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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 robust Al
Description:	Selective solar absorber: PVD coating with protection and antireflection layer based on oxide ceramic / cermet absorber multilayer / adhesion layer / aluminium substrate
Start of test:	December 2021
Completion of test:	May 2022
Expiration date:	May 2027 (The test result is no longer valid after substantial changes of the coating or substrate)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 as-received samples have been measured in order to determine the temperature for pre-conditioning by the use of 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	0.932	0.932	0.932	**0.932**
Emittance, ε_{100}	0.030	0.032	0.033	**0.032**
Temperature to be applied for pre-conditioning of the samples				**214°C**

Qualification for testing

In total, 18 samples have been pre-conditioned by tempering for 5 hours at the temperature given in Table 1. The optical properties after tempering were determined and they are presented in Table 2. The value of the solar absorptance and thermal emittance was determined for each of the 18 test samples as specified in clause 5.3 and 5.4 from ISO/EN 22975-3.

Table 2: Mean values of the optical properties of 18 samples after pre-conditioning

	Solar absorptance, α_s	Emittance, ε_{100}
Mean value	0.932	0.034
Standard deviation	0.001	0.002
Minimum value	0.930	0.030
Maximum value	0.935	0.037

After pre-conditioning, an adhesion test according to ISO 2409 (for soft samples) has been applied to three of the samples. The results are presented in Table 3.

Table 3: 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

According to clause 4.2 and 4.3 of the ISO 22975-3 standard, the test specimens are qualified for testing. The standard deviation for solar absorptance and thermal emittance is less than 0.01 and 0.04, respectively, and the adhesion test of the three samples was leading to a result grade ≤ 1.

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 different testing times (18, 36, 75, 150, 300 and 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	0.003	0.002	0.003	0.001	-0.002	-0.004
t_1 =	600 h					

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 at temperature level T_1 for a testing time t_1 = 600h:

- the PC(t_1) ≤ 0.015 (see Table 3) 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, May 2022

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Annex

Deviations from the testing method

None.

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.	ALMR211200xZ	0.932	0.030	0.931	0.032												
2.	ALMR211201xZ	0.932	0.032	0.931	0.034												
3.	ALMR211202xZ	0.932	0.033	0.931	0.033												
4.	ALMR211203xZ			0.935	0.031												
5.	ALMR211204xZ			0.931	0.032												
6.	ALMR211205xZ			0.933	0.030												
7.	ALMR211206xZ			0.930	0.031												
8.	ALMR211207xZ			0.931	0.035												
9.	ALMR211208xZ			0.933	0.033												
10.	ALMR211209xZ			0.930	0.035												
11.	ALMR211210xZ			0.930	0.035												
12.	ALMR211211xZ			0.931	0.035												
13.	ALMR211212xZ			0.933	0.036												
14.	ALMR211213xZ			0.931	0.035												
15.	ALMR211214xZ			0.932	0.037												
16.	ALMR211215xZ			0.933	0.035	0.933	0.040	0.934	0.040	0.934	0.043	0.935	0.039	0.935	0.033	0.941	0.042
17.	ALMR211216xZ			0.932	0.035	0.932	0.041	0.933	0.041	0.933	0.043	0.934	0.042	0.934	0.036	0.940	0.041
18.	ALMR211217xZ			0.931	0.034	0.932	0.041	0.933	0.040	0.933	0.041	0.934	0.042	0.934	0.035	0.938	0.044