Glazing for buildings —

Part 2: Code of practice for energy, light and sound

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Foreword

This part of BS 6262 has been prepared under the direction of Subcommittee B/520/4, Properties and glazing methods. It partially supersedes BS 6262:1982, which will be withdrawn upon publication of all seven parts of the newly revised and restructured BS 6262. BS 6262:1982 is being revised and restructured to simplify its use and will be published in seven parts:

— *Part 1: General methodology for the selection of glazing;*

— *Part 2: Code of practice for energy, light and sound;*

— *Part 3: Code of practice for fire, security and wind loading;*

— *Part 4: Code of practice for safety related to human impact;*

— *Part 5: Code of practice for frame design considerations;*

— *Part 6: Code of practice for special applications;*

— *Part 7: Code of practice for provision of information.*

Requirements for standards of workmanship for glazing have been published separately as BS 8000-7 and therefore this subject is not dealt with in this standard.

Since the correct selection of materials to be used in glazing for buildings depends on many factors, the recommendations in this part of the standard should be used in conjunction with those in the other parts.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 25 and a back cover.

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1 Scope

This part of BS 6262 gives information and recommendations for vertical glazing in the external walls and interiors of buildings, with respect to their effect on the energy, light and sound environments in the building.

These recommendations do not apply to:

a) patent glazing (see BS 5516-1);

b) glass in non-vertical applications (see BS 5516-2);

c) glazing for furniture and fittings (see BS 7376 and BS 7449);

d) glazing for commercial greenhouses (see BS 5502-21);

e) glazing for domestic greenhouses.

Requirements for standards of workmanship for glazing have been published separately as BS 8000-7 and therefore this subject is not dealt with in this standard.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN ISO 140-3, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurement of airborne sound insulation of building elements.*

BS EN ISO 717-1, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation.*

BS EN ISO 717-2, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 2: Impact sound insulation.*

3 Terms and definitions

For the purposes of this part of BS 6262, the following terms and definitions apply.

3.1
glazing (noun)
glass or plastics glazing sheet material, for installation into a building

3.2
glazing (verb)
action of installing glass, or plastics glazing sheet material, into a building

3.3
insulating glass unit
an assembly consisting of at least two panes of glass, separated by one or more spaces, hermetically sealed along the periphery, mechanically stable and durable

[BS EN 1279-1:2004, definition **3.1**]

NOTE The individual panes may be of different sizes and/or thicknesses.

3.4
coupled glazing
two panes of glazing spaced apart in an opening, either in the frame or glazed separately, to form an unsealed cavity

NOTE Coupled glazing is also known as secondary glazing.

3.5
pane
single piece of glass or plastics glazing sheet material, in a finished size ready for glazing

3.6
plastics glazing sheet material
plastics material in the form of a single sheet, or a combination of sheets laminated together, or an extruded multi-wall sheet

3.7
vertical glazing
glazing which is vertical, or within 15° of vertical

3.8
task lighting
lighting sufficient to enable tasks to be performed

NOTE Tasks include reading, machine operating, component assembly, etc.

3.9
amenity lighting
lighting for the appearance of an interior and its contents

3.10
passive solar gain
solar radiation in the form of energy and light which is transmitted through the glazing into the building and which can be utilized as a source of energy or to reduce the need for artificial lighting

4 Energy

4.1 General

Glazed areas in buildings should be designed so that account is taken of the overall energy balance in relation to the effects on the thermal comfort of occupants and the total annual energy implications of solar gain and energy loss.

These should be examined separately, since factors affecting one aspect of performance might have no effect on the other. Energy gain is due to transmission of solar radiant energy through the glass into the building. Solar energy is all at relatively short wavelengths and is controlled by using the glass to absorb or reflect the energy. Energy loss is due to the transfer of energy by conduction, convection and long wavelength radiation and can be influenced by a number of factors, e.g. incorporating air cavities, including gases of low thermal conductivity and/or low emissivity glass.

4.2 Thermal comfort

Energy transmission through glazing can significantly influence occupier comfort by raising or lowering room air temperatures. For example, hot sunny weather can give rise to excessive energy gains; and energy losses can occur through the glazing during cold weather or at night. Thermal comfort can also be influenced by direct radiation through the glazing and/or by radiation exchange between the glazing and the occupants.

4.3 Solar energy gain

Factors that can influence the amount of solar gain through the glazing include:

a) orientation;

b) glazed area;

c) shading devices, both internal and external;

d) properties of the glazing.

4.4 Total solar energy transmittance

4.4.1 *General*

Total solar energy transmittance is the proportion of solar radiation at normal incidence transferred through the glazing. It is composed of the direct transmittance (short wave component) and the part of the solar absorptance dissipated inwards by long wave radiation and convection (long wave component).

The total solar energy transmission properties of solar control glazings can be described by their shading coefficients. The shading coefficient is derived by comparing the properties of the solar control glazing with a clear float glass having a total solar energy transmittance of 0.87 (i.e. clear glass between 3 mm and 4 mm thick).

NOTE Total solar energy transmittance is also known as g value.

4.4.2 *Solar control glass*

4.4.2.1 *General*

Solar control glass can be manufactured in several forms (see **4.4.2.2**, **4.4.2.3** and **4.4.2.4**). The function of solar control glass is to reduce the total solar energy transmittance, which usually leads to a decrease in the transmission of the visible part of the solar spectrum. However some tints and coatings are able to attenuate preferentially non-visible solar radiation, leaving the transmission of the greater proportion of the visible radiation largely unchanged.

The application of ceramic frit fired into the surface of the glass can also be used to modify the energy and light transmission of the glass. The effect can be varied across a pane depending on the screen print pattern. The manufacturers should be consulted for specific details.

The relationship between light transmission and total solar energy transmission is referred to as the light/energy ratio. Some manufacturers use this as a descriptive code, quoting a light transmission figure followed by a total solar energy transmission figure.

NOTE The performance of typical glass products showing the relationship between light transmission and total solar energy transmission is illustrated in Figure 1 (the enclosed area represents the envelope enclosing most practically available architectural glass products).

There is no optimum light/energy ratio. The selection of an appropriate product depends on the requirements of the building. Solar gain may be relatively high, for making use of passive solar gains, or low, to reduce air-conditioning loads. Light transmission will depend on the extent to which daylight is used to obviate artificial lighting.

4.4.2.2 *Body tinted glass (increased absorption)*

Solar control properties and colour vary with the thickness of the glass. When used in insulating glass units, body tinted glass should be positioned as the outer pane because the energy due to the absorbed radiation is more easily dissipated to the outside.

NOTE Performances of a typical range of body tinted glass products are shown in Table 1, with the properties of clear float for comparison.

4.4.2.3 *Reflective coated glass*

Reflective coated glass uses the principle of increasing the direct reflection to maximize solar energy attenuation. In comparison with clear glass its absorption of solar energy is also increased.

NOTE 1 Compared with a float glass surface, these reflecting coatings (owing to their composition) exhibit lower levels of emissivity which improves their U value.

The advantages of such glass types are:

a) greater performance range than body tinted glass;

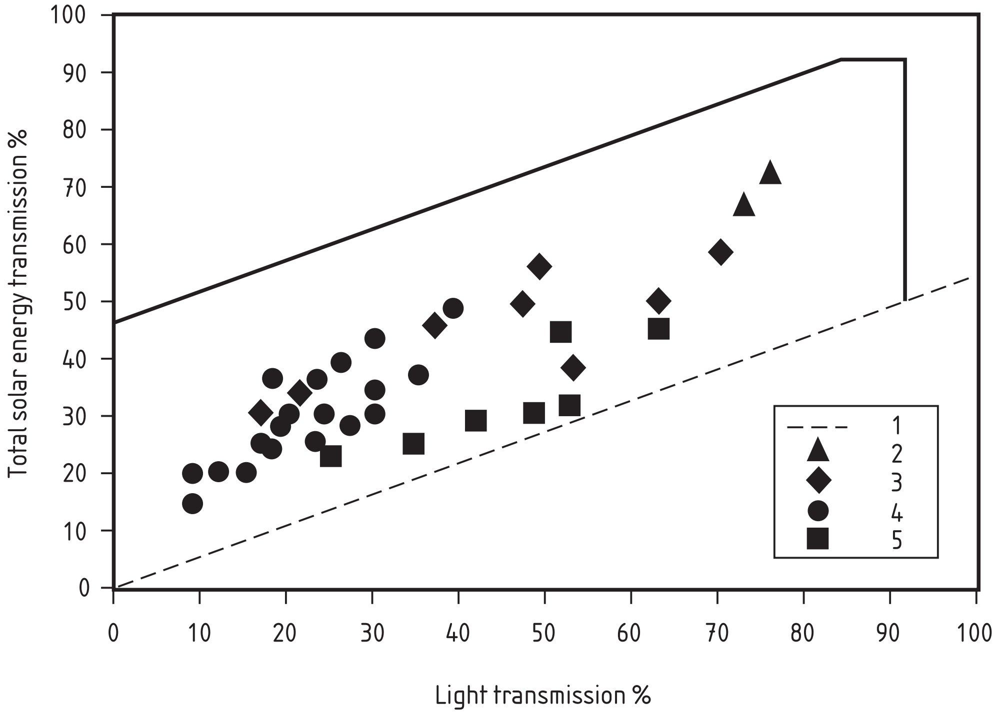
b) higher performances (greater solar energy attenuation);

c) light/energy ratios nearer to the theoretical limit;

d) a range of colour appearances in transmission and reflection.

NOTE 2 Performance data in comparison to clear glass is shown in Table 2.

The coatings may be placed on to body-tinted glass to extend the range of performances.



Key
1 Theoretical limit
2 Clear float glass
3 Tinted float glass
4 Coated glass
5 High performance coated glass

Figure 1 — Performance of different glass products showing the relationship between light transmission and total solar energy transmission

Table 1 — Properties of a typical range of clear and body-tinted glass products

Glass type and thickness	Light		Solar energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
4 mm clear	0.89	0.08	0.82	0.07	0.11	0.85	0.94	0.04	0.98
4 mm green	0.78	0.07	0.58	0.05	0.37	0.68	0.67	0.11	0.78
4 mm bronze	0.61	0.06	0.58	0.05	0.37	0.68	0.67	0.11	0.78
4 mm grey	0.55	0.05	0.55	0.05	0.40	0.65	0.63	0.12	0.75
6 mm clear	0.87	0.08	0.78	0.07	0.15	0.82	0.90	0.04	0.94
6 mm green	0.72	0.06	0.46	0.05	0.49	0.59	0.53	0.14	0.67
6 mm blue	0.54	0.05	0.46	0.05	0.49	0.59	0.53	0.14	0.67
6 mm bronze	0.50	0.05	0.46	0.05	0.49	0.59	0.53	0.14	0.67
6 mm grey	0.42	0.05	0.42	0.05	0.53	0.56	0.48	0.16	0.64
10 mm clear	0.84	0.07	0.70	0.07	0.23	0.76	0.80	0.07	0.87
10 mm green	0.61	0.06	0.29	0.04	0.67	0.46	0.33	0.20	0.53
10 mm bronze	0.33	0.04	0.29	0.04	0.67	0.46	0.33	0.20	0.53
10 mm grey	0.25	0.04	0.25	0.04	0.71	0.43	0.29	0.21	0.50

Table 2 — Properties of a typical range of clear glass and reflective coated glass products

Glass type and thickness	Light		Solar radiant energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
6 mm clear	0.87	0.08	0.78	0.07	0.15	0.82	0.90	0.04	0.94
6 mm silver	0.32	0.13	0.29	0.11	0.60	0.43	0.33	0.16	0.49
6 mm silver	0.20	0.23	0.16	0.18	0.66	0.31	0.18	0.17	0.35
6 mm silver	0.10	0.38	0.08	0.32	0.60	0.20	0.09	0.14	0.23
6 mm blue	0.40	0.10	0.32	0.10	0.58	0.46	0.37	0.16	0.53
6 mm blue	0.30	0.16	0.21	0.18	0.61	0.35	0.24	0.17	0.41
6 mm blue	0.20	0.20	0.15	0.21	0.64	0.29	0.17	0.17	0.34
6 mm bronze	0.26	0.17	0.20	0.14	0.66	0.35	0.23	0.18	0.41
6 mm bronze	0.10	0.19	0.06	0.21	0.73	0.21	0.07	0.17	0.24
6 mm grey	0.32	0.12	0.21	0.10	0.69	0.44	0.33	0.18	0.51

Table 3 — Properties of a typical range of laminated glass products with clear and tinted interlayers and clear glass

Laminated glass	Light		Solar radiant energy				Shading coefficients		
Colour and thickness	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
6.4 mm clear	0.87	0.08	0.77	0.07	0.16	0.81	0.89	0.04	0.93
6.4 mm brown	0.28	0.04	0.32	0.04	0.64	0.49	0.37	0.19	0.56
6.4 mm bronze	0.52	0.05	0.54	0.05	0.41	0.65	0.62	0.12	0.74
6.4 mm grey	0.44	0.05	0.51	0.05	0.44	0.62	0.59	0.13	0.72
6.4 mm marine	0.60	0.06	0.63	0.06	0.31	0.71	0.72	0.10	0.82
6.4 mm blue-grey	0.37	0.05	0.43	0.05	0.52	0.56	0.49	0.16	0.65
6.4 mm blue-green	0.73	0.07	0.69	0.07	0.24	0.75	0.79	0.07	0.86
6.4 mm white translucent	0.57	0.05	0.54	0.05	0.41	0.65	0.62	0.12	0.74

4.4.2.4 *Laminated glass*

Laminated glass is commonly constructed with clear glass and clear interlayers, but solar control properties can be incorporated into laminated glass by including either solar control glass or tinted interlayers or both.

Laminated glass with clear interlayers and solar control glass exhibits similar properties to the solar control glass from which it is made.

Laminated glass with a tinted interlayer acts in a similar manner to body tinted glass, by absorbing the solar radiation, but with a different range of colours and performances.

NOTE Performances of a typical range of laminated glass products with clear glass and tinted interlayers are shown in Table 3, with the properties of clear laminated glass for comparison.

4.4.2.5 *Insulating glass units*

Insulating glass units, whilst used primarily for improved thermal transmittance (U value), see **4.5**, can also improve the total solar energy transmittance. This improvement is a result of the incorporation of a second pane of glass together with the hermetically sealed airspace. The second glass panes can be any glass type. The main glasses used as the inner pane are clear glass, hard coat low emissivity glass or soft coat low emissivity glass.

NOTE 1 Soft coat low emissivity glass can be used as the hermetically sealed airspace protects the coating.

NOTE 2 Performances of a typical range of insulating glass units with clear float inner pane are shown in Table 4.

NOTE 3 Performances of a typical range of insulating glass units with hard coat low emissivity glass inner pane are shown in Table 5.

NOTE 4 Performances of a typical range of insulating glass units with soft coat low emissivity glass inner pane are shown in Table 6.

4.4.3 ***Solar control plastics glazing sheet materials***

Various coloured plastics glazing sheet materials are available that reduce the transmission of solar radiation. Manufacturers should be consulted for specific details.

4.4.4 ***Blinds and louvres***

The use of blinds or louvres in windows affects the window shading coefficient. This depends upon the solar optical properties of the glazing and the material of the blind, on the coefficients of energy transfer at the window surfaces, on the geometry and location of the blind, and the angular position of the sun. The manufacturer should be consulted for specific advice.

Table 4 — Properties of a typical range of insulating glass units with clear float inner pane

Outer pane	Light		Solar energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
Clear									
4 mm clear[a]	0.81	0.15	0.69	0.13	0.18	0.75	0.79	0.07	0.86
4 mm low iron[a]	0.83	0.15	0.75	0.14	0.11	0.81	0.86	0.07	0.93
6 mm clear	0.80	0.15	0.64	0.12	0.24	0.72	0.74	0.09	0.83
6 mm low iron	0.82	0.15	0.71	0.14	0.15	0.79	0.82	0.09	0.91
Body-tinted glass									
6 mm green	0.67	0.11	0.39	0.07	0.54	0.47	0.45	0.09	0.54
6 mm bronze	0.44	0.07	0.37	0.07	0.56	0.46	0.43	0.10	0.53
6 mm grey	0.39	0.07	0.36	0.07	0.57	0.46	0.41	0.12	0.53
6 mm blue	0.47	0.08	0.30	0.06	0.64	0.39	0.34	0.11	0.45
High performance coated									
6 mm clear	0.65	0.21	0.39	0.31	0.30	0.44	0.45	0.06	0.51
6 mm neutral	0.53	0.08	0.35	0.15	0.50	0.41	0.40	0.07	0.47
6 mm silver	0.51	0.36	0.28	0.41	0.31	0.31	0.32	0.04	0.36
Very high performance coated									
6 mm neutral	0.66	0.15	0.32	0.30	0.38	0.36	0.37	0.04	0.41

NOTE The properties are based on 6 mm clear float inner pane and 16 mm cavity unless otherwise indicated.

[a] With 4 mm inner pane.

Table 5 — Properties of a typical range of insulating glass units with hard coat low emissivity inner pane

Outer pane	Light		Solar energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
Clear									
4 mm clear[a]	0.75	0.17	0.59	0.16	0.25	0.71	0.68	0.14	0.82
4 mm low iron[a]	0.76	0.17	0.64	0.18	0.18	0.78	0.74	0.16	0.90
6 mm clear	0.74	0.17	0.55	0.15	0.30	0.69	0.63	0.16	0.79
6 mm low iron	0.76	0.17	0.61	0.17	0.22	0.77	0.71	0.18	0.89
Body-tinted glass									
6 mm green	0.62	0.13	0.34	0.08	0.58	0.43	0.39	0.10	0.49
6 mm bronze	0.41	0.08	0.31	0.08	0.61	0.42	0.36	0.12	0.48
6 mm grey	0.36	0.07	0.31	0.08	0.61	0.42	0.36	0.12	0.48
6 mm blue	0.44	0.09	0.26	0.07	0.67	0.34	0.30	0.09	0.39

NOTE The properties are based on 6 mm hard coat low emissivity glass inner pane and 16 mm cavity unless otherwise indicated.

[a] With 4 mm inner pane.

Table 6 — Properties of a typical range of insulating glass units with soft coat low emissivity inner pane

Outer pane	Light		Solar energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
Clear									
4 mm clear[a]	0.79	0.12	0.53	0.23	0.24	0.63	0.61	0.11	0.72
4 mm low iron[a]	0.81	0.12	0.57	0.28	0.15	0.68	0.66	0.12	0.78
6 mm clear	0.78	0.11	0.50	0.21	0.29	0.61	0.57	0.13	0.70
6 mm low iron	0.80	0.11	0.55	0.27	0.18	0.67	0.63	0.14	0.77
Body-tinted glass									
6 mm green	0.66	0.09	0.33	0.08	0.59	0.41	0.38	0.09	0.47
6 mm bronze	0.43	0.06	0.28	0.10	0.62	0.36	0.32	0.09	0.41
6 mm grey	0.38	0.06	0.27	0.11	0.62	0.36	0.31	0.10	0.41
6 mm blue	0.46	0.07	0.25	0.07	0.68	0.32	0.29	0.07	0.37

NOTE These properties are based on 6 mm soft coat low emissivity glass inner pane and 16 mm cavity unless otherwise indicated.

[a] With 4 mm inner pane.

4.5 Energy loss

4.5.1 *General*

Energy loss is quantified by the thermal transmittance or U value (W/m^2K).

NOTE For a full definition of thermal transmittance and its method of calculation see BS EN 673.

Glass and thin plastics glazing sheet materials readily conduct energy and so are poor insulators. To improve resistance to energy loss, insulating glass units or coupled windows should be used, since the air cavities provide extra thermal resistance.

Increasing the thickness of the glass or plastics glazing sheet material makes little difference to the U value of the glazing.

4.5.2 *Methods for improving thermal insulation*

4.5.2.1 *Use of low emissivity coatings*

Low emissivity (low-E) coatings have surface emissivities of less than 0.2 (see BS 952-1:1995). The use of such a coating on glass improves the thermal insulation. They are most efficient when used on the cavity surfaces of insulating glass units.

4.5.2.2 *Increasing the width of the air space*

Enhanced thermal insulation can be achieved by increasing the width of the airspace. However, there is a practical upper limit of about 16 mm. Above this width no extra thermal benefit is obtained due to convection of the gas in the cavity.

4.5.2.3 *Using gases of lower thermal conductivity*

Replacing the air in the cavity with, for example, argon, can improve the thermal insulation.

4.5.2.4 *Inhibiting convection within the air space*

Filling the cavity with cellular material reduces convection and makes the cavity a more efficient insulator. However, this usually results in loss of vision, since the materials are, at best, translucent.

4.5.2.5 *Evacuation of the air space*

In theory, a vacuum will eliminate energy transfer by conduction and convection. However, a vacuum puts high demands on the glass from the external air pressure.

NOTE Evacuation of the air space is currently considered to be technically impractical.

4.5.3 *Typical U values of glass products*

Table 7, Table 8 and Table 9 give typical U values.

Table 7 — Thermal transmittance (U value) of glass products: Single glazing

Glass thickness mm	**U value** W/m^2K
4	5.8
6	5.7
10	5.6
12	5.5
NOTE U values determined in accordance with BS EN 673.	

Table 8 — Thermal transmittance (U value) of glass products: Insulating glass units

Clear glass thickness and type mm	Cavity width mm	U value W/m²K	
		Air	Argon
4 + 4	6	3.3	3.1
	12	2.9	2.7
	16	2.7	2.6
	20	2.8	2.6
4 + 4 Low E (ϵ_d = 0.15)	6	2.7	2.3
	12	1.9	1.6
	16	1.7	1.5
	20	1.7	1.5
4 + 4 Low E (ϵ_d = 0.04)	6	2.5	2.0
	12	1.6	1.3
	16	1.4	1.2
	20	1.4	1.2
4 + 4 + 4	6	2.4	2.1
	12	1.9	1.8
	16	1.8	1.7
	20	1.8	1.7
4 Low E (ϵ_d = 0.15) + 4 + 4 Low E (ϵ_d = 0.15)	6	1.7	1.4
	12	1.7	1.0
	16	1.0	0.8
	20	0.9	0.8
4 Low E (ϵ_d = 0.04) + 4 + 4 Low E (ϵ_d = 0.04)	6	1.6	1.2
	12	1.0	0.7
	16	0.8	0.6
	20	0.7	0.6

NOTE 1 U values determined in accordance with BS EN 673.

NOTE 2 U values for argon gas-filled cavity based on 90 % argon/10 % air.

NOTE 3 ϵ_d is the declared (normal) emissivity.

Table 9 — Thermal transmittance (U value) of glass products: Coupled glazing

Clear glass thickness and type mm	Separation mm	U value W/m²K
4 + 4	25	2.8
	75	2.8
4 + 4 Low E (ϵ_d = 0.15)	25	1.7
	75	1.9

NOTE 1 U values determined in accordance with BS EN 673. (It has been assumed that there is no ventilation to the separation.)

NOTE 2 ϵ_d is the declared (normal) emissivity.

4.5.4 *U values of plastics glazing sheet materials*

Table 10 gives typical U values of some plastics glazing sheet materials. For detailed information on specific products the manufacturer should be consulted.

Table 10 — Thermal transmittance (U value) of single and double plastics glazing sheet materials

Sheet or unit mm	Airspace width mm	U value W/m^2K
Single		
3	—	5.5
5	—	5.3
Double		
3 + 3	3	3.6
	6	3.1
	9	2.9
	12	2.7
	16	2.6
	20	2.6
3 + 2 or 2.5 + 2.5	3	3.7
	6	3.2
	9	2.9
	12	2.8
	16	2.7
	20	2.7

4.5.5 *Recommendations for U values*

In the interests of energy efficiency, insulating glass units or double windows should be used in all new buildings and in all replacement glazing in existing buildings.

Consideration should be given to the installation of glazing with a U value less than 2.0 W/m^2K, which can be achieved by incorporating low emissivity glass in insulating glass units.

4.5.6 *Effect of framing*

The other major criterion which should be taken into consideration when designing a low U value window is the framing.

The type of frame can have a considerable effect on the overall U value of a window, particularly when high insulation glazing is used.

NOTE A simplified method for the determination of U values for windows is given in BS EN ISO 10077-1.

4.6 Condensation

4.6.1 *Room side condensation*

As thermal insulation of the glazing improves, the susceptibility to condensation on the room face of the glazing is reduced.

NOTE Condensation might occur after single glazed windows are replaced by double glazing due to the reduction in ventilation (see BS 5250).

4.6.2 *Interstitial condensation*

In insulating glass units, condensation in the cavities should be minimized by sealing and dehydrating the cavity.

In coupled windows, interstitial condensation problems can be reduced by venting the cavity to the outside.

4.6.3 *Exterior condensation*

On rare occasions, condensation might occur on the outermost glass surface of highly insulating glazing, e.g. low E glass, as a result of the reduction of energy conduction to the outside. This effect will only be prevalent at low sky temperature, i.e. clear sky, when there is a heavy dew.

4.7 Energy balance

The magnitude of solar energy gain through clear insulating glass units facing South, East and West can be much greater than the energy losses over the duration of the heating season. The glazing acts as a passive solar collector. This idea is encapsulated in the concept of "effective U value" (or energy balance), whereby the additional useful energy gain is offset against the energy loss. Manufacturers should be consulted about the effective U value of their products.

NOTE BS EN ISO 14438 describes how to obtain the effective U value.

4.8 Thermal safety of glass

Thermal safety of glass should be assessed considering the amount of radiation incident on the surface and the thermal capabilities of the glass. For example, the solar radiation intensity on the glass surface should be determined along with the air temperature range applicable to the location of the building. These measurements, together with the energy transfer coefficients and the glass absorption allow determination of the appropriate basic temperature difference between the central area of the glass and its edge. The difference is related to the thermal stress and then modified for the type of glazing system, taking account of extraneous effects resulting from curtains, blinds, back-up walls, proximity to heaters, etc., to derive a stress for actual service conditions.

NOTE 1 High air temperatures, low rates of air movement, and the insulation provided by curtains, blinds, back-up walls and multiple glazing tend to reduce the loss of energy and uphold the centre temperature. Low temperatures at the edges are maintained by conduction from the glass through the frame to a cold building structure with a large thermal capacity.

NOTE 2 Advice may be sought from the manufacturer of the glass as to methods for assessing the thermal safety of the glass.

The resultant service stress should then be compared with the design stress for the glass. If on comparison the service stress is less than or equal to the design stress, the glass and glazing system may be accepted as thermally safe provided that the edges of the glass are of adequate quality.

NOTE 3 Where the application of a solar control film is being considered to existing glazing, advice should be sought from the manufacturer on the effect of any additional thermal stress likely to be induced in the glass.

The normal mode of thermal breakage of glass is by the action of tensile stress located in and parallel to an edge, and so the breaking stress of the glass is mainly dependent on the extent and position of flaws in the edges. The condition of the glass edge is therefore extremely important.

Solar control glasses should not be nipped to size and any panes with shelled or vented edges should not be accepted for glazing in orientations subject to direct sunlight. Although a wheel-cut edge is the most satisfactory, laminated glasses with worked edges may be used.

Where clean-cut edges are not permitted, arrises should be created by a wet process, working parallel to the edge and not across the thickness, and the design implications of such an action should be examined.

Where solar control glasses are to be used in sliding doors and windows there is always the possibility that, when opened during sunny periods, the overlapping will function as double glazing with little ventilation in the air space, and it is this condition that should be assumed in assessing the thermal safety of glass.

Thermal safety assessment is based on the behaviour of glass in good condition and properly glazed. Even if the glass is shown to be thermally safe, this depends on close adherence to the recommended glazing procedures. All necessary precautions should be taken to see that only glass with edges of an acceptable condition is used. The glass should be stored and handled so that no contact with hard bodies can damage the edges and each pane or insulating glass unit should be carefully examined immediately before glazing.

Some solar control glasses can be toughened or heat strengthened and this gives a means of raising the design stress and ensuring safety from thermal fracture.

4.9 Thermal expansion

4.9.1 *Glass*

The coefficient of linear expansion of all the soda-lime silicate glass types (see BS EN 572-1) referred to in this code of practice, whether clear or tinted, annealed, laminated or toughened, is approximately $9.0 \times 10^{-6}\ K^{-1}$.

4.9.2 *Plastics glazing sheet materials*

Movement caused by temperature changes should be allowed for when cutting plastics glazing sheet material to fit into a frame. The coefficient of linear expansion for most plastics sheet materials is around 6.0×10^{-5} K^{-1} to 8.0×10^{-5} K^{-1}.

5 Light

5.1 Daylighting

5.1.1 *Daylighting prediction*

Daylighting prediction for interior spaces is usually based on "daylight factor" concepts. The daylight factor is a ratio, expressed as a percentage of the illuminance at a point on a given internal plane due to light received directly and indirectly from a sky of known or assumed luminance distribution, to the illuminance on a horizontal plane from an unobstructed hemisphere of the sky.

Windows which have a view of the high altitude (overhead) areas of the overcast sky, with corresponding high luminance, will admit more daylight to the interior. Caution should be exercised that these windows do not become a source of glare, because of the higher luminance. With a clear sky the opposite should be considered, together with orientation.

Integration of daylight and artificial light is important to the energy efficiency of buildings and should be considered carefully. Since the CIE (Commission Internationale de l'Eclairage) overcast sky (see Annex A) assumes no orientation effects, the estimates of daylight contribution can be in error. To correct this, orientation factors have been derived to be applied to the daylight factors.

NOTE Further information on the calculation of daylight factors can be found in BS 8206-2 .

5.2 User requirements from daylight

5.2.1 *Task lighting*

Standards of daylight provision for task lighting are set out in BS 8206-2 based on the provision of illumination on the working plane.

NOTE Task lighting cannot be provided by daylight alone for the entire working day throughout the year, and some form of artificial lighting is required to supplement available daylight.

Glazed areas should not be used excessively as a means to admit more daylight, as this might give rise to solar overheating (see Clause **3**).

5.2.2 *Energy conservation*

Good window design can, by reducing reliance on artificial lighting, be one of the largest single means of saving energy and should be carefully considered.

Account should be taken of room shape, window orientation, occupancy patterns and tasks, together with the relationship of windows to surrounding buildings and other obstructions. As with task lighting, possible solar overheating might result and similar precautions should be taken.

5.3 Light transmission properties of windows

Light transmission is defined as the fraction of visible light at normal incidence transmitted through the glazing. Typical light transmission properties of glass are given in Table 1, Table 2 and Table 3. For plastics glazing sheet materials, the manufacturer should be consulted.

Visible light has a spectral distribution corresponding to the CIE Standard Illuminant D65, approximately the same as daylight. The light transmittance for a CIE overcast sky with vertical or horizontal glazing, or for a sky of uniform luminance distribution, can be found by multiplying the tabulated light transmittance for normal incidence by the factors in Table 11.

Table 11 — Light transmission correction factors

Diffuse light source	Factor for glazing position	
	Vertical glazing	Horizontal glazing
CIE standard overcast sky	0.91	0.94
Uniform sky	0.92	0.92

Dirt on glazing reduces the light transmission, often by an appreciable extent before becoming noticeable. To ensure daylighting levels are adequate, an allowance for the reduced light transmission should be made in daylighting calculations by introducing a "dirt factor" between 0.7 and 1.0. Glass and plastics glazing sheet materials should be cleaned regularly.

5.4 Glazing properties and their influence on daylight quantity and quality

5.4.1 *Light transmission for task lighting*

The level of task lighting is determined principally by the light transmission of the glazing and the extent and size of the glazed area. The quality of the lighting and its distribution depend on the shape of the glazing, its position and orientation, and the nature of the internal space.

Clear glass, with a light transmission of 87 %, when correctly positioned in a window wall, with little obstruction and light coloured interior decoration, will provide adequate daylighting to a depth of about 6 m from the window.

NOTE Reducing the height of the window reduces the depth of daylight penetration and changing its shape and distribution influences the lighting levels and quality.

5.4.2 *Light transmission for amenity lighting*

Judgement of acceptability of an interior, where recreation and social contact predominate, is based on the appearance of the furnishings and the other occupants. This is determined by the areas of light and shade giving shape and detail. Thus, special attention should be paid to the "flow" of light within the interior and its intensity and distribution.

The visual success of the overall lighting system should be judged by the balance between "directional" light, which flows over and around the interior and its contents, and the "non-directional" diffuse light reflected from the walls, floor and ceiling.

5.4.3 *Light transmission for energy conservation*

Four distinct situations should be considered:

a) interiors where the average daylight factor is greater than 5 %;

b) rooflit interiors where the average daylight factor is less than 2 %;

c) rooflit or shallow sidelit interiors having average daylight factors of 2 % to 5 %;

d) deep sidelit rooms.

Where the average daylight factor exceeds 5 %, natural lighting should be adequate for most purposes during daylight hours.

In rooflit areas with average daylight factors less than 2 %, permanent supplementary lighting is usually required. Lighting controls should be arranged to switch or dim individual luminaries at fixed steps of illumination.

When the average daylight factor is between 2 % and 5 %, the supplementary lighting should be planned to take full advantage of available daylight. The provision of automatic controls for switching should result in significant energy savings. The position of luminaries should be carefully arranged in relation to the position of windows in order to preserve the daylit character. In deep sidelit spaces the supplementary lighting should be carefully zoned.

NOTE It is often advantageous to use local artificial task lighting and to use daylight to provide general background lighting.

Before any lighting system is satisfactorily specified, either as a totally daylit system or as an integrated daylight/artificial system, the amount and distribution of natural light should be predicted, using one of the many methods currently available (e.g. BS 8206-2).

5.5 Glare

5.5.1 *General*

Glare results from excessive contrast of illumination, or from an excess of illumination in the field of view. Reaction to it is subjective. When correctly designed, natural lighting should not be a glare problem.

NOTE Contrasts in excess of 10:1 in illumination in different parts of the field of view might give rise to glare in some form.

5.5.2 *Disability glare*

Reducing the light transmission of glazing from 87 % to 60 % produces a just perceptible reduction in disability glare caused by direct sunlight. Even when the light transmission of the glazing is as low as 10 %, some 10 000 lux can still be experienced and glare will almost certainly occur.

Glare can be reduced by some form of mechanical shading, e.g. a canopy, an overhanging floor, a balcony, or a louvre system. Alternatively, internal screening can be provided by louvres or blinds.

NOTE Any fixed shading system reduces the amount of natural light entering the building throughout the year, irrespective of whether there is a glare problem at any particular time.

It might also be possible to re-orientate the glazing to avoid entry of direct solar radiation. Alternatively, the interior layout can be suitably designed to eliminate glare.

5.5.3 *Discomfort glare*

Glazing products with light transmission lower than 50 % can ameliorate discomfort glare. These products decrease the sky luminance components but permanently reduce the admission of daylight. Alternatively, shading devices, internal or external, movable or fixed, may be used.

Other methods of reducing the problems of glare should be considered, including:

a) installation of windows in more than one wall to raise the general background illumination and, in so doing, to reduce the contrast between a window and its surrounding surfaces;

b) use of light coloured matt finishes for the window frames and the surrounding surfaces;

c) splayed reveals, to assist in reducing the contrast between the window and its surroundings;

d) use of slender glazing bars and transoms of high reflectance;

e) lowering window sills to allow increased illumination to enter, which increases the adaptation level and reduces the likelihood of discomfort glare.

5.6 Diffusion and obscuration

The nature of some glazing products (e.g., patterned or acid etched glass) can cause the direct incident solar beam to be scattered diffusely. Hence the window might assume an uncomfortably high brightness and become a discomfort glare source in its own right. Diffusing glazing used within the normal field of view should be used with caution.

5.7 Fading

Most materials can fade when subjected to either daylight (particularly direct sunlight) or artificial light. Fading is a complex phenomenon, involving many chemical reactions, initiated or accelerated by light of different wavelengths. Generally, the better quality dyes and pigments fade relatively slowly and react only to the shorter wavelengths (ultraviolet and the blue end of the visible spectrum). Other materials can fade quickly and might do so under light of much longer wavelengths. It is the combination of wavelength, available light and transmission which determines glass selection to minimize fading, not simply the UV transmission.

In order to minimize fading the following precautions should be taken.

a) Overall levels of illumination, both daylight and artificial should be reduced and in particular direct sunlight should be avoided. Shading (curtains) should be used and the glazing, artificial lighting and orientation controlled.

b) The time for which the object is exposed to the light should be reduced. Halving the time of exposure has the same effect as halving the light intensity.

c) The temperature should be reduced. All changes involved in fading proceed more rapidly at higher temperatures.

d) Transmission of the UV and blue end of the spectrum should be reduced by fitting appropriate glazing and artificial light sources.

NOTE Significant reduction in UV transmission can be achieved by using plastics glazing sheet materials or an appropriate interlayer in the construction of laminated glass. Reflective and tinted solar control glass can also aid in reducing fading.

The manufacturer should be consulted on appropriate values of UV transmittance of the various types of glass or plastics glazing sheet materials.

5.8 One way vision

Effective one way vision may be provided by suitably adjusting the amounts of reflection on each surface of the glazing and controlling the lighting levels on both sides of the glazing.

NOTE It is very difficult to obtain one way vision through external windows, as daylight cannot be controlled.

Venetian strip silvered glass or a reflective coated glass are two common materials used to achieve one way vision.

6 Sound

6.1 Introduction

Noise, i.e. unwanted sound, can be attenuated by employing thick glazing, insulating units, secondary glazing, laminated glass or any combinations of these. In order to maximize the acoustic benefits of the glazing, special consideration should be given to the actual frequency spectrum of the noise source.

NOTE Further information on the performance of glass can be obtained from BS EN 12758.

6.2 Source of noise

6.2.1 *Road traffic noise*

Road traffic noise is a very common problem, particularly in urban areas, where low frequency noise from engine and exhaust systems predominates. On faster roads, tyre noise (which is of higher frequency) becomes more important.

6.2.2 *Railway noise*

Railway noise has a similar spectrum to road traffic except that more middle frequency components are present. However, this noise is generally more tolerable than road traffic noise since the peaks are of short duration. It is generally accepted that railway noise can exceed road traffic noise by up to 10 dB for a similar level of disturbance.

6.2.3 *Aircraft noise*

Aircraft noise changes significantly with altitude, climatic conditions, type and load utilization of aircraft, and whether it occurs at landing or take-off. Take-off noise is dominated by low frequencies whereas landing noise contains strong high frequency components.

6.2.4 *Speech*

The important frequencies of speech lie between 500 Hz and 2 000 Hz (middle frequency dominated).

6.3 Specification of acoustic performance

Because the noise level produced by most noise sources and the sound reduction provided by building elements varies with frequency, this should be taken into account when specifying acoustic performance. Usually the noise level or sound reduction is specified in frequency bands.

For general building acoustics, the octave frequency bands are 125 Hz, 250 Hz, 500 Hz, 1 000 Hz, 2 000 Hz and 4 000 Hz. However, for some critical applications it is useful to extend the range down to 50 Hz and/or up to 5 000 Hz

When more detailed analysis is appropriate, these octave bands may be subdivided into three (except for the 4 000 Hz band) to give 16 one-third-octave bands at 100 Hz, 125 Hz, 160 Hz, 200 Hz, 250 Hz, 315 Hz, 400 Hz, 500 Hz, 630 Hz, 800 Hz, 1 000 Hz, 1 250 Hz, 1 600 Hz, 2 000 Hz, 2 500 Hz and 3 150 Hz.

6.4 Acoustic indices

6.4.1 *General*

Although the levels of noise and the amounts of sound reduction are usually measured in frequency bands, it is often convenient to reduce the information to single number quantities or indices (see **6.4.2, 6.4.3** and **6.4.4**). The indices R_W, C and C_{tr} describe sound reduction.

NOTE Of the previously used sound reduction indices (R_m, R_W and R_{TRA}) R_m is no longer required, R_W is effectively unchanged and R_{TRA} can be approximated by $R_W + C_{tr}$.

6.4.2 *Weighted sound reduction index, R_W*

The weighted sound reduction index is a single number rating used to describe the sound reduction of a building element when measured in a laboratory. It is calculated from the measured values in each one-third-octave band, which are known as the sound reduction indices *R*. The rating method is described in BS EN ISO 717-1 and BS EN ISO 717-2. The measurement method is described in BS EN ISO 140-3.

As with all single figure indices of acoustic performance, the ranking order is not always the same when applied to real noise exposure. Hence the introduction of the adaptation terms *C* and C_{tr}.

6.4.3 *Sound reduction against specific noises, $R_W(C;C_{tr})$*

The noise level in a room resulting from outside noise intrusion depends mainly on the level and frequency spectrum of the noise and the sound reduction characteristics of the windows. The weighted sound reduction index cannot be used directly to estimate the noise level in the room. To facilitate such calculations, BS EN ISO 717-1 and BS EN ISO 717-2 describe the calculation of two spectrum adaptation terms, *C* and C_{tr}. These can be added to R_W to give an indication of the sound reduction in dB of the window (or other building element) against typical noise sources which are listed in the standard, including motorway and urban road traffic. This information is presented as in the following example:

$$R_W(C;C_{tr}) = 41(0;-5) \text{ dB}$$

where: $R_W = 41$ dB;

$C = 0$ dB;

$C_{tr} = -5$ dB.

If an extended frequency range has been specified, it is denoted as in the following examples:

$C_{50\text{-}3150}$, $C_{50\text{-}5000}$, $C_{100\text{-}5000}$, $C_{tr;50\text{-}3150}$, $C_{tr;50\text{-}5000}$ and $C_{tr;100\text{-}5000}$.

6.4.4 *Mean sound reduction index, R_m*

The mean sound reduction index is no longer required, but there might be historical reasons for its use, so values for glass have been included in Table 12 and Table 13. For some materials the mean sound reduction index is the only available information, e.g. plastics glazing sheet materials (Table 14 and Table 15).

6.5 Sound reduction of a single glass pane

6.5.1 *General*

Glass has a very low sound absorption. Table 12 shows the sound reduction properties for different types of single glazing. Several factors affect the overall acoustic performance. These include the mass, coincidence resonance, gaps in frames, edge support conditions, lamination and pane dimensions (see **6.5.2, 6.5.3** and **6.5.4**).

6.5.2 *Effect of mass*

Doubling the glass thickness, and therefore the mass, results in about 4 dB increase in sound reduction.

6.5.3 *Coincidence resonance*

Coincidence resonance is characterized graphically by a "dip" in the sound reduction at a certain frequency. The frequency, f_c (measured in Hz), at which this occurs is inversely proportional to the glass thickness, determined from the formula

$$f_c = \frac{12\,000}{d}$$

where *d* is the glass thickness (mm).

6.5.4 *Lamination*

Instead of using ordinary solid (or monolithic) window glass the thickness may be split up into thinner components, each separated, but bonded together, by a softer interlayer material to form a laminated glass. This is common in safety and security applications and such lamination can also have acoustic benefits, particularly in the suppression of the coincidence resonance.

Two main types of interlayer material may be used, polyvinylbutyral (pvb) and polymethylmethacrylate (pmma).

There are important differences in the acoustic performances of these two kinds of interlayer. Polyvinylbutyral generally offers a smaller acoustic effect as it couples the individual glass plies together. With pmma, the individual plies of glass tend to act as if they were separate entities, so the residual resonances occur at frequencies which correspond closely with the individual glass components of the laminate. Thus, the pmma shifts these resonances to higher frequencies where, generally, they play a less important role in overall attenuation of common noises.

NOTE 1 PMMA is a generic name for a wide variety of resins. The acoustic performance of these resins can vary considerably with type.

NOTE 2 There are special types of pvb available with enhanced acoustic performance.

The manufacturer of the interlayer or laminated glass should be consulted for more information.

6.6 Sound reduction of insulating glass units and secondary glazing

6.6.1 *General*

In addition to those factors determining the sound reduction of single glass, there are additional factors with insulating glass units and secondary glazing. These include the use of different glass thicknesses, cavity width and gas filling (see **6.6.2, 6.6.3** and **6.6.4**). Table 13 shows typical sound reduction properties for insulating glass units and secondary glazing.

6.6.2 *Different glass thicknesses*

The individual resonances of the panes can be offset by ensuring that the component panes differ in thickness by at least 30 % (e.g. 10 mm + 6 mm, or 6 mm + 4 mm). Lamination of one pane produces a further small improvement and this is achieved regardless of which pane is laminated.

6.6.3 *Cavity width*

Over the usual cavity range of 6 mm to 16 mm for insulating glass units, there is little variation of acoustic performance. Where higher sound reduction of windows is required, cavity widths of greater than 100 mm might be needed. Sound absorbing lining of the reveals improves performance. Beyond 200 mm, significant further improvement is gained only by resorting to very large gaps.

6.6.4 *Gas filling*

For applications where middle frequency acoustic performance is critical (e.g. speech), insulating glass units can benefit from being filled with sulfur hexafluoride (SF_6) gas mixtures. However SF_6 introduces a significant resonance at 200 Hz to 250 Hz and, for noise dominated by low frequency components, such as traffic noise, this might be detrimental.

NOTE SF_6 is a potent greenhouse gas and its use is discouraged.

Argon filled units, used for improving thermal insulation, exhibit exactly the same acoustic performance as standard air-filled units of the same glass combination.

Table 12 — Typical sound reduction properties of single glazing

One-third-octave band centre frequency Hz	Sound reduction (dB) for glass thickness (mm)							
	4	6	6.4 pvb laminate	7 pmma laminate	10	12	13 pmma laminate	13.5 pvb laminate
100	17	16	21	23	24	24	27	25
125	18	19	20	26	21	29	30	28
160	16	20	21	25	25	31	30	27
200	19	22	20	26	23	28	31	27
250	20	24	24	27	28	29	33	31
315	22	25	25	28	28	31	33	31
400	25	28	27	30	31	29	35	33
500	27	30	29	32	33	33	37	35
630	28	32	32	33	34	32	38	37
800	30	34	34	35	33	31	40	37
1 000	32	35	34	36	31	32	40	36
1 250	33	35	35	38	29	32	41	35
1 600	34	32	34	39	30	36	40	37
2 000	34	26	31	40	33	39	38	41
2 500	31	27	31	40	36	42	41	44
3 150	24	30	35	38	37	45	45	47
4 000	26	33	39	36	40	47	51	50
R_W	29	31	32	36	33	34	39	37
C	–2	–2	–1	–1	–2	0	0	–1
C_{tr}	–3	–3	–3	–4	–3	–2	–2	–3
R_m	26	27	28	32	30	33	36	35

NOTE Toughened, coated, wired and patterned glass are acoustically the same as float glass of the same thickness.

Table 13 — Typical sound reduction properties of insulating glass units and secondary glazing

One-third-octave band frequency Hz	Sound reduction (dB) for glass / cavity width / glass (mm)								
	4/12/4	**6/12/4**	**6/12/6**	**10/12/4**	**10/12/6**	**10/12/6.4**	**6/100/4**	**6/150/4**	**10/200/6**
100	21	18	18	24	26	27	25	27	32
125	21	23	23	24	25	24	27	30	37
160	20	23	20	25	24	23	27	30	39
200	18	18	15	19	22	24	33	34	45
250	15	21	18	22	29	30	33	34	46
315	19	23	23	25	30	30	37	39	46
400	22	25	26	30	31	32	41	42	47
500	25	24	29	32	34	35	46	46	45
630	29	32	33	35	36	37	50	50	45
800	33	36	37	36	39	40	54	54	44
1 000	36	39	39	37	39	41	57	57	45
1 250	38	41	39	39	37	40	59	58	50
1 600	40	40	37	40	39	40	58	58	53
2 000	39	36	33	44	37	40	52	52	58
2 500	34	36	32	45	39	43	51	49	58
3 150	28	37	36	41	43	47	48	47	64
4 000	31	40	40	42	46	52	57	52	64
R_W	29	32	31	35	36	38	46	47	49
C	–1	–2	–1	–2	–1	–1	–2	–2	–1
C_{tr}	–4	–4	–4	–5	–3	–5	–7	–6	–4
R_m	27	29	29	32	33	35	44	44	47

6.7 Sound insulation of plastic glazing sheets

The sound insulation properties of plastics glazing sheet materials relate to mass. Table 14 gives the mean sound reduction index for various thicknesses of single plastics glazing sheet materials and Table 15 gives an estimation of the probable mean sound reduction index of double glazed plastics glazing sheet materials.

NOTE Further information might be available from the manufacturer.

Table 14 — Sound reduction: Single plastics glazing sheet material

Thickness mm	Mean sound reduction index dB
3	18
4	20
5	22
6	23
8	25
10	26
13	28

Table 15 — Sound reduction: Double glazing, both panels the same thickness of plastics glazing sheet material

Thickness	Estimated improvement in sound reduction index compared with single glazing of the same thickness for an air space of:				
mm	50 mm dB	100 mm dB	150 mm dB	200 mm dB	250 mm dB
3	9	12	13	14	15
4	9	12	14	15	15
5	9	13	14	15	16
6	10	13	14	16	16
8	10	14	15	16	16
10	11	14	15	16	17
13	12	14	15	17	17

Annex A (informative)
Design skies

Three types of design sky are in general use:

a) *CIE (Commission Internationale de l'Eclairage) overcast sky*

The CIE overcast sky is assumed to have sufficient cloud cover to eliminate any direct sunlight. As a result there are no orientation effects. The overhead (zenith) luminance is three times that at the horizon.

b) *CIE clear sky*

The CIE clear sky has a luminance distribution which varies with orientation, latitude and time of day depending on the position of the sun. The luminance distribution is higher at the horizon than overhead.

c) *Blue sky*

The blue sky is much the same as the CIE clear sky, and is referred to in some natural lighting publications produced prior to the definition of the CIE clear sky.

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