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Test Report

ISO 22975-3 Part 3: *Absorber Surface Durability*

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Part B

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 coating was tested according to ISO/EN 22975-3 Part 3 with regards to:

Part B: Stability with regards to high humidity and condensation

Test material

Commissioner:	ALMECO GmbH Claude Breda Strasse 3 D-06406 Bernburg, Germany
Trade name:	TiNOX energy Al
Description:	Selective solar absorber: PVD coating with protection and antireflection layer based on silica glass / cermet absorber multilayer / adhesion layer / aluminium substrate
Start of test:	October 2022
Completion of test:	February 2023
Expiration date:	February 2028 (The test result is no longer valid after substantial changes of the coating or substrate)

Test results

The test material has passed **part B (stability with regards to high humidity and condensation)** of the test according to ISO 22975-3 and it is qualified to be used in single glazed flat plate collectors.

Preliminary Testing

Sample conditioning

According to clause 5.2 of the ISO 22975-3 standard, the optical properties of three samples as-received were measured in order to determine the temperature for pre-conditioning using Table B.1 from the standard. The results are presented in Table 1.

Table 1: Optical properties of three as-received samples and pre-conditioning temperature

	Sample V1	Sample V2	Sample V3	Mean value
Solar absorptance, α_s	0.957	0.956	0.958	**0.957**
Thermal emittance, ε_{100}	0.041	0.056	0.047	**0.048**
Temperature to be applied for pre-conditioning of the samples				**213°C**

Qualification for testing

In total, 18 samples have been pre-conditioned by tempering for 5 hours at the temperature given in Table 1. After pre-conditioning, an adhesion test according to clause 5.5 of the ISO 22975-3 standard was performed for three of the samples. The results are presented in Table 2. As the adhesion test result grade is ≤ 1, according to clause 4.3 of the ISO 22975-3, the three samples have passed the adhesion test.

Table 2: Result of the adhesion test performed on three samples after pre-conditioning

	Sample 1	Sample 2	Sample 3
Adhesion test result grade	0	0	0

The optical properties of the remaining 15 samples were measured. The value of the solar absorptance and thermal emittance was determined as specified in clause 5.3 and 5.4 from ISO/EN 22975-3. The results are presented in Table 3.

Table 3: Mean values of the optical properties of 15 samples after pre-conditioning

	Solar absorptance, α_s	Thermal emittance, ε_{100}
Mean value	0.958	0.048
Standard deviation	0.001	0.004
Minimum value	0.957	0.040
Maximum value	0.959	0.053

The standard deviation for solar absorptance and thermal emittance is less than 0.01 and 0.04, respectively (Table 3). Thus, according to clause 4.2 and 4.3 of the ISO 22975-3 standard, the test specimens are qualified for testing.

Tests for determining the resistance to condensed water of absorber surfaces

According to the clause 7.4.1 of the ISO 22975-3 standard, three tempered samples were exposed to the first testing temperature level T_1 = 40°C for a testing time up to 600 h or until PC ≥ 0.05. Time t_1 is defined to be the latest testing time with PC ≤ 0.05. The optical properties determined after 600 h and the value of t_1 are presented in Table 4.

Table 4: PC mean value of three samples after testing at T_1 = 40°C and identification of t_1

Time of exposure	18 h*)	36 h*)	75 h*)	150 h*)	300 h*)	600 h
PC	-	-	-	-	-	0.007
t_1 =	600 h					

*) It was known from extensive preliminary tests on this absorber surface that no significant changes are to be expected as a result of exposure to condensation at 40°C. Therefore, the measurement of the optical properties after these short intervals was omitted.

According to the clause 7.4.2 of the ISO 22975-3 standard, the absorber coating is qualified with regards to its stability against high humidity and condensation if after testing for a testing time t_1 = 600h at temperature level T_1:

- the PC(t_1) ≤ 0.015 and
- the adhesion test of the three tested samples at T_1 was leading to a result grade ≤ 1.

Table 5: Results of the adhesion tests performed on three samples after the longest testing period at testing temperature T_1

	Sample 1	Sample 2	Sample 3
Adhesion test result grade	0	0	0

As the absorber coating meets the required conditions, the test material has passed part B (stability with regards to high humidity and condensation) according to ISO 22975-3 and it is qualified to be used in single glazed flat plate collectors.

SPF Institute for Solar Technology
Rapperswil, February 2023

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SPF Project manager

Stefan Brunold
SPF Deputy Head of Institute

Annex

Deviations from the testing method

The optical properties were determined only for 600h in this testing procedure. For the other testing times (18 h, 36 h, 75 h, 150 h and 300 h), they were evaluated in another project and significant changes occurred. All PC values were very small (PC ≤ 0.015), in the range needed for qualification.

Solar absorptance, α_s

Hemispherical reflectance was measured with a BRUKER VERTEX 80 UV-VIS-MIR Fourier-transform spectrophotometer equipped with an 150 integrating sphere. 'Spectralon' diffuse reflectance standard was used as a reflectance reference. The solar absorptance was calculated for airmass 1.5 using the hemispherical solar spectral irradiance data as described in ISO 9050:2003.

Thermal emittance, ε_{100}

For thermal emittance evaluation, the same instrument was used to measure the hemispherical reflectance, but with an 'Infragold' reflectance standard as a reference. The black body radiation spectrum for a temperature of 100°C (373 K) was used for the thermal emittance calculation. It was generated according to Planck's law of black body radiation.

Performance criterion, PC

The performance criterion, which shows the changes in performance of an absorber surface in terms of solar absorptance and thermal emittance, was calculated using Eq. 1. For classification of the durability of the absorber surface, the following performance requirement is applied, according to the ISO/EN 22975-3:2014 standard:

$$PC = -\Delta\alpha_s + 0.50\,\Delta\varepsilon \leq 0.05 \qquad \text{Eq. 1}$$

where: $\Delta\alpha_s$ is the change in solar absorptance, defined as:

$\Delta\alpha_s = \alpha_{s,t} - \alpha_{s,i}$, where $\alpha_{s,t}$ is the solar absorptance at the actual time of the test, and $\alpha_{s,i}$ represents the initial value of solar absorptance.

and $\Delta\varepsilon$ is the change in thermal emittance, defined as:

$\Delta\varepsilon = \varepsilon_t - \varepsilon_i$ where ε_t is the thermal emittance at the actual time of the test and ε_i represents the initial value of thermal emittance.

Testing chambers

A CTS humidity cabinet (type CL-40/350/S) 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 (± 1°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 a Teflon coating.

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Detailed Results

Nr.	Sample code	Reference		5h @ 215°C		18h		36h		75h		150h		300h		600h	
		α_s	ε_{100}	α_s	ε_{100}	α_s	ε_{100}	α_s	ε_{100}	α_s	ε_{100}	α_s	ε_{100}	α_s	ε_{100}	α_s	ε_{100}
1.	ALMC220900xZ	0.957	0.041	0.958	0.043												
2.	ALMC220901xZ	0.956	0.056	0.957	0.044												
3.	ALMC220902xZ	0.958	0.047	0.959	0.040												
4.	ALMC220903xZ			0.957	0.048												
5.	ALMC220904xZ																
6.	ALMC220905xZ																
7.	ALMC220906xZ			0.958	0.049												
8.	ALMC220907xZ			0.959	0.049												
9.	ALMC220908xZ			0.958	0.050												
10.	ALMC220909xZ			0.958	0.051												
11.	ALMC220910xZ			0.959	0.042											0.956	0.052
12.	ALMC220911xZ			0.959	0.044											0.957	0.048
13.	ALMC220912xZ			0.958	0.045											0.954	0.055
14.	ALMC220913xZ			0.959	0.048												
15.	ALMC220914xZ			0.958	0.051												
16.	ALMC220915xZ			0.958	0.053												
17.	ALMC220916xZ			0.958	0.053												
18.	ALMC220917xZ			0.958	0.052												