Fraunhofer Institut
Solare Energiesysteme

REPORT

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Qualification Tests of *TiNOX* Solar Collector Absorber Coating with Respect to Thermal Stability and Resistance to Humidity Involving Condensation

Commissioner

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Test materials

TiNOX on copper 3362

Arrival date of test materials

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Commission

Qualification testing of absorber surface durability according to the ISO draft proposal No.: CD 12 952.2 test procedures described below.

Summary

The Tinox absorber surface has passed the high temperature test and the condensation test, i.e., the absorber coating is qualified according to the test procedures concerning high temperature durability and resistance to high humidity and condensation described in ISO/CD 12952.2.

Test procedures

The coating was tested according to a proposal for ISO standard (ISO/CD 12952.2 - *Qualification test procedure for solar absorber surface durability*). The ISO standard proposal is primarily based on test procedures described in *"Accelerated Life Testing of Solar Energy Materials - Case Study of Some Selective Absorber Coating Materials for DHW Systems"*, a technical report of IEA Solar Heating and Cooling Programme Task X: Solar Materials Research and Development, *SP report 1994:13, ISBN 91-7848-472-3.*

The qualification tests include assessment of:

Thermal stability
Resistance to humidity and condensation

Measured properties are:

Solar absorptance, α_S
Thermal emittance, ε

Measurement of optical properties

Solar absorptance, α_S and thermal emittance, ε

Solar absorptance, α_S, was measured with a Bruker IFS 66 FT-spectrophotometer equipped with integrating spheres. Labsphere spectralon and diffuse-gold were used as reflectance references. α_S was calculated for airmass 1.5 using selected ordinates as described in ISO/CD 12952.2. ε was calculated for a temperature of 100 °C using the Planck radiation distribution for 373 K.

Testing chambers

Testing chambers fulfilling the requirements in ISO/CD 12952.2 were used.

In the thermal stability tests a Binder (volume 120 litre) circulating air oven was used. The temperatures were measured with a calibrated (±1 K) type K thermocouple.

In the high humidity and condensation tests HS-Simulatoren humidity cabinet, type HS-220 K49/C was used.

In the high humidity and condensation tests the samples were clamped against a water cooled metal sample holder, which was tilted 45°. The temperature of the samples was measured with a calibrated (± 1 K) Pt-100 sensor. The temperature of the cabinet was 5 K 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

$$PC = -\Delta\alpha_S + 0.25\Delta\varepsilon$$

where $\Delta\alpha_S$ and $\Delta\varepsilon$ are the changes in α_S and ε respectively.

Requirements for qualification:

A. Unaged absorber surface: To be qualified for testing, the set of test specimens shall have a standard deviation in determined values for solar absorptance of less than 0,01 and for determined values of thermal emittance a standard deviation less than 0,04.

B. Thermal stability: To be qualified the absorber surface has to fulfil the requirements in subclause 6.4 in ISO/CD 12952.2.

C. Resistance to high humidity and condensation: To be qualified the absorber surface has to fulfil the requirements in subclause 7.4 or 7.5 in ISO/CD 12952.2 depending on solar collector severity class.

Results

Optical properties of unaged absorber surface

The mean values of solar absorptance, α_s and thermal emittance, ε, for unaged TiNOX absorber are given in **Table 1** below.

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

Values	Optical properties of unaged absorber coatings	
	Solar Absorptance, α_S	Emittance, ε
Mean value ± standard deviation	0,946±0,001	0,038±0,003
Maximum value	0,947	0,043
Minimum value	0,945	0,034

The test specimens are qualified for testing according to ISO/CD 12952.2, since the standard deviation for solar absorptance and thermal emittance are less than 0,01 and 0,04, respectively.

Thermal stability of absorber surface

Three samples were tested according to the procedure described in ISO/CD 12952 subclause 6.3.

The extent of degradation (PC-function) for the absorber coating after 200 hours of exposure is given in **Table 2** below.

Table 2. The extent of degradation at 250 °C after 200 hours.

Sample	**Changes in optical properties after 200 hours at 250 °C**		
	$-\Delta\alpha$	$\Delta\varepsilon$	PC
1	0,006	0,026	0,013
2	0,006	0,028	0,013
3	0,006	0,027	0,013
Mean value	**0,006**	**0,027**	**0,013**

As can be seen in **Table 2** the PC-function never exceeds 0,05 for neither of the three test specimens. According to the test procedure described in the ISO standard proposal the coating was, therefore, tested at 300 °C for 75 hours. The results are given in **Table 3** below.

Table 3. Measured PC-values after 75 hours at 300 °C.

Sample	**Changes in optical properties after 75 hours at 300 °C**		
	$-\Delta\alpha$	$\Delta\varepsilon$	PC
1	0,039	0,014	0,043
2	0,037	0,015	0,037
3	0,036	0,013	0,039
Mean value	**0,037**	**0,014**	**0,040**

As can be seen in **Table 3** the values of the PC-function, in the 300 °C test, exceed the corresponding values in **Table 2**. The absorber surface is, therefore, qualified.

Resistance to humidity and condensation of absorber surface

Three samples were tested according to the procedure described in sec. 7.4. of ISO/CD 12952.2.
The values of the PC function versus the exposure time are given in **Table 4**.

Table 4. Extent of degradation (PC-function) after 80, 150, 300, and 600 hours at 40/45 °C in high humidity and condensation test.

Sample	Changes in optical properties at 40 °C sample temperature and 45 °C cabinet temperature after 80, 150, 300 and 600 hours, respectively											
	80 hours			150 hours			300 hours			600 hours		
	$-\Delta\alpha$	$\Delta\varepsilon$	PC	$-\Delta\alpha$	$\Delta\varepsilon$	PC	$-\Delta\alpha$	$\Delta\varepsilon$	PC	$-\Delta\alpha$	$\Delta\varepsilon$	PC
1	-0,002	-0.003	-0.003	-0.003	-0.003	-0.004	-0.004	0.011	0.001	-0.001	0.023	0.004
2	-0,002	0.001	-0.002	-0.002	0.007	0.000	-0.003	0.017	0.001	-0.001	0.031	0.007
3	-0,002	0.000	-0.002	-0.002	0.001	-0.002	-0.003	0.014	0.001	-0.001	0.025	0.005
Mean value	**-0,002**	**-0.001**	**-0.002**	**-0.002**	**0.002**	**-0.002**	**-0.003**	**0.014**	**0.001**	**-0,001**	**0.026**	**0.005**

As can be seen in **Table 4** the values of the PC-function are below 0,05 after 600 hours of exposure for all three test specimens. According to the test procedure described in subclause 7.4. of ISO/CD 12952.2 the coating was, therefore, tested at 60 °C for 85 hours. The results of the 60/65 °C test are given in **Table 5** below.

Table 5. Degradation of the coating after 85 hours at 60 °C in the high humidity and condensation test.

Sample	Changes in optical properties after 85 hours at 60 °C sample temperature and 65 °C cabinet temperature		
	$-\Delta\alpha$	$\Delta\varepsilon$	PC
1	-0.004	-0.001	-0.004
2	-0.003	0.005	-0,002
3	0.000	0.005	0.001
Mean value	**-0.002**	**0.003**	**-0.002**

The extent of degradation (PC-function) in the 60/65 °C test (-0,002) and in the 40 °C test (0.005) are both below 0.01 and differ less than 0.01 which means that the absorber surface is qualified for the application in ventilated flat-plate solar Moreover, the values of the PC-function never exceed 0,01.

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