CUSTOMER INFORMATION

Technical specification for arcon coatings

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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. Coated glass covered by this specification is developed for the use in multiple insulating glass units.

2 Coating methods and References to standards and guidelines

2.1 Coating methods

Industrial coating processes for flat glass can be divided into

- Physical processes (vacuum deposition technology)
- Chemical processes (CVD coating process and sol-gel coating process)

Coatings in terms of this specification are produced by the vacuum deposition technology.

2.2 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 EN 1279:	Glass in the building – Insulating glass units
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
ISO 11479-2:	Glass in building – Coated glass – Colour of façade

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

Muster-Verwaltungsvorschrift Technische Baubestimmungen (MVV-TB) chapter C2.11 “Products for buildings made of glass”

Guideline for the assessment of the visual quality of glass in building
(published by Federal Glazing Trade Association, Hadamar, and Federal Association for Architectural Glazing, Troisdorf, BV Flachglas, Troisdorf and VFF Fenster + Fassade, Frankfurt a.M.))

Guideline for the assessment of the visual quality of screen printing
(published by Bundesverband Flachglas Troisdorf and Fachverband Konstruktiver Glasbau, Köln.)

Guidelines for processing arcon soft coatings

Guidelines for processing arcon heat treatable coatings

3 Requirements on parameters for energy retention and thermal insulation

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: Information on 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	$\rho_{v,m}$ $\rho'_{v,m}$	$\rho_{v,d}$ $\rho'_{v,d}$	$\rho_{v,m} = \rho_{v,d} \pm 0.03$ $\rho'_{v,m} = \rho'_{v,d} \pm 0.03$
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	$\rho_{e,m}$ $\rho'_{e,m}$	$\rho_{e,d}$ $\rho'_{e,d}$	$\rho_{e,m} = \rho_{e,d} \pm 0.03$ $\rho'_{e,m} = \rho'_{e,d} \pm 0.03$
Normal Emissivity	EN 12898	ε_m	ε_d	$\varepsilon_m \leq \varepsilon_d + 0.02$, wenn $\varepsilon_d \geq 0.10$ $\varepsilon_m \leq \varepsilon_d + 0.01$, wenn $\varepsilon_d < 0.10$

4 Requirements on the mechanical properties

There is no generally acknowledged standard for tests on the scratch resistance of coated glass. Arnold/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 Arnold/arcon reserves the right to verify the mechanical properties with these internal procedures in order to evaluate the claim closing.

5 Defect assessment of coated glass

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 2.

[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

Tab. 2: Acceptance criteria for defects in coated glass according to DIN EN 1096-1

Defect	Acceptance criteria		
	Pane to pane	**Individaul 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:			
> 3mm		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

6 Colorimetric assessment of coated glass

6.1 Generally remarks on colour assessment

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

- Luminosity: a dark covered sky and very cloudy might reveal colour differences, invisible under direct sunlight Distance and angle of observation
- 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

[2] Uniformity defects: coating variations either within one pane or between neighboring panes which are visually disturbing see also chapter 6 of this specification.

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

6.2 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 Arnold/arcon is D65 (representing average day light) and the angle of observa-tion is 2°. In the CIELAB colour space, the L* value designates the brightness, a* designates the red and green pro-portions and b* the yellow and blue proportions (see Fig. 1). The colour and brightness can thereby be explicitly de-scribed by a point in a three-dimensional system of co-ordinates.

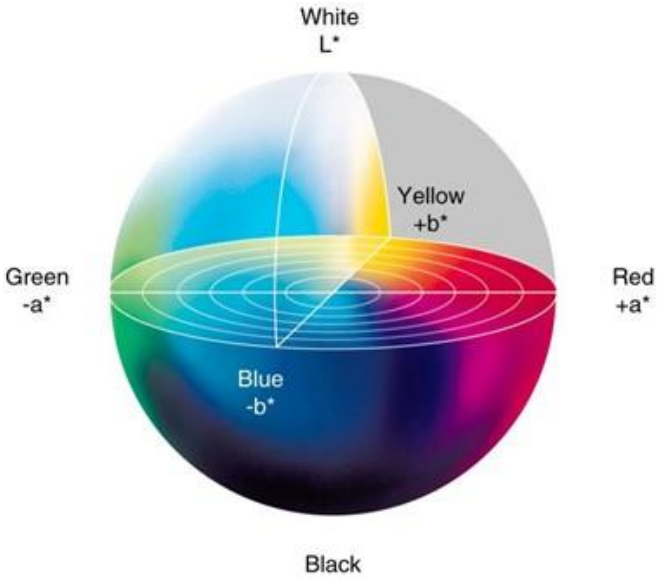

Fig. 1: CIELAB colour space

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:

$$\Delta L^* = L^*_{Probe2} - L^*_{Probe1}$$

$$\Delta a^* = a^*_{Probe2} - a^*_{Probe1}$$

$$\Delta b^* = b^*_{Probe2} - b^*_{Probe1}$$

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 Arnold/arcon position that this ΔE* value is not accurate enough in terms of glass colour evaluation. There-fore, only ΔL*, Δa* and Δb* values shall be considered.

6.3 How to measure a colour

The parameters L*, a* and b* can be measured by spectrophotometers used in the factory but also by using colorimeter 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 daytime, 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 re-flection under different angles of observation. When the façade is measured with a portable colorimeter, the coated pane should be evaluated[3].

6.4 In-situ colour measurement

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

6.4.1 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. According to ISO 11479-2 for glass coated as fixed dimensions, measurements shall not be undertaken nearer than 15cm from 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 measure-ments may be affected by the proximity of the frame and the edge of the insulating glass unit.

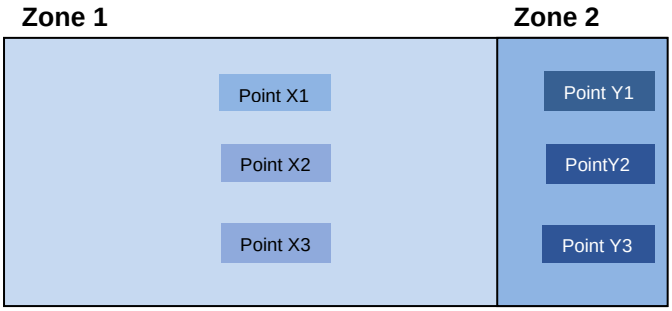

Fig. 2: Example of measurements undertaken at a minimum of three points in each zone representing the colour difference.

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.

$$\Delta L^* = L^*_{Bereich2} - L^*_{Bereich1} \quad (1)$$

$$\Delta a^* = a^*_{Bereich2} - a^*_{Bereich1} \quad (2)$$

$$\Delta b^* = b^*_{Bereich2} - b^*_{Bereich1} \quad (3)$$

The values of ΔL*, Δa* and Δb* shall meet the requirements given in 6.4.3.

6.4.2 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.

[3] Solar control coatings (coating on #2) shall be measured from outside. In contrast low-e coatings are usually positioned on IGU's #3 so that the coated single pane should be measured (otherwise the uncoated pane influences the measurement results).

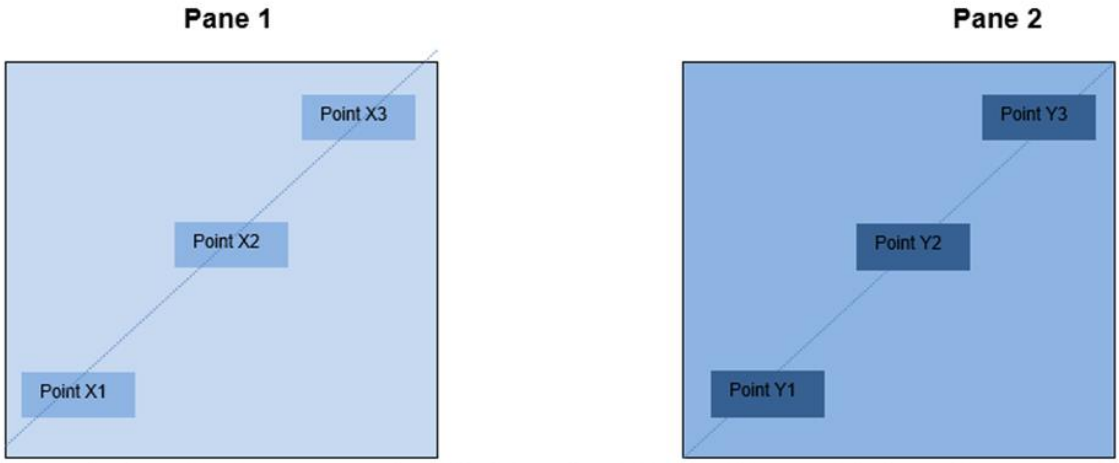

Figure 3: Example of measurements undertaken at a minimum of three points for each pane representing the colour difference

The reference pane may be compared with any of the four adjacent panes – above, below, to the left, or right. The comparison should only be undertaken for panes of the same product, 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. 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.

$$\Delta L^* = L^*_{Scheibe2} - L^*_{Scheibe1} \quad (4)$$

$$\Delta a^* = a^*_{Scheibe2} - a^*_{Scheibe1} \quad (5)$$

$$\Delta b^* = b^*_{Scheibe2} - b^*_{Scheibe1} \quad (6)$$

where pane 1 is the reference pane.

The values of ΔL*, Δa* and Δb* shall meet the requirements given in 6.4.3.

6.4.3 Requirements for Colour

The values of ΔL*, Δa* and Δb* determined in accordance with 6.4.1 and 6.4.2 shall meet the requirements given in Table 3.

Tab. 3: Requirements for Colour

	Solar control and low-e (#2)	Low-e (#3)
ΔL*	4	3
Δa*	3	3
Δb*	3	3

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.

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

Some 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, Arnold/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, 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 facade is possible, but Arnold/arcon strongly recommends the fabrication of samples in original size and the comparison among each other in advance.

6.6 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 shall only be evaluated by visual observation. The maximum angle must not exceed 45° (see Figure 4).

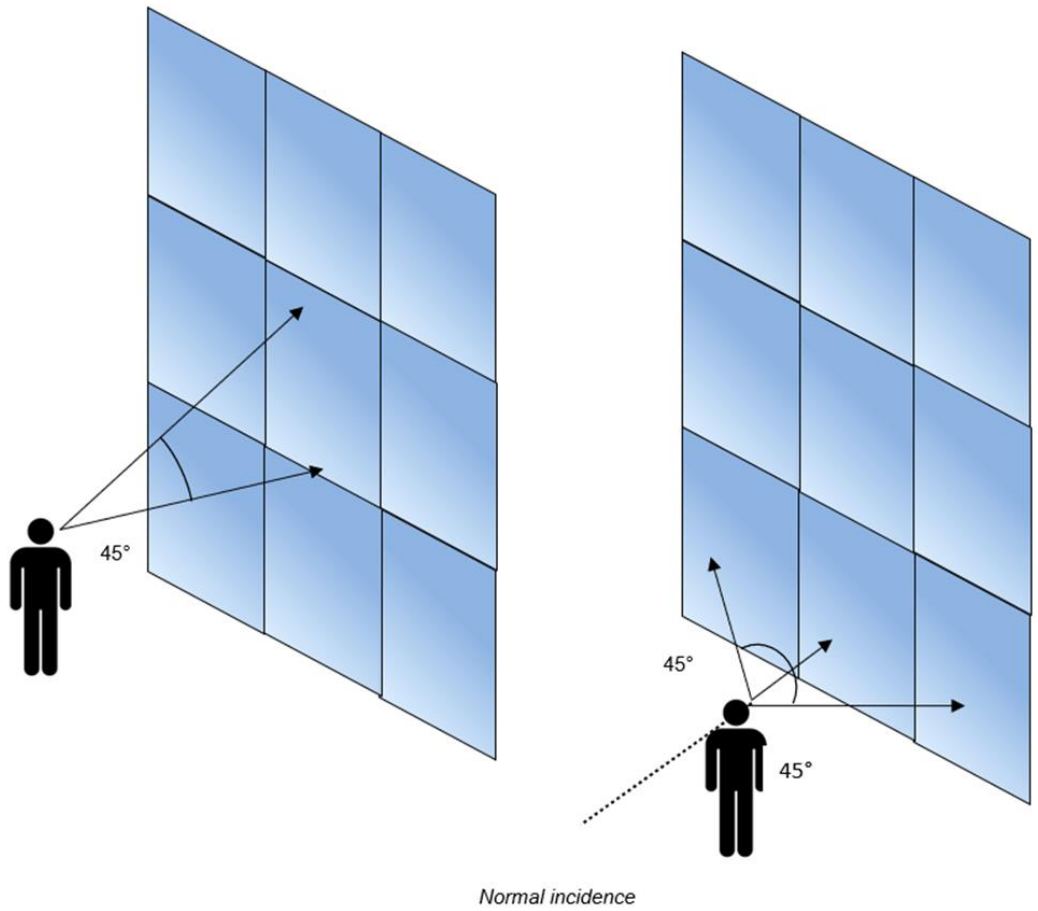

Fig.4: Visual observation of angle dependence