b) A means for monitoring the temperature of the module to an accuracy of ± 2,0 °C and repeatability of ± 0,5 °C. The temperature sensors shall be attached to the front or back surface of the module near the middle without obstructing any of the UV light incident on the active cells within the module. If more than one module is tested simultaneously, it will suffice to monitor the temperature of one representative sample.

c) Instrumentation capable of measuring the irradiance of the UV light produced by the UV light source at the test plane of the module(s), within the wavelength ranges of 280 nm to 320 nm and 320 nm to 400 nm with an uncertainly of ± 15 % or better.

d) A UV light source capable of producing UV radiation with an irradiance uniformity of ± 15 % over the test plane of the module(s) with no appreciable irradiance at wavelengths below 280 nm and capable of providing the necessary total irradiance in the different spectral regions of interest as defined in 4.10.3.

e) For light sources with a negligible spectral content in the visible range the module shall be short circuited. Alternatively the module can be connected to a load sized such that the module will operate near the maximum power point. The latter is recommended for light sources emitting a significant portion of light in the visible spectrum where the module exhibits a power equal to or larger than 20 % of its STC measured power.

4.10.3 Procedure

a) Using the calibrated radiometer measure the irradiance at the proposed module test plane and ensure that at wavelengths between 280 nm and 400 nm it does not exceed 250 W/m^2 (i.e. about five times the natural sunlight level) and that it has a uniformity of ± 15 % over the test plane.

b) According to the apparatus used as defined in 4.10.2 e) short-circuit or attach the resistive load to the module and mount it in the test plane at the location selected in a), normal to the UV irradiance beam. Make sure that the module temperature sensors read (60 ± 5) °C.

c) Subject the module(s) front side to a total UV irradiation of at least 15 kWh/m^2 in the wavelength range between 280 nm and 400 nm with at least 3 %, but not more than 10 % in the wavelength band between 280 nm and 320 nm, while maintaining the module temperature within the prescribed range.

4.10.4 Final measurements

Repeat the tests of MQT 01 and MQT 15.

4.10.5 Requirements

a) No evidence of major visual defects, as defined in IEC 61215-1.

b) Wet leakage current shall meet the same requirements as for the initial measurements.

4.11 Thermal cycling test (MQT 11)

4.11.1 Purpose

To determine the ability of the module to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature.

4.11.2 Apparatus

a) A climatic chamber with automatic temperature control with means for circulating the air inside and means to minimize condensation on the module during the test, capable of subjecting one or more modules to the thermal cycle in Figure 9.

b) Means for mounting or supporting the module(s) in the chamber, so as to allow free circulation of the surrounding air. The thermal conduction of the mount or support shall be low, so that, for practical purposes, the module(s) are thermally isolated.

c) Measurement instrumentation having an accuracy of ± 2,0 °C and repeatability of ± 0,5 °C for measuring and recording the temperature of the module(s).

d) Means for applying a continuous current. The value of the current is defined in the technology specific parts in this standard.

e) Means for monitoring the flow of current through each module during the test.

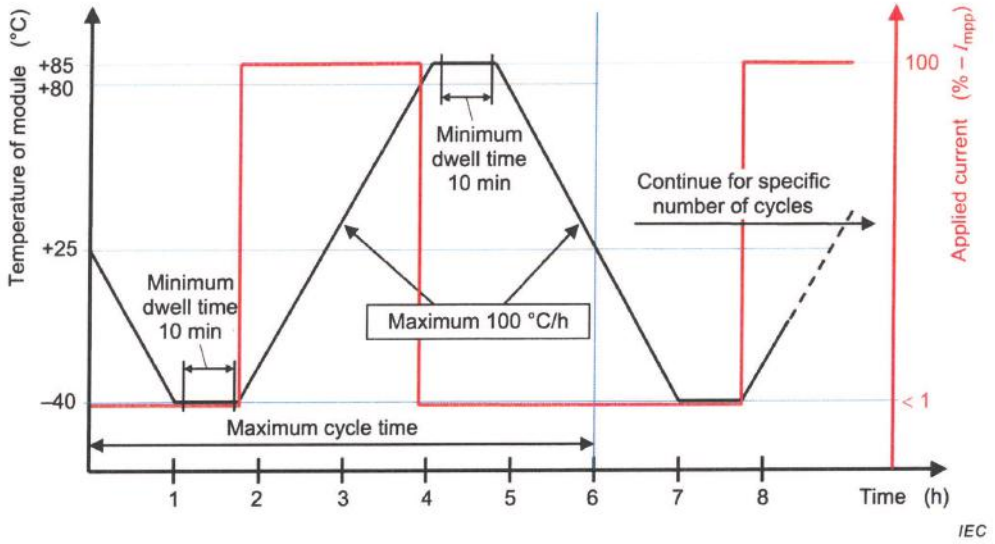

Figure 9 – Thermal cycling test – Temperature and applied current profile

4.11.3 Procedure

a) Attach a suitable temperature sensor to the front or back surface of the module(s) near the middle. If more than one module of the same type are tested simultaneously, it will suffice to monitor the temperature of one representative sample.

b) Install the module(s) at room temperature in the chamber.

c) Connect the temperature-monitoring equipment to the temperature sensor(s). Connect each module to the appropriate current supply by connecting the positive terminal of the module to the positive terminal of the power supply and the second terminal accordingly. During the thermal cycling test set the continuous current flow during the heat up cycle to the technology specified current in 4.11.2 at temperature from –40 °C to 80 °C. During cool down, the –40 °C dwell phase and temperatures above 80 °C the continuous current shall be reduced to no more than 1,0 % of the measured STC peak power current to measure continuity. If the temperature rises too fast (greater than 100 °C/h) at the lowest temperature, the start of the current flow can be delayed until the temperature has reached –20 °C.

d) Close the chamber and subject the module(s) to cycling between measured module temperatures of (–40 ± 2) °C and (+85 ± 2) °C, in accordance with the profile in Figure 9. The rate of change of temperature between the low and high extremes shall not exceed 100 °C/h and the module temperature shall remain stable at each extreme for a period of at least 10 min. The cycle time shall not exceed 6 h unless the module has such a high heat capacity that a longer cycle is required. The number of cycles shall be as shown in the relevant sequences in Figure 1 of IEC 61215-1:2016. Air circulation around the module(s) has to ensure compliance with each module under test meeting the temperature cycling profile.

e) Throughout the test, record the module temperature and monitor the current flow through the module(s).

NOTE In a module with parallel circuits, an open circuit in one branch will cause a discontinuity in the voltage but not cause the current to go to zero.

4.11.4 Final measurements

After a minimum recovery time of 1 h at (23 ± 5) °C and a relative humidity less than 75 % under open-circuit conditions, repeat the tests of MQT 01 and MQT 15.

4.11.5 Requirements

a) No interruption of current flow during the test; in the case of a module with parallel circuits, a discontinuity in current flow indicates an interruption of flow in one of the parallel circuit.

b) No evidence of major visual defects, as defined in IEC 61215-1.

c) Wet leakage current shall meet the same requirements as for the initial measurements.

4.12 Humidity-freeze test (MQT 12)

4.12.1 Purpose

To determine the ability of the module to withstand the effects of high temperature and humidity followed by sub-zero temperatures. This is not a thermal shock test.

4.12.2 Apparatus

a) A climatic chamber with automatic temperature and humidity control, capable of subjecting one or more modules to the humidity-freeze cycle specified in Figure 10.

b) Means for mounting or supporting the module(s) in the chamber, so as to allow free circulation of the surrounding air. The thermal conduction of the mount or support shall be low, so that, for practical purposes, the module(s) is (are) thermally isolated.

c) Measurement instrumentation having an accuracy of ± 2,0 °C and repeatability of ± 0,5 °C for measuring and recording the temperature of the module(s).

d) Means for monitoring, throughout the test, the continuity of the internal circuit of each module.

4.12.3 Procedure

a) Attach a suitable temperature sensor to the front or back surface of the module(s) near the middle. If more than one module of the same type is tested simultaneously, it will suffice to monitor the temperature of one representative sample.

b) Install the module(s) at room temperature in the climatic chamber.

c) Connect the temperature-monitoring equipment to the temperature sensor(s). Connect each module to the appropriate current supply by connecting the positive terminal of the module to the positive terminal of the power supply and the second terminal accordingly. During the humidity freeze test set the continuous current flow to no more than 0,5 % of the measured STC peak power current.

d) After closing the chamber, subject the module(s) to the number of cycles defined in sequence C in Figure 1 of IEC 61215-1:2016 in accordance with the profile in Figure 10. The maximum and minimum temperatures shall be within ± 2 °C of the specified levels and the relative humidity shall be maintained within ± 5 % of the specified value when the temperature is at the maximum value of 85 °C. Air circulation around the module(s) has to ensure compliance with each module under test meeting the temperature cycling profile.

e) Throughout the test, record the module temperature and monitor the current and voltage through the module.

4.12.4 Final measurements

After a recovery time between 2 h and 4 h at (23 ± 5) °C and a relative humidity less than 75 % under open-circuit conditions, repeat the tests of MQT 01 and MQT 15.

4.12.5 Requirements

a) No interruption of current flow or discontinuity in voltage during the test; in the case of a module with parallel circuits, a discontinuity in current flow indicates an interruption of flow in one of the parallel circuits.

b) No evidence of major visual defects, as defined in IEC 61215-1.

c) Wet leakage current shall meet the same requirements as for the initial measurements.

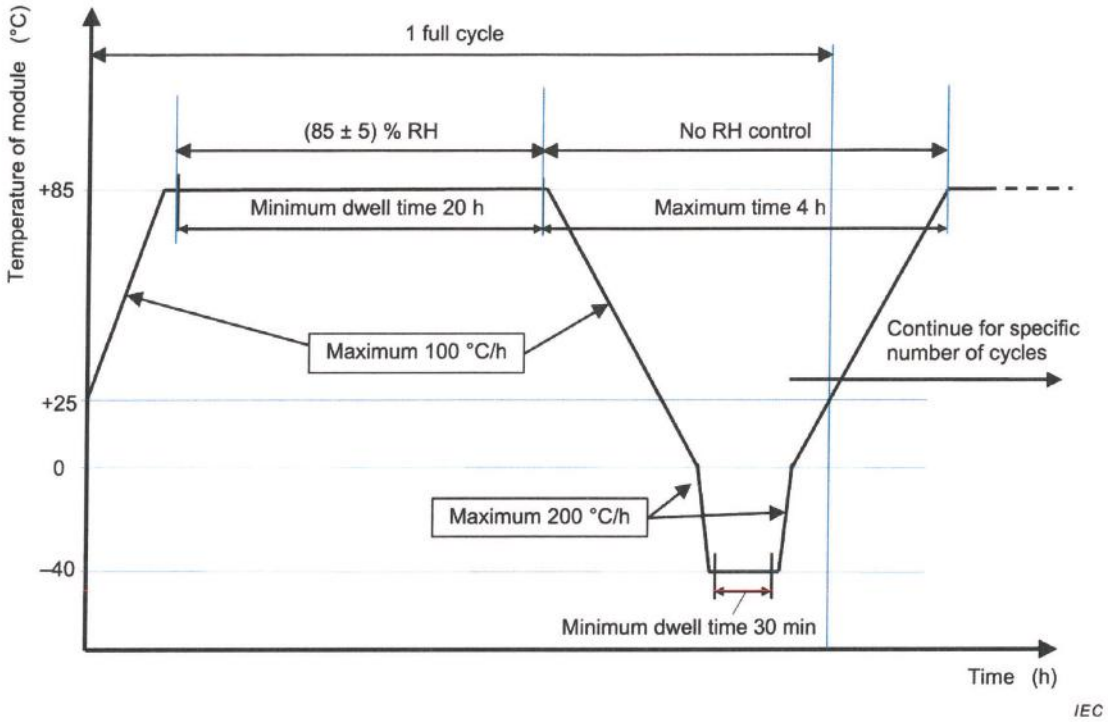

Figure 10 – Humidity-freeze cycle – Temperature and humidity profile

4.13 Damp heat test (MQT 13)

4.13.1 Purpose

To determine the ability of the module to withstand the effects of long-term penetration of humidity.

4.13.2 Procedure

The test shall be carried out in accordance with IEC 60068-2-78 with the following provisions.

Severities:

The following severities are applied.

Test temperature: (85 ± 2) °C

Relative humidity: (85 ± 5) %

Test duration: $\left(1000\ ^{+48}_{0}\right)$ h

4.13.3 Final measurements

After a recovery time of between 2 h and 4 h at (23 ± 5) °C and a relative humidity less than 75 % under open-circuit conditions, repeat the tests of MQT 01 and MQT 15.

4.13.4 Requirements

a) No evidence of major visual defects, as defined in IEC 61215-1.

b) Wet leakage current shall meet the same requirements as for the initial measurements.