

## ACCELERATED AGING TESTS OF ABSORBER COATINGS FOR UNGLAZED METALLIC SOLAR COLLECTORS

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### Summary

During the expected minimum life-span of 20 years, the absorber coating of unglazed thermal solar collectors is directly exposed to different stresses like heat, rain and ice. With increasing application possibilities for this type of collectors (e.g. for borehole regeneration), there is a need for the quality certification of absorber coatings. However, there is no standard procedure available to assess the durability of spectrally selective coatings for unglazed collectors. Existing aging tests (ISO 22975-3) are designed for absorber coatings used in glazed solar collectors, where the degradation loads (e.g. for humidity and condensation) are very different. Preliminary steps for developing an accelerated lifetime testing procedure are presented. First results showing the optical performance after aging of two spectrally selective absorber coatings on stainless steel are reported.

Keywords: unglazed solar thermal collectors, spectrally selective absorber coatings, time of wetness, accelerated aging, optical performance.

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### 1. Introduction

For certifying new absorber coatings, the expected service life must be predicted. Accelerated aging tests considering the relevant degradation factors are required. The in-service conditions and environmental stresses must be measured. High temperature, high humidity and moisture, and airborne pollutants were identified by the IEA Working Group MSTC (Materials in Solar Thermal Collectors) as the most relevant degradation factors for glazed flat plate collectors, used for domestic hot water production (Brunold et al., 2000). However, the loads in terms of humidity, condensation, snow/icing and hail largely differ in the case of unglazed collectors, because their absorber coating is directly exposed to the environmental stresses (Dudita et al., 2016).

Several degradation mechanisms are influencing the performance and lifetime of absorber coatings, including metal oxidation, elements diffusion and modification of the antireflective layer (Carlsson et al., 2000; Dudita et al., 2015a). This might influence the optical performance expressed by the solar absorptance ( $\alpha_s$ ) and thermal emittance ( $\epsilon_t$ ), and the long term durability of the absorber coating. High temperature increases the metal oxidation rate leading to a decrease in  $\alpha_s$  and an increase of  $\epsilon_t$ . Humid air and condensation occurring on the absorber surface can lead to hydration reactions of inorganic oxides and electrochemical corrosion. The corrosion can be accelerated by airborne pollutants.

Accelerated lifetime testing of materials is thus highly important for the service life estimation, especially for certification of new products prior to their market introduction. However, there is currently no standard procedure to assess the durability of unglazed metallic absorbers. Existing tests (ISO 22975-3) are specially designed for glazed solar collectors (Brunold et al., 2000).

For developing an accelerated lifetime testing (ALT) procedure, realistic loads for the absorber surface are needed. For unglazed solar thermal collectors, the degradation due to temperature and high humidity and condensation might be predominant. We have performed, as a first step, simulations to determine the temperature frequency distribution (TFD) and time of wetness (TOW) frequency distribution for the absorber surface. A representative TOW diagram which is needed to quantify the humidity induced stress, is presented in this paper. Wetting due to rain or due to environmental humidity condensing on the absorber surface was considered. Moreover, we have performed preliminary tests to assess the durability of new selective coatings on stainless steel substrate that can potentially be used in unglazed collectors. Our tests are based on the procedure mentioned in ISO 22975-3, nonetheless higher testing temperature were also included. Two samples from under development selective coatings were exposed to high humidity and condensation, at

constant temperature (sample temperature between 40 °C and 70 °C) and constant humidity (95% RH). The optical degradation of the coatings was monitored with the help of a Bruker IFS 66/S spectrometer with a custom made configuration. A detailed description of the experimental procedure is described elsewhere (Dudita et al., 2015b).

## 2. Durability assessment of spectrally selective absorber coatings for unglazed solar thermal collectors

The temperature frequency distribution and the time of wetness (TOW) expected for absorber plates of unglazed collectors in different system configurations were determined by means of transient system simulations (TRNSYS v.17). In particular, a heat pump heating system with a small ice storage tank, where the collectors are operated in very harsh conditions, was selected (Mojic et al., 2015). The simulation model of the collector (TRNSYS Type 832 v5.10) includes condensation, frost and rain heat gains. As boundary conditions for the simulations, weather data for different climatic regions were considered.

An example of a yearly time of wetness (TOW) frequency distribution (humidity or condensation) for an unglazed collector is represented in Fig. 1 together with the one specific for the glazed collectors from IEA SHC Task X. The climate data represent a typical year for Zürich (Switzerland), with a time resolution of 6 minutes. Since unglazed collectors are operated at lower temperatures and in the simulated system frequently below dew point, their TOW distribution shows much larger frequencies at low temperatures. Ultimately, the established load profiles, together with the experimentally determined activation energies for the different degradation modes, will be used to define the parameters of the accelerated aging tests.

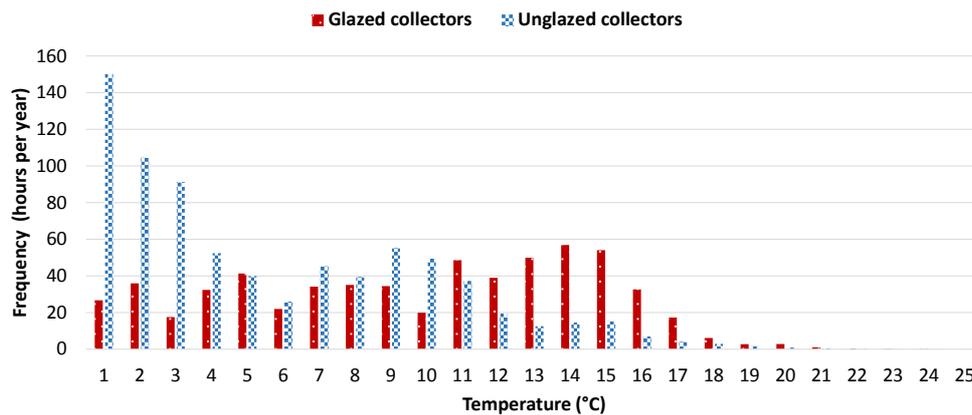
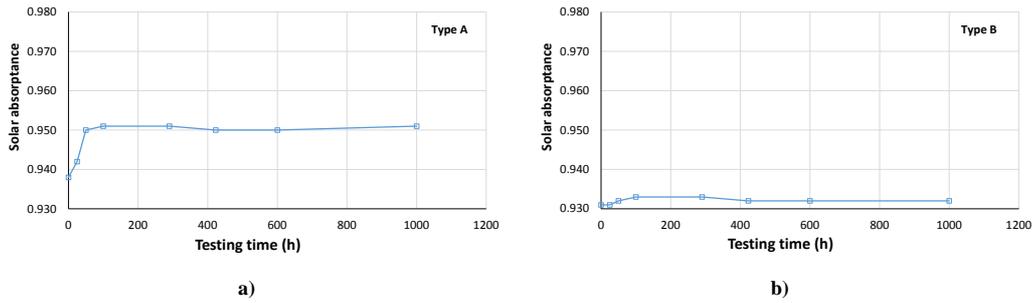
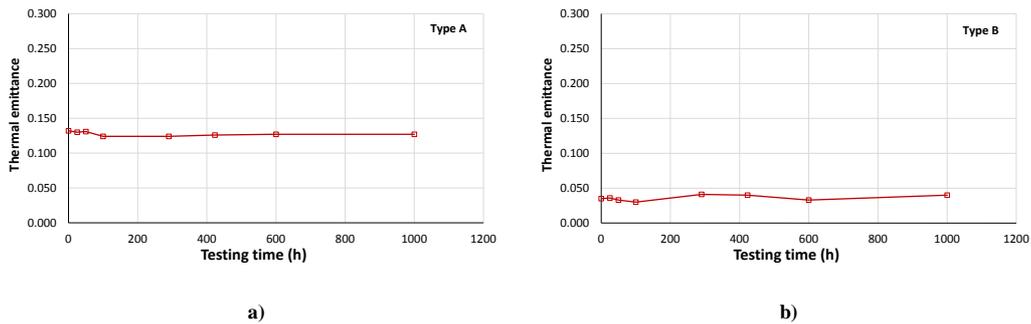


Fig. 1 Yearly time of wetness frequency distributions for absorber surfaces of glazed and unglazed collectors (criteria for the TOW were a relative humidity at the absorber surface of  $RH \geq 99\%$  or a rain rate  $\geq 3\text{mm/h}$ )

The resistance of absorber coatings to high humidity and condensation conditions was investigated for two different absorber coatings. An adapted procedure based on ISO 22975-3 for the qualification of solar absorber coatings used in glazed collectors was followed. Different testing sample temperatures (40°C to 70°C), high humidity and condensation conditions were applied for the two spectrally selective coatings (Type A and Type B) deposited via physical vapor deposition on stainless steel substrate. The optical performance expressed as the variation of solar absorptance and thermal emittance remained constant in the 40°C test (see Fig. 2 and Fig. 3). Higher testing temperatures (60°C and 70°C) were used to estimate the activation energy and the coatings lifetime.



**Fig. 2** Solar absorptance after different testing duration in high humidity (95%) and condensation at 40°C for two spectrally selective absorber coatings: Type A (a) and Type B (b)



**Fig. 3** Thermal emittance after different testing duration in high humidity (95%) and condensation at 40°C for two spectrally selective absorber coatings: Type A (a) and Type B (b)

### 3. Concluding remarks

The market of unglazed solar thermal collectors with spectrally selective coatings on metal substrate is continuously increasing as new applications like boreholes regeneration or combination with ice storages are emerging. There is currently no standard procedure to assess the durability of unglazed metal-based absorbers used for unglazed solar thermal collectors. However, accelerated lifetime testing of materials is highly important for the development and certification of (new) products prior to their market introduction. Introduction of new materials for the absorber coating is hindered by insecurities regarding lifetime.

First results of a project aiming at the development of an accelerated aging procedure for spectrally selective coatings on metal substrate for unglazed collectors are presented. Realistic load profiles, e.g. the yearly time of wetness (TOW) frequency distribution due to humidity or condensation generated by simulations are shown.

In order to propose an accelerating aging procedure, further studies are necessary. In particular, an appropriate Performance Criterion (PC) must be established to set limits on the acceptable change of the optical properties of the absorber coating, corresponding to an acceptable decrease of the performance of a typical energy system with uncovered solar collectors.

### 4. References

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