

## Evaluation of the quality of **sunselect**

The evaluation of the quality of **sunselect**, a selective coating on copper band, is carried out according to this directive. **sunselect** is intended for use as an absorbing surface in various types of solar collector with a closed housing. These include ventilated or sealed flat collectors, vacuum tube collectors and air collectors with a transparent cover.

### 1. Preface

INTERPANE Solar Beschichtungs GmbH & Co KG operates a continuous magnetron vacuum coating plant for the manufacture of the absorber band **sunselect**. This coating process consists of an air-to-air process without previous cleaning of the copper band. The bands are unwound from their coils and fed into the coating system. There they are coated using the magnetron sputter technique, fed out again and rewound onto coils optional with an intermediate layer (e. g. paper or plastic) rolled in as a separating layer.

### 2. Requirements for the copper band

The quality of **sunselect** is heavily dependent on the quality of the copper substrate. Therefore a quality assurance agreement has been made with the copper band manufacturers. This is based on the usual standards for the production of copper band, as well as the special requirements for the sputter coating process. The following standards are of particular importance:

- DIN EN 1652 Copper and copper alloys
- DIN 1791 Specifications for bands and band strips

and also the definition of the surface measures:

- DIN EN ISO 4287 Geometric product specifications (GPS) - Surface texture

Bearing in mind the current state of the technology in copper manufacture, the following surface characteristics of **sunselect** are not considered as part of the evaluation because of the characteristics of the copper substrate:

- Roller grooves and stripes
- Regular roller structures
- Inclusions

Further exclusions from the evaluation of **sunselect** (other than at the start and end of the coil):

- Colour variations caused by differences in viewing angle
- Contaminations of the outer surface (e.g. Fingerprints, dust, processing and condensation residues, etc.)
- Abrasion and chafe marks
- Creases and folds

**sunselect** is a semifinished production material which, after the coating procedure, is further processed into complete solar absorbers. In order to ensure the correct storage and processing of **sunselect**, a storage and processing directive has been written. This document is supplied with the product and must be strictly adhered to during the manufacture of absorbers (see appendix 1). A product specification sheet is also enclosed, in appendix 2.

### 3. Testing

In the testing of **sunselect** the energy efficiency values (absorptance  $\alpha$  and emittance  $\epsilon$ ), the visual surface characteristics (visual inspection of the coated surface for spots and stains, scratches, bumps and dents), and colour characteristics, defined with the help of the CIE-Lab colour measurement system, are separately considered. These tests take place online during the coating process. The durability of **sunselect** is also tested in the form of an accelerated ageing (boiling water test, thermal stress test and ISO draft proposal CD 12952.2) followed by a check of the energy efficiency values. The tests take place in the laboratory, at the end of each coil. The energy efficiency values and the resistance to ageing of **sunselect** are considered to be major characteristics, whereas the visual surface qualities and the colour characteristics are minor characteristics.

During the online test obvious defects on the coated surface are marked with a coloured pen and for full-width material also with a paper flag, which protrudes from the side of the coil. The nature of the defect is entered into the documentation accompanying the coil, with a note of the distance from the start of the coil. The affected area is regarded as scrap; it may not be used for manufacturing purposes and is excluded from this evaluation directive. A 100% complete visual online inspection by the personnel of INTERPANE Solar is not possible. The manufacturer is strongly recommended to carry out his own visual check of the surface before using **sunselect** in the production process.

### 3. Energy efficiency - Technical values $\alpha$ and $\varepsilon$

The technical values for energy efficiency,  $\alpha$  and  $\varepsilon$  (solar absorptance and thermal emittance) of **sunselect** are determined from the reflection spectra in the visible and infrared wavelengths (300 nm - 20  $\mu\text{m}$ ). The absorption efficiency is measured using the spectral data in the wavelength range 300 nm to 2500 nm in convolution with the solar radiation spectrum (AM 1.5 lt. ASTM E 891-87 and ISO 9845-1). The emittance is calculated by convolution of the spectral data in the wavelength range 2.5  $\mu\text{m}$  to 20  $\mu\text{m}$  with the spectrum of the black body at 100 °C (see appendix 3).

The online measurement of absorptance is performed with a diode array spectrometer, using wavelength spectra in the range 380 nm to 1650 nm, which is equipped with an integrating sphere as the probe. For the measurement of the emittance an emissiometer, with an integral spectrum between 1  $\mu\text{m}$  and 20  $\mu\text{m}$ , is in use. The measurement of absorption and emission always happen in relation to a reflection standard. The measurements are taken approximately every 50 m along the band. The data is recorded in the documentation accompanying every coil.

Variations in the absorptance and emittance are allowed. The permitted variation from the rated values is +/- 2 %.

**Solar absorptance:**  $\alpha = 95 \%$

**Thermal emittance:**  $\varepsilon = 5 \%$

The basis for this evaluation is the online measurement by INTERPANE Solar.

### 3.2 Visual surface qualities

For the evaluation of the visual surface qualities of **sunselect** the product must be observed from a distance of around 3 m, perpendicular to the surface, in diffuse daylight, without direct sunlight. Reflections must be avoided in all cases.

The visual evaluation of the coated surface is performed by INTERPANE Solar, online during the coating process.

#### **Stains, spots (so-called 'pinholes'):**

Objections  $\leq 1$  mm are not taken into account. Accumulations of spots and stains  $> 1$  mm should be avoided. The size of the spot or stain may not exceed 3 mm. A template is used to measure the defect size.

### **Bumps and dents:**

Individual bumps and dents are permitted up to a maximum of 1 mm height/depth and a diameter of up to 3 mm. Max. 5 items per meter of copper band.

### **Scratches:**

Scratches may have a maximum width of 0.1 mm. Individual scratches may be no more than 15 mm long, with a total length of all scratches per meter of max. 45 mm.

## **3.3 Colour qualities**

The colour qualities of **sunselect** are determined using the reflection spectrum in the visible wavelength range. Using these spectra, the colour coordinates  $L^*$  (brightness),  $a^*$  (red-green axis) and  $b^*$  (yellow-blue axis) can be determined. These values determine the chromaticity coordinate  $E^*$ . The colour values of **sunselect** must be within the predetermined colour coordinates. The measurement of the colour coordinates is carried out according to DIN 50 33 (CIE-Lab).

The colour coordinates are measured online during the coating process, with the help of a diode array spectrometer, equipped with an integrating sphere as the probe. The colour value  $\Delta b^*$  describes the colour variation in the yellow-blue axis, and  $\Delta a^*$  describes the colour variation in the red-green axis. The brightness value and its variation  $\Delta L^*$  are uncritical values as these do not influence the "chroma". The colour coordinates are noted in the documentation accompanying every coil.

### **Permitted variations**

The basis for the evaluation of the colour of **sunselect** are two sample colour matches prepared by INTERPANE Solar and provided to customers. The colour coordinates of the colour matches are determined by INTERPANE Solar and made available to the customer in the form of a measurement protocol. The colour of **sunselect** must be within the range of the predetermined colour coordinates of the colour match. These evaluation directives are provided with the measurement protocol for the colour matches in appendix 4.

## **3.4 Ageing test**

The accelerated ageing test of **sunselect** is carried out according to the test procedure ISO draft proposal CD 12952.2 (also known as the Task-X-Test). The procedure includes subjecting the coating to adverse temperatures, humidity and condensation. The test takes place in stages, beginning with lower temperatures and short test times, until the sample fails.

After this the energy efficiency values of the tested sample and a control sample are measured and a so-called "Performance Criterion" (PC) is determined. The PC is used to show the changes in the optical characteristics of the absorber surface after the ageing test. It is defined as:

$$PC = - \Delta\alpha + 0.25 \cdot \Delta\epsilon \leq 0.05$$

This means that the durability test is considered to have been passed if the sum of the weighted energy efficiency values ( $\alpha$  and  $\epsilon$ ) after the ageing does not vary by more than 5 % between the stressed and unstressed sample. **sunselect** fulfils the PC up to a maximum stress limit of 300 °C. Therefore stagnation safety is assured and a working lifespan of 25 years can be expected (see appendix 5).

#### 4. Quality control

The internal production checks include continuous and ongoing screening of the predetermined quality parameters. All of the measuring equipment needed for the checks is regularly recalibrated as part of the QM process. Measured values are documented, samples used for laboratory tests are archived. In addition to the internal quality tests **sunselect** is subjected to an external product evaluation by registered test institutes. Only results from the measurements made by these test institutes are accepted. INTERPANE Solar reserves the right to commission tests on **sunselect** itself.

## Appendices

1. Storage and processing directives for **sunselect**, version: January 2002
2. **sunselect** product specification, version: January 2002