

Qualification Test of Solar Absorber Coating Durability

- 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 (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:

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

Test material

Commissioner:

ALMECO GmbH
Claude Breda Straße 3
D-06406 Bernburg, Germany

Trade name:

TiNOX energy Al

Description:

Protection and antireflection layer on the basis of an Oxide – CERMET absorber multilayer – adhesion layer – Aluminium substrate

Date of delivery:

August 2013

Expiration date:

September 2016
(The test result is no longer valid after substantial changes of the coating or substrate)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, 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 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 Snijstaal, type S 30 I (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 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	0.952	0.036
Standard deviation	0.000	0.001
Minimum value	0.951	0.034
Maximum value	0.953	0.038

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:

$$T_{\text{Stagnation}} = 214^{\circ}\text{C}$$

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 " $\alpha(\text{AR})$ " has to be used for the solar absorptance, for collectors equipped with non-coated solar glass, column " α " has to be used.

		$\epsilon \rightarrow$	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11
$\alpha(\text{AR})$	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).

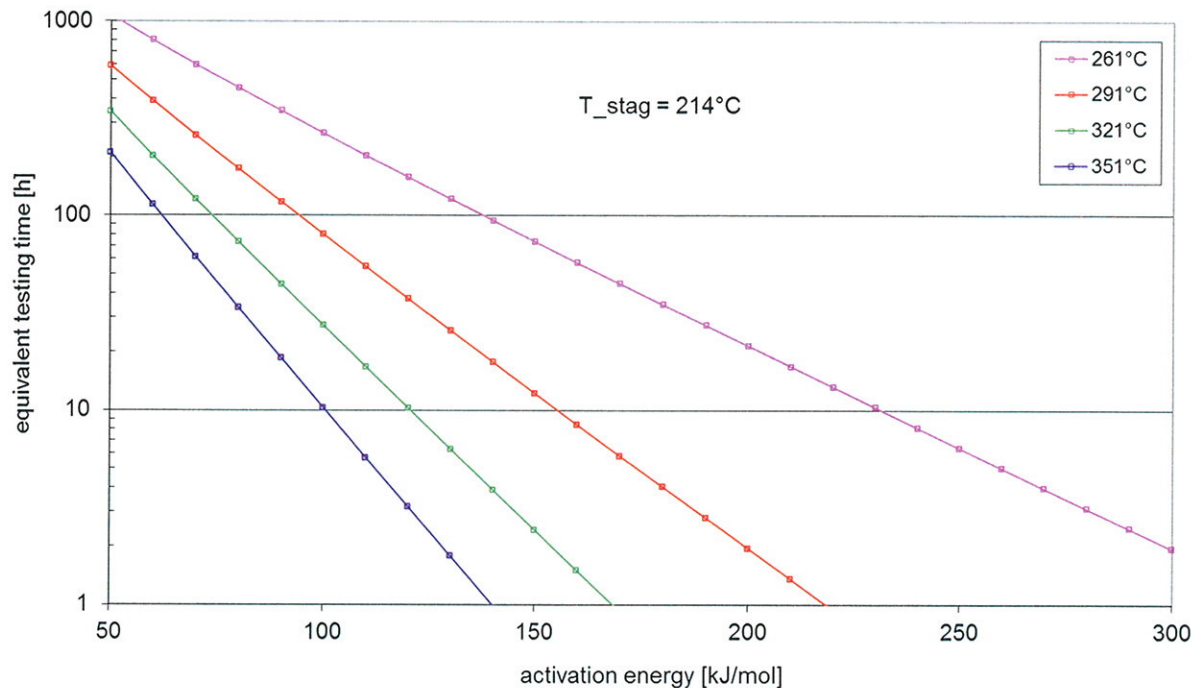


Figure 1 Equivalent testing times for the absorber tested for different testing temperatures.

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		
	$-\Delta\alpha_s$	$\Delta\epsilon_{100}$	PC	$-\Delta\alpha_s$	$\Delta\epsilon_{100}$	PC	$-\Delta\alpha_s$	$\Delta\epsilon_{100}$	PC
1	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.002	0.002
2	0.001	0.002	0.002	0.001	0.002	0.002	0.001	0.004	0.003
3	0.001	-0.002	0.000	0.001	-0.001	0.001	0.000	0.001	0.001
mean			0.001			0.001			0.002

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

sample	Changes in optical properties at 291 °C sample temperature					
	300h			600h		
	$-\Delta\alpha_s$	$\Delta\epsilon_{100}$	PC	$-\Delta\alpha_s$	$\Delta\epsilon_{100}$	PC
1	0.001	0.001	0.002	0.002	-0.001	0.002
2	0.000	0.002	0.001	0.001	0.003	0.003
3	0.001	-0.001	0.001	0.003	0.000	0.003
mean			0.001			0.002

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 **Error! Reference source not found.** 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.

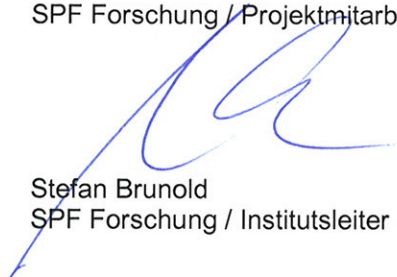
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