

(19)



(11)

EP 3 323 952 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
08.07.2020 Bulletin 2020/28

(51) Int Cl.:
E04B 1/80 (2006.01) **E06B 3/663 (2006.01)**
E06B 3/67 (2006.01)

(21) Application number: **16199627.7**

(22) Date of filing: **18.11.2016**

(54) MULTICHAMBER GAS-FILLED INSULATED GLASS UNIT

GASGEFÜLLTE ISOLIERTE MEHRKAMMERGLASEINHEIT

UNITÉ DE VERRE ISOLANT À PLUSIEURS CHAMBRES REMPLIE DE GAZ

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(43) Date of publication of application:
23.05.2018 Bulletin 2018/21

(73) Proprietor: **Kralj, Ales**
Ljubljana (SI)

(72) Inventors:
• **Kralj, Ales**
Ljubljana (SI)
• **Znidarsic, Matjaz**
1000 Ljubljana (SI)
• **Halilovic, Miroslav**
1000 Ljubljana (SI)

(74) Representative: **Marn, Jure**
Ljubljanska ulica 9
2000 Maribor (SI)

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URL:http://www.euglass.com/products/agc_glaverbel/Summary-tables.pdf [retrieved on 2017-05-16]**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to technical solutions in the area of transparent or translucent heat insulation based on the principle of multipane glazing units for general use, in particular in civil engineering, and more particular in prefabricated building envelopes or integrated facades. More particularly, the present invention relates to a multi-chamber gas-filled insulated glass unit comprising an outer pane, an inner pane, and at least three chambers arranged between said outer and inner panes.

BACKGROUND OF THE INVENTION

[0002] Thermal insulation of buildings is important in achieving a reduction of energy consumption. An effective thermal insulation requires corresponding insulation systems with low effective thermal conductivity. For this purpose, transparent or translucent glazed systems using hermetically sealed composite panels have been proposed, which are also known as "insulating glass units" in the art. Currently, insulating glass units with three glass panes are common, which are referred to as triple glass insulating units in the art. More recently, so-called "quad glass units" have been introduced, having an outer pane, an inner pane and two low emissivity coated intermediate panes stacked in between, which are typically thinner than the inner and outer panes. The intermediate panes form chambers between each other and between themselves and the inner or outer panes.

[0003] By increasing the number of intermediate panes, and hence the number of chambers formed, the overall heat transfer coefficient, also referred to as the "U-value" in the art, can in principle be decreased. However, even the clearest mineral glass or polymer film panes absorb light passing through. This causes solar heating of the individual panes of the glass units, and in particular of the intermediate panes. With increasing temperature of the intermediate panes, also the pressure of the gas contained in the chambers increases, which in turn may lead to breakage of the intermediate panes. Moreover, excessive temperatures as well as increased pressure may also lead to a failure of ordinary sealing materials.

[0004] In order to avoid breakage of intermediate panes due to thermal stress, it is possible to use strengthened glass, such as chemically strengthened glass, or toughened glass, which is less prone to break under thermal stress.

[0005] As compared to ordinary "annealed glass", toughened or tempered glass is typically a fully tempered glass, having a strength that exceeds the strength of annealed glass by a factor of e.g. 4 to 6. However, "heat strengthened glass" can also refer to glass that has been heat strengthened such as to acquire a still considerably higher strength than annealed glass, although not quite the strength obtainable with fully tempered glass.

[0006] In chemical strengthening, the glass is strengthened by a chemical surface finishing process. For example, the glass may be submersed in a bath containing a potassium salt which causes sodium ions in the glass surface to be replaced by potassium ions from the bath solution, which effectively leads to a state of compression in the surface of the glass and a compensating tension in the core. While tempered or chemically strengthened glass may indeed reduce the risk of breakage of intermediate panes upon thermal stress, their use severely increases the manufacturing costs of corresponding glass units.

[0007] In order to deal with heat induced pressure in multichamber gas-filled insulated glass units, EP 2 729 635 B1 suggests a multichamber structure with an inner pane, and outer pane, and a group of four sealed chambers formed between the outer pane and a divider pane, wherein the sealed chambers are filled with insulating gas. The four sealed chambers are formed by three intermediate panes, which may be formed by polymer films. Between the divider pane and the inner pane, an open chamber is formed, which allows for pressure equalization with a surrounding atmosphere of said unit. When the insulating gas within the group of sealed chambers expands due to heating, this will cause the divider pane to bulge out towards the inner pane, thereby decreasing the volume of the open chamber while leading to a decrease in the pressure of the insulating gas within the group of sealed chambers by giving way to their expansion. Since the open chamber allows for an exchange of air with a surrounding atmosphere, the pressure within the open chamber will not increase, and correspondingly, the inner pane will not or at least not significantly bulge out. In this way, this prior art construction allows for dealing with the heating of the intermediate panes and the pressure increase associated therewith. WO 2013/006144 A1 discloses a IGU with all the features of the preamble of claim 1.

[0008] Examples of glass panes and optical performance thereof can be found in Age Glass UK Ltd.: "Performance Summary Tables", 30. December 2008, pages 380-407.

SUMMARY OF THE INVENTION

[0009] The object underlying the invention is to provide a multichamber gas-filled insulating glass unit allowing for comparatively low U-values at moderate manufacturing costs. This problem is solved by a multichamber gas-filled

insulated glass unit according to claim 1. Preferable embodiments are defined in the dependent claims.

[0010] According to the invention, the multichamber gas-filled insulating glass unit comprises an outer pane having a solar direct transmittance $\tau_{e,outer}$ according to EN 410:2011 and a solar direct absorptance $\alpha_{e,router}$ according to EN 410:2011, and an inner pane. Moreover, the unit comprises at least three chambers arranged between said outer pane and inner pane, wherein adjacent chambers are divided by intermediate panes. $\alpha_{e,inter}$ denotes the solar direct absorption according to EN 410:2011 of the intermediate panes, and the two intermediate panes closest to said outer pane have an average value $av(\alpha_{e,inter})$ of their solar direct absorptions. The chambers comprise a group of sealed chambers, wherein said group of sealed chambers as a whole is hermetically sealed, and each of said chambers among said group of sealed chambers is filled with an insulating gas having a thermal conductivity of λ . The values for $\tau_{e,outer}$, $\alpha_{e,router}$, $av(\alpha_{e,inter})$ and the total number N of outer, inner and intermediate panes is chosen such that a parameter T, which is defined as:

$$T = 106 \cdot \alpha_{e,outer}^{0.07} \cdot \tau_{e,outer}^{0.32} \cdot av(\alpha_{e,inter})^{0.32} \cdot \left(N \left[1 + \frac{\lambda - \lambda_{ar}}{\lambda_{kr} - \lambda_{ar}} \cdot 0.4 \right] \right)^{0.466}$$

obeys $T < 80$,

wherein λ_{ar} is the thermal conductivity of a mixture of 90% argon and 10% air, and λ_{kr} is the thermal conductivity of a mixture of 95% krypton and 5% air.

[0011] Herein the values for λ , N and the corrected emissivity ε of said panes are chosen such that the EN 673:2011 U-value is less than 0.5 W/(m²·K). EN 673:2011 and all other norms referred to herein refer to the version valid on the priority date of the present application. Moreover, the solar direct transmittance $\tau_{e,outer}$ of the outer pane (1) is 0.5 or less, and $av(\alpha_{e,inter})$ is 0.15 or less, preferably 0.11 or less, and most preferably 0.09 or less.

[0012] The inventor has devised a new class of glass units under the following considerations. With the paradigm of reducing the thermal transmission (U-value) of a transparent or translucent insulating glass units while keeping total solar heat gain, the so-called g-value or SHGC, high, usually a high solar energy flux is caused to pass through the insulating glass unit, and hence through the intermediate panes. High solar heat gain is intended to reduce building heating need in winter. In summer such insulating glass units need to be equipped with additional exterior shading devices to prevent building overheating. However, when one reduces the U-value sufficiently, the need for strong solar heating in winter actually diminishes. The inventor has put particular emphasis on use in comparatively cold climates, such as climates found at above 45° geographical latitude. While the insolation intensity on the earth (equator, noontime, 0° inclination) may be as high as 1060 W/m², at a latitude of 45°, and for vertical walls, the insolation from March to October never exceeds 768 W/m² (see the HOURLY CLEAR-SKY INSOLATION TABLES in Renewable and Efficient Electric Power Systems, Gilbert M. Masters ISBN 0-471-28060-7, 2004 John Wiley & Sons, Inc.).

[0013] Accordingly, the inventor tried to devise a class of glass units which allow for keeping the temperatures at the intermediate panes within reasonable limits such as to avoid excessive thermal stress both, to the panes themselves, as well as to the sealing material of the unit. For applications in northern countries, an upper bound for the thermal stress to be expected in use could be estimated assuming "critical conditions" at an outside temperature of 40°C, an inside temperature of 24°C and an insolation intensity of 783 W/m². While at 45° latitude the insolation intensity in winter months may actually reach higher values, such as 825 W/m², this is overcompensated by the lower outside temperatures when it comes to thermal stress on the unit, such that the above referenced "critical conditions" of 40°C outside, 24°C inside and an insolation intensity of 783 W/m² can indeed be regarded as the worst-case scenario with regard to thermal stress to the unit.

[0014] Then, under this "critical conditions", 144 different designs have been simulated and evaluated. It turns out that, particularly at higher numbers of chambers/panes, many standard choices of optical parameters for the panes will lead to severe overheating. However, it was also found that the above referenced parameter T serves as a very reliable indicator for estimating the highest temperature among the intermediate panes under the above referenced "critical conditions". Accordingly, using the definition of the parameter T and keeping it within the bounds defined in claim 1 allows the skilled person to select suitable optical properties for the outer and intermediate panes such as to avoid the problems associated with overheating as described above. In fact, by keeping the parameter T low enough, the use of the additional open chamber as described in EP 2 729 635 B1 may even be omitted.

[0015] Note that the above definition of T even allows for choosing different numbers N of outer, inner and intermediate panes, or in other words, different numbers of chambers within the glass unit. Herein, the definition of T however employs

what could be regarded as an "effective number of panes" $N \left[1 + \frac{\lambda - \lambda_{ar}}{\lambda_{kr} - \lambda_{ar}} \cdot 0.4 \right]$, which accounts for the thermal

conductivity λ of the insulating gas used in the group of sealed chambers. If the insulating gas corresponds to a mixture of 90% argon and 10% air, the effective number of panes corresponds to the true number of panes. However, if the insulating gas corresponds a mixture of e.g. 95% krypton and 5% air, the effective number of panes corresponds to 1.4 times the true number of panes. For other insulating gases, effective numbers of panes can be calculated as defined in

above, which would correspond to an interpolation between these two choices of insulating gases.

[0016] Although there is a rather complex interplay between the various parameters of the panes employed in the glass unit, remarkably the peak temperature among the intermediate panes can be quite reliably be predicted based on the solar direct transmittance $\tau_{e,outer}$ and the solar direct absorptance $\alpha_{e,outer}$ of the outer pane, in combination with the average value $av(\alpha_{e,inter})$ of the solar direct absorptance of the two intermediate panes closest to said outer pane and the "effective number of panes" as defined above. This allows the skilled person to make appropriate choices for the employed panes, and in particular surprisingly reveals that overheating can be prevented even for glass units having a comparatively high number of chambers, for example five chambers, such that five chamber units can be provided without having to employ particularly heat stable sealing materials and without having to resort to strengthened or toughened intermediate panes.

[0017] In a preferred embodiment, the parameters $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ and the total number N of outer, inner and intermediate panes is chosen such that $T > 50$, preferably $T > 55$, and most preferably $T > 60$.

[0018] In a preferred embodiment, the thermal conductivity λ of the insulating gas, the total number N of outer, inner and intermediate panes and the corrected emissivity ε of said panes is chosen such that the U-value of the entire unit is less than $0.3 \text{ W}/(\text{m}^2 \cdot \text{K})$. Herein, the "corrected emissivity" is used as recommended by EN 410:2011 EN 673:2011 and EN 12898. This definition of "corrected emissivity" is analogous to the hemispherical emissivity in the NFRC standards.

[0019] In a preferred embodiment said number of chambers is between 3 and 7, preferably 4 or 5, and most preferably 5. Using four, and even more preferably five chambers, very low U-values can be obtained. This means that the need for strong solar heating in winter diminishes, and that consequently, comparatively low solar direct transmittance $\tau_{e,outer}$ values may be used, which in turn allow for avoiding excessive heating of the intermediate panes under critical conditions. In fact, for use in northern countries, embodiments with five chambers allow for particularly energy-efficient buildings with no or very little additional heating needed in winter, and acceptable solar heating in summer.

[0020] In various embodiments, all of said chambers within said group of sealed chambers may be individually sealed such as to prevent any gas exchange with other chambers among said group of sealed chambers. In other words, if a number of chambers is individually hermetically sealed, then the group of chambers formed thereby is likewise hermetically sealed as a whole. In preferred embodiments, however, some, and in particular all of said chambers among said group of sealed chambers are not individually sealed with regard to one another such as to allow for a gas exchange and equalization of pressure among themselves. For example, small openings could be provided in the intermediate panes separating the chambers within said group of sealed chambers. In the alternative, the material used for the intermediate panes could simply be a material that is not completely gas tight and hence allows for gas exchange and pressure equalization. This could for example be the case when polymer films or sheets are used for the intermediate panes.

[0021] In some embodiments, all of said chambers are part of said group of sealed chambers. In other words, in these embodiments, no open chamber as disclosed in EP 2 729 635 B1 is employed. Instead, by choosing the parameters $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ and the total number N of outer, inner and intermediate panes such as to minimize T sufficiently, insulated glass units can be provided which keep the heating even under critical conditions low enough such that such open chambers can be dispensed with.

[0022] Nevertheless, in alternative embodiments, the unit comprises an open chamber which allows for a pressure equalization with a surrounding atmosphere of said unit, in particular the outside of a building in which the unit is to be installed. Herein, said open chamber is preferably adjacent to said inner pane of said unit. However, in alternative embodiments, there may be one or two sealed chambers between the open chamber and the inner pane.

[0023] In preferred embodiments some or all of the intermediate panes separating chambers within the group of sealed chambers are formed by glass sheets, in particular sheets from non-strengthened glass. Herein, "non-strengthened glass" refers to annealed glass, which has not been subjected to chemical strengthening or tempering. Due to the inventive choice of the parameters $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ and N, the intermediate panes will only moderately heat up and not be subjected to excessive strain, such that in the preferred embodiments, no strengthened glass for the intermediate panes will be needed.

[0024] Instead of using glass, some or all of the intermediate panes can be formed by transparent polymer sheets or films, in particular polyester films. Very good results can be achieved using films having a thickness of about 0.1 mm. The polymer sheets and films will often not be completely gas tight, and hence allow for the aforementioned gas transfer and seasonal pressure equalization between adjacent chambers, without having to provide for additional openings.

[0025] In a preferred embodiment, some or all of the intermediate panes are formed by monolithic glass having a thickness of 1.9 to 4.0 mm, preferably 2.0 to 3.0 mm.

[0026] In a preferred embodiment some or all of the intermediate panes are made from refined glass having a low content of iron oxides. These types of glass are known as "low iron glass" in the art. Iron oxides tend to exhibit a high absorption in the NIR range, but also in the visible part of the solar radiation. By employing low iron glass, the heating of intermediate panes can further be reduced.

[0027] As mentioned above, according to the invention $av(\alpha_{e,inter})$ is 0.15 or less, preferably 0.11 or less, and most preferably 0.09 or less. With so little solar direct absorptance, excessive heating of intermediate panes can be prevented, even if four, five or even more chambers are employed.

[0028] In a preferred embodiment, some or all of the intermediate panes are equipped with a low emissivity coating having a corrected emissivity ε according to EN 410:2011 in a range of 0.020 to 0.120, preferably in a range of 0.030 to 0.050, and most preferably in a range of 0.033 to 0.037. Note that currently, low emissivity coatings having an emissivity ε of as low as approximately 0.01 are available, and could be regarded as the obvious choice in many respects, since they are convenient for reaching exceptionally low U-values per gas gap. However, in the preferred embodiments of the invention, higher emissivity values in the ranges defined above are employed, to further prevent overheating of the intermediate panes. Sufficiently low U-values of the glass unit as a whole can be obtained by choosing a sufficiently large number of chambers, such as four, and more preferably five.

[0029] In embodiments where an open chamber is employed, the intermediate pane separating the open chamber from an adjacent one of the chambers of the group of sealed chambers is preferably made from tempered float glass or chemically strengthened glass, preferably having a thickness of 2.0 to 6.0 mm. These types of glass panes allow for withstanding the pressure-induced flexing exerted by the group of sealed chambers.

[0030] In preferred embodiments, each of said chambers has a width larger than 5 mm, preferably larger than 8 mm, and most preferably larger than 12 mm.

[0031] In a preferred embodiment, some or all of the intermediate panes are spaced from an adjacent one of said outer pane, inner pane or other intermediate pane by means of a spacer, in particular a metal spacer or a plastic spacer with gas barrier, where such barrier is preferably formed by a metal sheet. Since the inventive choice of the parameters $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ and N will prevent excessive heating, in many applications hybrid plastic spacers with metal gas barriers can be used instead of more heat resistant all metal spacers.

[0032] In a preferred embodiment, the width of some or all of said spacers is

- between 16 and 24 mm, preferably between 18 and 20 mm in case said chambers within the group of sealed chambers is predominantly filled by argon or air, and in particular by an argon-air mixture, or
- between 12 and 18 mm, preferably between 14 and 16 mm in case said chambers within the group of sealed chambers is predominantly filled by krypton, and in particular by a krypton- air mixture.

[0033] In a preferred embodiment, the outer pane is a solar control glass. In the art, a "solar control glass" is understood to be a glass with reduced solar energy transmission, where such reduced solar energy transmission is achieved with energy absorption and/or reflection. For example, monolithic transparent glass panes may have a solar direct transmittance of as high as 91%, while solar control glass allows for achieving a solar direct transmittance of 60% or less.

[0034] In a preferred embodiment, the outer pane is spectrally selective in that the transmittance for invisible NIR light is lower than that of visible light, in particular by a factor of 2, preferably by a factor of at least 4.

[0035] In preferred embodiments of the invention, the solar direct transmittance $\tau_{e,outer}$ is 0.6 or less.

[0036] Preferably, said outer pane is equipped with a system, in particular a photochromatic, thermochromatic or electro-chromatic system for dynamically changing the value of $\tau_{e,outer}$, said system allowing for reducing the value of $\tau_{e,outer}$ to 0.6 or below. This way, solar heating in winter times can be more fully exploited while excessive heating on particularly sunny days can be avoided.

[0037] In a preferred embodiment, the solar direct absorption $\alpha_{e,outer}$ of said outer pane is between 0 and 0.9, preferably between 0.1 and 0.5.

[0038] In a preferred embodiment, said outer and/or inner pane is provided with single or double sided low emissivity coating. In addition or alternatively, said outer pane may be provided with a coating that provides for self-cleaning and/or low reflection.

[0039] In preferred embodiments, said outer pane is a monolithic or composite pane having a thickness of 4 mm or more.

[0040] In preferred embodiments, said inner pane is a monolithic or composite pane having a thickness of 3 mm or more. In alternative embodiments, said inner pane may be a one- or two-gap insulating glass unit.

[0041] In preferred embodiments, said inner pane is a safety glass, in particular a toughened glass having a thickness of 5 mm or more, or a laminated glass of two or more glass panes each having a thickness of at least 4 mm, with resin films, in particular PVB films stacked in between.

[0042] In preferred embodiments, the glass unit has a total thickness of at least 47 mm, preferably at least 69 mm.

[0043] In preferred embodiments, said glass unit is a building element for use in building envelopes or facades.

SHORT DESCRIPTION OF THE FIGURES

[0044]

5 Fig. 1 is a schematic sectional view of a multichamber gas-filled insulated glass unit according to an embodiment of the invention, in which no open chamber is used.

Fig. 2 is a schematic sectional view of a multichamber gas-filled insulated glass unit according to another embodiment of the invention, in which an open chamber is employed.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0045] For the purposes of promoting an understanding of the principles of the invention, reference will now be made to a preferred embodiment illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated glass unit and such further applications of the principles of the invention as illustrated therein being contemplated as would normally occur now or in the future to one skilled in the art to which the invention relates.

[0046] Fig. 1 shows a multichamber gas-filled insulated glass unit 10 according to a first embodiment of the invention. The glass unit 10 comprises an outer pane 1 which is facing outside when the unit is installed in a building, and an inner pane 2 facing inside when installed. Between the inner and outer panes 1, 2, three intermediate panes 4 are provided, thereby forming a total of four chambers 3 arranged between said outer pane 1 and inner pane 2, which are divided by said intermediate panes 4. The intermediate panes 4 are separated from each other and from the outer and inner panes 1, 2 by means of spacers 5.

[0047] The entire unit 10 is sealed by an edge sealant 6, which in the embodiment shown is made from polysulfide. Moreover, although not shown in the figure, a further sealing is provided between spacers 5 and the inner, outer and intermediate panes 1, 2, 4, which in the embodiment shown is a butyl sealing.

[0048] The four chambers 3 form a group of sealed chambers, where the group of sealed chambers 3 as a whole is hermetically sealed. Each of the chambers 3 within the group of sealed chambers is filled with an insulating gas, which in the embodiment shown is assumed to be a mixture of 90% argon and 10% air.

[0049] The outer pane 1 shown is an at least 4 mm thick monolithic or composite pane, which may be translucent or fully transparent. The strength of the outer pane 1 can be selected according to the wind protection requirements of the building where the glass unit 10 is to be employed. The outer pane 1 is characterized by a solar direct transmittance $\tau_{e,outer}$ according to EN 410:2011 and a solar direct absorptance $\alpha_{e,outer}$ according to EN 410:2011. In the embodiment shown, the outer pane 1 is a solar control pane with reduced solar energy transmission, which is achieved by appropriate energy absorption and/or reflection. More particularly, the solar direct transmittance $\tau_{e,outer}$ is chosen to be less than 60%, but may in some embodiments be chosen to be less than 50%, less than 40% or even less than 30%.

[0050] In particularly favorable embodiments, the outer pane 1 can be provided with a chromatic, thermochromatic or electrochromatic system for dynamically changing the value of the solar direct transmittance $\tau_{e,outer}$. Also, the outer pane 1 is equipped with low reflection, easy to clean, self-cleaning and/or low emissivity coating on the outside to reduce exterior condensation. Other functional coatings may likewise be provided.

[0051] In a specific embodiment, the outer pane 1 is a solar control toughened glass having a thickness of 8 mm provided with a spectrally selective coating, yielding a solar direct transmittance $\tau_{e,outer}$ according to EN 410:2011 of 0.245 and a solar direct absorptance $\alpha_{e,outer}$ according to EN 410:2011 of 0.45.

[0052] The inner pane 2 may be a monolithic or composite glass having a thickness of at least 3 mm. The glass may be either etched or fully transparent. In the alternative, the inner pane could also be made from polymer or composites thereof. In practice, the inner pane 2 is to be selected according to occupant safety requirements. For example, the inner pane 2 may be a one- or two-gap insulating glass unit. A suitable safety glass for use as the inner pane to could be formed by a toughened or chemically strengthened glass having a thickness of 6 mm, or a laminated glass of two glass panes each having a thickness of 4 mm or more, typically 6 mm or more, with PVB films stacked in between. The inner pane 2 may also have a low emissivity coating, which is formed by a special thin-film coating on the glass pane surface, such that thermal infrared radiation emission is reduced. The inner pane 2 may have a low reflection coating on one or both of its sides.

[0053] The intermediate panes 4 are characterized by their solar direct absorptance $\alpha_{e,inter}$ according to EN 410:2011. However, for the thermal behavior of the glass unit 10 as a whole, the optical properties of the two intermediate panes 4 closest to said outer pane 1 are of most importance. Accordingly, special attention is given herein to the average value $av(\alpha_{e>inter})$ of the solar direct absorptance $\alpha_{e,inter}$ of these two intermediate panes 4 closest to the outer pane 1. Note that in various embodiments, the solar direct absorptance $\alpha_{e,inter}$ of all intermediate panes in the form may be identical.

In preferred embodiments, $av(\alpha_{e,inter})$ is 0.15 or less, preferably 0.11 or less, and most preferably 0.09 or less. With so little solar direct absorptance, excessive heating of intermediate panes can be prevented, even if four, five or even more chambers are employed.

[0054] In the embodiment shown, all of the intermediate panes 4 are formed by monolithic glass having a thickness of 2.1 mm. In other embodiments, the thickness may range from 1.9 to 4.0 mm, preferably 2.0 to 3.0 mm. In the embodiment shown, the monolithic glass is a refined glass having a low content of iron oxides, which help in achieving the low absorptance.

[0055] Moreover, in the embodiment shown, the intermediate panes 4 are equipped with a low emissivity coating having an emissivity ε according to EN 410:2011 in a range of 0.020 to 0.120, preferably in a range of 0.030 to 0.050, and most preferably in a range of 0.033 to 0.037. The coating is preferably one-sided. Note that currently, low emissivity coatings having an emissivity ε of as low as approximately 0.01 are available, and could be regarded as an attractive choice for lowering the U-values per gas gap, and consequently the U-value of the glass unit 10 as a whole. However, in the preferred embodiments of the invention, higher emissivity values in the ranges defined above are employed, to assist in preventing overheating of the intermediate panes 4. Sufficiently low U-values of the glass unit as a whole can still be obtained by choosing a sufficiently large number of chambers, such as four chambers as shown in Fig. 1, and five chambers as shown in Fig. 2.

[0056] In the embodiment shown in Fig. 1, the four chambers 3 comprise a group of sealed chambers, which as a whole is hermetically sealed. However, the intermediate panes 4 might or might not be gas tight. In preferred embodiments, the intermediate panes 4 are not gas tight, such that a gas exchange and an equalization of pressure among the chambers 3 is possible. For example, the intermediate panes 4 can have openings formed therein, or be simply made of a non-gastight material, such as a thin polymer film, which likewise allows for a gas exchange.

[0057] The spacers 5 are chosen to provide a suitable distance between the outer, intermediate and inner panes 1, 4, 2. For the argon-air mixture employed in the embodiment shown, an optimum width of the spacers 5 is 18 to 20 mm. In the alternative, if the insulating gas is mainly based on krypton, the optimum chamber width is smaller, and the spacers 5 would have a width between 14 and 16 mm. The spacers 5 can be made from stainless steel. However, since the glass unit 10 of the invention allows for preventing excessive heating, plastic hybrid spacers 5 with metal gas barriers can likewise be used.

[0058] Fig. 2 shows a second embodiment of the present invention, showing a multichamber gas-filled insulated glass unit 10 which is very similar to that of Fig. 1, and likewise comprises an outer pane 1, and inner pane 2, three intermediate panes 4, four spacers 5 and an edge sealant 6. However, the embodiment of Fig. 2 further comprises an open chamber 3.1 provided adjacent to the inner pane 2. The open chamber 3.1 allows for a pressure equalization with a surrounding atmosphere of the unit 10. For this purpose, a specific spacer 5.1 is provided which has an opening 4.2 allowing for the air exchange. Glass units employing this type of open chambers 3.1 are disclosed in EP 2 729 635 B1. An intermediate pane 4.1 is provided, which separates the open chamber 3.1 from the group of sealed chambers 3. Since the intermediate pane 4.1 receives the pressure from the group of open chambers 3 upon expansion of the insulating gas, it will preferably be toughened.

[0059] In the embodiments of the invention, the optical properties of the outer pane 1 and the intermediate panes 4, 4.1 must be carefully chosen such that an overheating of the intermediate panes 4 is prevented, which overheating could cause failure of the intermediate panes 4, the edge sealant 6 and the butyl sealant. Particularly when employing four or more chambers, usually an excessive heating is expected, which is why insulating glass units with 4, 5 or even more chambers are generally unknown. An exception to this is the aforementioned multichamber gas-filled unit disclosed in EP 2 729 635 B1 having a group of 4 sealed chambers and one open chamber, wherein the open chamber allows for ameliorating thermal stress due to heating.

[0060] The glass units 10 of figures 1 and 2 are specifically devised for applications in northern countries, where an upper bound for the thermal stress is assumed to occur at critical conditions that may be resembled by an outside temperature of 40°C, an inside temperature of 24°C and an insolation intensity of 783 W/m². In other words, the optical properties of the components of the unit 10 must be chosen such that an excessive heating under these critical conditions is prevented, but it is per se not obvious which optical parameters specifically need to be considered, nor how they interact in the internal heating of the glass unit 10. In the embodiments of the invention, the values for $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ and the total number N of outer, inner and intermediate panes, as well as the thermal conductivity λ of the insulating gas in the chambers 3 within the group of sealed chambers are chosen such that a parameter T, which is defined as:

$$T = 106 \cdot \alpha_{e,outer}^{0.07} \cdot \tau_{e,outer}^{0.32} \cdot av(\alpha_{e,inter})^{0.32} \cdot (N \left[1 + \frac{\lambda - \lambda_{ar}}{\lambda_{kr} - \lambda_{ar}} \cdot 0.4 \right])^{0.466}$$

is smaller than the 95, preferably smaller than 90, more preferably smaller than 85 and most preferably smaller than 80.

[0061] The parameter T can be regarded as an estimate of the peak temperature in °C among the intermediate panes employed in the unit. This has been confirmed by a large number of simulations of different constructions of glass units. When limiting the peak temperature of the intermediate panes 4 to below 80°C, the thermal stress to the panes 4, the butyl sealing and the edge sealing 6 is found to be tolerable, such that non-strengthened intermediate panes 4 and cheap sealing materials can be used, thereby keeping the total costs of the glass unit 10 low.

[0062] Choices for the values for $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ N leading to higher values of T, such as 90 or even 95 can likewise lead to useful glass units, for example when the higher risk, extra expense for suitable sealing material and strengthened glass for the intermediate panes is accepted, or if the building is located or oriented such that the above referenced critical conditions will never be achieved. However, in any case the choice shall be such that a value of T = 95 is not exceeded.

[0063] For example, a specific choice of parameters for the embodiment of Fig. 2 would be as follows: The insulating glass unit 10 of Fig. 2 has a height of 1500 mm and a width of 1000 mm. The outer pane 1 is a solar control pane of 8 mm toughened glass, which on its inner side is coated with a spectrally selective coating with a solar direct transmission $\tau_{e,outer}$ of 0.245 and a solar direct absorption $\alpha_{e,outer}$ of 0.45. The three intermediate panes 4 are polymer films having a solar direct absorption $\alpha_{e,inter}$ of 0.11 and a low emissivity coating with a corrected emissivity ε of 0.11. The pane 4.1 separating the open chamber 3.1 from the adjacent sealed chamber 3 is formed by a 4 mm thick tempered float glass having a solar direct absorption $\alpha_{e,inter}$ of 0.15, and a low emissivity coating with an emissivity ε of 0.034. The four sealed chambers 3 are each filled with a mixture of 90% argon and 10% air. Between the spacers 5, foils 4 and glass panes 1, 4.1, 5, a butyl sealant is provided. All spacers 5, 5.1 have a width of 20 mm. The entire unit is sealed with a 6 mm thick polysulfide edge sealant 6. The unit 10 as a whole has a U-value of 0.29 W/(m² K), a solar heat gain coefficient (SHGC) of 0.17 and a visible light transmission of 29%.

[0064] The unit 10 was tested with the program Window 7.2.39 for the temperature distribution among the components of the unit 10 at the aforementioned "critical conditions" (insulation 783 W/m², outside temperature 40°C with calm clear sky conditions, interior temperature 24°C), with the thermal calculations carried out according to ISO 15099 and NFRC insulation standard. The temperatures of the panes from outside pane 1 to inside pane 2 thus obtained were 64, 75, 71, 60, 39, and 31°C. In other words, the temperature of all intermediate panes was kept below 80°C. Using the calculation of the parameter T according to the above definition, a value of 73 is obtained, which is indeed very close to the peak temperature observed among the intermediate panes 4 at 75°C.

[0065] Although a preferred exemplary embodiment is shown and specified in detail in the drawings and the preceding specification, these should be viewed as purely exemplary and not as limiting the invention. It is noted in this regard that only the preferred exemplary embodiments are shown and specified, and all variations and modifications should be protected that presently or in the future lie within the scope of protection of the invention as defined in the claims.

Claims

1. A multichamber gas-filled insulated glass unit (10), comprising:

an outer pane (1) having a solar direct transmittance $\tau_{e,outer}$ according to EN 410:2011 and a solar direct absorptance $\alpha_{e,outer}$ according to EN 410:2011,
an inner pane (2),
at least three chambers (3, 3.1) arranged between said outer pane and inner pane, wherein adjacent chambers (3) are divided by intermediate panes (4, 4.1), wherein the two intermediate panes (4) closest to said outer pane (1) have an average value $av(\alpha_{e,inter})$ of the solar direct absorptance $\alpha_{e,inter}$ according to EN 410:2011,
wherein said chambers (3) comprise a group of sealed chambers (3), wherein said group of sealed chambers (3) as a whole is hermetically sealed, and each of said chambers (3) among said group of sealed chambers is filled with an insulating gas having a thermal conductivity of λ ,

characterised in that

the values for $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ and the total number N of outer, inner and intermediate panes (1, 2, 4, 4.1) are chosen such that a parameter T, which is defined as:

$$T = 106 \cdot \alpha_{e,outer}^{0.07} \cdot \tau_{e,outer}^{0.32} \cdot av(\alpha_{e,inter})^{0.32} \cdot (N \left[1 + \frac{\lambda - \lambda_{ar}}{\lambda_{kr} - \lambda_{ar}} \cdot 0.4 \right])^{0.466}$$

obeys $T < 80$,

wherein λ_{ar} is the thermal conductivity of a mixture of 90% argon and 10% air, and

λ_{kr} is the thermal conductivity of a mixture of 95% krypton and 5% air,

wherein the values for λ , N and the corrected emissivity ε of said panes are chosen such that the EN 673:2011 U-value is less than $0.5 \text{ W}/(\text{m}^2 \cdot \text{K})$, wherein the solar direct transmittance $\tau_{e,outer}$ of the outer pane (1) is 0.5 or less and/or wherein said outer pane (1) is equipped with a system for dynamically changing the value of $\tau_{e,outer}$, said system allowing for reducing the value of $\tau_{e,outer}$ to 0.6 or below,
 5 and wherein $av(\alpha_{e,inter})$ is 0.15 or less.

2. The glass unit (10) of claim 1, wherein the values for $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ and N are chosen such that $T > 50$, preferably $T > 55$ and most preferably $T > 60$.

10 3. The glass unit (10) of claim 1 or 2, wherein the values for λ , N and the corrected emissivity ε of said panes are chosen such that the EN 673:2011 U-value is less than $0.3 \text{ W}/(\text{m}^2 \cdot \text{K})$.

4. The glass unit (10) of one of the preceding claims, wherein said number of chambers (3, 3.1) is between 3 and 7, preferably 4 or 5, and most preferably 5, and/or
 15 wherein each of said chambers (3, 3.1) has a width larger than 5 mm, preferably larger than 8 mm, most preferably larger than 12 mm.

5. The glass unit (10) of one of the preceding claims, wherein all of said chambers (3) within said group of sealed chambers (3) are individually sealed such as to prevent any gas exchange with other chambers (3) among said group of sealed chambers (3), or wherein some, and in particular all of said chambers (3) among said group of sealed chambers (3) are not individually sealed with regard to one another such as to allow for a gas exchange and equalization of pressure among said not individually sealed chambers (3).
 20

6. The glass unit (10) of one of the preceding claims, wherein all of said chambers (3) are part of said group of sealed chambers (3), or
 25 wherein said unit (10) comprises an open chamber (3.1) which allows for pressure equalization with a surrounding atmosphere of said unit (10), in particular the outside of a building in which the unit is to be installed, wherein said open chamber (3.1) is preferably adjacent to said inner pane (2) of said unit.

7. The glass unit (10) of one of the preceding claims, wherein some or all of the intermediate panes (4) separating chambers within the group of sealed chambers (3) are formed by:

- glass sheets, in particular sheets from non-strengthened glass, or
- transparent polymer sheets or films, in particular polyester films.

8. The glass unit (10) of claim 7, wherein said some or all of the intermediate panes (4) are formed by monolithic glass having a thickness of 1.9 to 4.0 mm, preferably 2.0 to 3.0 mm, and/or
 35 wherein said some or all of the intermediate panes (4) are made from refined glass having a low content of iron oxides.

9. The glass unit (10) of one of the preceding claims, wherein $av(\alpha_{e,inter})$ is 0.11 or less, and preferably 0.09 or less.

10. The glass unit (10) of one of the preceding claims, wherein some or all of the intermediate panes (4, 4.1) are equipped with a low emissivity coating having a corrected emissivity ε according to EN 410:2011 in a range of 0.020 to 0.120, preferably in a range of 0.030 to 0.050, and most preferably in a range of 0.033 to 0.037.
 45

11. The glass unit (10) of one of claims 6 to 10, wherein the intermediate pane (4.1) separating the open chamber from an adjacent one of the chambers (3) of the group of sealed chambers (3) is made from tempered float glass or chemically strengthened glass, preferably having a thickness of 2.0 to 6.0 mm.

12. The glass unit (10) of one of the preceding claims, wherein some or all of the intermediate panes (4, 4.1) are spaced from an adjacent one of said outer pane (1), inner pane (2) or other intermediate panes (4, 4.1) by means of a spacer (5), in particular a spacer having a metal gas barrier,
 50 wherein the width of some or all of said spacers (5) is preferably

- between 16 and 24 mm, preferably between 18 and 20 mm in case said chambers (3) within the group of sealed chambers (3) are predominantly filled by argon or air, and in particular by an argon-air mixture, or
- between 12 and 18 mm, preferably between 14 and 16 mm in case said chambers within the group of sealed chambers (3) are predominantly filled by krypton, and in particular by a krypton- air mixture.

13. The glass unit (10) of one of the preceding claims, wherein the outer pane (1) is spectrally selective in that the transmittance for invisible NIR light is lower than that of visible light, in particular by a factor of at least 2, preferably by a factor of at least 4, or wherein said system for dynamically changing the value of $\tau_{e,outer}$ of the outer pane (1) is a photochromatic, thermochromatic or electro-chromatic system.
14. The glass unit (10) of one of the preceding claims, wherein the solar direct absorption $\alpha_{e,outer}$ of said outer pane (1) is between 0 and 0.9, preferably between 0.1 and 0.5, and/or wherein said outer pane (1) is provided with a low emissivity coating on one or both sides, and/or wherein said outer and/or inner pane (1, 2) is provided with a coating or coatings that provides for self-cleaning and/or low reflection, and/or wherein said outer pane (1) is a monolithic or composite pane having a thickness of 4 mm or more, and/or wherein said inner pane (2) is a monolithic or composite pane having a thickness of 3 mm or more, or wherein said inner pane (2) is a one- or two-gap insulating glass unit, or wherein said inner pane (2) is a safety glass, in particular a tempered glass having a thickness of 5 mm or more, or a laminated glass of two or more glass panes each having a thickness of at least 4 mm, with polymer film or films, in particular PVB film or films stacked in between, and/or wherein the glass unit (10) has a total thickness of at least 47 mm, preferably at least 69 mm.
15. The glass unit (10) of one of the preceding claims, wherein said glass unit (10) is a building element for use in building envelopes or facades.

Patentansprüche

1. Gasgefüllte isolierte Mehrkammerglaseinheit (10), umfassend:

eine Außenscheibe (1) mit einer solaren direkten Durchlässigkeit $\tau_{e,outer}$ gemäß EN 410:2011 und einer solaren direkten Absorption $\alpha_{e,outer}$ gemäß EN 410:2011,
 eine Innenscheibe (2),
 mindestens drei Kammern (3, 3.1), die zwischen der Außenscheibe und der Innenscheibe angeordnet sind, wobei benachbarte Kammern (3) durch Zwischenscheiben (4, 4.1) geteilt sind, wobei die zwei Zwischenscheiben (4), die der Außenscheibe (1) am nächsten sind, einen Mittelwert $av(\alpha_{e,inter})$ der solaren direkten Absorption $\alpha_{e,inter}$ gemäß EN 410:2011 aufweisen,
 wobei die Kammern (3) eine Gruppe von versiegelten Kammern (3) umfassen, wobei die Gruppe von versiegelten Kammern (3) als Ganzes hermetisch versiegelt ist und jede der Kammern (3) aus der Gruppe von versiegelten Kammern mit einem Isoliergas mit einer Wärmeleitfähigkeit λ gefüllt ist,
dadurch gekennzeichnet, dass
 die Werte für $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ und die Gesamtzahl N von Außen-, Innen- und Zwischenscheiben (1, 2, 4, 4.1) so gewählt sind, dass ein Parameter T, der definiert ist als:

$$T = 106 \cdot \alpha_{e,outer}^{0,07} \cdot \tau_{e,outer}^{0,32} \cdot av(\alpha_{e,inter})^{0,32} \cdot (N [1 + \frac{\lambda - \lambda_{ar}}{\lambda_{kr} - \lambda_{ar}} \cdot 0,4])^{0,466}$$

T < 80 folgt,

wobei λ_{ar} die Wärmeleitfähigkeit eines Gemischs aus 90 % Argon und 10 % Luft ist, und λ_{kr} die Wärmeleitfähigkeit eines Gemischs aus 95 % Krypton und 5 % Luft ist,
 wobei die Werte für λ , N und das korrigierte Emissionsvermögen ε der Scheiben derart ausgewählt sind, dass der U-Wert gemäß EN 673:2011 weniger als 0,5 W/(m² • K) ist, wobei die solare direkte Durchlässigkeit $\tau_{e,outer}$ der Außenscheibe (1) 0,5 oder weniger ist und/oder wobei die Außenscheibe (1) mit einem System zum dynamischen Verändern des Wertes $\tau_{e,outer}$ ausgestattet ist, wobei das System das Reduzieren des Wertes $\tau_{e,outer}$ auf 0,6 oder weniger ermöglicht,
 und wobei $av(\alpha_{e,inter})$ 0,15 oder weniger beträgt.

2. Glaseinheit (10) nach Anspruch 1, wobei die Werte für $\tau_{e,outer}$, $\alpha_{e,outer}$, $av(\alpha_{e,inter})$ und N so ausgewählt sind, dass T > 50, vorzugsweise T > 55 und am meisten bevorzugt T > 60.

3. Glaseinheit (10) nach Anspruch 1 oder 2, wobei die Werte für λ , N und das korrigierte Emissionsvermögen ε der Scheiben so ausgewählt sind, dass der U-Wert gemäß EN 673:2011 weniger als 0,3 W/(m² • K) beträgt.
4. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei die Anzahl der Kammern (3, 3.1) zwischen 3 und 7, vorzugsweise 4 oder 5 und am meisten bevorzugt 5 beträgt, und/oder wobei jede der Kammern (3, 3.1) eine Breite größer als 5 mm, vorzugsweise größer als 8 mm, am meisten bevorzugt größer als 12 mm aufweist.
5. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei alle der Kammern (3) innerhalb der Gruppe von versiegelten Kammern (3) einzeln versiegelt sind, um jeglichen Gasaustausch mit anderen Kammern (3) aus der Gruppe von versiegelten Kammern (3) zu verhindern, oder wobei einige und insbesondere alle der Kammern (3) aus der Gruppe von versiegelten Kammern (3) nicht einzeln in Bezug zueinander versiegelt sind, um einen Gasaustausch und einen Druckausgleich unter den nicht einzeln versiegelten Kammern (3) zu ermöglichen.
6. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei alle der Kammern (3) Teil der Gruppe von versiegelten Kammern (3) sind, oder wobei die Einheit (10) eine offene Kammer (3.1) umfasst, die einen Druckausgleich mit einer umgebenden Atmosphäre der Einheit (10) ermöglicht, insbesondere der Außenseite eines Gebäudes, in dem die Einheit zu installieren ist, wobei sich die offene Kammer (3.1) vorzugsweise benachbart zu der Innenscheibe (2) der Einheit befindet.
7. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei einige oder alle der Zwischenscheiben (4), die Kammern innerhalb der Gruppe von versiegelten Kammern (3) trennen, gebildet sind durch:
 - Glasplatten, insbesondere Platten aus nicht verstärktem Glas, oder
 - transparente Polymerfolien oder -filme, insbesondere Polyesterfilme.
8. Glaseinheit (10) nach Anspruch 7, wobei die einigen oder alle der Zwischenscheiben (4) aus monolithischem Glas mit einer Dicke von 1,9 bis 4,0 mm, vorzugsweise 2,0 bis 3,0 mm gebildet sind, und/oder wobei die einigen oder alle der Zwischenscheiben (4) aus raffiniertem Glas mit einem geringen Gehalt an Eisenoxiden hergestellt sind.
9. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei $av(\alpha_{e,inter})$ 0,11 oder weniger und vorzugsweise 0,09 oder weniger beträgt.
10. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei einige oder alle der Zwischenscheiben (4, 4.1) mit einer Beschichtung mit niedrigem Emissionsvermögen mit einem korrigierten Emissionsvermögen ε gemäß EN 410:2011 in einem Bereich von 0,020 bis 0,120, vorzugsweise in einem Bereich von 0,030 bis 0,050 und am meisten bevorzugt in einem Bereich von 0,033 bis 0,037 ausgestattet sind.
11. Glaseinheit (10) nach einem der Ansprüche 6 bis 10, wobei die Zwischenscheibe (4.1), die die offene Kammer von einer benachbarten der Kammern (3) der Gruppe von versiegelten Kammern (3) trennt, aus gehärtetem Schwimmglass oder chemisch verstärktem Glas hergestellt ist, das vorzugsweise eine Dicke von 2,0 bis 6,0 mm aufweist.
12. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei einige oder alle der Zwischenscheiben (4, 4.1) von einer benachbarten von der Außenscheibe (1), der Innenscheibe (2) oder anderen Zwischenscheiben (4, 4.1) mittels eines Abstandshalters (5), insbesondere eines Abstandshalters mit einer Metallgassperre beabstandet sind, wobei die Breite einiger oder aller der Abstandshalter (5) vorzugsweise
 - zwischen 16 und 24 mm, vorzugsweise zwischen 18 und 20 mm beträgt, falls die Kammern (3) innerhalb der Gruppe von versiegelten Kammern (3) überwiegend mit Argon oder Luft und insbesondere mit einem Argon-Luft-Gemisch gefüllt sind, oder
 - zwischen 12 und 18 mm, vorzugsweise zwischen 14 und 16 mm beträgt, falls die Kammern innerhalb der Gruppe von versiegelten Kammern (3) überwiegend mit Krypton und insbesondere mit einem Krypton-Luft-Gemisch gefüllt sind.
13. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei die Außenscheibe (1) insofern spektral selektiv ist, als dass die Durchlässigkeit für unsichtbares NIR-Licht geringer als die von sichtbarem Licht ist, insbesondere

um einen Faktor von mindestens 2, vorzugsweise um einen Faktor von mindestens 4, oder wobei das System zum dynamischen Verändern des Wertes $\tau_{e,outer}$ der Außenscheibe (1) ein photochromatisches, thermochromatisches oder elektrochromatisches System ist.

14. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei die solare direkte Absorption $\alpha_{e,outer}$ der Außenscheibe (1) zwischen 0 und 0,9, vorzugsweise zwischen 0,1 und 0,5 beträgt, und/oder wobei die Außenscheibe (1) auf einer oder beiden Seiten mit einer Beschichtung mit geringem Emissionsvermögen versehen ist, und/oder wobei die Außen- und/oder Innenscheibe (1, 2) mit einer Beschichtung oder Beschichtungen versehen ist, die für Selbstreinigung und/oder geringe Reflexion sorgen, und/oder wobei die Außenscheibe (1) eine monolithische oder Verbundscheibe mit einer Dicke von 4 mm oder mehr ist, und/oder wobei die Innenscheibe (2) eine monolithische oder Verbundscheibe mit einer Dicke von 3 mm oder mehr ist, oder wobei die Innenscheibe (2) eine Isolierglaseinheit mit einer oder zwei Lücken ist, oder wobei die Innenscheibe (2) ein Sicherheitsglas ist, insbesondere ein gehärtetes Glas mit einer Dicke von 5 mm oder mehr, oder ein laminiertes Glas aus zwei oder mehr Glasscheiben mit einer Dicke von jeweils mindestens 4 mm, mit Polymerfilm oder -filmen, insbesondere PVB-Film oder -filmen, die dazwischen gestapelt sind, und/oder wobei die Glaseinheit (10) eine Gesamtdicke von mindestens 47 mm, vorzugsweise mindestens 69 mm aufweist.
15. Glaseinheit (10) nach einem der vorhergehenden Ansprüche, wobei die Glaseinheit (10) ein Bauelement zur Verwendung in Gebäudehüllen oder Fassaden ist.

Revendications

1. Unité de verre isolant à plusieurs chambres remplie de gaz (10), comprenant :

une vitre externe (1) présentant une transmittance solaire directe $\tau_{e,externe}$ selon la norme EN 410:2011 et une absorbance solaire directe $\alpha_{e,externe}$ selon la norme EN 410:2011, une vitre interne (2),

au moins trois chambres (3, 3.1) disposées entre lesdites vitres externe et interne, les chambres adjacentes (3) étant séparées par des vitres intermédiaires (4, 4.1), les deux vitres intermédiaires (4) les plus proches de ladite vitre externe (1) présentant une valeur moyenne $av(\alpha_{e,inter})$ de l'absorbance solaire directe $\alpha_{e,inter}$ selon la norme EN 410:2011,

lesdites chambres (3) comprenant un groupe de chambres scellées (3), ledit groupe de chambres scellées (3) dans son ensemble étant hermétiquement scellé, et chacune desdites chambres (3) parmi ledit groupe de chambres scellées étant remplie d'un gaz isolant présentant une conductivité thermique de λ ,

caractérisé en ce que

les valeurs de $\tau_{e,externe}$, $\alpha_{e,externe}$, $av(\alpha_{e,inter})$ et le nombre total N des vitres externe, interne et intermédiaires (1, 2, 4, 4.1) sont choisis de telle sorte qu'un paramètre T, défini comme étant :

$$T = 106 \cdot \alpha_{e,externe}^{0,07} \cdot \tau_{e,externe}^{0,32} \cdot av(\alpha_{e,inter})^{0,32} \cdot (N [1 + \frac{\lambda - \lambda_{kr}}{\lambda_{kr} - \lambda_{ar}} \cdot 0,4])^{0,466} \text{ obéit à } T < 80,$$

où λ_{ar} représente la conductivité thermique d'un mélange de 90 % d'argon et 10 % d'air et λ_{kr} représente la conductivité thermique d'un mélange de 95 % de krypton et 5 % d'air,

où les valeurs de λ , de N et de l'émissivité corrigée ε desdites vitres sont choisies de telle sorte que la valeur U de la norme EN 673:2011 soit inférieure à 0,5 W/(m² • K), où la transmittance solaire directe $\tau_{e,externe}$ de la vitre externe (1) vaut 0,5 ou moins et/ou ladite vitre externe (1) étant équipée d'un système pour changer dynamiquement la valeur de $\tau_{e,externe}$, ledit système permettant de réduire la valeur de $\tau_{e,externe}$ à 0,6 ou moins, et où $av(\alpha_{e,inter})$ vaut 0,15 ou moins.

2. Unité de verre (10) selon la revendication 1, lesdites valeurs de $\tau_{e,externe}$, $\alpha_{e,externe}$, $av(\alpha_{e,inter})$ et N sont choisies de telle sorte que $T > 50$, de préférence $T > 55$ et plus préférablement $T > 60$.

3. Unité de verre (10) selon la revendication 1 ou 2, lesdites valeurs de λ , de N et de l'émissivité corrigée ε desdites vitres étant choisies de telle sorte que la valeur U de la norme EN 673:2011 soit inférieure à 0,3 W/(m² • K).

4. Unité de verre (10) selon l'une quelconque des revendications précédentes, ledit nombre de chambres (3, 3.1) étant compris entre 3 et 7, de préférence 4 ou 5, et plus préférablement 5 et/ou chacune desdites chambres (3, 3.1) présentant une largeur supérieure à 5 mm, de préférence supérieure à 8 mm, idéalement supérieure à 12 mm.
5. Unité de verre (10) selon l'une des revendications précédentes, toutes lesdites chambres (3) au sein dudit groupe de chambres scellées (3) étant scellées individuellement de manière à empêcher tout échange de gaz avec d'autres chambres (3) parmi ledit groupe de chambres scellées (3), ou une partie et en particulier la totalité desdites chambres (3) parmi ledit groupe de chambres scellées (3) n'étant pas scellées individuellement les unes par rapport aux autres de manière à permettre un échange de gaz et une égalisation de pression parmi lesdites chambres non scellées individuellement (3).
6. Unité de verre (10) selon l'une des revendications précédentes, toutes lesdites chambres (3) faisant partie dudit groupe de chambres scellées (3), ou ladite unité (10) comprenant une chambre ouverte (3.1) qui permet une égalisation de la pression avec une atmosphère environnante de ladite unité (10), en particulier l'extérieur d'un bâtiment dans lequel l'unité doit être installée, ladite chambre ouverte (3.1) étant de préférence adjacente à ladite vitre interne (2) de ladite unité.
7. Unité de verre (10) selon l'une des revendications précédentes, une partie ou la totalité des vitres intermédiaires (4) séparant les chambres au sein du groupe de chambres scellées (3) étant formées par :
 - des feuilles de verre, en particulier des feuilles de verre non renforcé, ou
 - des feuilles ou films de polymère transparents, en particulier des films de polyester.
8. Unité de verre (10) selon la revendication 7, ladite partie ou totalité des vitres intermédiaires (4) étant formée de verre monolithique ayant une épaisseur de 1,9 à 4,0 mm, de préférence de 2,0 à 3,0 mm, et/ou ladite partie ou totalité des vitres intermédiaires (4) étant fabriquées à partir de verre affiné présentant une faible teneur d'oxydes de fer.
9. Unité de verre (10) selon l'une quelconque des revendications précédentes, $av(\alpha_{e,inter})$ valant 0,11 ou moins, et de préférence 0,09 ou moins.
10. Unité de verre (10) selon l'une quelconque des revendications précédentes, une partie ou la totalité des vitres intermédiaires (4, 4.1) étant équipées d'un revêtement à faible émissivité présentant une émissivité corrigée ε selon la norme EN 410:2011 dans la plage de 0,020 à 0,120, de préférence dans la plage de 0,030 à 0,050, et idéalement dans la plage de 0,033 à 0,037.
11. Unité de verre (10) selon l'une quelconque des revendications 6 à 10, ladite vitre intermédiaire (4.1) séparant la chambre ouverte de l'une adjacente des chambres (3) du groupe de chambres scellées (3) étant fabriquée en verre flotté trempé ou en verre chimiquement renforcé, ayant de préférence une épaisseur de 2,0 à 6,0 mm.
12. Unité de verre (10) selon l'une quelconque des revendications précédentes, une partie ou la totalité des vitres intermédiaires (4, 4.1) étant espacées d'une vitre adjacente parmi la vitre externe (1), ladite vitre interne (2) ou les autres vitres intermédiaires (4, 4.1) au moyen d'une entretoise (5), notamment une entretoise dotée d'une barrière métallique contre les gaz, la largeur d'une partie ou de la totalité desdites entretoises (5) étant de préférence
 - entre 16 et 24 mm, de préférence entre 18 et 20 mm dans le cas où lesdites chambres (3) au sein du groupe de chambres scellées (3) sont majoritairement remplies d'argon ou d'air, et en particulier par un mélange argon-air, ou
 - entre 12 et 18 mm, de préférence entre 14 et 16 mm dans le cas où lesdites chambres au sein du groupe de chambres scellées (3) sont principalement remplies de krypton, et en particulier d'un mélange krypton-air.
13. Unité de verre (10) selon l'une quelconque des revendications précédentes, ladite vitre externe (1) étant spectralement sélective en ce que la transmittance pour la lumière NIR invisible est inférieure à celle de la lumière visible, en particulier d'un facteur d'au moins 2, de préférence d'un facteur d'au moins 4, ou ledit système pour changer dynamiquement la valeur de $\tau_{e,externe}$ de la vitre externe (1) est un système photochromatique, thermochromatique ou électro-chromatique.

14. Unité de verre (10) selon l'une quelconque des revendications précédentes, l'absorption solaire directe $\alpha_{e, \text{externe}}$ de ladite vitre externe (1) étant comprise entre 0 et 0,9, de préférence entre 0,1 et 0,5, et/ou ladite vitre externe (1) étant pourvue d'un revêtement à faible émissivité sur un ou deux côtés, et/ou
 5 lesdites vitres externe et/ou interne (1, 2) étant pourvues d'un ou plusieurs revêtements qui assurent un auto-nettoyage et / ou une faible réflexion, et/ou
 ladite vitre externe (1) étant une vitre monolithique ou composite ayant une épaisseur de 4 mm ou plus, et/ou
 ladite vitre interne (2) étant une vitre monolithique ou composite ayant une épaisseur de 3 mm ou plus, ou
 ladite vitre interne (2) étant une unité de verre isolant à un ou deux espaces, ou ladite vitre interne (2) étant un verre
 10 de sécurité, en particulier un verre trempé ayant une épaisseur de 5 mm ou plus, ou un verre feuilleté de deux vitres ou plus ayant chacune une épaisseur d'au moins 4 mm, un ou plusieurs films de polymère, en particulier un ou plusieurs films de PVB étant empilés entre elles, et/ou
 ladite unité de verre (10) ayant une épaisseur totale d'au moins 47 mm, de préférence d'au moins 69 mm.

15 15. Unité de verre (10) selon l'une quelconque des revendications précédentes, ladite unité de verre (10) étant un élément de construction pour utilisation dans la construction d'enveloppes ou de façades.

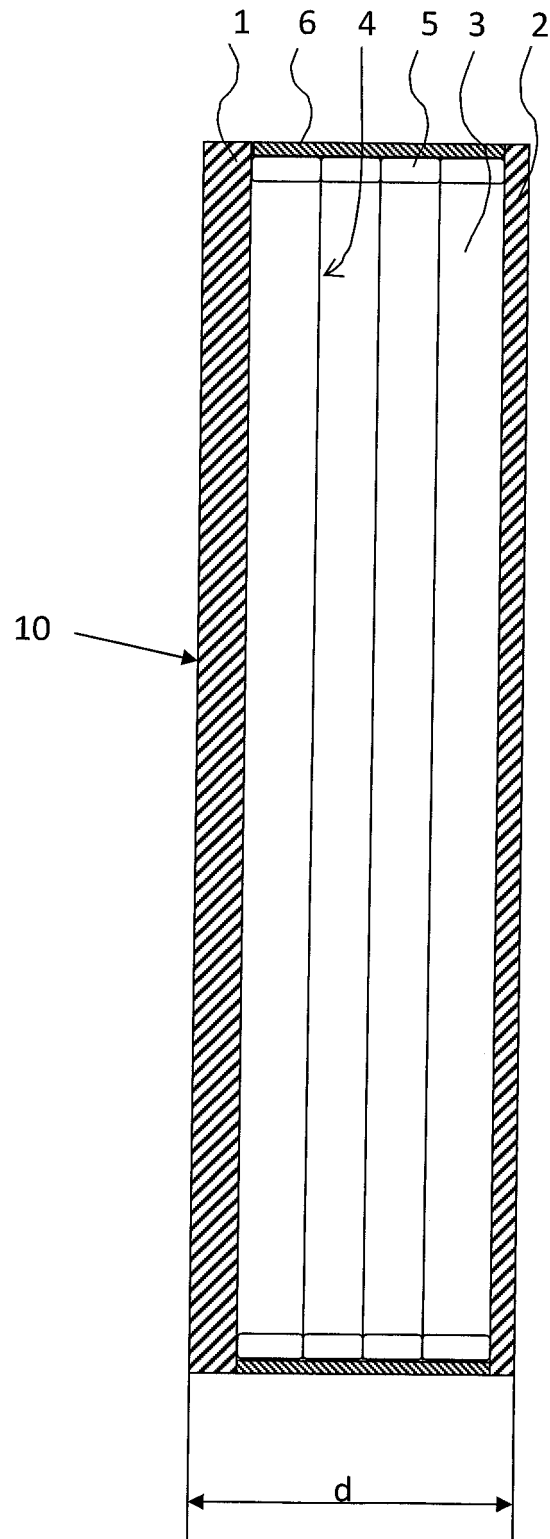


Fig. 1

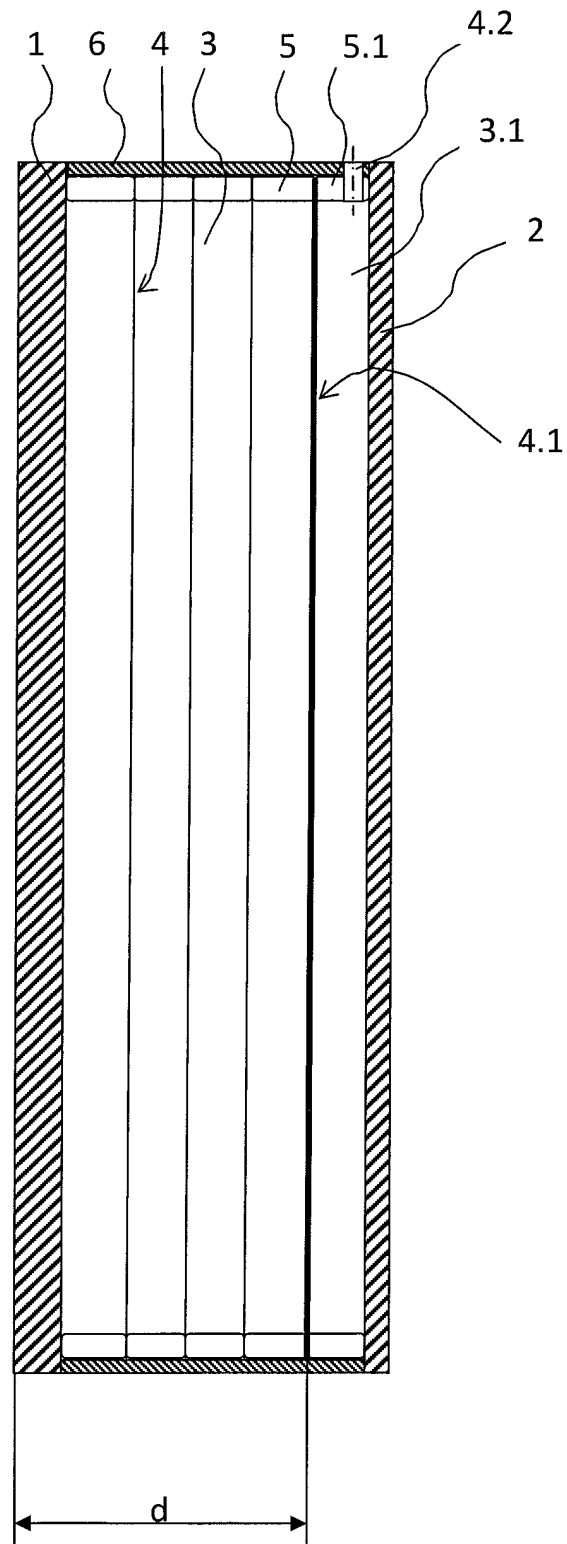


Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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