loses its insulating properties and gas leak occurs, which lead to a reduction in the energy properties of the entire transparent structure. Permissible annual gas leakage from the glass system is 1% [1]. However, the gas leakage is not constant in time, therefore the decrease is not linear, depends on several aspects such as used sealants, rate of degradation and other side influences. Numerical analysis using computer software represents an effective method of detecting the influence of the filling gas concentration on the thermal insulating ability of the glass system and then impact on the analyzed thermal field. Using dynamic or stationary softwares allows the application of complex mathematical–physical theories [2]. Decreasing the surface temperature on the inner surface can lead to condensation, so it is essential to maintain the lowest surface temperature of the structure safely above the dew point temperature θ_{dp}. Minimum surface temperature of transparent structures (frames, non-transparent and transparent opening panels) in areas with relative air humidity up to 50% must be $\theta_{si,w}$ [3]:

$$\theta_{si,w} > \theta_{si,w,N} = \theta_{dp}, \qquad (1)$$

where $\theta_{si,w,N}$ (°C) is the minimal required inside surface temperature value of transparent envelope parts, θ_{dp} (°C) the dew point temperature, $\theta_{si,w}$ (°C) the inside surface temperature of transparent envelope part.

The purpose of this analysis is to compare the six concepts of the glass system, differing in the use of filler gas in the gap between the glasses and width of gap. The analysis leads to determining the dependence of the thermal insulation properties on the filling gas concentration. Furthermore, it is necessary to quantify the change in surface temperature over the glazing circumference over time and subsequently to locate the point with the lowest surface temperature based on the thermal field. The influence of water vapor is not considered.

The measurement of filler gas concentration in real conditions is complicated. This parameter of the glass system implicitly expresses the heat transfer coefficient U_g. There are several ways to determine U_g. The first option is the calculation according to STN EN 673 [4], another option is the measurement according to STN EN 674 [5] or according to STN EN 675 [6]. Harmonized EN 1279+5+A1 imposes an obligation to express U_g by calculation method according to STN EN 673. The procedure according to STN EN 674 or STN EN 675 can only be used if U_g cannot be determined by calculation [7].

2. Designed detail of window

Frame construction. Selected is aluminium non-welding with interrupted thermal bridge. Frame depth is 112 mm in all considered cases. Heat transfer coefficient of frame U_f is 0.72 W/m²·K. The following frame parameters are considered for simulation in Physibel – Bistra: $\lambda = 204$ W/m·K; $\rho = 2700$ kg/m³; $c = 880$ J/kg·K.

Glass system. Conceived is as double and triple. Together, six different systems are designed, changing the filling gas (air, Argon, Krypton) and the thickness of the gap between the glasses depending on the filler gas used (13, 12, 8 mm). The concept of glass systems in which the gas concentration drops in such a way that the leaked gas is replaced by air

Fig. 1. Compositions of examined floor heating systems and thickness of layers

Table 1. Features of chosen gases

Gas fill type (100%)*	Optimum gas space width (mm) [3]	Thermal conductivity coefficient λ (W/m·K)*
Air	13	$2.496\cdot10^{-2}$
Argon	12	$1.684\cdot10^{-2}$
Krypton	8	$0.900\cdot10^{-2}$

* Thermal conductivity coefficient of chosen gases is related to temperature 10 °C and concentration of 100% of gas, normalized boundary conditions used [4].

in the glass system, but under real conditions the gas would not be replaced by air, but a negative pressure would be created in the glass system. However, the software used does not allow this option.

Fig. 2. Air filled triple and double glass system (A1, A2), Argon filled triple and double glass system (B1, B2), Krypton filled triple and double glass system (C1, C2)

Table 2. Composition os the structure of brick wall (layers are stated in direction from interior to exterior)

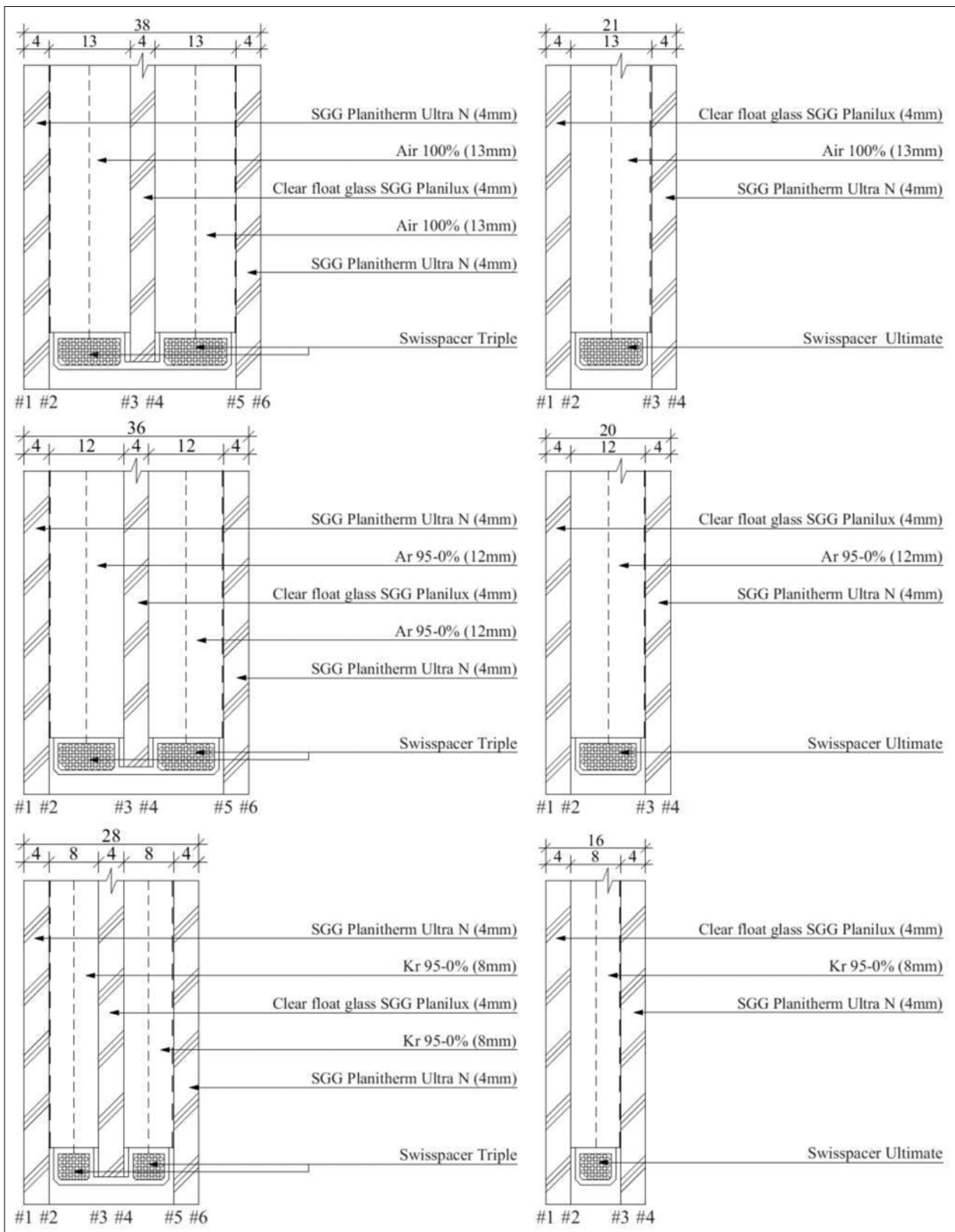| No.	Name of layer	D (m)	λ (W/m²·K)	c (J/kg·K)	ρ (kg/m³)
1	Lime-cement plaster	0.012	0.450	790.0	1350.0
2	Ceramic brick (mineral wool inside)	0.440	0.066	1000.0	700.0
3	Silicone plaster	0.015	0.700	900.0	1700.0

Construction of wall. Composition of considered brick wall is in Table 2. Computed thermal transmittance of the wall is $U = 0.15$ W/m²·K.

Boundary conditions. The design temperature for numerical analysis is given by calculation according to 73 0540-3 [9]; $\theta_i = 20$ °C. There are several alternatives to selecting external design temperature. Consideration is given to the winter period so that it is possible to check the minimum temperature on the inner surface of the structure during the winter period. It is possible to consider the external design temperature according to the temperature range in which the structure is located; Kosice, Slovakia $\theta_e = -13$ °C [9]. It is also possible to select the average design temperature for the most unfavourable month of the year from the thermal reference year. In this case, the most unfavourable month is December and the design temperature would be 3.1 °C [10]. This reasoning is used for simulations in stationary boundary conditions. In the case of dynamic boundary conditions, temperatures measured over the time (for a certain period) would be used as in the case of research at the Faculty of Civil Engineering in Kosice, where researchers applied real values measured [11].

Selected structures. Final design is the result of combination partial segments described beforehand. In all cases is window frame seated in the middle of the ceramic brick. The same composition is used as well. Structures are varied in overall depth of glass system.

3. Methodology

Window 7.4.14 simulation software. Used computer program for calculating thermal performance of windows and other window properties. Window 7.4.14 [12] implements the ISO 15099 algorithms and includes additional functionalities.

Physibel software. Used for 2D heat transfer analysis [13]. Simulation is standard method to predict thermal performance of structure.
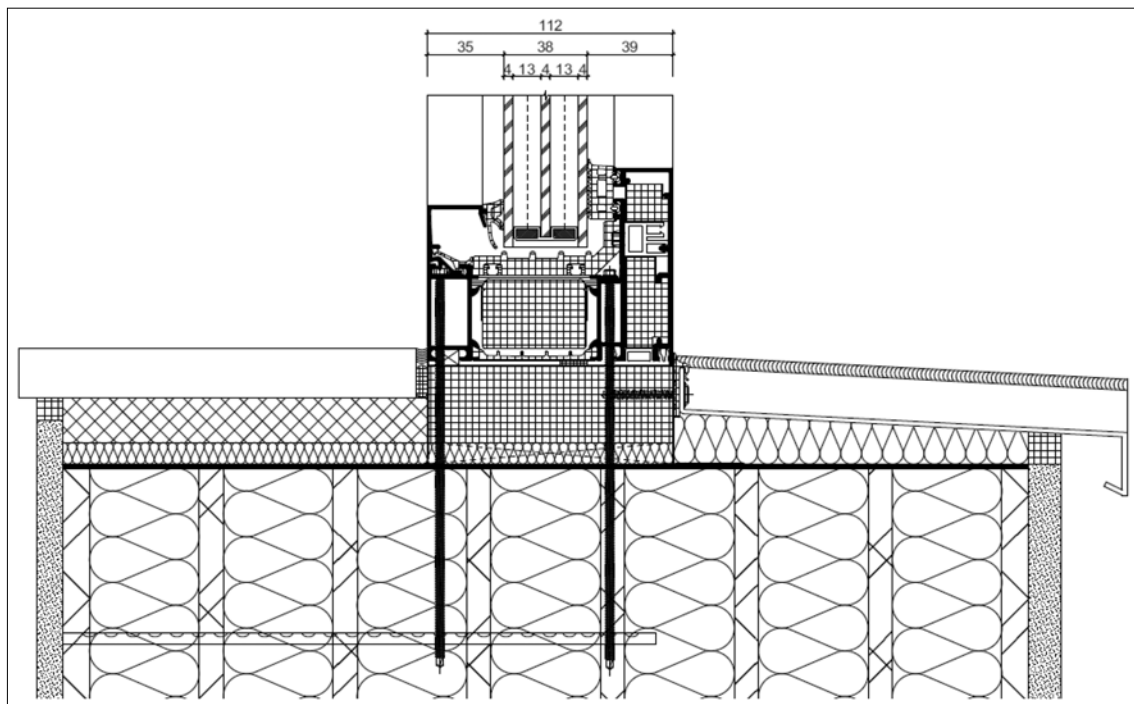

Fig. 3. Air filled triple glass system in aluminum frame seated in the middle of brick wall

Table 3. Results of air filled triple and double glass system (A1, A2), Argon filled triple and double glass system (B1, B2), Krypton filled triple and double glass system (C1, C2)

Triple glass system (left)

ID	Filler gases	Composition (mm)	Overall thickness (mm)	Temperature of outside, inside air (°C)	Dimensions width x height (mm)	Tilt (°)	Mixture of gases	Heat transfer coefficient U_g (W/m².K)	Solar factor g (-)	*Temp. outer surface layer 1 (°C)	*Temp. inner surface layer 1 (°C)	*Temp. outer surface layer 3 (°C)	*Temp. inner surface layer 3 (°C)	Thermal conductivity coefficient λ_g (W/m.K)
Air 1xPlaniclear, 2xPlanitherm Ultra N (2,5) 4-13-4-13-4mm														
1	Air	4-13-4-13-4	38	-13; 20	1000x1000	90	Air(100%)	0.878	0.474	-12.3	-12.1	16.2	16.3	0.040
Ar,Air; 1xPlaniclear, 2xPlanitherm Ultra N (2,5) 4-12-4-12-4mm														
1	Ar, Air	4-12-4-12-4	36	-13; 20	1000x1000	90	Ar(95%), Air(5%)	0.703	0.474	-12.5	-12.4	17.0	17.1	0.031
2							Ar(90%), Air(10%)	0.714	0.474	-12.4	-12.4	17.0	17.1	
3							Ar(85%), Air(15%)	0.725	0.474	-12.4	-12.3	16.9	17.0	
4							Ar(80%), Air(20%)	0.736	0.474	-12.4	-12.3	16.8	16.9	
5							Ar(75%), Air(25%)	0.748	0.474	-12.4	-12.3	16.8	16.9	
6							Ar(70%), Air(30%)	0.759	0.474	-12.4	-12.3	16.7	16.8	
7							Ar(65%), Air(35%)	0.770	0.474	-12.4	-12.3	16.7	16.8	
8							Ar(60%), Air(40%)	0.782	0.474	-12.4	-12.3	16.6	16.7	
9							Ar(55%), Air(45%)	0.793	0.474	-12.4	-12.3	16.6	16.7	
10							Ar(50%), Air(50%)	0.805	0.474	-12.3	-12.2	16.5	16.6	0.035
11							Ar(45%), Air(55%)	0.816	0.474	-12.3	-12.2	16.5	16.6	
12							Ar(40%), Air(60%)	0.828	0.474	-12.3	-12.2	16.4	16.5	
13							Ar(35%), Air(65%)	0.839	0.474	-12.3	-12.2	16.3	16.5	
14							Ar(30%), Air(70%)	0.851	0.474	-12.3	-12.2	16.3	16.4	
15							Ar(25%), Air(75%)	0.862	0.474	-12.3	-12.2	16.2	16.3	
16							Ar(20%), Air(80%)	0.874	0.474	-12.3	-12.1	16.2	16.3	
17							Ar(15%), Air(85%)	0.885	0.474	-12.3	-12.1	16.1	16.2	
18							Ar(10%), Air(90%)	0.897	0.474	-12.2	-12.1	16.1	16.2	
19							Ar(5%), Air(95%)	0.909	0.474	-12.2	-12.1	16.0	16.1	
20							Ar(0%), Air(100%)	0.920	0.474	-12.2	-12.1	15.9	16.1	0.039
Kr,Air; 1xPlaniclear, 2xPlanitherm Ultra N (2,5) 4-8-4-8-4mm														
1	Kr, Air	4-8-4-8-4	28	-13; 20	1000x1000	90	Kr(95%), Air(5%)	0.607	0.474	-12.6	-12.5	17.5	17.6	0.022
2							Kr(90%), Air(10%)	0.632	0.474	-12.5	-12.5	17.4	17.5	
3							Kr(85%), Air(15%)	0.658	0.474	-12.5	-12.4	17.2	17.3	
4							Kr(80%), Air(20%)	0.685	0.474	-12.5	-12.4	17.1	17.2	
5							Kr(75%), Air(25%)	0.713	0.474	-12.5	-12.4	17.0	17.1	
6							Kr(70%), Air(30%)	0.742	0.474	-12.4	-12.3	16.8	16.9	
7							Kr(65%), Air(35%)	0.771	0.474	-12.4	-12.3	16.7	16.8	
8							Kr(60%), Air(40%)	0.802	0.474	-12.3	-12.2	16.5	16.6	
9							Kr(55%), Air(45%)	0.833	0.474	-12.3	-12.2	16.4	16.5	
10							Kr(50%), Air(50%)	0.866	0.474	-12.3	-12.2	16.2	16.3	0.029
11							Kr(45%), Air(55%)	0.899	0.474	-12.2	-12.1	16.1	16.2	
12							Kr(40%), Air(60%)	0.932	0.474	-12.2	-12.1	15.9	16.0	
13							Kr(35%), Air(65%)	0.967	0.474	-12.2	-12.0	15.7	15.8	
14							Kr(30%), Air(70%)	1.002	0.474	-12.1	-12.0	15.5	15.7	
15							Kr(25%), Air(75%)	1.037	0.474	-12.1	-11.9	15.4	15.5	
16							Kr(20%), Air(80%)	1.074	0.474	-12.0	-11.9	15.2	15.3	
17							Kr(15%), Air(85%)	1.111	0.474	-12.0	-11.8	15.0	15.2	
18							Kr(10%), Air(90%)	1.148	0.474	-11.9	-11.8	14.8	15.0	
19							Kr(5%), Air(95%)	1.186	0.474	-11.9	-11.7	14.7	14.8	
20							Kr(0%), Air(100%)	1.225	0.474	-11.9	-11.7	14.5	14.6	0.039

Double glass system (right)

ID	Filler gases	Composition (mm)	Overall thickness (mm)	Temperature of outside, inside air (°C)	Dimensions width x height (mm)	Tilt (°)	Mixture of gases	Heat transfer coefficient U_g (W/m².K)	Solar factor g (-)	*Temp. outer surface layer 1 (°C)	*Temp. inner surface layer 1 (°C)	*Temp. outer surface layer 2 (°C)	*Temp. inner surface layer 2 (°C)	Thermal conductivity coefficient λ_g (W/m.K)
Air 1xPlaniclear, 1xPlanitherm Ultra N(3) 4-13-4mm														
1	Air	4-13-4	21	-13; 20	1000x1000	90	Air(100%)	1.612	0.556	-11.4	-11.2	12.7	12.9	0.037
Ar,Air; 1xPlaniclear, 1xPlanitherm Ultra N (3) 4-12-4mm														
1	Ar, Air	4-12-4	20	-13; 20	1000x1000	90	Ar(95%), Air(5%)	1.328	0.617	-11.7	-11.6	14.0	14.2	0.030
2							Ar(90%), Air(10%)	1.344	0.617	-11.7	-11.5	13.9	14.1	
3							Ar(85%), Air(15%)	1.361	0.617	-11.7	-11.5	13.8	14.0	
4							Ar(80%), Air(20%)	1.377	0.617	-11.7	-11.5	13.8	13.9	
5							Ar(75%), Air(25%)	1.393	0.616	-11.7	-11.5	13.7	13.9	
6							Ar(70%), Air(30%)	1.410	0.616	-11.6	-11.5	13.6	13.8	
7							Ar(65%), Air(35%)	1.426	0.616	-11.6	-11.4	13.5	13.7	
8							Ar(60%), Air(40%)	1.443	0.616	-11.6	-11.4	13.5	13.6	
9							Ar(55%), Air(45%)	1.459	0.616	-11.6	-11.4	13.4	13.6	
10							Ar(50%), Air(50%)	1.475	0.616	-11.6	-11.4	13.3	13.5	0.033
11							Ar(45%), Air(55%)	1.492	0.615	-11.6	-11.3	13.2	13.4	
12							Ar(40%), Air(60%)	1.509	0.615	-11.5	-11.3	13.1	13.3	
13							Ar(35%), Air(65%)	1.525	0.615	-11.5	-11.3	13.1	13.3	
14							Ar(30%), Air(70%)	1.541	0.615	-11.5	-11.3	13.0	13.2	
15							Ar(25%), Air(75%)	1.557	0.615	-11.5	-11.3	12.9	13.1	
16							Ar(20%), Air(80%)	1.573	0.614	-11.5	-11.2	12.8	13.1	
17							Ar(15%), Air(85%)	1.590	0.614	-11.4	-11.2	12.8	13.0	
18							Ar(10%), Air(90%)	1.606	0.614	-11.4	-11.2	12.7	13.0	
19							Ar(5%), Air(95%)	1.622	0.614	-11.4	-11.2	12.6	12.8	
20							Ar(0%), Air(100%)	1.638	0.614	-11.4	-11.2	12.5	12.8	0.036
Kr,Air; 1xPlaniclear, 1xPlanitherm Ultra N (3) 4-8-4mm														
1	Kr, Air	4-8-4	16	-13; 20	1000x1000	90	Kr(95%), Air(5%)	1.168	0.619	-11.9	-11.8	14.7	14.9	0.021
2							Kr(90%), Air(10%)	1.199	0.618	-11.9	-11.7	14.6	14.8	
3							Kr(85%), Air(15%)	1.233	0.618	-11.9	-11.7	14.4	14.6	
4							Kr(80%), Air(20%)	1.269	0.618	-11.8	-11.6	14.3	14.4	
5							Kr(75%), Air(25%)	1.306	0.617	-11.8	-11.6	14.1	14.3	
6							Kr(70%), Air(30%)	1.346	0.616	-11.7	-11.5	13.9	14.1	
7							Kr(65%), Air(35%)	1.387	0.616	-11.7	-11.5	13.7	13.9	
8							Kr(60%), Air(40%)	1.430	0.615	-11.6	-11.4	13.5	13.7	
9							Kr(55%), Air(45%)	1.474	0.615	-11.6	-11.4	13.3	13.5	
10							Kr(50%), Air(50%)	1.519	0.614	-11.5	-11.3	13.1	13.3	0.027
11							Kr(45%), Air(55%)	1.565	0.614	-11.5	-11.3	12.9	13.1	
12							Kr(40%), Air(60%)	1.613	0.613	-11.4	-11.2	12.6	12.9	
13							Kr(35%), Air(65%)	1.661	0.613	-11.4	-11.1	12.4	12.6	
14							Kr(30%), Air(70%)	1.710	0.612	-11.3	-11.1	12.2	12.4	
15							Kr(25%), Air(75%)	1.760	0.612	-11.2	-11.0	11.9	12.2	
16							Kr(20%), Air(80%)	1.810	0.611	-11.2	-10.9	11.7	12.0	
17							Kr(15%), Air(85%)	1.861	0.611	-11.1	-10.9	11.5	11.7	
18							Kr(10%), Air(90%)	1.912	0.610	-11.1	-10.8	11.2	11.5	
19							Kr(5%), Air(95%)	1.964	0.610	-11.1	-10.7	11.0	11.3	
20							Kr(0%), Air(100%)	2.016	0.609	-11.0	-10.7	10.8	11.0	0.035

*Temperatures of surfaces are related to center of glass

4. Results

The purpose of the analysis was to demonstrate the effect of the decrease of the concentration of the filling gas on the heat transfer coefficient of the glass system. In Tables 3 and 4 values of the heat transfer coefficient and the surface temperatures of individual glass surfaces are obtained from Window 7.4.14 calculation. Under the given boundary conditions and the physical model used, the surface temperature did not fall below 9.26 °C (dew point) nor in one of the cases considered, that is, in selected cases, a drop in the concentration of the filling gas to zero (in the glass system, insulating gas does not affect the thermal performance of the glass system to such an extent that condensation occurs on the surface of the transparent structure). Thermal insulating properties in the form of heat transfer coefficient have been impaired as a result of a decrease in the gas concentration in the glass system (see Table 5).

The values in the table show that the greatest influence on the heat transfer coefficient was mani-

Table 4. Results of considered triple and double glass system in case of same width of gas filled space

Kr,Air; 1xPlaniclear, 2xPlanitherm Ultra N (2,5) 4-12-4-12-4mm

ID	Filler gases	Composition (mm)	Overall thickness (mm)	Temperature of outside, inside air (°C)	Dimensions width x height (mm)	Tilt (°)	Mixture of gases	Heat transfer coefficient U_g (W/m²·K)	Solar factor g (-)	*Temperature of outer surface of layer 1 (°C)	*Temperature of inner surface of layer 1 (°C)	*Temperature of outer surface of layer 3 (°C)	*Temperature of inner surface of layer 3 (°C)	Thermal conductivity coefficient λ_g (W/m.K)
1	Kr, Air	4-12-4-12-4	36	-13; 20	1000x1000	90	Kr(95%), Air(5%)	0.579	0.474	-12.6	-12.5	17.6	17.7	0.027
2							Kr(90%), Air(10%)	0.593	0.474	-12.6	-12.5	17.6	17.6	
3							Kr(85%), Air(15%)	0.606	0.474	-12.6	-12.5	17.5	17.6	
4							Kr(80%), Air(20%)	0.619	0.474	-12.6	-12.5	17.4	17.5	
5							Kr(75%), Air(25%)	0.632	0.474	-12.5	-12.5	17.4	17.5	
6							Kr(70%), Air(30%)	0.645	0.474	-12.5	-12.4	17.3	17.4	
7							Kr(65%), Air(35%)	0.658	0.474	-12.5	-12.4	17.2	17.3	
8							Kr(60%), Air(40%)	0.672	0.474	-12.5	-12.4	17.2	17.3	
9							Kr(55%), Air(45%)	0.686	0.474	-12.5	-12.4	17.1	17.2	
10							Kr(50%), Air(50%)	0.701	0.474	-12.5	-12.4	17.0	17.1	0.031
11							Kr(45%), Air(55%)	0.717	0.474	-12.4	-12.3	16.9	17.0	
12							Kr(40%), Air(60%)	0.735	0.474	-12.4	-12.3	16.9	17.0	
13							Kr(35%), Air(65%)	0.754	0.474	-12.4	-12.3	16.8	16.9	
14							Kr(30%), Air(70%)	0.775	0.474	-12.4	-12.3	16.7	16.8	
15							Kr(25%), Air(75%)	0.796	0.474	-12.4	-12.2	16.6	16.7	
16							Kr(20%), Air(80%)	0.819	0.474	-12.3	-12.2	16.4	16.6	
17							Kr(15%), Air(85%)	0.843	0.474	-12.3	-12.2	16.3	16.4	
18							Kr(10%), Air(90%)	0.868	0.474	-12.3	-12.2	16.2	16.3	
19							Kr(5%), Air(95%)	0.894	0.474	-12.2	-12.1	16.1	16.2	
20							Kr(0%), Air(100%)	0.920	0.474	-12.2	-12.1	15.9	16.1	0.039

Kr,Air; 1xPlaniclear, 1xPlanitherm Ultra N (3) 4-12-4mm

ID	Filler gases	Composition (mm)	Overall thickness (mm)	Temperature of outside, inside air (°C)	Dimensions width x height (mm)	Tilt (°)	Mixture of gases	Heat transfer coefficient U_g (W/m²·K)	Solar factor g (-)	*Temperature of outer surface of layer 1 (°C)	*Temperature of inner surface of layer 1 (°C)	*Temperature of outer surface of layer 2 (°C)	*Temperature of inner surface of layer 2 (°C)	Thermal conductivity coefficient λ_g (W/m.K)
1	Kr, Air	4-12-4	20	-13; 20	1000x1000	90	Kr(95%), Air(5%)	1.233	0.621	-11.9	-11.7	14.4	14.6	0.028
2							Kr(90%), Air(10%)	1.258	0.621	-11.8	-11.7	14.3	14.5	
3							Kr(85%), Air(15%)	1.282	0.621	-11.8	-11.6	14.2	14.4	
4							Kr(80%), Air(20%)	1.305	0.620	-11.8	-11.6	14.1	14.3	
5							Kr(75%), Air(25%)	1.328	0.620	-11.7	-11.6	14.0	14.2	
6							Kr(70%), Air(30%)	1.351	0.619	-11.7	-11.5	13.9	14.1	
7							Kr(65%), Air(35%)	1.373	0.619	-11.7	-11.5	13.8	14.0	
8							Kr(60%), Air(40%)	1.394	0.619	-11.7	-11.5	13.7	13.9	
9							Kr(55%), Air(45%)	1.415	0.618	-11.6	-11.5	13.6	13.8	
10							Kr(50%), Air(50%)	1.435	0.618	-11.6	-11.4	13.5	13.7	0.032
11							Kr(45%), Air(55%)	1.454	0.617	-11.6	-11.4	13.4	13.6	
12							Kr(40%), Air(60%)	1.472	0.617	-11.6	-11.4	13.3	13.5	
13							Kr(35%), Air(65%)	1.490	0.617	-11.6	-11.4	13.2	13.4	
14							Kr(30%), Air(70%)	1.509	0.616	-11.5	-11.3	13.1	13.3	
15							Kr(25%), Air(75%)	1.523	0.616	-11.5	-11.3	13.1	13.3	
16							Kr(20%), Air(80%)	1.540	0.615	-11.5	-11.3	13.0	13.2	
17							Kr(15%), Air(85%)	1.560	0.615	-11.5	-11.3	12.9	13.1	
18							Kr(10%), Air(90%)	1.583	0.615	-11.4	-11.2	12.8	13.0	
19							Kr(5%), Air(95%)	1.609	0.614	-11.4	-11.2	12.7	12.9	
20							Kr(0%), Air(100%)	1.637	0.614	-11.4	-11.2	12.5	12.7	0.036

*Temperatures of surfaces are related to center of glass

Table 5. Resulting differences between the initial and final heat transfer coefficient values

Glass system	Initial heat transfer coefficient $U_{g(95\%)}$ (W/m²·K)	Final heat transfer coefficient $U_{g(0\%)}$ (W/m²·K)	Difference between initial and final U_g value (W/m²·K)
A1	0.878	0.878	–
A2	1.612	1.612	–
B1	0.703	0.920	0.217
B2	1.328	1.638	0.310
Cl	0.607	1.225	0.618
C2	1.168	2.016	0.848

fested in the case of Krypton insulating double glass system, where the gap between the glasses also plays a role compared to other cases of reduced thickness of 8 mm.

In Table 4, there are rankings of the triple and double glass system filled with Krypton with a gap between glasses of 12 mm compared to 8 mm gap values. In the case of triple glass system, the initial value of heat transfer coefficient dropped from 0.607 W/m²·K to 0.579 W/m²·K (difference is 0.028 W/m²·K), while the final value increased due to a decrease in Krypton concentration in the case of an 8 mm wide gap, a value of 1.225 W/m²·K and, in the case of a 12 mm wide gap, a value of 0.920 W/m²·K (difference is 0.305 W/m²·K).

5. Conclusion

As a result of the demonstrable effect of decreasing gas concentration in the glass gap in the thermal performance of the glass system, selected concepts of glass systems differing in key parameters have been assessed. After the numerical analysis, one of the glass systems was assessed in simulation where a model with the same boundary conditions as the calculation was created in order to get as close as possible to the calculation and realistic conditions of the buildings to which the glass systems could be located. The resulting effect on the heat transfer coefficient is in some cases milder, in others more pronounced. Explaining the physical model with further simula-
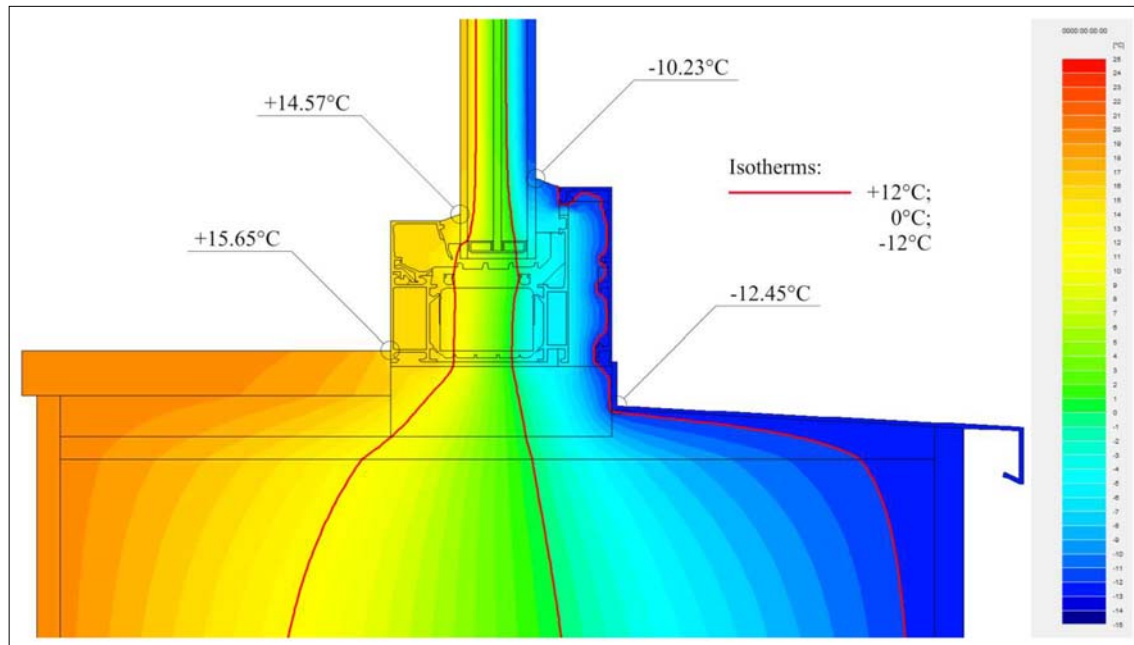
48

Fig. 4. Distribution of thermal field of air filled triple glass system (according to Fig. 3)
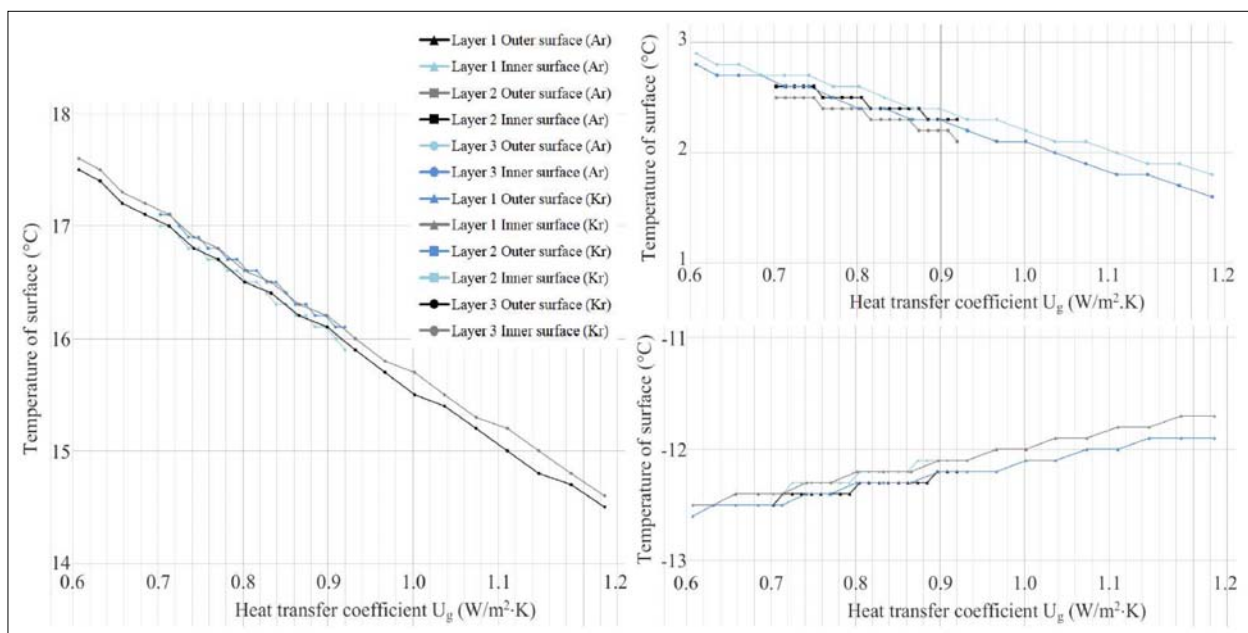

Fig. 5. Results of Argon filled triple glass system (B1) and Krypton filled triple glass system

tions leads to more accurate results applicable to further research.

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