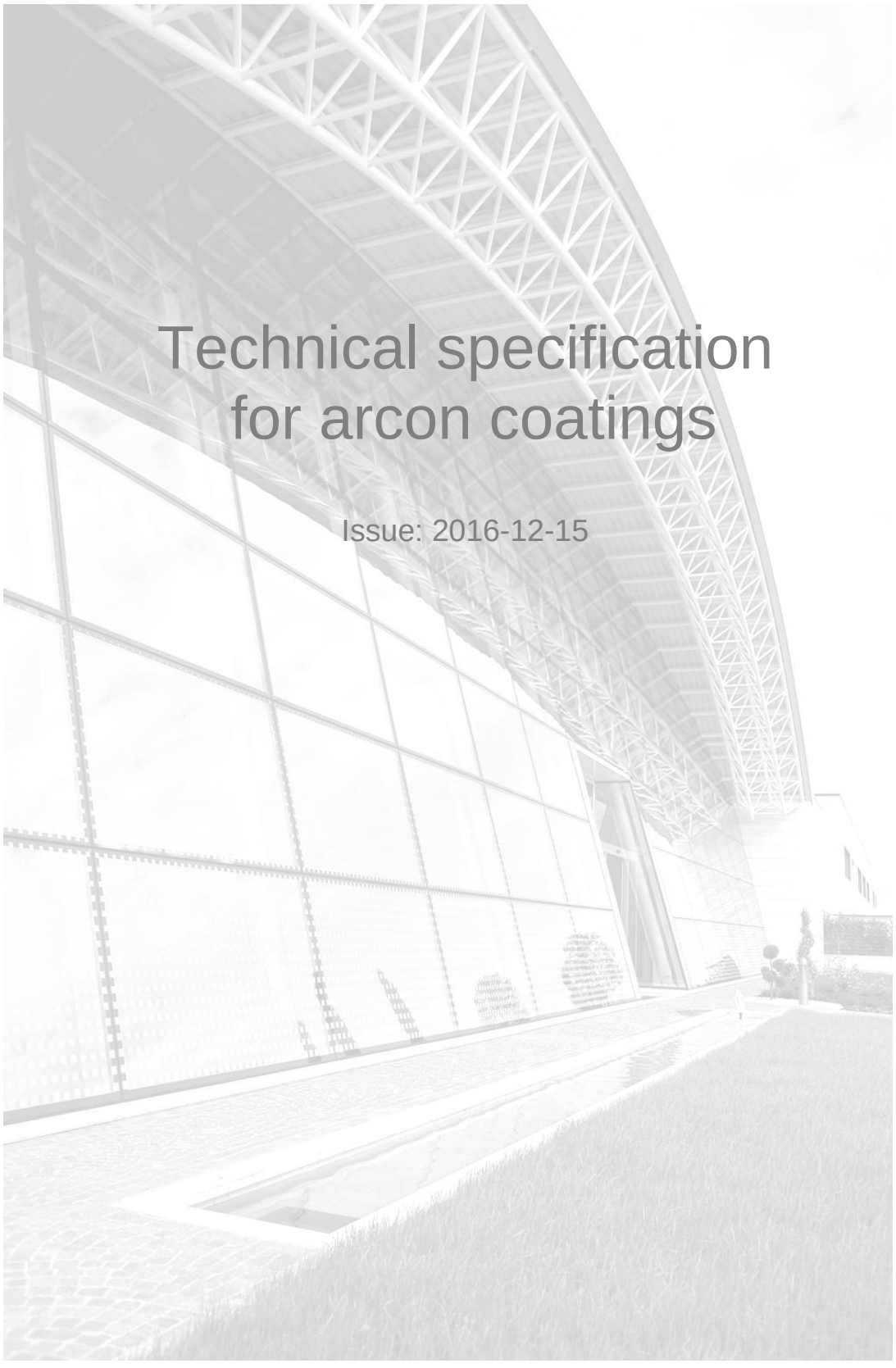
arcon
perfektion in glas



Technical specification for arcon coatings

Issue: 2016-12-15

1 Scope of validity

The “Technical Specification for arcon Coatings” applies to all low-e and solar control coatings for glazing in normal residential houses or commercially used buildings produced at the locations Feuchtwangen and Bucha. The coated glass referred to in this specification is float glass, thermally toughened safety glass, laminated safety glass made of thermally toughened safety glass and laminated safety glass coated by magnetron sputtering.

2 References to standards and guidelines

(in the respectively newest valid edition)

DIN EN 1096:	Glass in the building - coated glass
DIN EN 572:	Glass in the building – Basic soda lime silicate glass products
DIN EN 12150:	Glass in the building - Thermally toughened soda lime silicate safety glass
DIN EN 1863:	Glass in the building - Partially pre-stressed lime soda glass
DIN EN 12543:	Glass in the building - Laminated glass and laminated safety glass
DIN 58196-6:	Optical coatings - Part 6: Testing of the adhesion with a tape
DIN EN 410:	Glass in the building – Determination of luminous and solar characteristics of glazing
DIN EN 12898:	Glass in the building - Determination of the emmissivity
DIN 5033:	Colorimetry – Colorimetric measures
DIN 6174:	Colorimteric evaluation of colour differences of surface colours according to the CIELAB formula

GEPVP Code of Practice for in-situ Measurement and Evaluation of the Colour of Coated Glass used in Facades (issued by “European Association of Flat Glass Manufacturers”)

German Bauregelliste A part1 chapter 11 “Products for buildings made of glass”

Guideline for the assessment of the visual quality of glass in building (issued by Federal Glazing Trade Association, Hadamar, and Federal Association for Architectural Glazing, Troisdorf)

Guideline for the assessment of the visual quality of screen printing (issued by Bundesverband Flachglas Großhandel, Isolierglasherstellung, Veredelung e.V.)

Guidelines for processing arcon soft coatings

Guidelines for processing arcon heat treatable coatings

3 Parameters and terms

The parameters and terms used in this specification are defined in “References to standards and guidelines”.

4 Requirements on parameters for energy retention and thermal insulation

The specifications for the photometric and energetic parameters are valid for specific build-up IGU mentioned in the currently valid test certificate.

The parameters of the photometric and energetic properties of the coated single pane listed in Table 1, which are necessary for energy retention and thermal insulation, are determined by calculation and/or measurement according to DIN EN 410.

The emissivity rating is determined according to DIN EN 12898. The requirements specified in Table 1 are applicable.

Tab. 1: Specification of photometric and energetic parameters [1]

Parameter	Determined according to	Determined value	Specified value	Requirement
Light Transmission	EN 410	$\tau_{v,m}$	$\tau_{v,d}$	$\tau_{v,m} = \tau_{v,d} \pm 0.03$
Light Reflectance	EN 410	$\rho_{v,m}$	$\rho_{v,d}$	$\rho_{v,m} = \rho_{v,d} \pm 0.03$
Solar Energy Transmission	EN 410	$\tau_{e,m}$	$\tau_{e,d}$	$\tau_{e,m} = \tau_{e,d} \pm 0.03$
Solar Energy Reflectance	EN 410	$\rho_{e,m}$	$\rho_{e,d}$	$\rho_{e,m} = \rho_{e,d} \pm 0.03$
Normal Emissivity	EN 12898	ε_m	ε_d	$\varepsilon_m \leq \varepsilon_d + 0.02$

Coated glass by arcon is developed for the use in multiple insulating glass units.
Tolerances for the coated single pane are given in Table 1. Especially when 2 coated single glass panes are used in triple insulating glass units (TGU), tolerances for the photometric and energetic parameters of the TGU can be increased due to error propagation.

[1] Index m: indicates that the specified value is a value determined by measurement or calculation
Index d: indicates that the specified value is a fixed value

5 Colorimetric assessment of coated glass

5.1 How to quantify a colour

The colour appearance of a surface is influenced by three factors:

- the colour of the light source
- the sensation of colour of an individual observer (human eye)
- the colour of a surface

The measurement of the reflected light spectrum is a suitable basis for the colorimetric measurement of coated glass to assess the exterior appearance of a facade and the transmitted spectrum to assess the view through the glass. Explicit values can be determined from the spectra to describe the colour (e. g. D65, 2° or 10° standard observer). The standard illumination adopted by arcon is D65 (representing average day light) and the angle of observation is 2°. In the CIELAB colour space, the L* value designates the brightness, a* designates the red and green proportions and b* the yellow and blue proportions (see Fig. 1). The colour and brightness can thereby be explicitly described by a point in a three-dimensional system of co-ordinates.

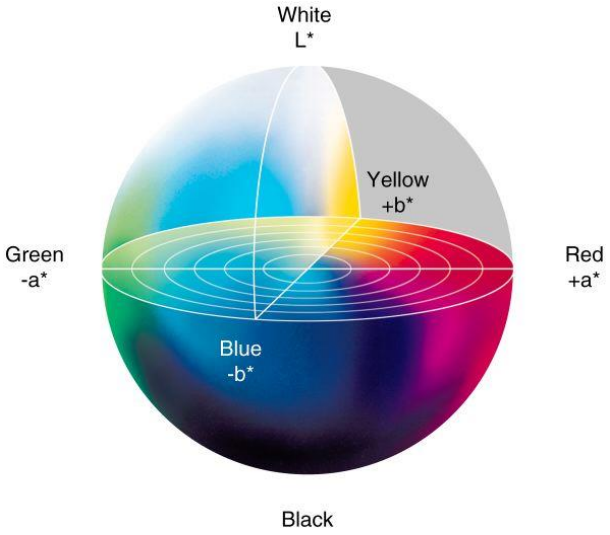


Fig.1: CIELAB colour space

The parameters L*, a* and b* can be used for quantifying the aesthetics of a facade, observed from the outside (in reflection), or to characterize the properties of transmission of light through a glass of pane.

The differences of colour can be quantified using tolerances on the parameters L*, a* and b*, which are noted as ΔL*, Δa* and Δb*, respectively, and calculated as in following equations:

$\Delta L^* = L^*_{\text{object 2}} - L^*_{\text{object 1}}$

$\Delta a^* = a^*_{\text{object 2}} - a^*_{\text{object 1}}$

$\Delta b^* = b^*_{\text{object 2}} - b^*_{\text{object 1}}$

In the field of colour measurement, it is common to refer to a ΔE* value, combining ΔL*, Δa* and Δb* values.

$$\Delta E^* = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})}$$

It is the arcon position that this ΔE* value is not accurate enough in terms of glass colour evaluation. Therefore, only ΔL*, Δa* and Δb* values shall be considered.

5.2 How to measure a colour

The parameters L*, a* and b* can be measured by spectrophotometers used in the factory but also by using colorimeters which can be handheld instruments and of small size, directly useable on site. These instruments have the same response to colour as the human eye. Since the colour measurement are referenced to the standard light source D65 and the 2° standard observer precise results independent of external factors like day time, environment, background, etc. can be derived.

Portable colorimeters currently used on site are limited to the measurement of colour in reflection, with an angle of observation corresponding to the vertical. Online instruments can measure the characteristics of glass panes in reflection under different angles of observation.

5.3 In-situ colour measurement

The following paragraphs describe the procedures used on site for measuring the colour of the coated glass product.

5.3.1 Colour differences in reflection within one glass pane

For colour differences within the same glass pane (e. g. bands or stains), the parameters L*, a* and b* shall be measured with a portable colorimeter. The measurements shall be undertaken at a minimum of three points in each zone representing the colour difference. An example is illustrated in Figure 2. For cut sizes and thermally toughened glass, measurements shall not be undertaken at any point within 10cm of an edge. This is due to the potential for the colour near to the edge to differ slightly from the colour in the centre. Furthermore, the measurements may be affected by the proximity of the frame and the edge of the insulating glass unit.

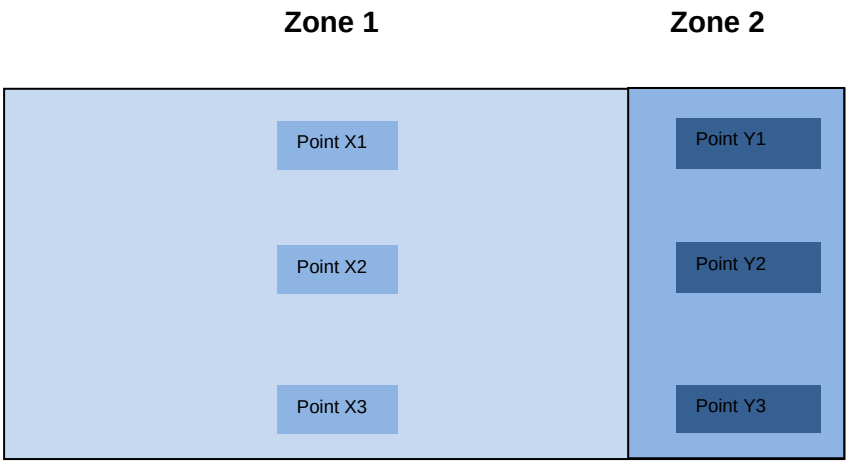


Figure 2:Example of measurements undertaken at a minimum of three points in each zone representing the colour difference

The ΔL*, Δa* and Δb* values shall be calculated based on the difference between the average values for each zone, in accordance with equations (1), (2) and (3), respectively.

$$\Delta L^* = L^*_{Zone2} - L^*_{Zone1} \quad (1)$$

$$\Delta a^* = a^*_{Zone2} - a^*_{Zone1} \quad (2)$$

$$\Delta b^* = b^*_{Zone2} - b^*_{Zone1} \quad (3)$$

The values of ΔL*, Δa* and Δb* shall meet the requirements given in 5.4.

ΔE* shall not be determined (see chapter 5.1).

5.3.2 Colour differences between adjacent panes

For colour differences in reflection between two adjacent panes, the parameters L*, a* and b* shall be measured with a portable colorimeter. For each pane representing the colour difference, the measurements shall be undertaken at a minimum of three points (i.e. along a diagonal). An example is illustrated in Figure 3.

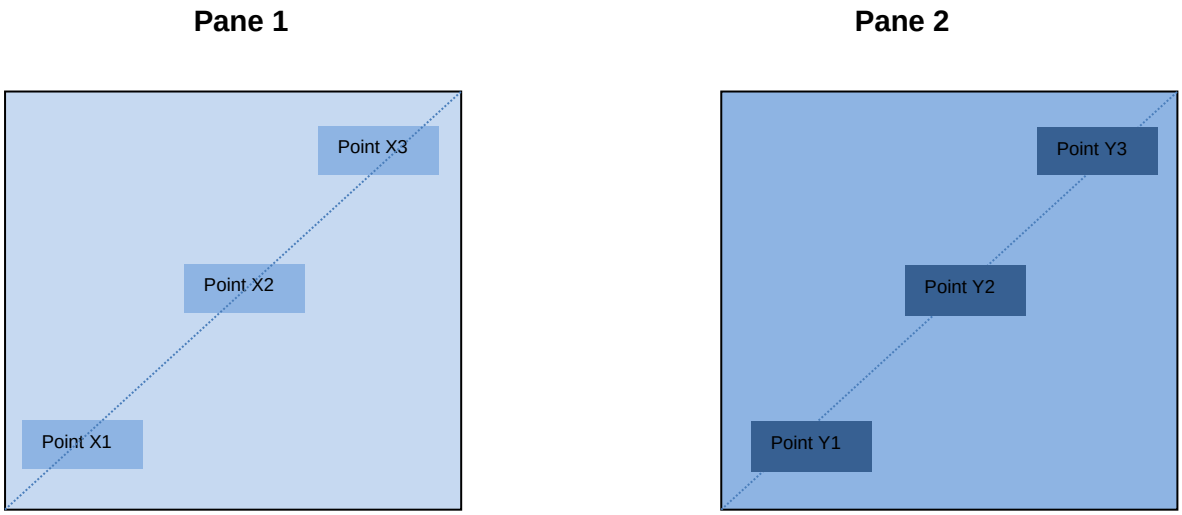


Figure 3: Example of measurements undertaken at a minimum of three points for each pane representing the colour difference

Note 1:

The reference pane may be compared with any of the four adjacent panes – above, below, to the left, or right.

Note 2:

The comparison should only be undertaken for panes of the same glass type, composition and background conditions and situated on the same elevation.

The average values of L*, a* and b* shall be determined for each pane. An example is given in Table 2.

Tab. 2: Example of determining the average values of L, a* and b* for one pane (e.g. pane 2)*

Pane 2 Y=1, 2, 3, …	L*	a*	b*
Measuring point1	L^*_{Y1}	a^*_{Y1}	b^*_{Y1}
Measuring point2	L^*_{Y2}	a^*_{Y2}	b^*_{Y2}
Measuring point3	L^*_{Y3}	a^*_{Y3}	b^*_{Y3}
Average	L* Pane 2 = $(L^*_{Y1} + L^*_{Y2} + L^*_{Y3})/3$	a* Pane 2 = $(a^*_{Y1} + a^*_{Y2} + a^*_{Y3})/3$	b* Pane 2 = $(b^*_{Y1} + b^*_{Y2} + b^*_{Y3})/3$

The ΔL*, Δa* and Δb* values shall be calculated based on the difference between the average values for each pane, in accordance with equations (4), (5) and (6), respectively.

$$\Delta L^* = L^*_{Pane2} - L^*_{Pane1} \quad (4)$$

$$\Delta a^* = a^*_{Pane2} - a^*_{Pane1} \quad (5)$$

$$\Delta b^* = b^*_{Pane2} - b^*_{Pane1} \quad (6)$$

where pane 1 is the reference pane.

The values of ΔL*, Δa* and Δb* shall meet the requirements given in 5.4.

ΔE* shall not be determined (see chapter 5.1)

5.4 Requirements for Colour

The values of ΔL*, Δa* and Δb* determined in accordance with 5.3.1 and 5.3.2 shall meet the requirements given in Table 3.

Tab. 3: Requirements for Colour

ΔL*	4
Δa*	4
Δb*	4

The production tolerances are maintained to ensure that a homogeneous colour appearance of the buildings facade as specified in Table 3 is accomplished. Alternative requirements for colour according to product and project are possible on request.

5.5 Colour appearance of non heat treatable and heat treatable version of one product

Some arcon coatings are available both as non heat treatable and heat treatable version (e. g. sunbelt A70 and sunbelt HT A70). Heat treatable versions are marked with “HT” and need to be heat treated for their best performance.

Radiation properties of both non heat treatable and heat treatable version are adapted.

Although both non heat treatable and heat treatable version of one product are matched in terms of colour, arcon strongly recommends the fabrication of samples in original size and the comparison among each other in advance when a jointly use in one facade is intended.

Furthermore, arcon coatings marked with “oHT” (“optional heat treatable”) can be used either tempered or annealed. The simultaneously use of annealed (e. g. float, LSG) and tempered (e. g. safety glass) version of one product in a façade is possible, but arcon strongly recommends the fabrication of samples in original size and the comparison among each other in advance.

5.6 Angle dependence of architectural coatings

The colour appearance of low-e and solar control coatings especially with a high selectivity can change with angle of view. These variations can only be measured online. Currently there is no on site instrument on the market.

Consequently the homogeneity of the colour of the facade viewed under an angle can only be evaluated by visual observation. The maximum angle must not exceed 45° (see Figure 4)

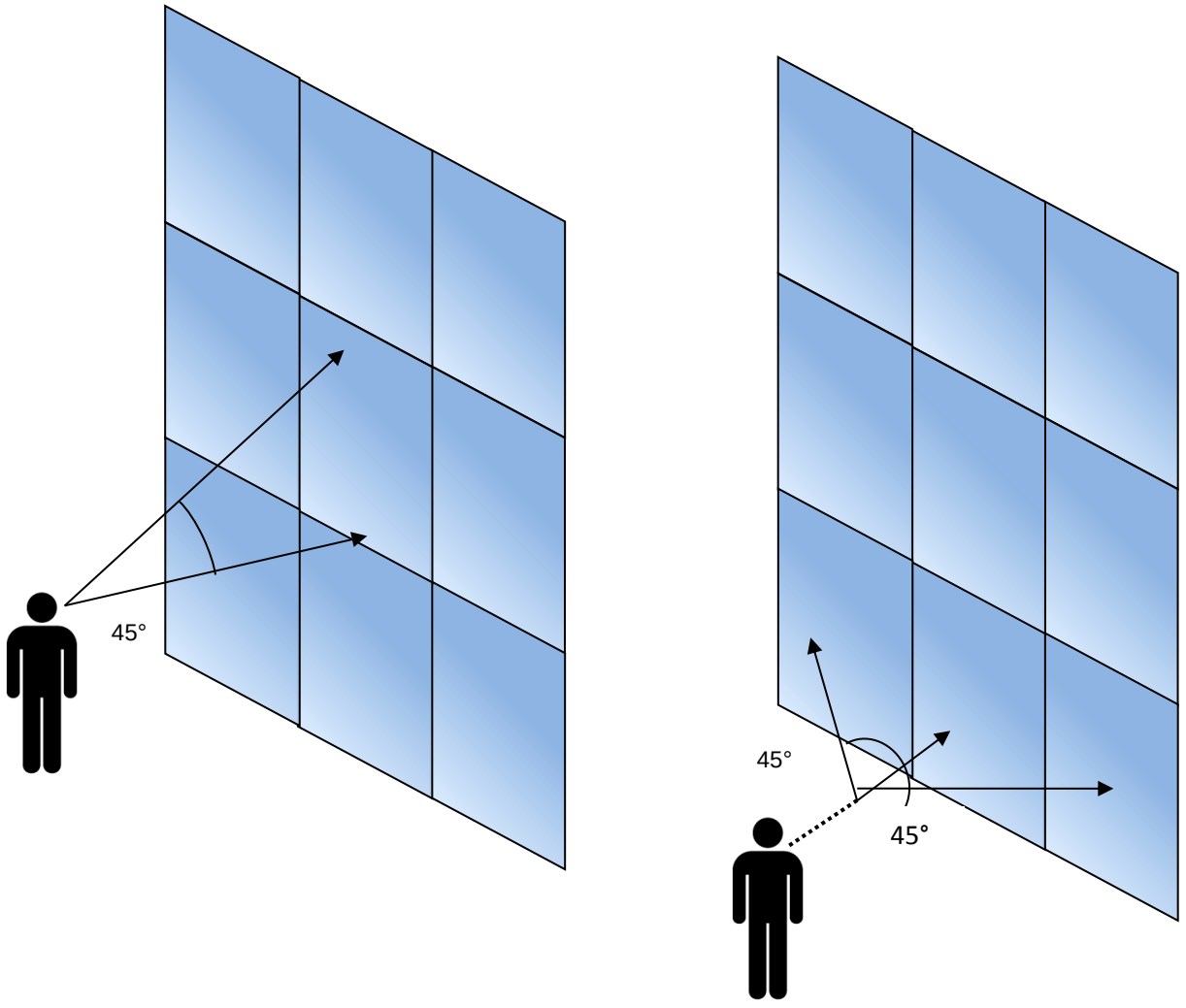


Fig.4: Visual observation of angle dependence

5.7 Generally remarks on colour assessment

For the assessment of the reflected colour (outside view of the façade) solar control products (sun-belt) must be placed on surface #2 and low-e products on surface #3 in an IGU. The facade is viewed normal the surface.

Differences of colour as viewed from the interior of the building are not considered as a defect.

In transmission colour differences may also be observed. These differences cannot be measured on site as no device is available. This colour can only be evaluated by visual observation.

The transmission as well as reflection colour is influenced not only by the coating but also by the glass type, glass thickness and the uncoated pane in the IGU.

One must realize that the notion of colour is linked to the impression and perception of the individual, the sensibility of the eye being a very personal characteristic.

Furthermore, a variety of conditions affect how a colour looks, for instance when observing the facade of a building from the outside,

- Luminosity: a dark covered sky and very cloudy might reveal colour differences, invisible under direct sunlight.
- Distance and angle of observation.
- Type and colour of mullions and transoms.
- Distance between two adjacent glass panes.
- The eye of the observer.
- Background: the absence of any lighting in the building (dark background), might increase the perception of colour differences.
- Environment: presence or absence of other buildings which are likely to reflect in the facade…

Thermally toughened safety glass demonstrate so-called “anisotropy effects” in the form of stripes or circles of grey or coloured reflexes. The visibility of the anisotropies in heat treated glass depends on the weather and the attitude of the sun, the type and thickness of the glass and the viewing angle and can be further reinforced and changed in colour if the glass is coated. Anisotropy effects are inherent to the manufacturing process. They are not regarded as a cause for complaint.

Heat strengthened safety glass with no opaque silk-screen print (depended on the individual design) cannot be colour measured reliable.

6 Requirements on the mechanical properties

There is no generally acknowledged standard for tests on the scratch resistance of coated glass. arcon monitors both the scratch resistance and the delamination resistance during production by an internal company test method.

The assessment of the adhesion strength on site is conducted according to DIN 58196-6, using a commonly available, transparent adhesive tape type “Tesa 57370” from Beiersdorf. The loads on the tested samples are exerted according to resolution K1 as specified in Section 4 of the above standard.

In case of claims arcon reserves the right to verify the mechanical properties with these internal procedures in order to evaluate the claim closing.

7 Defect assessment of coated glass

7.1 Assessment of stock sizes and cut sizes of coated glass respectively

The assessment of coated glass is based on European Standard 1096-1. The acceptance criteria for defects as described in chapter 7.4 of this standard are given in Table 4.

Tab. 4: Acceptance criteria for defects in coated glass according to DIN EN 1096-1

Defect type	**Acceptance criteria**		
	Pane to pane	**Individual pane**	
Uniformity[2]/ stain	Allowed as long as not visually disturbing	Allowed as long as not visually disturbing	
		Main area	**Edge area**
Punctual:	Not applicable		
Spots/Pinholes:			
> 3 mm		Not allowed	Not allowed
>2 mm and ≤ 3 mm		Allowed if not more than 1/m²	Allowed if not more than 1/m²
Clusters		Not allowed	Allowed as long as not in area of through vision
Scratches:			
> 75 mm		Not allowed	Allowed as long as they are separated by > 50 mm
≤ 75 mm		Allowed as long as local density is not visually disturbing	Allowed as long as local density is not visually disturbing

[2] Uniformity defects: coating variations either within one pane or between neighboring panes which are visually disturbing see also chapter 5 of this specification

7.2 Assessment of insulating glass units (IGU)

The assessment of insulating glass units assembled with coated glass is based on "Guidelines for the assessment of the visual quality of glass in building"[3], excerpts of which are contained in Table 5. This guideline is an acknowledged and accepted principle for the assessment of defects in IGU.

Tab. 5: Permissible values for the assessment of glass in building (in conjunction with coated glass)

Zone	The following are allowable per unit:
R	External shallow damage to the edge or conchoidal fractures which do not affect the glass strength and which do not project beyond the width of the edge seal.
	Internal conchoidal fractures without loose shards, which are filled by the sealant.
	Unlimited spots or patches of residue or scratches.
E	**Inclusions, bubbles, spots, stains, etc.:** Pane area ≤ 1m²: max.4 @ < 3mm ∅ Pane area > 1m²: max.1 @ < 3mm ∅ per peripheral m of edge length
	Residues (spot-shaped) in the gas-filled cavity:: Pane area ≤ 1m²: max. 4 @ < 3mm ∅ Pane area > 1m²: max. 1 @ < 3mm ∅ per peripheral m of edge length
	Residues in the gas-filled cavity: whitish grey or transparent–max.1 ≤ 3cm²
	Scratches: sum of individual lengths: max. 90 mm – individual length: max. 30 mm
	Hairline scratches: not admissible in higher concentration
M	**Inclusions, bubbles, spots, stains, etc.:** Pane area ≤ 1m²: max. 2 @ < 2mm ∅ 1m² < pane area ≤ 2m²: max. 3 @ < 2mm ∅ Pane area > 2m²: max. 5 @ < 2mm ∅
	Scratches: sum of individual lengths: max. 45 mm – individual length: max. 15 mm
	Hairline scratches: not admissible in higher concentration
E + M	Max. number of permissible values as in zone E Inclusions, bubbles, spots, blemishes etc. of 0.5 -1.0 mm are permissible without restriction to a zone, except in clusters. A cluster is regarded to exist when at least 4 inclusions, bubbles, spots, blemishes etc. exist within a circular area with a diameter of ≤ 20 cm.
Comments:	

[3] The guideline was prepared by the Technical Advisory Board of the Institute of the Glazing Trade for Glazing Technology and Window Manufacture, Hadamar and the Technical Committee of the Federal Association for Architectural Glazing, Troisdorf

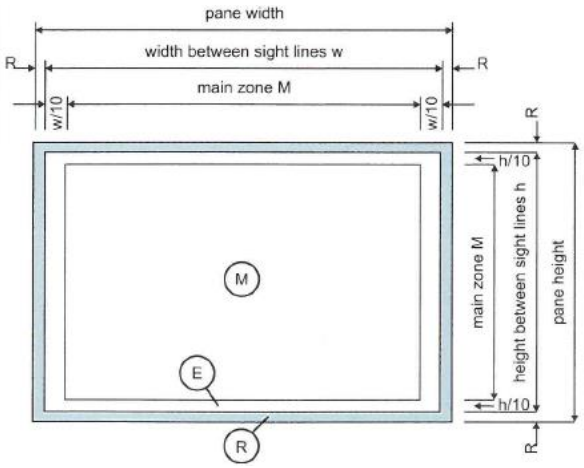
Discrepancies of dimensions ≤0.5mm will not be taken into account. The optical distored fields they cause may not be more than 3mm in diameter.

Allowable discrepancies for three-layer thermal insulating glass, laminated sheet and laminated safety glass:

The allowable frequency of discrepancies in the zones E and M is increased by 25% per additional glass unit and per laminated glass pane over the above values. The result is allways rounded up.

Toughened safety glass, heat-strengthened glass, laminated sheet and laminated safety glass of toughened safety glass and/or heat-strengthened glass:

1. The local roller waves on the glass surface (except for toughened safety glass and heat-strengthened glass of ornamental glass) may not exceed 0.3mm relative to a length of 300mm.
2. The warp relative to the total glass edge length (except for toughened safety glass and heat-strengthenend glass of ornamental glass) may not be greater than 3mm per 1000mm glass edge length. Greater warps may occur for square or near square formats (up to 1:1.5) and for single panes with a normal thickness <6mm.



R = rebate zone
the visually concealed area in the installed state (no limits on discrepancies, with the exception of mechanical damage to the edges)

E = edge zone
Area around edge with width w/10 or h/10 respectively – see diagram (less stringent assessment)

M = main zone
(most stringent assessment)