1. WHAT IS BI-COLOR ?

BI-COLOR is a glass pane which is coated with ceramic colours. The colours are permanently attached to the glass by means of a special manufacturing process. The decades of experience of BGT Bischoff Glastechnik began with the use of colours in the industrial field. For cooker panels and doors the colours had to withstand high temperature variations as well as frequent chemical and mechanical stresses from cleaning agents and equipment. Through thorough and persistent further development in quality and multiplicity, colour-printed glazing is also used today both for internal as well as external construction in the building sector. Alongside their use as design elements the colours also fulfill additional functions. To name just a few:

Reduction in the level of radiation from the sun, reduction in dazzle, screening, light scatter, safety etc.

These functions are used for example in applications such as roof glazing, balustrades, partition walls, facades, luminous ceilings and indicator panels.

The product described in the following:
BI-ThermColor® is shown in the special application as protection from sun and dazzle.

You can obtain additional details of the physical properties of the glass as well as possible applications and design criteria for BI-COLOR from the BGT Product Information Sheet BI-TENSIT.

2. WHAT IS BI-ThermColor® ?

BI-ThermColor® is an insulating glass development which permits freely-determinable protection from sun and dazzle in addition to which the design can also be individually configured.

The characteristics of this glass are primarily determined by the ceramic colour coating (colours and degree of printing), the type of glass and the thickness of the glass. An additional criterion arises in the use of metal-oxide coated glass. From the totality of these criteria come the design and technical radiation advantages which also lead to significant cost savings in the cooling load.

3. CONSTRUCTION AND FUNCTIONING PRINCIPLE

3.1 **Construction**

The construction of BI-ThermColor® is variable and is orientated to the criteria of radiant transmittance and the required strength. In principle it is similar to the other types of insulating glass. The minimum configuration consists of two panes with a colour coating at position 2.

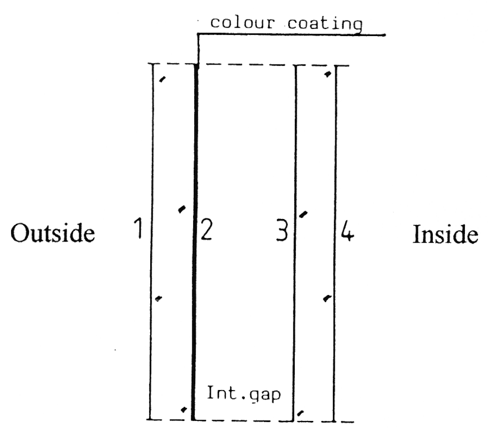


Fig. 1: Minimum configuration BI-ThermColor®

If higher strength or chip binding is required (e. g. for overhead glazing), it is also possible to use laminated safety glass combinations of tempered glass and/or heat strengthened glass.

The essential difference from the other types of insulating glass is the colour coating. This is the construction criterion for the required radiant transmittance of the rays from the sun. If additional requirements are placed on thermal protection it is recommended that glass with a thermal insulation layer (such as Low-E glass or K glass) is used.

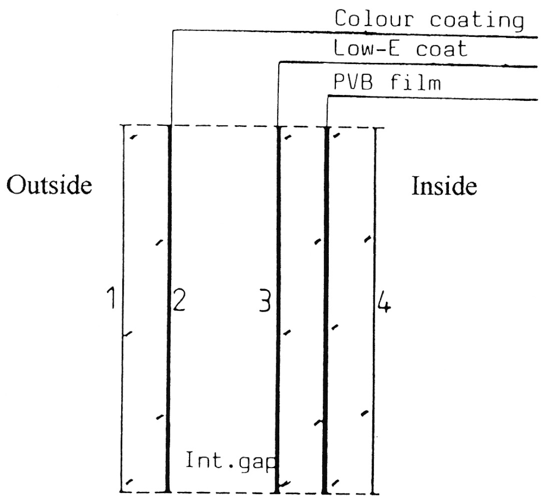


Fig. 2: Example of BI-ThermColor® as laminated safety glass with Low-E coat.

3.2 **Functioning principle**

BI-ThermColor® is not just an unusual design product but in fact is much more a multifunctional insulating glass, whose existence and objective use lies in the control of the required radiant transmittance. By means of the colour coating the radiant transmittance is reduced and thus the shading factor is improved. The level of improvement is in direct proportion to the degree of printing (see 4.1.4) and the selected colours.

4. PRODUCT PARAMETERS

4.1 **Colour coating**

4.1.1 Colours

The selection of colours influences the light transmitting capacity and the energy transmission. In general lighter colours have higher light transmitting capacity than darker colours. Light colours also offer the advantage of greater energy reflection and thereby lower heat absorption than dark glass, which reflect their high heat potential via the secondary discharge (including inwards). Orientation to the RAL colour spectrum (RAL colour register 840 HR) is also possible with ceramic colours. Special colours can be supplied if desired by customers. Thereby we provide complete freedom for colourful designs.

Ceramic colours achieve the following properties through the stove-enamelling process:

- Abrasion-resistant
- Acid-resistant (except in the case of hydrofluoric acid)
- Largely resistant to caustics
- Resistant to solvents
- UV resistant (light-fastness according to value 8 on the wool scale, in comparison organic colours such as lacquers have the value 4)
- Thermal shock resistance up to approx. 150 K (tempered glass) and 100 K (heat strengthened glass)

Four colour categories are available for planners

a. **Opaque colours**
Opaque colours have a covering properties, they can act as complete screens and are almost impervious to light. They are suitable for technical radiation and design applications, if the print is not intended to fully cover the surface.

b. **Translucent colours**
Translucent colours are admixtures of opaque colours and also cannot be seen through. Their special properties are in their good light scatter and light transmitting capacity, which can sometimes be varied up to over 40 %. Glass panes, which are coated with translucent colours, are particularly suitable for backlit applications such as for example luminous ceilings, advertising or information panels.

c. **Transparent colours**
Transparent colours have high light transmitting capacity and can be seen through. In contrast with the opaque colours, transparent glass colours possess lower resistance to acids and alkaline liquids. Therefore in the case of façade design the colour should be applied to talk to BGT on this subject.

4.1.2 Colour application

The colour is applied using a screen printing process or by cylindrical rollers .

- The (more expensive) colour application by means of screen printing produces an especially uniform and fine surface, which generates excellent light scatter when a floodlight is shone through it.
- When colour is applied by roller a slight ribbed structure is generated in the colour coating.

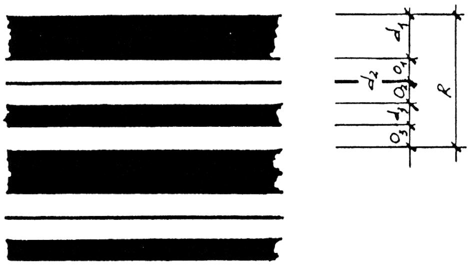
4.1.3 Stove-enamelling process

The colours are applied by enamelling at about 650 °C. At the same time the glass is heat strengthened (tempered) by controlling its cooling speed. According to DIN 1249 Part 12 in the case of colour-coated glass the bending strength in the compression bond zone is 120 N/mm^2 and in the tensile bond zone it is 75 N/mm^2.

4.1.4 Degree of printing

The ratio of the printed surface with respect to the whole surface of a glass unit is expressed as the degree of printing. The choice of décor determines the degree of printing. Vice versa, a new décor can be defined starting with the desired degree of printing. The unit and information on the degree of printing is given in %.
To calculate the degree of printing it is necessary to know the definition of the respective repeat pattern (the smallest pattern unit of a selected décor, which through its multiplication provides the complete décor).

Here follow two examples of the calculations for the degree of printing:

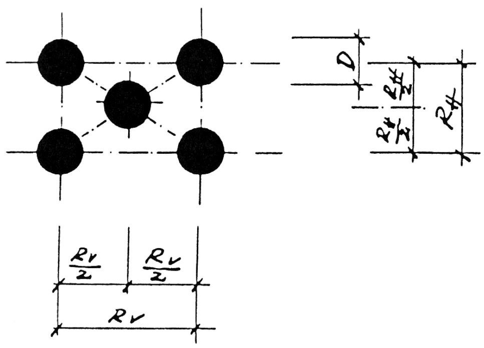


R = Repeat

$R = d_1 + d_2 + d_3 + o_1 + o_2 + o_3$

$$\text{Degree of printing } a = \frac{d_1+d_2+d_3}{R}$$

Fig. 3: Determination of degree of printing for a striped décor.



$$\text{Degree of printing } a = \frac{\pi * d^2}{2 * RV * RH}$$

Fig. 4: Determination of the degree of printing for a dot décor, with 1/2 offset.

4.2 **Glass types**

Several types of glass are available to the planner:

a. Float glass

Due to its relatively high proportion of iron-oxide of about 0,1 %, this glass has an inherent colour (iridescent green). This results in the colour effect changing with increased glass thickness if the colour coating has been applied on the side of the pane away from the observer (which is the normal situation).

b. Low iron-oxide glass

Unlike float glass this glass has a significantly lower proportion of iron-oxide (Fe_2O_3 approx.. 0,015 %). The inherent colouring can thus be neglected so that virtually no falsification of the colour occurs. Low iron-oxide glass is particularly suitable for applications in which light must pass through the glass (e.g. luminous ceilings or roof glazing) and in which good neutral colour reproduction and optimal light scatter are necessary.

c. Coloured glass

In addition melt-coloured glass (e.g. parsol bronze, ...) can be used. However it is essential to note that due to the high inherent level of colour in this glass the colour effect to the coating is significantly changed when looked through.

4.3 **Glass thickness**

The glass thickness has a direct influence on the light transmitting capacity and the total energy transmission. Thus the light transmitting capacity of a 5 mm float glass pane, with respect to the light sensitivity of the human eye, is about 89 %. The total energy transmission is about 84 % with the same pane thickness. Both values decrease as the pane thickness increases. In addition with increasing glass thickness (as already indicated und Point 4.2) the colour effect of a colour coating is also altered.

4.4 **Further parameters**

Further parameters, which can influence the technical radiation effect and the optical quality of BI-ThermColor ® must be taken into account if metal (oxide)-coated sun and thermal insulated glass panes are to be included in the configuration. The principle of these coatings is based on the fact that certain types of ray (particularly those in the visible range of 380 - 780 nm) are allowed to pass through, whilst other rays (with wave lengths over 780 nm) are reflected by the applied coating. The coatings can also be used for colourings such as silver and gold. The declaration of technical values varies from manufacturer to manufacturer and can be looked up in the various product documents produced by the manufacturers. It is fundamentally possible to integrate coated glass into a BI-ThermColor configuration with ceramic coating. The total technical radiation values are then found from the interrelationship of all the radiation criteria.

5. APPLICATIONAL AREAS

5.1 **Façade renovation**

Façade renovation, for example it old façades have to be panelled with glass, is often desirable in order to retain the original character of the building and/or to achieve the integration of the building into the environment.

5.2 **Façade configuration for new buildings**

Façade configuration for new buildings: The colours and décors here permit individual designs and an individual character can thus be achieved for the building. Within the building technical light and radiation advantages can be achieved with BI-ThermColor® which would not be possible with traditional glass.

5.3 **Roof and balustrade glazing**

Roof and balustrade glazing where the glass components are included in the internal room design.
To achieve the desired physical radiation data an optimum combination of décor, colours and degree of printing can be selected (calculations are computer-aided). For cetain combinations standard values are available (see configuration examples under Point 7).

6. BENEFITS

The unique characteristics of BI-Therm Color® offer the planner particular benefits in the following areas:

6.1 **Selectable technical radiation data**

The degree of printing and the colours are the control factors for the energy transmission into a building with a specified glass construction.

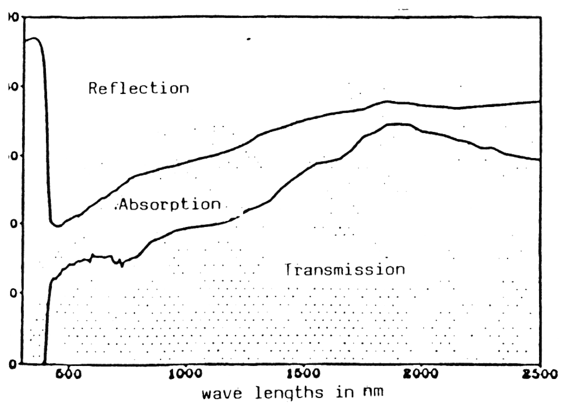


Fig. 5: Spectral transmittance of 5 mm float glass with white opaque colour coating

If an alternative colour is selected for the coating the radiation pattern is quantitatively altered as shown below.

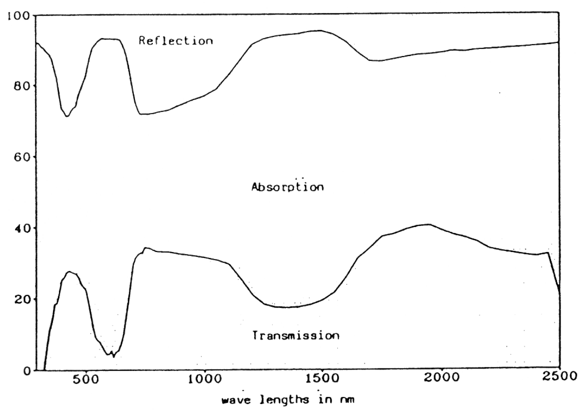


Fig. 6: Spectral transmittance of 5 mm float glass with blue opaque colour coating

From this we find that

a. by changing the colour (with the same degree of printing) the radiation transmittance and the light transmittance as the subordinate variable can be reduced or increased, and

b. this change takes place in a colour-dependent variable relationship.

This is valid in principle for all standard colours. The degree of printing is derived from the décor. The following types of radiation are influenced by a colour coating:

6.1.1 Total energy transmittance

The total energy transmittance g-value is the percentage proportion of the energy transmittance with respect to the solar radiation within the wave range of 320 to 2500 nm. The individual variables are the direct solar energy transmittance and secondary thermal losses (calculated according to DIN 67507). The figure is given as a %. The décor of BI-ThermColor® can be selected so that with a steep radiation angle (sun almost overhead) a relatively reduced inward radiation energy is produced. The reduced room temperature resulting from this has a direct influence on the reduction of the cooling load and hence the costs.

6.1.2 b-factor

The b factor, also called the „shading coefficient“ according to VDI 2078 gives the ratio between the g value of a glass pane and the g value of a 3 mm thick single pane of glass. This ratio, called the „medium transmission factor b“ is a decisive value in calculating the cooling load. Through the correct coating a controlled inward radiation energy is achieved and the b-factor is positively set up.

6.1.3 Reflection

The radiated proportion of reflection is influenced by the colours and the selected décor (proportion of coating). An example of different reflections with dependence on the colours can be seen in Figs. 6 and 7.

6.1.4 Light transmission

The light transmission is a measure of the visible radiated proportion, which is directly transmitted, (wave lengths from 380 to 780 nm) with respect to the brightness sensitivity of the humam eye. The figure is given in %. As a reference value the figure of 100 % would be an unglazed opening (s. also DIN 5034).

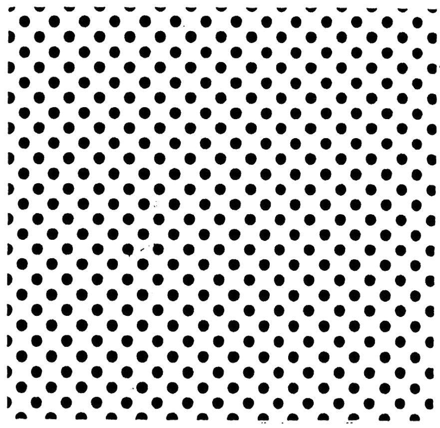


Fig. 8: Example of full-surface printing with décor

6.1.5 Internal room lighting

Optimal inside room lighting with reduced dazzle is another feature of BI-ThermColor®. Light surfaces appear like a luminous light ceiling with an ideal light scatter to those inside the room. If the glazing is inclued in the internal room design, for example as roof or balustrade glazing, then as well as the technical radiation advantages many different design options are also provided.

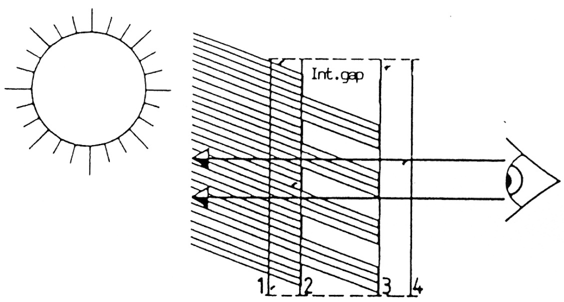


Fig. 9: Venetian blind effect with two-sided printing

6.2 Individual colours and décors for building design

6.2.1 Décor classes

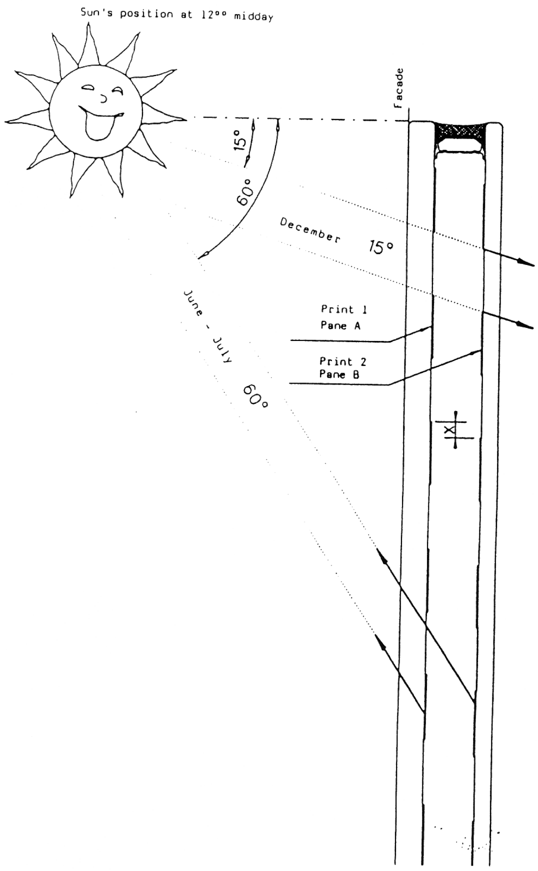
In order to be able to also take advantage of the design options three different classes of décor are available (in addition to complete surface colour coverings:

a. Uniform patterns serve to provide the full-surface design of glass surfaces. These are best used where an homogenous design appearance is required. Apart from the technical radiation advantages there is also a visual benefit here. A view to the outside is permitted. Inside the printing has a barrier effect, this is also called a curtain effect.

The insulating glass unit described in Sketch 10 is printed with stripes. The printing of pane 1 is offset by some millimetres from the print on pane 2. The rays of the high summer sun cannot be directly radiated in. The rays, which come in at a lower angle from the winter sun, can pass through largely unhindered.

b. Partial coatings are mainly used for covering purposes. For example as screening in order to cover any masonry, which lies behind the glass, or to provide UV protection for insulating glass panes, to protect the edge bond.

Fig. 10:



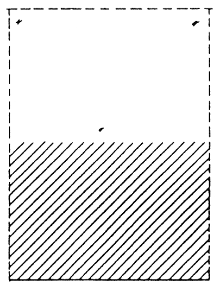


Fig. 11: Example of partial printing as screening

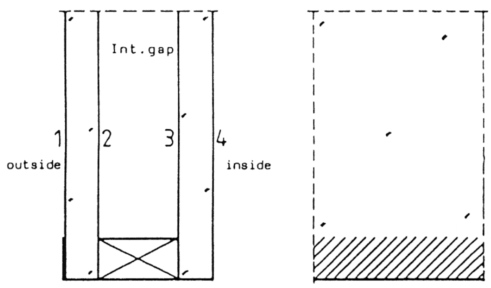


Bild 12: Example of partial printing as UV protection for edge bond.

c. A graduated grid offers particularly interesting design options through the increasing or decreasing degree of printing. According to the direction of the installation of the degree of printing it can reduce the solar radiation when the sun is high.

This example of BI-ThermColor® shows how shading of the sun in summer and solar energy gain in the winter can be ideally combined.

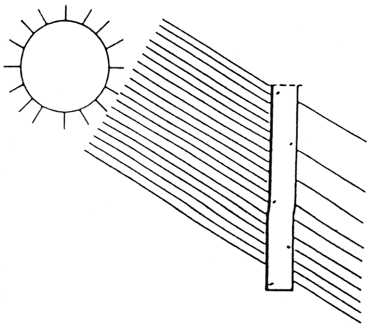


Bild 14: RAL quality stamp

Bild 13: Control of energy transmission by means of graduated grid printing

6.2.2 <u>Design</u>

The design can be with single or multi-coloured décor. As décor dot screens, ornaments, symbols, company logos, texts etc. can be used. Moreover it is also possible to apply a full coloured surface behind the décor design. In the building design it is thus possible to create the décors so that an individual pattern is presented on every glass element and/or one projected design can be created on the complete building.

All design options are present to also permit the inclusion of other materials such as steel, concrete, natural stone or ceramics into an integrated design with glass and to create a defined relationship to the environment.

6.3 **Quality monitoring**

As a manufacturer of insulating glass over many years a high quality standard for BGT Bischoff Glastechnik is only to be expected. On top of this BGT Bischoff Glastechnik is also a member of the German quality association for multi-pane insulating glass, which includes freewill self and external quality controls.