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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, 2, 3]. 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:

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

Test material

Commissioner: ALMECO-TINOX GMBH
Triebstraße 3
D-80993 München

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: October 2008

Expiration date: January 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(The test result is no longer valid after substantial changes of the coating or substrate)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 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 °C) 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	0.944	0.031
Standard deviation	0.001	0.004
Minimum value	0.943	0.023
Maximum value	0.945	0.041

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:

$$T_{\text{Stagnation}} = 208^{\circ}\text{C}$$

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.

α (AR)	$\epsilon > \alpha$	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11
		0.98		235	230	226	222	219	216	213	211	208	206
0.97		233	228	224	221	218	215	212	209	207	204	202	200
0.96		231	227	223	219	216	213	210	208	205	203	201	199
0.95	1.00	229	225	221	218	214	211	209	206	204	202	200	198
0.94	0.99	228	223	219	216	213	210	207	205	202	200	198	196
0.93	0.98	226	222	218	214	211	208	206	203	201	199	197	195
0.92	0.97	224	220	216	213	210	207	204	202	199	197	195	193
0.91	0.96	222	218	214	211	208	205	203	200	198	196	194	192
0.90	0.95	220	216	213	209	206	204	201	199	196	194	192	191
0.89	0.94	219	215	211	208	205	202	200	197	195	193	191	189
0.88	0.93	217	213	209	206	203	200	198	196	193	191	190	188
0.87	0.92	215	211	208	204	202	199	196	194	192	190	188	186
0.86	0.91	213	209	206	203	200	197	195	193	190	189	187	185

Basing on the typical stagnation temperature, the equivalent testing times can be calculated (see Figure 1 Equivalent testing times for the absorber tested for different testing temperatures. Figure 1).

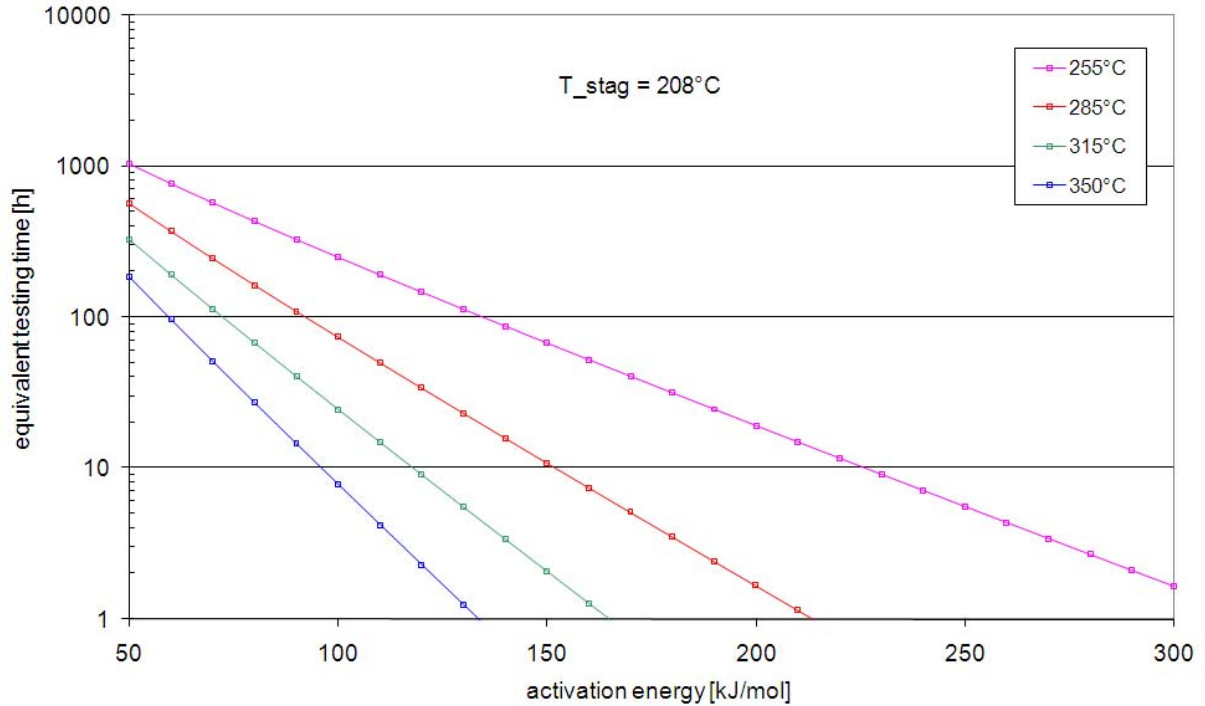


Figure 1 Equivalent testing times for the absorber tested for different testing temperatures.

As initial testing temperature 285°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 285°C is given in Table 3a & 3b below.

Table 3a The extent of degradation at the 285°C test.

sample	Changes in optical properties at 285 °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	0.002	0.000	-0.001	-0.002	-0.002	0.005	0.000	0.005
2	-0.001	0.006	0.002	-0.001	0.002	0.000	0.005	-0.001	0.005
3	-0.001	-0.003	-0.003	-0.001	-0.003	-0.003	0.004	-0.003	0.003
mean			0.000			-0.002			0.004

Table 3b The extent of degradation at the 285 °C test.

sample	Changes in optical properties at 285 °C sample temperature					
	300h			600h		
	$-\Delta\alpha_s$	$\Delta\varepsilon_{100}$	PC	$-\Delta\alpha_s$	$\Delta\varepsilon_{100}$	PC
1	0.009	0.003	0.010	0.013	0.001	0.013
2	0.009	0.010	0.014	0.014	0.006	0.017
3	0.010	0.005	0.012	0.014	0.001	0.014
mean			0.012			0.015

As can be seen in Table 3a & 3b the mean value of the PC-function for the three test specimens was 0.015 after the maximum testing time of 600h. This value is >0.01 , thus a new test at a temperature of 315°C has to be carried out. The equivalent testing time at this temperature for the minimal activation energy of 50kJ/mol is 346h [3].

Table 4 The extent of degradation at the 315°C Test.

sample	Changes in optical properties at 315 °C sample temperature		
	346h		
	$-\Delta\alpha_s$	$\Delta\varepsilon_{100}$	PC
1	0.017	0.008	0.021
2	0.017	0.015	0.024
3	0.018	0.014	0.025
mean			0.023

The extent of degradation after the 315°C test is higher than after 600h at 285°C, see Table 3a, 3b & 4. This result implies an activation energy $> 50\text{kJ/mol}$ for the observed optical degradation. 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) had the result grade 0 (i.e. no adhesion problem). Thus, the absorber coating has qualified with regards to its thermal stability.

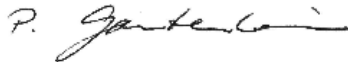
4. References

- [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.: Advanced Procedure for the assessment of the lifetime of solar absorber coatings. *Solar Energy Materials and Solar Cells*, Volume 84, Issues 1-4 , October 2004, Pages 275-289

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