# Qualification Test of Solar Absorber Coating Durability

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# Part 1

The test procedure applied is basing on the service life assessment methodology developed by the IEA-SHCP under consideration of the latest further developments of the procedure [1].The full test consists of 3 parts:

***Part 1: Stability with regards to high temperature***

*Part 2: Stability with regards to high humidity and condensation*

*Part 3: Stability with regards to atmospheric corrosion ($SO_2$)*

The test allows the qualification of solar absorber coatings to be used in ventilated flat plate collectors with a maximum loss in system performance of 5% during 25 years of operation. The loss in performance was evaluated according the performance criterion function:

**$PC = -\Delta\alpha_S + 0.5\Delta\varepsilon_{100}$.**

| | |
|---|---|
| **Test material** | |
| ***Commissioner:*** | ALMECO GmbH<br>Claude Breda Straße 3<br>D-06406 Bernburg, Germany |
| ***Trade name:*** | TiNOX energy Cu |
| ***Description:*** | Protection and antireflection layer on the basis of an Oxide – CERMET absorber multilayer – adhesion layer – Copper substrate |
| ***Date of delivery:*** | August 2013 |
| ***Expiration date:*** | September 2016<br>(The test result is no longer valid after substantial changes of the coating or substrate) |
| **Test results** | |
| The test material has passed part 1 of the test, i.e. with regards to the thermal stability the absorber is qualified to be used in single glazed flat plate collectors. | |

## Measuring of optical properties

### Solar absorptance, $\alpha_S$

Solar absorptance, $\alpha_S$, was measured with a BRUKER IFS 66 UV-VIS-MIR Fourier-transform spectrophotometer equipped with an integrating sphere. 'Spectralon' diffuse reflectance standard was used as a reflectance reference. $\alpha_S$ was calculated for airmass 1.5 using hemispherical solar spectral irradiance data as described in ISO 9845-1.

### Thermal emittance, $\varepsilon_{100}$

The thermal emittance, $\varepsilon_{100}$, was measured using the same instrument as for solar absorptance measurements. However, an 'Infragold' reflectance standard was used as a reference. The black body radiation spectrum for a temperature of 100°C (373 K) was used for the calculation of $\varepsilon_{100}$. It was generated according to Planck's law of black body radiation.

## Testing chambers

A Snijstaal, type S 30 l (volume 30 litre) circulating air oven was used for high temperature exposure. The temperatures were measured with a calibrated ( ±1 K) Pt-100 sensor.

## Evaluation of test results

The degradation of the absorber surfaces was evaluated according to a performance criteria function which is defined as

$$PC = -\Delta\alpha_S + 0.5\Delta\varepsilon_{100}$$

where $\Delta\alpha_S$ and $\Delta\varepsilon_{100}$ are the changes in $\alpha_S$ and $\varepsilon_{100}$ respectively.

## 1. Optical properties of unaged absorber surface

The mean values of solar absorptance, $\alpha_s$ and thermal emittance, $\varepsilon_{100}$, for unaged absorbers are given in Table 1 below.

**Table 1 Optical properties of unaged absorber samples. The values given are the mean values of 21 samples.**

| Values | Optical properties of unaged absorber coatings | |
|---|---|---|
| | Solar Absorptance, $\alpha_s$ | Emittance, $\varepsilon_{100}$ |
| Mean value | 0.949 | 0.041 |
| Standard deviation | 0.001 | 0.001 |
| Minimum value | 0.947 | 0.038 |
| Maximum value | 0.951 | 0.043 |

The test specimens are qualified for testing, since the standard deviation for solar absorptance and thermal emittance are less than 0.01 and 0.04, respectively.

## 2. Test conditions

For the determination of testing temperature and testing time, the typical stagnation temperature as a function of the optical properties of the absorber was taken from Table 2:

**$T_{Stagnation}$ = 214°C**

**Table 2 Typical stagnation temperature for a flat plate collector as a function of the optical properties of the solar absorber coating. For collectors equipped with anti-reflective coated glass, the column "α(AR)" has to be used for the solar absorptance, for collectors equipped with non-coated solar glass, column "α" has to be used.**

| | | ε → | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| α (AR) | α | | | | | | | | | | | | |
| 1 | | | 233 | 229 | 226 | 222 | 219 | 216 | 214 | 211 | 209 | 207 | 205 |
| 0.99 | | | 232 | 228 | 224 | 221 | 218 | 215 | 212 | 210 | 207 | 205 | 203 |
| 0.98 | | | 230 | 226 | 222 | 219 | 216 | 213 | 211 | 208 | 206 | 204 | 202 |
| 0.97 | | | 228 | 224 | 221 | 218 | 215 | 212 | 209 | 207 | 204 | 202 | 200 |
| 0.96 | | | 227 | 223 | 219 | 216 | 213 | 210 | 208 | 205 | 203 | 201 | 199 |
| 0.95 | 1.00 | | 225 | 221 | 218 | 214 | 211 | 209 | 206 | 204 | 202 | 200 | 198 |
| 0.94 | 0.99 | | 223 | 219 | 216 | 213 | 210 | 207 | 205 | 202 | 200 | 198 | 196 |
| 0.93 | 0.98 | | 222 | 218 | 214 | 211 | 208 | 206 | 203 | 201 | 199 | 197 | 195 |
| 0.92 | 0.97 | | 220 | 216 | 213 | 210 | 207 | 204 | 202 | 199 | 197 | 195 | 193 |
| 0.91 | 0.96 | | 218 | 214 | 211 | 208 | 205 | 203 | 200 | 198 | 196 | 194 | 192 |
| 0.90 | 0.95 | | 216 | 213 | 209 | 206 | 204 | 201 | 199 | 196 | 194 | 192 | 191 |
| 0.89 | 0.94 | | 215 | 211 | 208 | 205 | 202 | 200 | 197 | 195 | 193 | 191 | 189 |
| 0.88 | 0.93 | | 213 | 209 | 206 | 203 | 200 | 198 | 196 | 193 | 191 | 190 | 188 |

Basing on the typical stagnation temperature, the equivalent testing times can be calculated (see Figure 1).

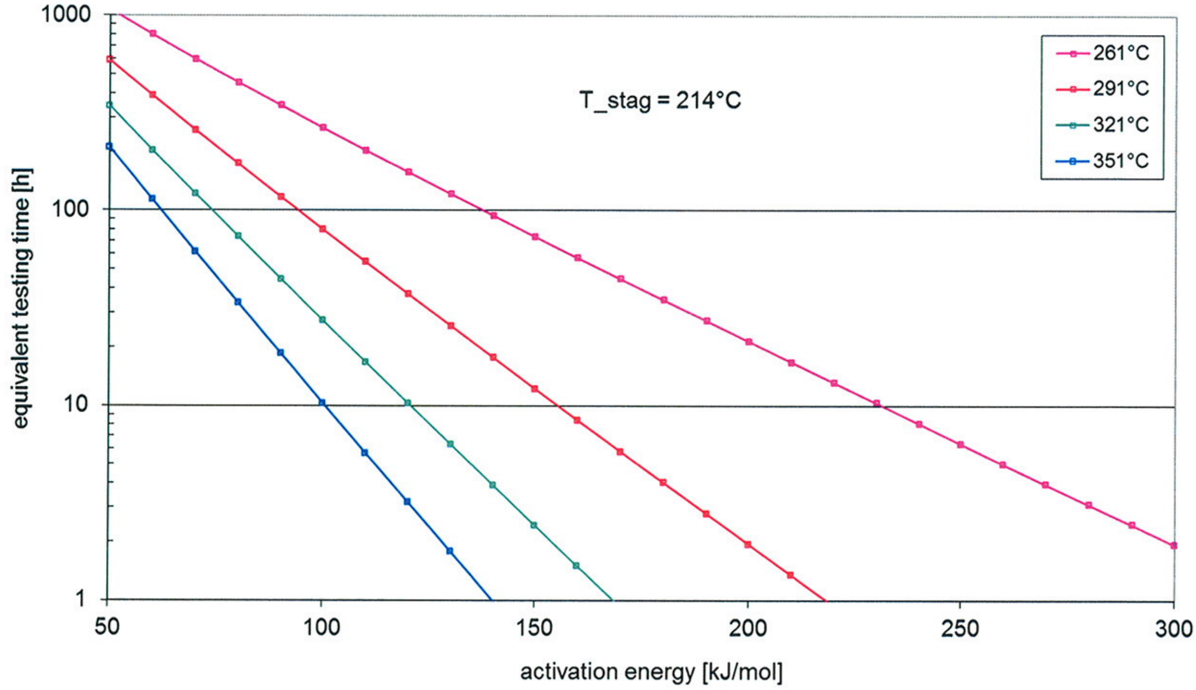


**Figure 1 Equivalent testing times for the absorber tested for different testing temperatures.**

As initial testing temperature 291°C has been selected. Thus, the maximum testing time was determined to be 600h, corresponding to a minimum activation energy of 50kJ/mol.

## 3. Test results

The extent of degradation (PC-function) for the absorber coating after exposure at 291°C is given in Table 3 & Table 4 below.

**Table 3 The extent of degradation at the 291°C test.**

| sample | Changes in optical properties at 291 °C sample temperature | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 36h | | | 75h | | | 150h | | |
| | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC |
| 1 | 0.001 | 0.001 | 0.002 | 0.001 | 0.000 | 0.001 | 0.002 | 0.006 | 0.005 |
| 2 | 0.001 | 0.001 | 0.002 | 0.001 | 0.000 | 0.001 | 0.002 | 0.006 | 0.005 |
| 3 | 0.002 | 0.002 | 0.003 | 0.002 | 0.003 | 0.004 | 0.003 | 0.000 | 0.003 |
| **mean** | | | **0.002** | | | **0.002** | | | **0.004** |

**Table 4 The extent of degradation at the 291 °C test.**

| sample | Changes in optical properties at 291 °C sample temperature | | | | | |
|---|---|---|---|---|---|---|
| | 300h | | | 600h | | |
| | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC |
| 1 | 0.003 | 0.003 | 0.005 | 0.005 | 0.004 | 0.007 |
| 2 | 0.003 | 0.003 | 0.005 | 0.004 | 0.001 | 0.005 |
| 3 | 0.003 | 0.004 | 0.005 | 0.004 | 0.004 | 0.006 |
| **mean** | | | **0.005** | | | **0.006** |

As can be seen in Table 3&4 the mean value of the PC-function for the three test specimens does not exceed 0.01 after the maximum testing time of 600h. For this reason no secondary temperature test was needed for qualification [1]. The tested coating is thus supposed to withstand the thermal loads of a flat plate collector described in Table 2 for more than 25 years. The cross cut test (ISO 2409 for soft coatings) had the result GT 0 (i.e. no adhesion problem). Thus, the absorber coating has qualified with regards to its thermal stability.

## 4. References

[1] prEN 12975-3-1:2011; Solar Energy - Collector components and materials-Part 3: Absorber surface durability.

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