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 (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:	ALANOD Aluminium-Veredelung GmbH & Co. KG Egerstrasse 12 DE-58256 Ennepetal
Trade name:	sunselect
Description:	Tin oxide on chromium oxynitride on copper
Date of delivery:	Mai 2012
Expiration date:	Dezember 2015 (The test result is no longer valid after substantial changes of the coating or substrate)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 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 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	0.928	0.025
Standard deviation	0.001	0.003
Minimum value	0.928	0.020
Maximum value	0.929	0.031

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												
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
0.87	0.92		211	208	204	202	199	196	194	192	190	188	186
0.86	0.91		209	206	203	200	197	195	193	190	189	187	185
0.85	0.90		208	204	201	198	196	193	191	189	187	185	183
0.84	0.89		206	203	199	197	194	192	190	187	186	184	182
0.83	0.88		204	201	198	195	193	190	188	186	184	182	181

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

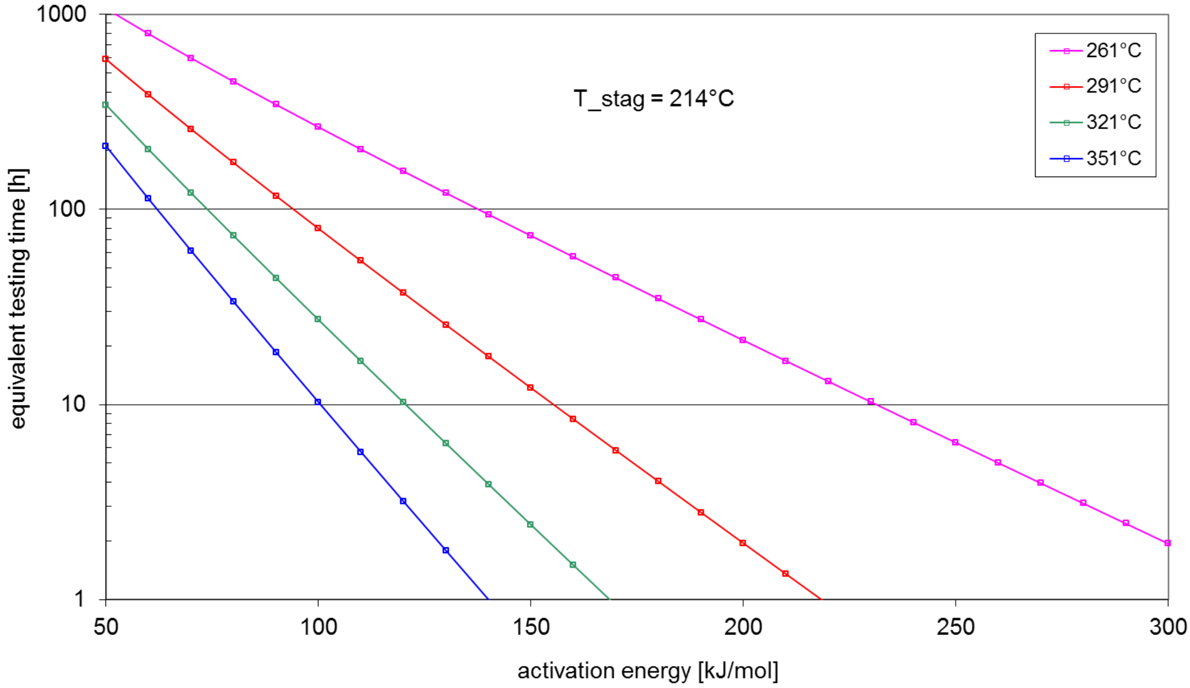

Figure 1 Equivalent testing times for the absorber tested for different testing temperatures.

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	0.013	-0.006	0.010	0.015	-0.008	0.011	0.016	-0.010	0.011
2	0.013	-0.008	0.009	0.015	-0.007	0.012	0.016	-0.011	0.011
3	0.013	-0.006	0.010	0.015	0.007	0.012	0.016	-0.011	0.011
mean			**0.010**			**0.011**			**0.011**

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	0.019	-0.009	0.015	0.021	-0.007	0.018
2	0.019	-0.009	0.015	0.020	-0.007	0.017
3	0.019	-0.010	0.014	0.021	-0.010	0.016
mean			**0.014**			**0.017**

As can be seen in Table 3&4 the mean value of the PC-function for the three test specimens was >0.01 but < 0.05 after the maximum testing time. For this reason secondary temperature test was needed for qualification.

Table 5 The extent of degradation at the 321°C test

sample	Changes in optical properties at 321 °C sample temperature		
	350h		
	$-\Delta\alpha_s$	$\Delta\varepsilon_{100}$	PC
4	0.050	0.011	0.056
5	0.045	0.018	0.054
6	0.053	0.018	0.062
mean			**0.057**

The secondary test was carried out at a temperature of 321°C. The equivalent testing time for this temperature and the minimal activation energy of 50kJ/mol is 350h (see Figure 1). The PC-function of this secondary test (321°C) was higher than the PC-function at the equivalent time of the first test (291°C). The activation energy is thus higher than 50kJ/mol and the estimated degradation after 25 years of use in a flat plate collector is less than the measured PC of 0.017.

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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