

Crystalline silicon terrestrial photovoltaic (PV) modules — Design qualification and type approval

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British Standard

ICS 31.260

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National foreword

This British Standard has been prepared by Subcommittee EPL/47/3 and is the English language version of EN 61215:1995, *Crystalline silicon terrestrial photovoltaic (PV) modules — Design qualification and type approval*, published by the European Committee for Electrotechnical Standardization (CENELEC). Apart from two minor editorial corrections it is identical with IEC 1215, first edition 1993.

Cross-references

Publication referred to	Corresponding British Standard
	BS 2011 <i>Environmental testing</i>
EN 60068-1:1994 (IEC 68-1:1988)	Part 1.1:1989 <i>General and guidance</i>
HD 323.2.3 S2:1987 (IEC 68-2-3:1969)	Part 2.1Ca:1977 Test Ca. <i>Damp heat, steady state</i>
HD 323.2.21 S3:1988 (IEC 68-2-21:1983)	Part 2.1U:1984 Test U. <i>Robustness of terminations and integral mounting devices</i>
HD 478.2.1 S1:1989 (IEC 721-2-1:1982)	BS 7527 <i>Classification of environmental conditions</i> Part 2: <i>Environmental conditions appearing in nature</i> Section 2.1:1991 <i>Temperature and humidity</i> .
EN 60891:1994 (IEC 891:1987+A1:1992)	BS EN 60891:1995 <i>Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices</i>
	BS EN 60904: <i>Photovoltaic devices</i>
EN 60904-1:1993 (IEC 904-1:1987)	Part 1:1993 <i>Measurement of photovoltaic current-voltage characteristics</i>
EN 60904-3:1993 (IEC 904-3:1989)	Part 3:1993 <i>Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data</i>
QC 001002:1986	BS QC 001002:1991 <i>Rules of procedure of the IEC Quality Assessment System for Electronic Components (IECQ)</i>

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 32, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Descriptors: Photovoltaic (PV) module, crystalline silicon, design, qualification, testing, pass criteria, marking

English version

Crystalline silicon terrestrial photovoltaic (PV) modules Design qualification and type approval

(IEC 1215:1993)

Modules photovoltaïques (PV) au silicium
cristallin pour application terrestre
Qualification de la conception et homologation
(CEI 1215:1993)

Terrestrische photovoltaische (PV) Module aus
kristallinem Silizium
Konstruktionsqualifikation und Typzulassung
(IEC 1215:1993)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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Foreword

The text of the International Standard IEC 1215:1993, prepared by IEC TC 82, Solar photovoltaic energy systems, was submitted to the formal vote and was approved by CENELEC as EN 61215 on 1995-03-06 without any modification.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1996-03-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1996-03-01

For products which have complied with the relevant national standard before 1996-03-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 2001-03-01.

Annexes designated “normative” are part of the body of the standard. In this standard, Annex ZA is normative. Annex ZA has been added by CENELEC.

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1 Scope and object

This International Standard lays down IEC requirements for the design qualification and type approval of terrestrial photovoltaic modules suitable for long-term operation in moderate open-air climates, as defined in IEC 721-2-1. It applies only to crystalline silicon types. Standards for thin-film modules and other environments, such as marine or equator conditions, are under consideration.

This standard does not apply to modules used with concentrators.

The object of this test sequence is to determine the electrical and thermal characteristics of the module and to show, as far as is possible within reasonable constraints of cost and time, that the module is capable of withstanding prolonged exposure in climates described in the scope. The actual lifetime expectancy of modules so qualified will depend on their design, their environment and the conditions under which they are operated.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 68-1:1988, *Environmental testing — Part 1: General and guidance*.

IEC 68-2-3:1969, *Environmental testing — Part 2: Tests — Test Ca: Damp heat, steady state*.

IEC 68-2-21:1983, *Environmental testing — Part 2: Tests — Test U: Robustness of terminations and integral mounting devices*.

IEC 410:1973, *Sampling plans and procedures for inspection by attributes*.

IEC 721-2-1:1982, *Classification of environmental conditions — Part 2: Environmental conditions appearing in nature — Temperature and humidity*.

IEC 891:1987, *Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic (PV) devices*.

Amendment No. 1 (1992)

IEC 904-1:1987, *Photovoltaic devices — Part 1: Measurements of photovoltaic current-voltage characteristics*.

IEC 904-3:1989, *Photovoltaic devices — Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*.

QC 001002:1986, *Rules of Procedure of the IEC Quality Assessment System for Electronic Components (IECQ)*.

Amendment No. 1 (1992)

3 Sampling

Eight modules for qualification testing (plus spares as desired) shall be taken at random from a production batch or batches, in accordance with the procedure given in IEC 410. The modules shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and have been subjected to the manufacturer's normal inspection, quality control and production acceptance procedures. The modules shall be complete in every detail and shall be accompanied by the manufacturer's handling, mounting and connection instructions, including the maximum permissible system voltage.

When the modules to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report (see clause 8).

4 Marking

Each module shall carry the following clear and indelible markings:

- name, monogram or symbol of manufacturer;
- type or model number;

- serial number;
- polarity of terminals or leads (colour coding is permissible);
- maximum system voltage for which the module is suitable.

The date and place of manufacture shall be marked on the module or be traceable from the serial number.

5 Testing

The modules shall be divided into groups and subjected to the qualification test sequences in Figure 1, carried out in the order laid down. Each box refers to the corresponding subclause in this standard. Test procedures and severities, including initial and final measurements where necessary, are detailed in clause 10.

NOTE Where the final measurements for one test serve as the initial measurements for the next test in the sequence, they need not be repeated. In these cases, the initial measurements are omitted from the test.

In carrying out the tests, the tester shall strictly observe the manufacturer's handling, mounting and connection instructions. Test given in 10.4 may be omitted if the temperature coefficients α and β are already known.

Test conditions are summarized in Table 1.

6 Pass criteria

A module design shall be judged to have passed the qualification tests, and therefore to be IEC type approved, if each test sample meets all the following criteria:

- a) the degradation of maximum output power at standard test conditions (STC) does not exceed the prescribed limit after each test nor 8 % after each test sequence;
- b) no sample has exhibited any open-circuit or ground fault during the tests;
- c) there is no visual evidence of a major defect, as defined in clause 7;
- d) the insulation test requirements are met after the tests.

If two or more modules do not meet these test criteria, the design shall be deemed not to have met the qualification requirements. Should one module fail any test, another two modules meeting the requirements of clause 3 shall be subjected to the whole of the relevant test sequence from the beginning. If one or both of these modules also fail, the design shall be deemed not to have met the qualification requirements. If, however, both modules pass the test sequence, the design shall be judged to have met the qualification requirements.

7 Major visual defects

For the purposes of design qualification and type approval, the following are considered to be major visual defects:

- a) broken, cracked, bent, misaligned or torn external surfaces;
- b) a crack in a cell whose propagation could remove more than 10 % of that cell's area from the electrical circuit of the module;
- c) bubbles or delamination forming a continuous path between any part of the electrical circuit and the edge of the module;
- d) loss of mechanical integrity, to the extent that the installation and/or operation of the module would be impaired.

8 Report

Following type approval, a certified report of the qualification tests, with measured performance characteristics and details of any failures and re-tests, shall be prepared by the test agency in accordance with IECQ procedure QC 001002. A copy of this report shall be kept by the manufacturer for reference purposes.

9 Modifications

Any change in the design, materials, components or processing of the module may require a repetition of some or all of the qualification tests to maintain type approval.

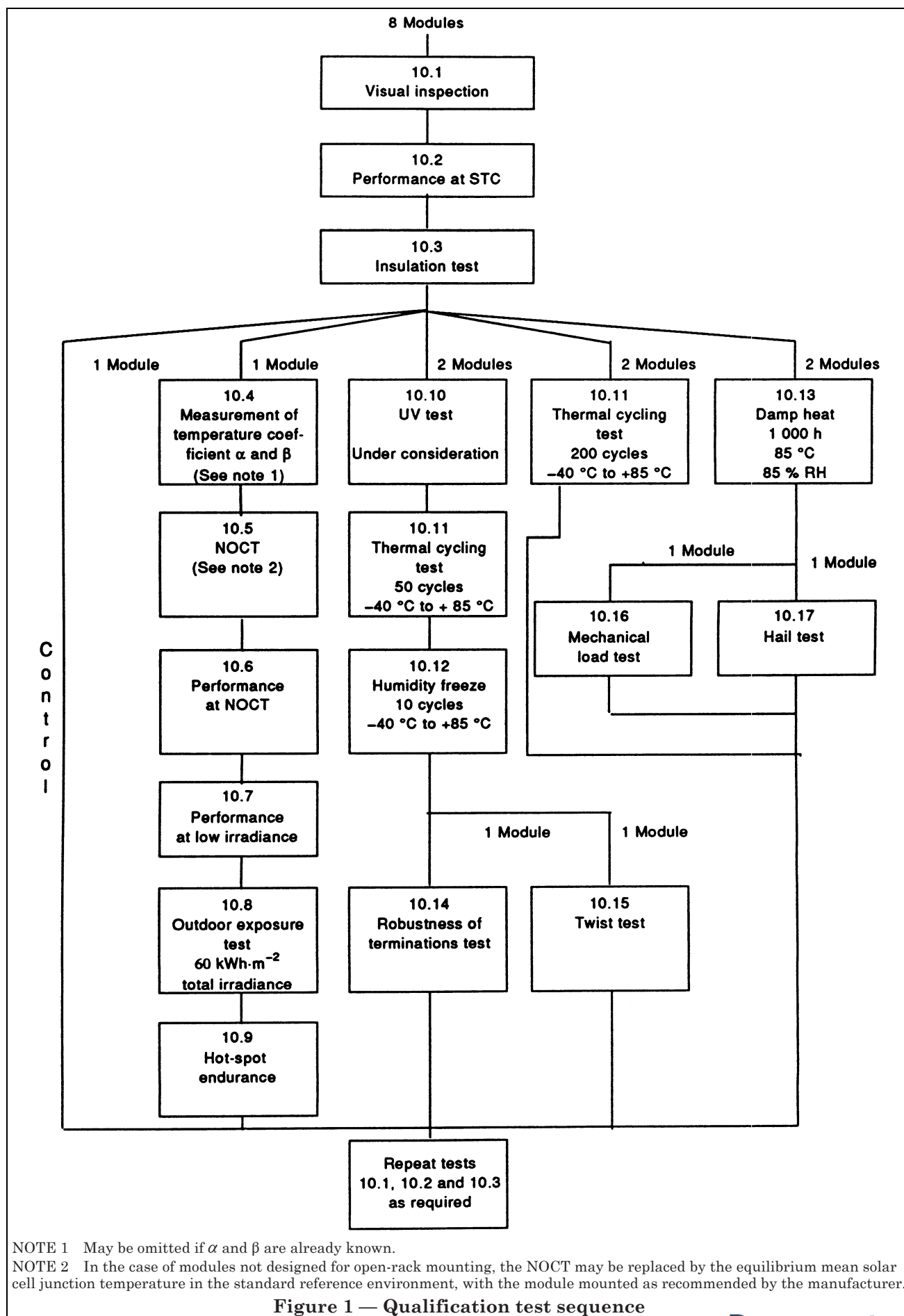


Figure 1 — Qualification test sequence

Table 1 — Summary of test levels

Test	Title	Test conditions
10.1	Visual inspection	See detailed inspection list in 10.1.2
10.2	Performance at STC	Cell temperature: 25 °C; irradiance: 1 000 W m ⁻² with IEC 904-3 reference solar spectral irradiance distribution
10.3	Insulation test	1 000 V d.c. + twice the open-circuit voltage of the system at STC for 1 min. Insulation resistance not less than 50 MΩ at 500 V d.c.
10.4	Measurement of temperature coefficients	See detail in 10.4
10.5	Measurement of NOCT	Total solar irradiance: 800 W m ⁻² Ambient temperature: 20 °C Wind speed: 1 m s ⁻¹
10.6	Performance at NOCT	Cell temperature: NOCT Irradiance: 800 W m ⁻² with IEC 904-3 reference solar spectral irradiance distribution
10.7	Performance at low irradiance	Cell temperature: 25 °C Irradiance: 200 W m ⁻² with IEC 904-3 reference solar spectral irradiance distribution
10.8	Outdoor exposure test	60 kWh m ⁻² total solar irradiation
10.9	Hot-spot endurance test	Five 1-h exposures to 1 000 W m ⁻² irradiance in worst-case hot-spot condition
10.10	UV test	Under consideration
10.11	Thermal cycling test	50 and 200 cycles from – 40 °C to + 85 °C
10.12	Humidity freeze test	10 cycles from + 85 °C, 85 % RH to – 40 °C
10.13	Damp heat test	1 000 h at + 85 °C, 85 % RH
10.14	Robustness of terminations test	As in IEC 68-2-21
10.15	Twist test	Deformation angle: 1,2°
10.16	Mechanical load test	Two cycles of 2 400 Pa uniform load, applied for 1 h to front and back surfaces in turn
10.17	Hail test	25 mm diameter ice ball at 23,0 m s ⁻¹ , directed at 11 impact locations

10 Test procedures

10.1 Visual inspection

10.1.1 Purpose

To detect any visual defects in the module.

10.1.2 Procedure

Carefully inspect each module under an illumination of not less than 1 000 lux for the following conditions:

- cracked, bent, misaligned or torn external surfaces;
- broken cells;
- cracked cells;
- faulty interconnections or joints;
- cells touching one another or the frame;
- failure of adhesive bonds;
- bubbles or delamination forming a continuous path between a cell and the edge of the module;

- tacky surfaces of plastic materials;
- faulty terminations, exposed live electrical parts;
- any other conditions which may affect performance.

Make note of and/or photograph the nature and position of any cracks, bubbles or delamination, etc. which may worsen and adversely affect the module performance in subsequent tests.

10.1.3 Requirements

Visual conditions other than the major visual defects listed in clause 7 are acceptable for the purposes of type approval.

10.2 Performance at STC

10.2.1 Purpose

To determine how the electrical performance of the module varies with load at STC (cell temperature: $25\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, irradiance: $1\,000\text{ W m}^{-2}$) using natural sunlight or a class A simulator conforming to the requirements of IEC 904-3.

10.2.2 Procedure

Determine the current-voltage characteristic of the module at STC, in accordance with IEC 904-1. When necessary, make temperature and irradiance corrections in accordance with IEC 891.

10.3 Insulation test

10.3.1 Purpose

To determine whether or not the module is sufficiently well insulated between current carrying parts and the frame.

10.3.2 Test conditions

The test shall be made on modules at ambient temperature of the surrounding atmosphere (see IEC 68-1) and in a relative humidity not exceeding 75 %.

10.3.3 Procedure

- a) Connect the shorted output terminals of the module to the positive terminal of a d.c. insulation tester with a current limitation.
- b) Connect the exposed metal parts of the module to the negative terminal of the tester. If the module has no frame or if the frame is a poor electrical conductor, mount the module on a metallic simulated support structure, which is to be connected to the negative terminal of the tester.
- c) Increase the voltage applied by the tester at a rate not exceeding 500 V s^{-1} to a maximum equal to $1\,000\text{ V}$ plus twice the maximum system voltage (i.e. the open-circuit voltage of the system at STC). Maintain the voltage at this level for 1 min. If the maximum system voltage does not exceed 50 V , the applied voltage shall be 500 V .
- d) Reduce the applied voltage to zero and short-circuit the terminals of the tester for 5 min, while still connected to the module.
- e) Remove the short circuit.
- f) Apply a d.c. voltage of not less than 500 V to the module, with the tester connected as in steps a) and b). Determine the insulation resistance.

10.3.4 Test requirements

- no dielectric breakdown (less than $50\text{ }\mu\text{A}$) or surface cracking during step c);
- insulation resistance not less than $50\text{ M}\Omega$.

10.4 Measurement of temperature coefficients

10.4.1 Purpose

To determine the temperature coefficients of current (α) and voltage (β) from module measurements. The coefficients so determined are valid at the irradiance at which the measurements were made. For linear modules, they are also valid over an irradiance range of $\pm 30\%$ of this level. This procedure supplements that in IEC 891 for measuring these coefficients from a representative set of single cells.

10.4.2 Apparatus

- a) Solar simulator (class B or better), conforming to future standard IEC (under consideration). Means to measure irradiance, short-circuit current and open-circuit voltage in accordance with clause 2 of IEC 904-1.

NOTE The use of a pulsed solar simulator is preferred, since it creates little additional heat that could affect the module during the measurement. If a steady-state simulator is used, it should be equipped with shutter or equivalent means to minimize the period of irradiance to 0,5 s or less.

- b) Means to measure the surface or cell temperature of the module to an accuracy of $\pm 0,5\text{ }^{\circ}\text{C}$.
- c) A chamber capable of accommodating the module, equipped with a transparent window and means for evenly heating and cooling the contents over the temperature range of interest.

10.4.3 Procedure

- a) Determine the short-circuit current of the module at the desired irradiance at room temperature, in accordance with IEC 904-1.
- b) Mount the test module in the chamber and a suitable irradiance monitor outside the chamber within the simulator beam. Connect to the instrumentation.
- c) Close the chamber and set the irradiance so that the test module produces the short-circuit current determined in item a). Use the irradiance monitor to maintain this irradiance setting throughout the test.
- d) Heat the module to the maximum temperature of interest, switch off the heater and allow the module to cool evenly.
- e) As the module cools, take measurements of the short-circuit current and open-circuit voltage at $5\text{ }^{\circ}\text{C}$ intervals over a range of interest of at least $30\text{ }^{\circ}\text{C}$.

NOTE The complete current-voltage characteristic may be measured at each temperature to determine the curve correction factor K, in accordance with clause 5 of IEC 891.

- f) Plot the values of I_{sc} and V_{oc} as functions of temperature and construct a least-squares-fit curve through each set of data.
- g) From the slopes of the current and voltage curves at a point midway between the minimum and maximum temperatures of interest, calculate α and β , the temperature coefficients for the module.

10.5 Measurement of nominal operating cell temperature (NOCT)

10.5.1 Purpose

To determine the NOCT of the module.

10.5.2 Introduction

NOCT is defined as the equilibrium mean solar cell junction temperature within an open-rack mounted module in the following standard reference environment (SRE):

- | | |
|------------------------|--|
| — Tilt angle: | at normal incidence to the direct solar beam at local solar noon |
| — Total irradiance: | 800 W m^{-2} |
| — Ambient temperature: | $20\text{ }^{\circ}\text{C}$ |
| — Wind speed: | 1 m s^{-1} |
| — Electrical load: | nil (open circuit). |

NOCT can be used by the system designer as a guide to the temperature at which a module will operate in the field and it is therefore a useful parameter when comparing the performance of different module designs. However, the actual operating temperature at any particular time is affected by the mounting structure, irradiance, wind speed, ambient temperature, sky temperature and reflections and emissions from the ground and nearby objects. For accurate performance predictions, these factors shall be taken into account.

Two methods for determining NOCT are described.

The first, called “the primary method”, is universally applicable to all PV modules. In the case of modules not designed for open-rack mounting, the primary method may be used to determine the equilibrium mean solar cell junction temperature in the SRE, with the module mounted as recommended by the manufacturer.