1. DESCRIPTION

1.1 **What is BI-TENSIT**

For more than 30 years BGT Bischoff Glastechnik has made thermally upgraded flat glass. The brand name for thermally fully-tempered glass is BI-TENSIT. This glass is particularly resistant to impact, strike and bending stresses as well as thermal loads.

The manufacturer-neutral designation for this product is single-pane safety glass (ESG) or tempered glass. It is sometimes incorrectly called hardened glass.

1.2 **Manufacture**

It is manufactured from normal flat glass (float glass or other types). The glass is tempered after cutting and further processing. Mechanical processing such as edge grinding, drilling etc. is not possible after thermal treatment. In the horizontal tempering process the glass is heated up to the softening temperature of approx. 670° C. The dwell time in the furnace is controlled according to the respective glass thickness, so that the glass reaches the lowest softening range. Afterwards the glass is quickly brought down to approx. 200° C in an airflow and then cooled off below this. Due to rapid cooling the outer zones of the pane quickly harden and the core pf the pane contracts. This process is prevented by the already-hardened outer zones. This brings about the characteristic stress distribution in tempered glass (see schematic illustration in Fig. 1)

If this internal stress is influenced at any point by damage or if it is overloaded, the glass disintigrates into a network of relatively small cumbs (approx. 0,5 - 2 cm² in size). From the amount of crumb structure remaining the degree of temper can be obtained.

ESG BI-TENSIT is made in a horizontal process. The thermal treatment during horizontal processes offers the following advantages over vertical tempering: No suspension points on the glass, higher degree of flatness and lower anisotropic reflection.

<u>TEMPERING</u>

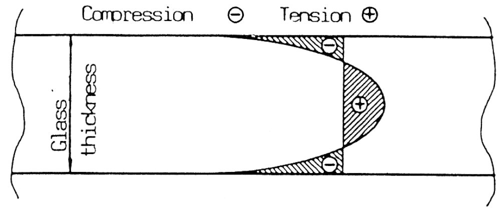


Fig. 1: Stress curve for BI-TENSIT

1.3 **Brand symbol/quality**

BI-TENSIT glass panes are marked with the following brand symbol.

Bild 2: Brand symbol for BI-TENSIT

The marking method is specified for the manufacturer according to DIN 1249. This marking can be left off if required by the customer.

As one of the very few manufacturers to do so BGT has the quality of its BI-TENSIT glass monitored externally.

This external monitoring is carried out by the MPA (Material Testing Institute) in Darmstadt and refers to glass thicknesses of 6, 8, 10, 12, 15 and 19! mm. By including the 19 mm thick panes (DIN 1249 only requires a max. of 15 mm glass thickness) in the external monitoring system, the planner is provided with a secure means of designing particularly sophisticated problem solutions in glass. In further documention colour enamelled safety glass BI-COLOR is also considered. This is intended to provide the reader with a comprehensive overview of tempered glass.

2. PROPERTIES

2.1 **Impact strength**

The impact strength of massive hard bodies which includes glass is determined with the aid of falling tests.

The impact strength is an important value for the serviceability.

To obtain conclusive information the tests are carried out with different falling bodies. The values (in Table 1) give the fall heights up to which no breakage occurs.

Table 1: Fall heights of falling bodies in (mm), in which no breakage occurred on BI-TENSIT glass

BI-TENSIT Glass thickness in mm	Fall height in (mm) for different falling bodies		
	Steel ball 1,04 kg (DIN 52 338)	Leather bulb 45 kg (DIN 52 337)	Steel body 10 kg (DIN 52 343)
4	1000	1200	100
5	1600	900	200
6	2500	900	300
8	2200	1200	700
10	2500	1200	900
12	2500	1200	900

2.2 **Bending strength**

According to DIN 1249 Part 12 the bending strength is defined as the minimum bending stress which leads to a breaking probability of 5 % for a confidence level of 0,95.

BI-TENSIT has been tested by the MPA (DIN 52 303.A Testing of flat glass with two-sided support) and is also externally monitored (see Point 1.3).

The following values for minimum bending strength are guaranteed (see Table 2).

Table 2: Bending strength for different types of glass

Glass type	Bending strength N/mm²
BI-TENSIT	
- from float glass	120
- from cast glass	90
BI-COLOR	
- in the bending compression zone	120
- in the bending tension zone	75

2.3 **Temperature resistance and other phys. data**

Temperature

- Temperature resistant up to 300 °C (DIN 1249 Part 10)
- Resistance to thermal shocks across the pane surface = **150 K** (normal float glass achieves a max. of only 40 K)
- Coefficient of elongation (20° C, 300° C) $\alpha = 9 * 10^{-8} K^{-1}$
- Heat transition coefficient k = 5,8 W/m²K (DIN 4108 Part 14)

Modulus of elasticity

E = 7,0 * 10^4 N/mm² (DIN 1249 Part 10)

Compressive strength

700 - 900 N/mm²

Hardness

MOHS scratch hardness 5 - 6
KNOOP 470 HK 0,1/20 (DIN 1249 Part 10)

Light transmission

BI-TENSIT: Corresponds with that of the basis glass (About 89 % with a glass thickness of 5 mm).

BI-COLOR: The light transmission of BI-Color also depends on the colour and the selected décor. (See the Product Information Sheet for BI-ThermColor®).

Anisotropic

The stress zones, which are required and arise from the thermal process, lead to double refraction of the light (anisotropic). These can be seen in the presence of polarized light (light with wave parallelity) as slight clouds or rings in spectral colours. Since natural daylight, depending on the weather and the time of day, shows different proportions of polarized light, this phenomenen of coloured rings or similar coloured shapes can also be observed with different intensity.

This phenomenen, which is sometimes also called irisation, has physical origins. The intensity of the anisotropic effect is significantly lower for horizontally-tempered glass than for vertically-tempered glass.

Roller imprinting

Because of the contact of the glass with the rollers during the horizontal thermal tempering process surface deformation takes place, which leads to a reduction in the surface smoothness. This appearance, which is also known as „roller wave“ depends on the glass thickness.
On top of this a change in the surface in the form of spot formation can also be seen.

3. APPLICATIONS

3.1 Roof and exterior shell glazing

Here in particular façade glass panes or canopy roofing, which can also be enamel coated, can be used as well as BI-COLOR products.

In addition insulating glazing can also be used for roof glazing (ESG must be outer pane) or as safety elements (ESG on room side). No possibility of damage by hail or snow load are here the special advantages of BI-TENSIT (this is repaid in the case of greenhouse structures by lower insurance premiums). If enamel panes are used for insulating glazing then additional technical radiation and design advantages arise (see Produkt Information Sheet: BI-ThermColor®).

3.2 Interior fittings

BI-TENSIT can be used for internal fittings in many ways and makes sense wherever one or all of the following criteria are required:

- ✓ Safety
- ✓ Transparence
- ✓ Coloured design (BI-COLOR)
- ✓ Simple cleaning
- ✓ Noise protection
- ✓ Protection from draughts
- ✓ Ageing resistance
- ✓ Screening (BI-COLOR)

The areas of application for example are: Stair railing designs, protection devices, internal doors, partition walls, partition cabinets, safety-glazed door systems etc. Or in the sanitary area: Shower cubicles, wall cladding (BI-COLOR), shelves wash basin retainers (BI-COLOR)

3.3 Public areas

BI-TENSIT tempered glass is used in public areas for sound protection walls on motorways or for the glazing of bus shelters. In both applications the use of BI-COLOR is also possible and is often desired.

3.4 Industrial areas

A large spectrum of applications for BI-TENSIT and BI-COLOR is found in the production of household devices and control cabinets, the commercial vehicle and the furniture industry.

In addition to the criteria given in Point 3 of safety, transparence, coloured design and simple cleaning BI-TENSIT and BI-COLOR also offer a high resistance to thermal shocks of 150 K.

With respect to the areas mentioned above the following applications are found:

<u>Household devices</u>: Switch facings/surrounds, doors, heat-reflecting internal panels, shelves

<u>Control cabinets</u>: Doors, viewing windows

<u>Furniture:</u> Doors, shelves with/without coloured enamel (screen printed)

<u>Light fittings:</u> For the medical area, in tunnel building and industrial areas.

In the automotive area this product is supplied under the product name: BI-VETRAL. For Europe, USA and Canada various offical approvals exist for this product. Thus for example in the vehicle area ECE tests carried out according to the German Road Traffic Approval Regulations (STVZO) have resulted in general design approval (ABG) being granted for both tempered glass as well as insulating glass. Tests on BI-VETRAL for use by German Railways have also been successfully carried out.

Examples of various types of stamp

BI-VETRAL
ESG/TEMPERED
(E1) 43R-001137
DOT 349 M 61 AS 2
0123456789
• • • •

Fig. 3: BI-VETRAL tempered glass for 5 mm translucent float glass - tested according to ABG § 22 of STVZO, marked with corresponding number.

Fig. 4: BI-VETRAL tempered glass for German Railways. Thickness 4 to 9,5 mm

When applying the stamp it is necessary that when supplying to German Railways the delivery is reported to the DB quality inspection service or their repesentatives for quality testing. This must be requested by the customer. The inspector is commissioned by BGT. The quality inspection is then carried out by BGT in the presence of the quality inspector.

Please enquire about further approvals for vehicle windscreens/windows.

4. CONSTRUCTION CRITERIA

4.1 **Panel fixing**

Panel fixings are classified as either linear or point supported.

Fundamental requirements:

- Contact between glass and metal, glass and glass or between glass and masonry must always be avoided even unter the influences of load and temperature.
- The support should not constrain the panel.
- The support should be designed so that it is permanent and weather resistant according to the latest technology.

Linear supported panels
(DIN 18516 Part 4) for ventilated façades.

In the case of two- or three sided linear-supported panels the glass recess must be at least the thickness of the glass plus $1/_{500}$ of the span, however it must be at least 15 mm.
Any slippage of the ESG panes must be prevented by distance pieces (normally made of Elastomer, hardness 60 to 80 Shore A).
Where the support system leaves an exposed bottom edge the ESG panes must be supported to the right and left. The supporting surface which carries the inherent glass weight must be rectangular and its dimension must be at least glass unit x glass thickness.

Point-supported panels
(DIN 18516 Part 4) for ventilated façades

In the case of point-supported panels the clamping area over the glass must be at least 1000 m^2 and the glass recess depth at least 25 mm.

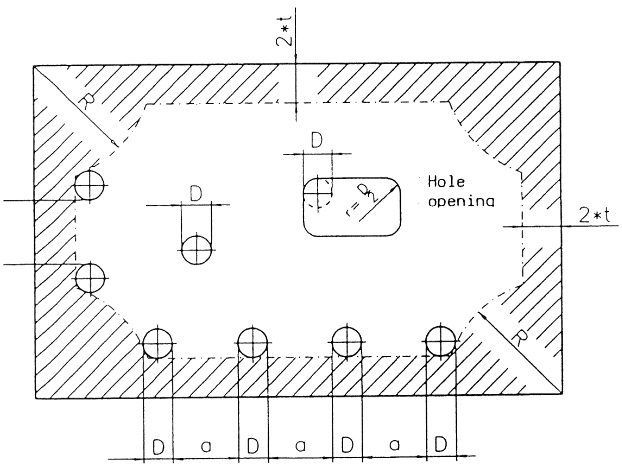
In the case of retainers which are arranged in the immediate vicinity of the corner of the panel the clamping surface should be arranged asymmetrically. Thereby the ratio of the length of the side to one of the right-angled retainers surrounding the corner of the panel must be at least 1 : 2,5.

ESG panes, which are supported by point-supporting retainers with clamping effect and which are arranged away from the corners of the panes, must also be sucured mechanically if necessary to carry the inherent weight, e. g. by means of bolts in holes in the panes or shoes. Other types of fixing must be approved by the fixing must be approved by the respective building authority by means of individual agreements.

4.2 **Drilled holes**

Drilled holes are to be positioned so that the edge of the hole is at least 2 x the glass thickness from the edge of the glass. In addition the spacing from hole to hole measured from the edges of the holes must also always be 2 x the glass thickness.

At the corners a hole may only be drilled if there is a minimum distance in the radius of 5 x Glass thickness (see Sketch). For glass thicknesses ≤ 10 mm the hole diameter must be at least the glass thickness. In the case of glass thicknesses >10 mm the drilled holes must be 1,5 ∗ t (Glass thickness).



= Non-permitted area for drilled hole

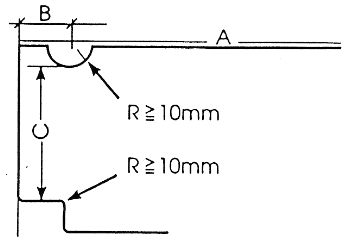
D = Hole diameter
a = Hole spacing (from edge of hole to edge of hole)
t = Glass thickness

For t ≤ 10 mm: D ≥ 1,0 · t, R = 4 · t		
For t≥ 12 mm: D ≥ 1,5 · t, R = 5 · t		
2 drilled holes		a = 2 · t
3 drilled holes	in a	a = 3 · t
4 drilled holes	row	a = 4 · t
For more than 4 drilled holes		Increase the minimum spacings

Fig 5: Non-permitted area for drilled holes in BI-TENSIT

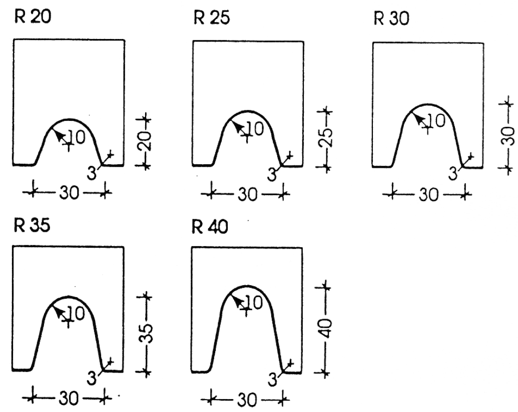
4.3 **Cut-outs**

The types and spacing of cut-outs in rectangular glass panes can be found in the following sketches.

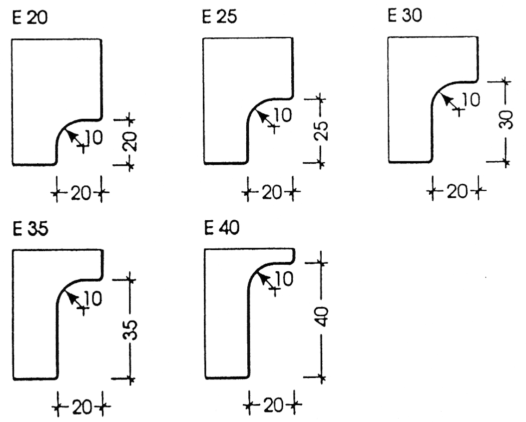


The depth of edge or corner cut-outs is to be subtracted from the whole width dimension to determine the side ratio. The maximum side ratio C:A is 1:10.
If other cut-outs are necessary, ≥ 10 mm must be provided for the internal radii.

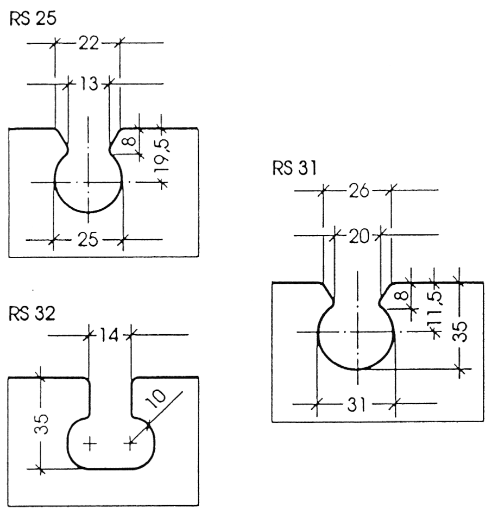
Standard edge cut-outs



Corner cut-outs

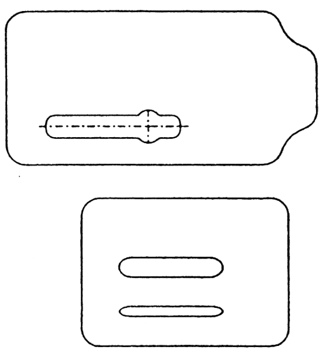


Other possible cut-outs

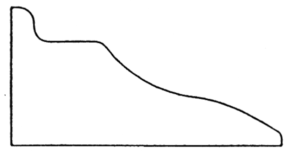


The up-to-date CNC controlled water jet cutting unit reliably cuts glass panes of thicknesses from 1 to 65 ! mm and in the maximum dimensions 2000 x 4000 mm, normally using water as the medium. This unit permits the cutting of shapes and complicated cut-outs with high precision and quality.

Examples of shapes and cut-outs made by the water jet cutting unit.



Panes with cut-outs, for example for handles or ventilation slots



Panes with irregular edges

The processing tolerances of the corner and edge cut-outs is +/- 2 mm. The positional tolerances correspond with the surface tolerances.

4.4 **Tolerances**

Flatness (straightness)

Flatness depends on the thickness, length, width and the side ratio of the pane.
According to DIN 1249 Part 12 the deviation from straightness can be subdivided into two types:

- Flatness deviation over the glass edge length (also called "overall bow")
- Flatness deviation with respect to a measured length of 300 mm (also called "local bow")

The flatness deviation with respect to a measured length of 300 mm must not be more than 0,3 mm for all types of glass except for cast glass.

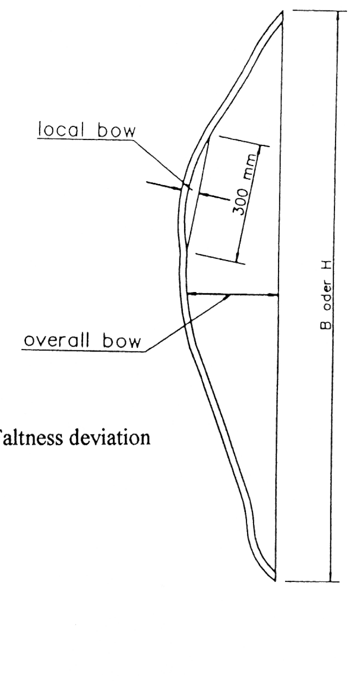


Fig. 6: Faltness deviation

Table 3: Flatness deviation over the length of the edge of the glass for different glass thicknesses and types (DIN 1249 Part 12)

Glass thickness in mm	Glass type and flatness deviation		
	BI-TENSIT from plate/float glass	**BI-TENSIT** from cast glass/raw plate glass	**BI-COLOR** colour-printed glass
4	1 %	1 %	1 %*
5	1 %	1 %	1 %*
6	0,3 %	1 %	0,3 %
8	0,3 %	1 %	0,3 %
10	0,3 %	1 %	0,3 %
12	0,3 %	--	0,3 %
15	0,3 %	--	0,3 %
19	0,3 %	--	0,3 %*

* Not included in DIN 12 49 Part 12.

Tolerances for length and widths

Tabelle 4: Tolerances over lengths and widths (DIN 1249 Part 12)

Glass lengths and widths in mm	Glass thicknesses and tolerances in mm	
	Thickness ≤ 8	Thickness > 8
≤ 500	+/- 1,0	+/- 2,0
> 500 ≤ 1000	+/- 1,5	+/- 2,0
> 1000 ≤ 1500	+/- 2,0	+/- 2,0
> 1500 ≤ 2500	+/- 2,5	+/- 2,5
> 2500 ≤ 3000	+/- 3,0	+/- 3,0
> 3000 ≤ 3500	+/- 4,0	+/- 4,0
< 3500	+/- 5,0	+/- 5,0

Tolerances for drilled holes

Table 5: Tolerances for hole diameters

Hole diameters	Tolerances
< 40 mm	+/- 1,0 mm
< 100 mm	+/- 1,5 mm
> 100 mm	+/- 2,0 mm
The tolerances for the spacings of drilled holes are the same as the tolerances for the pane dimensions	

4.5 Stress

Stress in the façade

The following criteria are to be set for the permitted stress levels in the façade according to DIN 18516, Part 4;

a. Minimum bending strength (see table 2, Point 2.2)

b. Threefold safety against failure

c. Permitted sag f for the free edge of the pane and the middle of the pane depending on the length of the largest pane edge $l_{max} : f \leq l_{max}/100$

Fundamentally façade panels must be given a heat soak test before delivery according to DIN 18516 Part 4. This minimizes the risk of breakage due to nickel sulphide inclusions. For the dimensioning of façade panels with four-sided support, special graphs have been developed from which the correct glass thicknesses can be read off with respect to:

- Length and width of façade panels
- Height above top surface of land
- Location in building ground plan

(see Appendix).

Stress in the internal fittings

In the case the applications are assessed by the building authority.

Stress in protection devices

Protection devices are intended to protect people from falling. There are no generally-valid technical regulations (such as DIN), which specify a permitted stress level.

Protection devices must in principle withstand the following stresses;

- Leaning on by people (spar DIN 1055)
- Impact by human bodies (simulated by the pendulum impact test DIN 52 337 Part 1 "soft impact")
- Local impact safety (simulated by the pendulum impact test DIN 52 337 Teil 2 "hard impact")
- In addition in the case of protection devices in external areas the wind load must be taken into account.

The evidence of spar stress can be done purely theoretically (evidence of structural stability). Conclusions from the pendulum impact test always refer to the geometry and supporting details of the trial set-up. They cannot be transferred to apply to other structures. Accordingly every planned structure has to be tested in its geometry and supporting details in case the building authority requires proof of impact stress.

Since the requirements of the building authorities are not yet uniform no application charts are shown here.
If necessary strength information can be provided for special applications.
Item-related evidence of strength can be prepared by BGT Bischoff Glastechnik against payment.

The evidence of strength depends on:

- **Glass type**
- **Glass design**
- **Glass geometry**
- **Stress**
- **Supporting position, and**
- **Bearing details**

When making enquiries in order to carry out the calculations for obtaining individual evidence the following information is required:

- Desired glass type
- Installation level and falling height
- Type of building use (public, private)
- In the case of external areas: Position of the panels on the building structure
- Size of individual panels
- Type of retainer
- Structural details

Further stresses

There are nor generally-valid technical regulations for use in buildings outside the façade (such as DIN), which would specify a permitted stress.

5. GLASS TYPES AND DIMENSIONS

Table 6: Maximum size of tempered glass **BI-TENSIT** and **BI-COLOR** (enamelled).

Glass-thick-ness in mm	Maximum size BI-TENSIT W x H in mm	Maximum size BI-COLOR W x H in mm
4	1000 x 2000	1000 x 2000
5	Furnace 1: 1500 x 3000 Furnace 2: 1670 x 6900	1500 x 3000 1670 x 4000
6	Furnace 1: 2150 x 4500 Furnace 2: 1670 x 6900 Furnace 3: 2850 x 6000	2850 x 6000
8	Furnace 1: 2150 x 4500 Furnace 2: 1670 x 6900 Furnace 3: 2850 x 6000	2850 x 6000
10	Furnace 1: 2150 x 4500 Furnace 2: 1670 x 6900 Furnace 3: 2850 x 6000	2850 x 6000
12	Furnace 1: 2150 x 4500 Furnace 2: 1670 x 6900 Furnace 3: 2850 x 6000	2850 x 6000
15	Furnace 1: 1800 x 4000*) Furnace 2: 1670 x 4000*) Furnace 3: 2850 x 6000	2850 x 6000
19	Furnace 1: 1800 x 4000*) Furnace 2: 1670 x 4000*) Furnace 3: 2850 x 6000	*)
Max. pane weight: Furnace 1: 250 kg Furnace 2: 500 kg Furnace 3: 570 kg		

*) upon request

The maximum side ratio is 1:10

Minimum dimensions:

BI-TENSIT: 100 x 250 mm
BI-COLOR: 100 x 250 mm (screen printing)
200 x 300 mm (cylinder printing)