

SOLAR KEYMARK SCHEME RULES ANNEX F

Requirements for freeze resistance test of evacuated tube collectors with Heat Pipes following EN ISO 9806:2013

1 General

Evacuated tube and flat glazed collectors are designed for outdoor use under local climate conditions. If a collector is claimed to be freeze resistant, periods with freezing temperatures shall not cause any permanent damages.

Within the current issue of EN ISO 9806:2013, there's now an amendment dealing also with the problem of internal fluids with the risk of freezing:

*This test is not applicable to collectors for which it is clearly stated in the installation manual that they may only be used with an antifreeze fluid or air. Neither is it to be used where special means are used to prevent water in a permanently filled collector loop from freezing e.g. by antifreeze algorithm unless **additional liquids with the risk of freezing** are used as e.g. in many heat pipes.*

This test procedure especially developed for heat pipe collectors should be included in the next revision of the collector standard or in the new work item for a component standard ISO 22975-2 "heat pipes for evacuated tubes – Durability and performance".

It could directly be integrated as the third recommended test procedure into chapter 15, EN ISO 9806:2013.

Since 1st of January 2014 this test is mandatory for collectors using heat pipes, if new certificates will be issued or if any reliability tests will be required for retention of an already existing Solar Keymark certificate.

After implementation of this procedure as a mandatory test within the collector or component standard, this Solar Keymark test procedure might be deleted.

2 Freeze Resistance test for Evacuated tubes using heat pipes

2.1 Objective

This test is intended to assess the extent to which evacuated tube collectors using heat pipes can withstand freezing and freezing/ thaw cycles. This test is independent from the statement, that the collector may only be used with anti-freeze liquid as there's a closed second liquid loop within the heat-pipe with the risk of freezing.

This procedure is applicable to heat pipes integrated into single glass tubes, to those integrated into all glass tubes as well as integrated into flat plate collectors. The test could be performed either on completely assembled collectors as well as on assembled heat pipe-evacuated tube combinations and single heat pipes. For tests on single heat pipes, please take the recommendation within Chapter 2.3 into account.

2.2 Apparatus and procedure

2.2.1 Freezing devices

An appropriate climate chamber or other methods to fulfil the minimum requirements out of Table 1 needs to be used. The lowest set temperature needs to be low enough to reach the fluid temperature limit of $-20\pm 2^{\circ}\text{C}$.

2.2.2 Test conditions

With some minor adaptations, the existing test procedure out of EN ISO 9806:2013 could also be used for freeze resistance testing of heat pipes.

Table 1: Test requirements

| Test parameter | Requirements EN ISO 9806:2013 | Adapted procedure for Heat Pipe Collectors |
|-----------------------|--|---|
| Tilt angle | Lowest recommended tilt angle or 30° | Highest recommended tilt angle or 60°(whichever is higher) |
| Reference temperature | Fluid within collector loop (absorber) | Fluid within Heat Pipe |
| Freezing requirements | > 30 min absorber content (-20 ± 2)°C | > 30 min. Heat Pipe Fluid < (-20 ± 2)°C |
| Thawing requirements | > 30 min absorber content >10°C | > 30 min. Heat Pipe Fluid > 10°C |
| No. of Cycles | 3 | 20 |
| Cycle duration | < 5 h | ca. 12 h* |
| Total duration | < 24 h | ca. 10 Days* |
| Test sample | Complete Collector | Test of single tubes with integrated heat pipes possible |
| No. of samples | 1 | At least 10 preconditioned Heat Pipes for freeze test, one for ref. Temp. and one as reference sample |

*depending on the freezing method, example, if a climate chamber will be used for freezing of all glass tubes including heat pipes

2.2.3 Initial Inspection

Before starting the test procedure, a detailed initial inspection on every single sample has to be done. The dimensions of the bottom (fluid filled) part of each heat pipe need to be recorded in detail.

Besides retaining some (conditioned) heat pipes for comparative measurements (also necessary for heat pipes integrated into single glass tubes), the initial measurement should be done at precise defined positions like suggested in the following picture. If there are heat pipes with cylindrical shapes of the fluid filled part, the point of measurement should be based on the coplanar area of the end of the tube. For conic shaped tubes, the comparative measurement between a pipe performing freeze test and one didn't performing the test, but going through the same preconditioning seems to be an applicable solution.

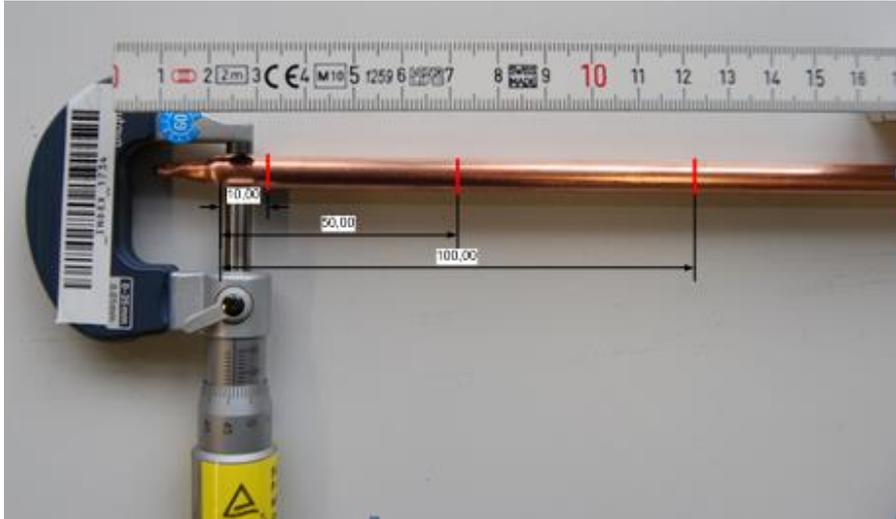


Fig. 1: Definition of initial positions for diameter determination [mm]

For heat pipes integrated into single glass tubes, a pre-test measurement of dimension is not possible without damaging the glass and loss of vacuum. For this kind of collectors, an intensive visual inspection and photo documentation shall be performed. Depending on the uniformity of the pipe dimension (diameter), the number of retained heat pipes need to be enlarged to take the production tolerances into account.

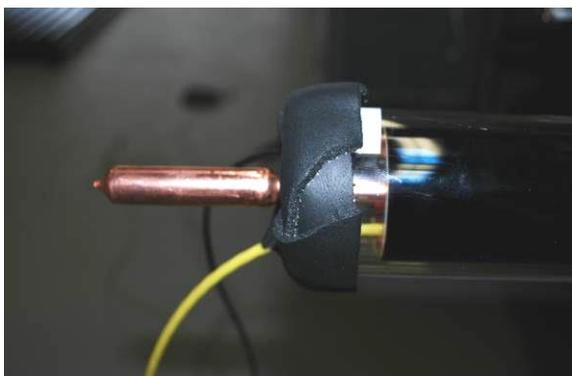
2.2.4 Heat Pipe preconditioning

As an influence of exposure and degradation on the freeze test results could not be excluded, the heat pipes need to pass a complete outdoor exposure test according to chapter 11 and high temperature test according to chapter 9 of EN ISO 9806 (unless there is more experience). Within this test, the heat pipes need to be able to operate like under stagnation temperature while assembled as a complete collector. For sure, it is also possible to use heat pipes, which had passed through outdoor exposure test within standard collector testing.

2.2.5 Sample preparation

If only heat pipes and ETC combination instead of complete assembled collectors will be used for testing, the evacuated tube shall be protected against convection between inside and chamber if necessary. A thermal insulation of each pipe/ tube is not required.

As a result, the main heat transfer will proceed into the heat pipe via the condenser. It will be possible to test single evacuated tubes with heat pipes under the same conditions than complete evacuated tube collectors.



Prevention of thermal convection



Reference temperature sensor

2.2.6 Reference temperature sensor

The temperature sensor will be fixed on the lower end of one reference heat pipe close to the expected maximum level of fluid. The permanent temperature detection during test will be used as an indicator, if the fluid reached the limits explained in Table 1.

For single-glass heat pipes (with glass metal compound), one sample needs to be opened on the top of the condenser and a temperature sensor will be inserted inside the pipe down to the bottom (fluid). There's no effect on the vacuum in the glass tube when using this procedure. On the other hand the vacuum in the heat pipe is lost. This leads to a different freezing behaviour than the "original" heat pipe, freezing is on the other hand depending quite low on the pressure in this magnitudes used in heat pipes, so the measured temperature is similar to the one in the heat pipes to test. Even without the full quantity of fluid inside the heat pipe, a temperature value close to the real fluid temperature is able to detect. This method could also be used for heat pipes within all-glass tubes.

The fluid temperature shall be recorded to a standard uncertainty of 1 K.

The heat pipe including the reference temperature sensor will not be used for evaluation!

2.2.7 Sample "preservation"

As there might be negative influence on the freeze test by storing the heat pipes horizontal after pre-conditioning, it will be required to keep the heat pipes with a minimum tilt angle of 15° to ensure, that the fluid with all inhibitors and particles is only inside the bottom part of the pipe without any risk of "sedimentation" before starting the freeze test.

Note: This is only important for freeze testing, as the heat pipe is not going into operation during freeze testing. This is not a general requirement.

2.3 Freeze test

During freeze test, all requirements given in Table 1 shall be fulfilled. There might be other ways to freeze the heat pipes beside the use of climate chambers. The detection of the reference temperature is an obligation for each method.

The test could be performed on single heat pipes, heat pipes integrated into evacuated tubes and complete assembled collectors. The chosen method will influence the cycle duration and testing effort. As a compromise between realistic freezing (via condenser) and cycle duration, the test method with integrated heat pipes will be recommended, if a climate chamber for freezing will be used. If a low temperature fluid loop will be used for freezing, the test will be performed on the complete assembled collector.

Note: As the freezing behaviour on single heat pipes differs from the assembled ones, this faster procedure should only be applied for heat pipes using fluid with low freezing temperatures below the test temperature from Table 1.

2.4 Final Inspection

After the last freezing cycle, a detailed final inspection with photo documentation for every heat pipe shall be made. If possible, the same points as during initial inspection should be used for diameter detection as well as every widened part in between.

For heat pipes integrated into single glass tubes, the initial dimension needs to be determined on an appropriate number of retained heat pipes. If the production tolerances are taken into account, the acceptance criteria is still applicable.

2.5 Results

The number of cycles carried out shall be reported. The collector shall be inspected for leakage, breakage, distortion and deformation (widening). Beside the visual check, the relevant tube diameter shall be compared with the initial values. These shall be reported together with the fluid temperatures

reached during the cycles and the time spent by the collector at the test temperatures. The tilt angle used for the test shall also be reported.

Criteria for Acceptance:

Based on the experience, measurement uncertainties, production tolerances and limits for visual detection of deformation, the maximum acceptable value for widening of tube diameter is 2.5%. If only one tube is failing, the complete test will be counted as failed!