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Qualification Test of Solar Absorber Coating Durability

- Part 2

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, 2, 3]. The full test consists of 3 independent 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 (SO₂)

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:

$$PC = -\Delta\alpha_s + 0.5\Delta\epsilon_{100}$$

Test material

| | |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Commissioner: | ALMECO-TINOX GMBH Triebstraße 3 D-80993 München |
| 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: | March 2009 |
| Expiration date: | July 2012 (The test result is no longer valid after substantial changes of the coating or substrate) |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 has qualified to be used in single glazed flat plate collectors.

Measuring of optical properties

Solar absorptance, α_S

Solar absorptance, α_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. α_S was calculated for airmass (AM) 1.5 using hemispherical solar spectral irradiance data as described in ISO 9845-1.

Thermal emittance, ε_{100}

The thermal emittance, ε_{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 ε_{100} . It was generated according to Planck's law of black body radiation.

Testing chambers

A Horstmann humidity cabinet, type HS 220 K 45 (volume 0.22m³) was used for the condensation tests.

The samples were mounted on a water cooled metal sample holder, which was tilted 45°. The temperature of the samples was measured with a calibrated ($\pm 1^\circ\text{C}$) Pt-100 sensor. The temperature of the cabinet was 5°C higher than the sample temperature. The humidity inside the cabinet was 95% RH. The samples were electrically insulated from the sample holder by Teflon films.

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 α_S and ε_{100} respectively.

1. Optical properties of unaged absorber surface

The mean values of solar absorptance, α_s and thermal emittance, ϵ_{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, α_s | Emittance, ϵ_{100} |
| Mean value | 0.948 | 0.043 |
| Standard deviation | 0.001 | 0.004 |
| Minimum value | 0.947 | 0.038 |
| Maximum value | 0.950 | 0.051 |

The test specimens are qualified for testing, since the standard deviation for solar absorptance α_s and thermal emittance ϵ_{100} are less than 0.01 and 0.04, respectively.

2. Test conditions

To assure permanent condensation of water on the absorber surface, the ambient temperature was kept 5°C above the sample temperature at a humidity level of 95%. Figure 1 shows the testing times which are equivalent to the load caused by humidity and wetness in a standard flat plate collector during 25 years of operation.

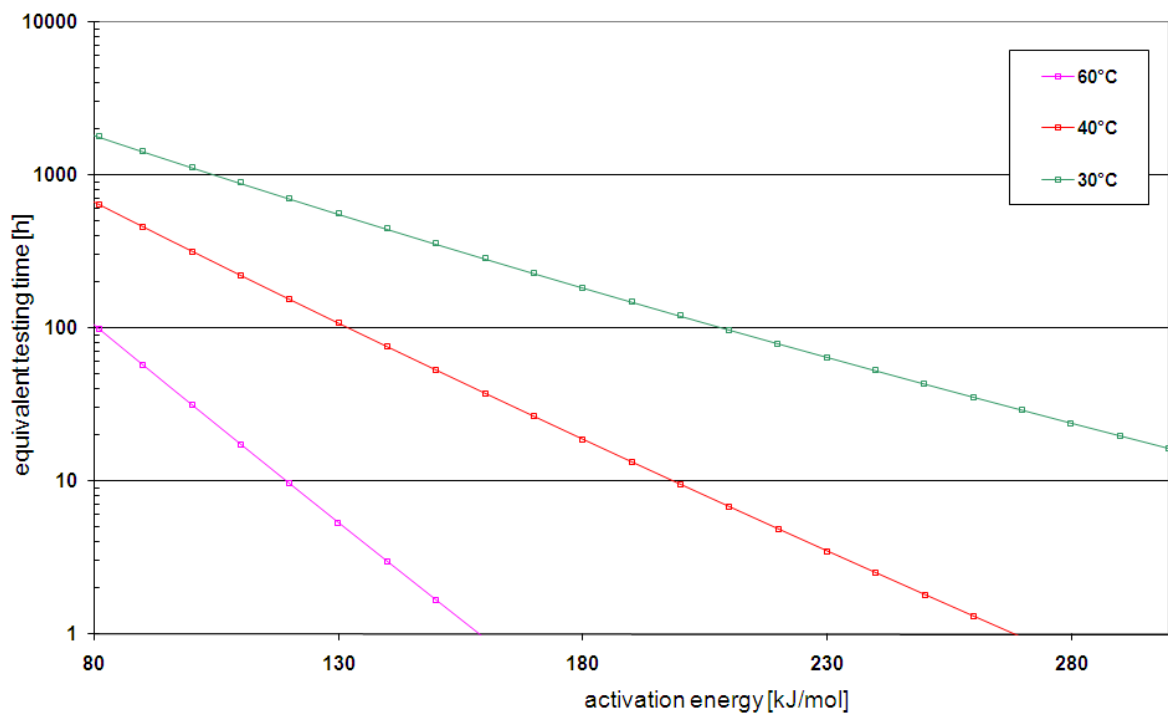


Figure 1 Equivalent testing times for the absorber tested for different testing temperatures.

As initial testing temperature 40°C has been selected. Thus, the maximum testing time was determined to be 600h, corresponding to a minimum activation energy of 80kJ/mol.

3. Test Results

The extent of degradation (PC-function) for the absorber coating after exposure at 40°C under continuous condensation is given in Table 2a & 2b below.

Table 2a The extent of degradation at the 40°C condensation test.

| sample | Changes in optical properties at 40°C sample temperature | | | | | |
|-------------|----------------------------------------------------------|---------------------------|---------------|-------------------|---------------------------|---------------|
| | 75h | | | 150h | | |
| | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC |
| 1 | -0.002 | 0.001 | -0.002 | -0.002 | -0.002 | -0.003 |
| 2 | -0.002 | 0.000 | -0.002 | -0.001 | -0.003 | -0.003 |
| 3 | -0.002 | -0.002 | -0.003 | -0.005 | 0.002 | -0.004 |
| mean | | | -0.002 | | | -0.003 |

Table 2b The extent of degradation at the 40°C condensation test.

| sample | Changes in optical properties at 40°C sample temperature | | | | | |
|-------------|----------------------------------------------------------|---------------------------|---------------|-------------------|---------------------------|---------------|
| | 300h | | | 600h | | |
| | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC | $-\Delta\alpha_s$ | $\Delta\varepsilon_{100}$ | PC |
| 1 | -0.004 | 0.003 | -0.003 | -0.004 | 0.002 | -0.003 |
| 2 | -0.002 | -0.004 | -0.004 | -0.004 | 0.002 | -0.003 |
| 3 | -0.005 | 0.001 | -0.005 | -0.006 | 0.003 | -0.005 |
| mean | | | -0.004 | | | -0.004 |

As can be seen in Table 2a & 2b the mean value of the PC-function for the three test specimens does not exceed 0.015 after the maximum testing time of 600h. For this reason no secondary condensation test was needed for qualification[2].

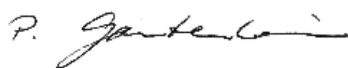
The cross cut test (ISO 2409) had the result grade 0 (i.e. no adhesion problem). Thus, the absorber coating has qualified with regards to its stability against high humidity and condensation.

4. References

- [1] Brunold, S.; Frei, U.; Carlsson, B.; Möller, K.; Köhl, M.; (2000). Accelerated Life Testing of Solar Absorber Coatings: Testing Procedure and Results. *Solar Energy* 68, 313-323.
- [2] Carlsson, B.; Möller, K.; Köhl, M.; Frei, U.; Brunold, S. (2000). Qualification Test Procedure for Solar Absorber Surface Durability. *Solar Energy Materials and Solar Cells* 61, 225-275.
- [3] Köhl, M.; Heck, M.; Brunold, S.; Frei, U.; Carlsson, B.; Möller, K.; (2004) Advanced Procedure for the assessment of the lifetime of solar absorber coatings. *Solar Energy Materials and Solar Cells*, 84, 275-289

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