LIGHTING GLOBAL
Catalyzing Markets for Modern Lighting

AN INNOVATION OF
IFC International Finance Corporation World Bank Group
THE WORLD BANK

LIGHTING GLOBAL

Quality Assurance Protocols

3.0

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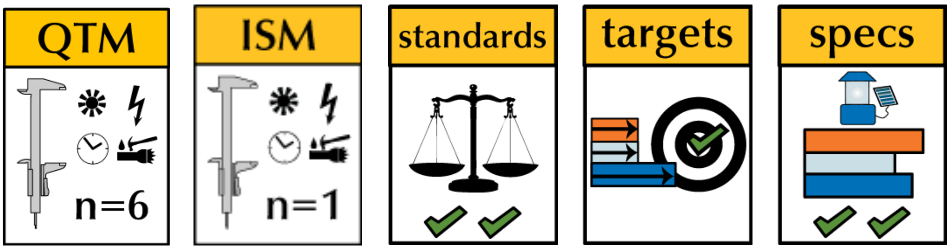


Lighting Global

Lighting Global, a joint IFC and World Bank program, seeks to accelerate the development of commercial off-grid lighting markets in Sub-Saharan Africa, Asia, and beyond as part of the World Bank Group's wider efforts to improve access to energy. Lighting Global is associated with partner programs Lighting Africa and Lighting Asia. For more information, visit www.lightingafrica.org.

Lighting Global is implemented in partnership with: The Africa Renewable Energy and Access Grants Program (AFREA), The Asia Sustainable and Alternative Energy Program (ASTAE), The Energy Sector Management Assistance Program (ESMAP), The Global Environment Facility (GEF), The Good Energies Inc., Italy, Luxembourg, The Netherlands, Norway, The Public-Private Infrastructure Advisory Facility (PPIAF), The Renewable Energy and Energy Efficiency Partnership (REEEP), The United States.

About the World Bank: The World Bank is a vital source of financial and technical assistance in developing countries worldwide, with a mission to help reduce global poverty and improve living standards. However, it is not a bank in the common understanding of the term. Rather, it is comprised of two unique development institutions owned by 185 member countries—the International Bank for Reconstruction and Development (IBRD) and the International Development Association (IDA). Each institution plays a different but supportive role.

The IBRD focuses on middle income and creditworthy poor countries, while IDA focuses on the poorest countries in the world. Together, they provide low-interest loans, interest-free credit, and grants to developing countries for education, health, infrastructure, communications, and many other purposes. The World Bank concentrates on building the climate for investment, jobs, and sustainable growth to enable economies to grow, and investing in and empowering poor people to participate in development. For more information, visit www.worldbank.org

About IFC: IFC, a member of the World Bank Group, is the largest development institution focused on the private sector in developing countries. IFC creates opportunity for people to escape poverty and improve their lives—by providing financing to help businesses employ more people and provide essential services, mobilizing capital from others, and delivering advisory and risk-management services to ensure sustainable development. In a time of global economic uncertainty, IFC's new investments climbed to a record $18 billion in fiscal 2010. For more information, visit www.ifc.org

CONTENTS

1 Introduction

This quality assurance (QA) protocol defines the core policies that guide implementation of Lighting Global Quality Assurance activities.

Lighting Global delivers quality assurance and market intelligence services to programs that support robust, well-functioning markets for affordable off-grid lighting that can positively impact the lives of the 1.3 billion people who currently lack access to modern lighting and energy services.

This QA protocol applies to stand-alone rechargeable electric lighting appliances or kits that can be installed by a typical user without employing a technician.

This document presents a quality assurance framework that includes product specifications (a framework for interpreting test results), test methods, and standardized specifications sheets (templates for communicating test results).

The Lighting Global QA protocol is designed to be a bridging measure that will guide the market until an alternative international norm is established, such as an IEC technical specification. Once an alternative norm is established that has similar scope and utility, the Lighting Global QA protocol plans to reference that norm.

1.1 Intended Users

The Lighting Global QA protocol is designed to serve a broad range of organizations that are active in the off-grid lighting space. Key organization types that may benefit from the use of the QA protocol and ways that they may use it are listed below. In some sections of this document, a description of the application of the section contents is offered to help provide context for each type of user.

- **Market support programmes** are programmes that support the off-grid lighting market with financing, consumer education, awareness, and other services. Market support programmes often use quality assurance to qualify for access to services like:
    - greenhouse gas reduction certifications or other incentives
    - access to financing (trade or consumer finance)
    - use of a buyer seal and certification (government or non-governmental institutional backing, consumer or "business to business" seals)
    - participation in a public product information database (e.g., standardized specifications sheets)
    - access to a business network or trade group
    - business support and development services
    - access to market intelligence
    - participation in consumer awareness campaigns
- **Manufacturers and distributors** need to verify the quality and performance of products from different batches and potential business partners. Manufacturers and distributors often use quality assurance plans or requirements to:
    - support quality control processes at a manufacturing plant or upon receipt of goods from a contract manufacturer
    - choose products to distribute

- **Bulk procurement programmes** facilitate or place large orders for devices from a distributor or manufacturer. Bulk procurement programmes may use quality assurance to:
  - provide devices to a particular, relatively small group of end-users whose needs are understood (e.g., project developers and implementers for an electrification project may include quality assurance requirements in the GS of an electrification project (see the IEC TS 62257 3))
  - organize a subsidy, buy-down, or giveaway programme that will serve a broad set of users
- **Trade Regulators** are typically government policymakers and officials who craft and implement trade and tax policy. Regulators may use quality assurance requirements to:
  - qualify for exemption from tax or duties
  - establish requirements for customs

1.2 Contents in brief

This document establishes the framework for creating a product specification—the basis for evaluating quality for a particular context. Product specifications include minimum requirements for quality standards, warranty requirements, and/or performance targets. Products are compared to specifications based on test results and other information about the product. The product specification framework is flexible and can accommodate the goals of diverse organizations and institutions.

There is a range of tests outlined in this document; some are simple enough to be completed in the field by project developers while others require laboratory equipment. The tests and inspections are designed to be widely applicable across different markets, countries, and regions.

Standardized specifications sheets are also defined that can be used to communicate the test results. Combined with a set of product specifications, the information in the standardized specifications sheet can inform the use of a quality and/or performance label.

1.3 Document History

This document derives from the Lighting Africa Quality Test Method and other supporting documents originally developed to support the Lighting Africa program. In addition it includes key input from a round of stakeholder feedback in early 2012, whose participants included:

- A number of manufacturers and distributors of off-grid lighting products
- Solar Energy Centre (India)
- The Energy and Resources Institute (TERI, India)
- The Bureau of Indian Standards (BIS)
- Kenya Bureau of Standards
- Fraunhofer Institute for Solar Energy Systems (Germany)
- The German Agency for International Cooperation (GIZ)
- Navigant Consulting

Version 3.0: current version, rescoped and reworked to support a broad range of global stakeholders and renamed "Lighting Global Quality Assurance Protocol." Combines LA-QTM v.2, Lighting Africa Standards and Targets framework, and Standardized Specifications Sheets.

Version 2.0: replaced June 2012, called "Lighting Africa Quality Test Methods," refined based on program experience.

Version 1.0: original test methods authored by Fraunhofer Institute for Solar Energy Systems for the Lighting Africa program.

2 Normative references

IEC 60529: Degrees of protection provided by enclosures (IP Code)

IEC 60904-1: Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics

IEC 62509: Battery charge controllers for photovoltaic systems - Performance and functioning

IEC 60891: Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics

IEC 61951-2: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 2: Nickel-metal hydride

IEC 61960: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications

IEC 61951-1: Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 1: Nickel-cadmium

ISO 17025: Competence of Testing and Calibration Laboratories

ISO 9001: Quality Management Standard

PVRS 7A DC supplied lighting systems with fluorescent lamps for PV stand-alone systems

CIE084: The measurement of luminous flux

CIE127: Measurement of LEDs

IESNA LM-78-07: IESNA approved method for total luminous flux measurement of lamps using an integrating sphere photometer

IESNA LM-79-08: Electrical and photometric measurement of solid-state lighting products

CIE 15:2004

CIE 13.3

CIE 177

3 Definitions

3.1

illuminance (of an elementary surface) (symbol E) [IEV 723-08-30]

The luminous flux received by an elementary surface divided by the area of this surface.

NOTE In the SI system of units illuminance is expressed in lux (lx) or lumens per square metre (lm/m^2)

3.2

capacity (of a cell or a battery) [IEV 486-03-01]

The quantity of electricity (electric charge), usually expressed in amperes-hour (Ah), which a fully charged battery can deliver under specified conditions.

3.3

device under test (DUT)

A particular sample that is being measured or observed.

3.4

life (of a lamp) [IEV 845-07-61]

The total time for which a lamp has been operated before it becomes useless, or is considered to be so according to specified criteria.

NOTE Lamp life is usually expressed in hours.

3.5

life test [IEV 845-07-62]

Test in which lamps are operated under specified conditions for a specified time or to the end of life and during which photometric and electrical measurements may be made at specified intervals.

3.6

service life (of a battery) [IEV 486-03-23]

The period of useful life of a battery under specified conditions.

3.7

light unit [821-02-38]

Assembly inside a casing of all parts such as lamps, optical apparatus, coloured glass, terminals, necessary to exhibit a light aspect.

3.8

lux [IEV 845-01-52]

SI unit of illuminance: illuminance produced on a surface of area 1 square metre by a luminous flux of 1 lumen uniformly distributed over that surface.

3.9

full width half maximum (FWHM) [IEV 731-01-57]

The range of a variable over which a given characteristic is greater than 50 % of its maximum value.

NOTE FWHM may be applied to characteristics such as radiation patterns, spectral linewidths, etc. and the variable may be wavelength, spatial or angular properties, etc., as appropriate.

3.10

ampere (symbol A) [IEV 112-02-07]

SI unit of electric current, equal to the direct current which, if maintained constant in two straight parallel conductors of infinite length, of circular cross-section with negligible area, and placed 1 metre apart in vacuum, would produce between these conductors a force per length equal to 2×10^{-7} N/m.

NOTE CGPM definition is as follows: "The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length."

3.11

multimeter [IEV 312-02-24]

Multirange, multifunction measuring instrument intended to measure voltage, current and sometimes other electrical quantities such as resistance.

3.12

ammeter [IEV 313-01-01]

Instrument intended to measure the value of a current.

3.13

voltmeter [IEV 313-01-03]

Instrument intended to measure the value of a voltage.

3.14

illuminance meter [IEV 845-05-16]

Instrument for measuring illuminance.

3.15

photometer [IEV 845-05-15]

Instrument for measuring light.

3.16

pyranometer

Instrument for measuring incident global (direct-beam and diffuse) solar radiation.

3.17

integrating sphere [IEV 845-05-24]

Hollow sphere whose internal surface is a diffuse reflector, as non-selective as possible. Used to determine the total luminous flux (lumen output) of a lighting device.

NOTE An integrating sphere is used frequently with a radiometer or photometer.

3.18

goniophotometer [IEV 845-05-22]

Photometer for measuring the directional light distribution characteristics of sources, luminaires, media or surfaces.

3.19

power supply [IEV 151-13-76]

Electric energy converter which draws electric energy from a source and supplies it in a specified form to a load.

3.20

overvoltage protection [IEV 448-14-32]

Protection intended to operate when the power system voltage is in excess of a predetermined value.

3.21

undervoltage (low voltage) protection [IEV 448-14-33]

Protection intended to operate when the power system voltage is reduced to less than a predetermined value.

3.22
GS
General Specification of the electrification project.

3.23
IP class (or IP rating)
Ingress protection—Degree of protection provided by enclosures for electrical equipment against penetration by foreign bodies and dust / water.

3.24
portable
Products or subsystems are portable when two or more of the main components (energy source, energy storage, and light source) are connected in a way that makes the product or subsystem easy for an individual to carry.

3.25
fixed
Products or subsystems are fixed when the main components (energy source, energy storage, and light source) are designed for permanent or semi-permanent mounting and use in place.

3.26
separate
Products are separate when no solar module is present or the solar module is connected to other components via a long enough cable that the solar module could collect energy outdoors while the other product components remain indoors.

3.27
integrated
Products are integrated when the solar module is integrated into the same casing as the other components or the solar module is connected to other components via a cable that is too short to allow the solar module to collect energy outdoors while the other product components remain indoors.

3.28
Metadata
Information that relates a test result to a specific sample and provides context about the result (e.g., specific test method used).

3.29
Light emitting diode; LED (abbreviation) [IEV 845-04-40]
solid-state device embodying a p-n junction, emitting optical radiation when excited by an electric current

3.30
Compact fluorescent lamp; CFL (abbreviation)
a discharge lamp of the low pressure mercury type in which most of the light is emitted by one or several layers of phosphors excited by the ultraviolet radiation from the discharge, typically self-ballasted with a tube that is wound in a spiral or arched shape to make it "compact" as opposed to linear fluorescent lamps.

4 System limits

4.1 System description

4.1.1 Components

A stand-alone lighting kit typically comprises:

- Main components
  - an **energy source** (one or more of the following)
    - solar photovoltaic module (integrated, supported by or completely separate from the casing)
    - mechanical charger (hand crank, pedal power, or other)
    - general DC power input (normally used with a central charging station or AC-DC converters to charge via grid power)
  - one or several **light sources** (typically CFL or LED)
  - an **energy storage** device (one of several battery types)

- Enclosure and other components
  - a **casing or several casings** (including some translucent parts in many cases)
  - **circuits** (battery charge and discharge controller, regulated voltage and current sources),
  - **wiring** to connect the circuits to each other and the main components
  - **fasteners** to secure components in the casings.
  - **switches** for light control/selection
  - **cables and connectors**
  - **status indicators** / user feedback
  - **accessories** (auxiliary power outlet, mobile phone charging interface, radio, fan, etc.)
  - **hardware** for mounting

4.1.2 Product categories

Stand-alone lighting kits can be placed into one of four categories based on the arrangement of components. It is important to categorize them because they have different inherent utility to the user and will encounter different environmental conditions based on their design.

Different quality standards and performance targets may apply to different categories.

Some kits that have multiple, independent lighting points may fit into more than one category, with different parts of the kit in different categories.

The first word in each category name refers to the portability of the system.

- *Fixed* systems are designed for permanent or semi-permanent mounting and use in place.
- *Portable* systems are inherently portable, with the light source and energy storage components permanently or temporarily joined.

The second word refers to the arrangement of a solar module, if one is present, with respect to the other main components.

- *Separate* systems have no solar module present or the solar module is connected to other components by a cable that is sufficiently long to place the solar module outdoors in a location with good solar access while the other components remain indoors.
- *Integrated* systems have a solar module integrated in the same casing as the other components or it is otherwise designed so the whole product must be left outdoors to charge via the solar module.

The four system types that can be derived from the categories listed above are:

a) **Fixed separate (fixed indoors):** products that are not inherently portable and are used indoors. The light source(s) are separated from the battery by cables and cannot easily be used beyond the reach of the cables. If the product is solar-charged, the solar module is also separate from the battery and connected by a cable that is sufficiently long to place the solar module outdoors in a location with good solar access while the battery remains indoors.

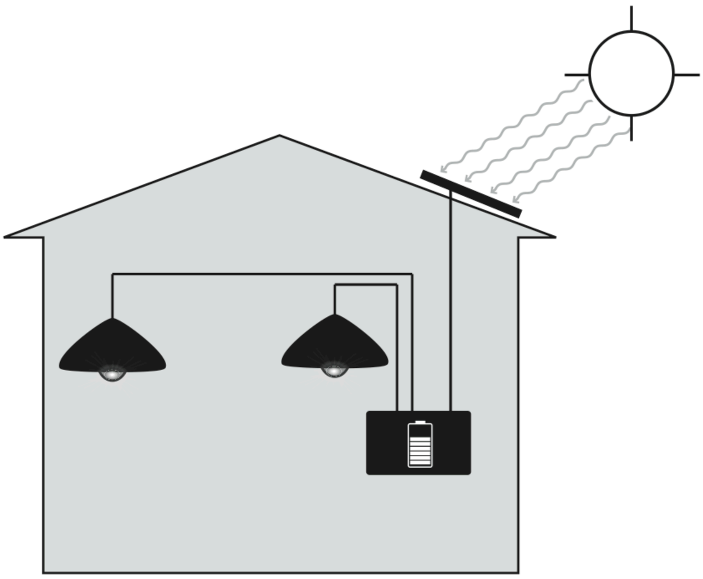


Figure 1 – Fixed Separate (fixed indoors) system—example arrangement of components

b) **Portable separate:** products that are portable, with a battery and light source permanently or temporarily joined. If the product is solar-charged, the solar module is also separate from the battery and connected by a cable that is sufficiently long to place the solar module outdoors in a location with good solar access while the battery remains indoors.

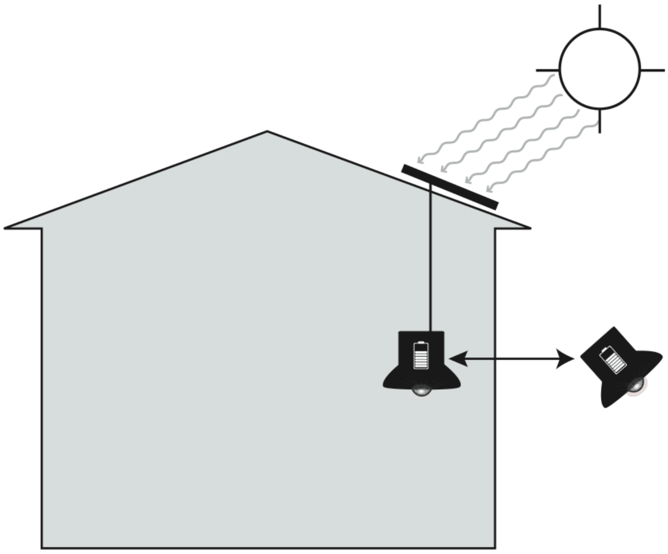


Figure 2 – Portable Separate system—example arrangement of components

c) **Portable integrated**: products that are portable and are charged with a solar module that is integrated in the casing or is otherwise designed so the whole product must be left outdoors to charge via the solar module.

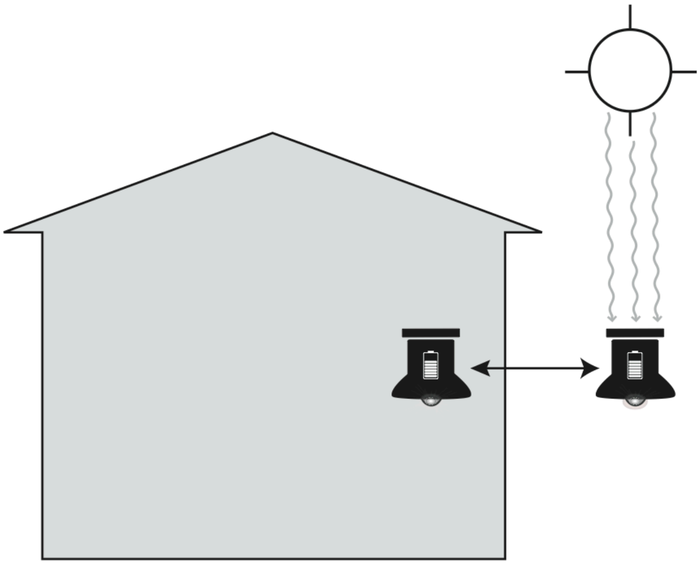


Figure 3 – Portable integrated system—example arrangement of components

d) **Fixed integrated (fixed outdoors)**: products that are not inherently portable and are charged with a solar module that is integrated in the casing or is otherwise designed so the whole product must be left outdoors to charge via the solar module. These may also include lighting points that can be placed indoors.

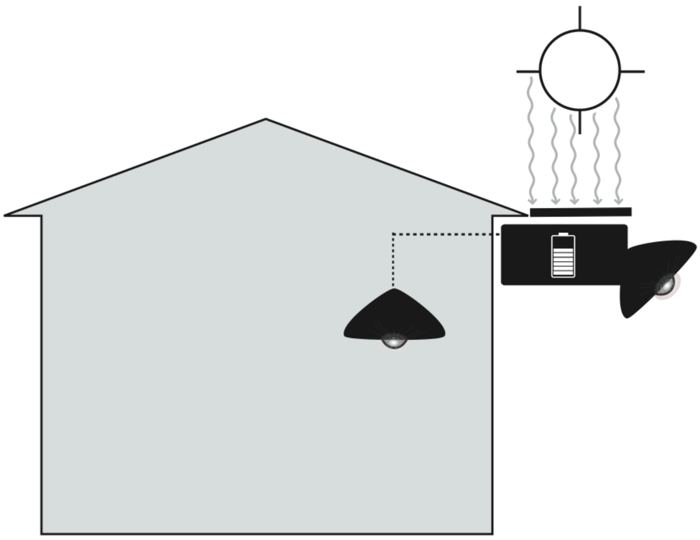


Figure 4 – Fixed integrated (fixed outdoors) system—example arrangement of components

4.1.3 Lighting kit parts

Lighting kits may also be divided into several subsystems, as defined below. The subsystems are nested beginning with the smallest subsystem and working down to complete kits.

a) Light Source(s): individual LED, CFL, or other light emitting components

b) Array(s): single or grouped light sources that can be controlled independently from other arrays

c) Light Point(s): house one or more arrays and can be moved with respect to other light points, if there are more than one

d) Lighting Unit(s): stand-alone parts of the kit, each with an independent battery that powers one or more light points. Note: it is appropriate to categorize each light unit (as described in4.1.2 Product categories) separately, since the arrangement of battery and light point(s) may be different in different light units.

e) Lighting Kit: the overall package of integrated components, including one or several lighting units.

The figure below illustrates how a hypothetical lighting kit can be subdivided and categorized. The levels of division are labelled with letters, corresponding to the descriptions above. There are six light sources (A) in this kit divided among four arrays (B). Two of the three light points (C) have one array; the third light point (in the middle—C2) has two arrays. Note that one of the arrays—the one with three light sources—is turned off and the others are on. There are two light units (D). The light unit on the left (D1) can be categorized as portable separate; the other light unit (D2) can be categorized as fixed separate (fixed indoors). Both units are included in a single lighting kit (E).

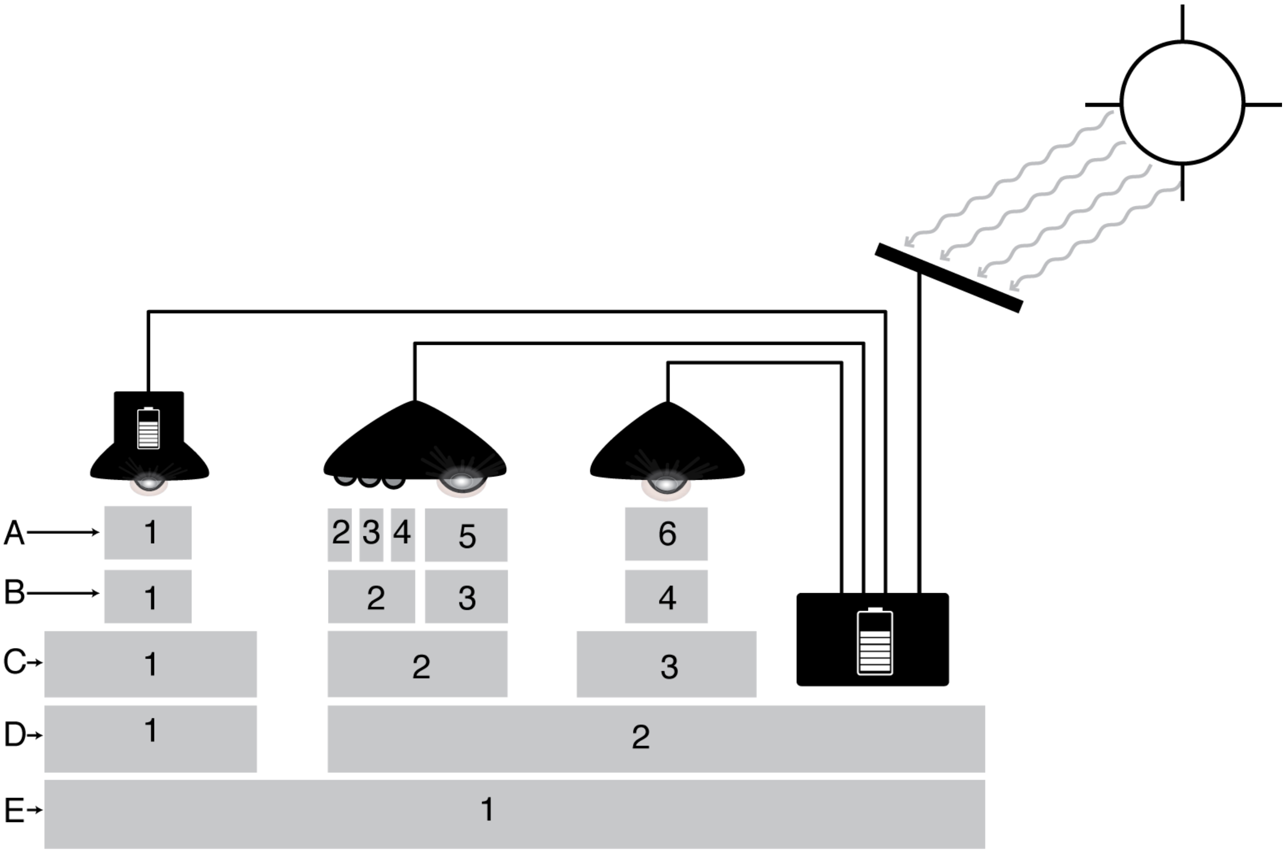


Figure 5 – Division of a lighting kit into subsystems—illustrative example

4.1.4 Additional system elements

In addition to technical elements, a system may also include:

- **packaging** with information about the product
- **user's manual**(s)
- various **advertising** for the product across media: print, radio, television, internet, and others.
- **warranty** support from the manufacturer

4.2 System measurements and observations

This section describes aspects of an off-grid lighting product that can be measured and/or observed to ascertain its quality and performance. The aspects are grouped into categories, and each aspect begins with a description of its relevance. The aspects can be measured and/or observed using test procedures, which are generally classified as "A" or "B." Class A test procedures will generally result in measurements that are more accurate or less subjective than class B procedures, but class A procedures are also generally more costly to implement. The appropriateness of class A or class B procedures depends on the particular aspect and context of the testing. The description of each aspect concludes with a description of the result from the test procedure, the units, and an example result. In some cases, multiple pieces of information are grouped in a single aspect for clarity and concision.

4.2.1 Product design, manufacture, and marketing aspects

4.2.1.1 Arrangement of components

The arrangement of components is a critical aspect to observe because it determines the product category. Different arrangements will offer different utility to the end-user.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): n/a

c) Result: A description of each separate electronic enclosure and what is housed in or mounted on each.

d) Units: Qualitative description

e) Example: Enclosure A contains the battery and has a gooseneck light point protruding from the top. Enclosure B is a remote lighting point with ambient, omnidirectional LEDs mounted on the outside; it is connected to enclosure A with a cable. A solar module with a cable for connection powers enclosure A.

4.2.1.2 Charging system information

This notes all the available options for charging the device. The key items to note are whether the device can be charged by "central" charging (e.g., via electric grid connection or at a central charging station), "independent" charging (e.g., via an included photovoltaic or electromechanical generator), or both. The available charging options can help determine the utility of the device for users based on the run time aspects (see section 4.2.6).

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Self-reported by manufacturer

c) Result: For each charging option,

   1) Charger type

   2) Central or independent

d) Units: Qualitative type

e) Example: Two charging options. 1) Independent solar charging via the included module; 2) central grid charging via an auxiliary input designed for use with mobile phone chargers (not included).

4.2.1.3 Lighting system information

This describes the types of light sources used in the product and their arrangement. This is important for understanding the general product design.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Self-reported by manufacturer

c) Result: A description of the type, number, and arrangement of light sources.

d) Units: Qualitative description

e) Example: See 4.1.3 Lighting kit parts.

4.2.1.4 Energy storage system information

This describes the type and number of energy storage systems included in the product.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Self-reported by manufacturer

c) Result: The type and number of batteries in the system

d) Units: Qualitative description

e) Example: Unit A has a lithium-ion battery with a rating of 2 000 mAh; Unit B has a lithium-ion battery with a rating of 1 000 mAh.

4.2.1.5 Battery easy replaceability

This is an assessment of whether a low-skill technician can easily replace the battery with only a screwdriver (i.e., no soldering). It is important for considering the relevance of battery replacement information. Some batteries have longer lifetimes than others, so replaceability may be less important.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): n/a

c) Result: A yes or no result on whether it is "easy" to replace the battery

d) Units: Yes/no

e) Example: Yes, battery is easily replaceable.

4.2.1.6 Battery general aspects

Those aspects of the battery(-ies) that are important for understanding selection of replacement batteries.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Self-reported by manufacturer or reference component rating

c) Result (for each battery present):

   1) Battery chemistry

   2) Nominal voltage

   3) Package type

   4) Package size

   5) Connection type

d) Units: Qualitative type

e) Example: A sealed lead-acid 4 V prismatic package, 20 mm x 20 mm x 60 mm, wire lead connections.

4.2.1.7 Packaging and user's manual information

Information about the packaging, user's manual, and other consumer-facing information helps establish a baseline for comparing measured values in truth-in-advertising assessments. It may also be important to document if certain programmes require particular information to be included in the manual, such as instructions for end-of-life disposal, particularly for batteries and other potentially hazardous components.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Self-reported by manufacturer

c) Result: There are two types of result

   1) Photographic documentation of the packaging and manual (or digital copies of the original proofs)

   2) Notes on the type of manual and which languages are included

d) Units: Qualitative type and photographs

e) Example: [Photographs attached to test reports], "the user's manual is a single-sheet included in the package and includes pictograms with explanations in Hindi, English, French, and Swahili."

4.2.1.8 Warranty information

The terms and duration of warranty coverage provided to end-users are important factors for engendering confidence in stand-alone off-grid lighting and trying to prevent early failure. In practice, servicing warranties is highly variable depending on the structure of supply and service chains.

f) Class A Test procedure(s): Appendix G: visual screening

g) Class B Test procedure(s): Appendix E: manufacturer self-reported information

h) Result: Detailed warranty terms and a "concise" version that highlights the key points of coverage and duration.

i) Units: Qualitative type

j) Example: [Detailed warranty terms are documented in scanned attachments to test report], Coverage is against manufacturing defects or under normal use conditions. The product in general is covered for 6 months from the time of purchase; the PV module is warranted for 2 years.

4.2.1.9 Auxiliary features information

This notes all the auxiliary features present on the product. The incorporation of mobile phone charging or power for radios, for instance, can be important purchasing factors for a consumer.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Appendix E: manufacturer self-reported information

c) Result: List of included auxiliary features.

d) Units: Qualitative type

e) Example: The product has mobile phone charging capability and a radio.

4.2.1.10 Other visual screening results

This incorporates various other important results obtained from visual screening (Appendix G), including, but not limited to, component dimensions, component masses, the number of light output settings, and provided specifications.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Self-reported by manufacturer

c) Result: Various results including qualitative descriptions and quantitative measurements.

d) Units: Qualitative descriptions and quantitative measurements

e) Example (for one result): The product's lamp unit and control box have masses of 0,3 kg and 1,5 kg, respectively.

4.2.2 Product durability and workmanship aspects

4.2.2.1 Water protection – enclosure

This provides a description of the product enclosure's ability to keep out water in terms of IP Class. For products intended to be used and/or charged outside, water protection is important for product function as well as user safety.

a) Class A Test procedure(s): Appendix V: Physical and water ingress protection test according to IEC 60529 or using the alternative methods (V.4.3) if the alternative method results unequivocal.

b) Class B Test procedure(s): Appendix V: Physical and water ingress protection test

c) Result: Pass/fail for IP class (second digit) and a description of degree of water protection provided by enclosure

d) Units: Pass/fail and Qualitative description

e) Example: The product passes IP x3. The product's enclosure contains tight fitting components, all of which have gaskets to prevent water intrusion.

4.2.2.2 Water protection – circuit protection and drainage

This provides a description of any drainage means incorporated into a product and/or circuit board protection methods used in the product. The incorporation of drainage or circuit board protection is crucial for products intended to be outdoors that have enclosures providing little to no water intrusion protection.

a) Class A Test procedure(s): Appendix G: visual screening combined with Appendix E: manufacturer self-reported information

b) Class B Test procedure(s): Appendix E: manufacturer self-reported information

c) Result: Description of drainage or circuit protection methods used.

d) Units: Qualitative description

e) Example: The product has a conformal coating on its circuit board as well as drainage holes in the base of the enclosure to allow drainage of collected water.

4.2.2.3 Physical ingress protection

This provides a description of the degree of protection from the intrusion of foreign objects a product's enclosure provides in terms of IP class. Physical ingress protection is important for user safety as well as product functionality.

f) Class A Test procedure(s): Appendix V: Physical and water ingress protection test according to IEC 60529 or using the alternative methods (V.4.2) if the alternative method results unequivocal.

g) Class B Test procedure(s): Appendix V: Physical and water ingress protection test

h) Result: Pass/fail for IP class (first digit) and Description of degree of physical ingress protection.

i) Units: Pass/fail and Qualitative description

j) Example: The product passes IP 4x; the product enclosure's components fit together snugly without gaps, so that only tiny particulate matter (e.g., dust) could intrude.

4.2.2.4 Drop resistance

This provides an evaluation of a product's robustness and ability to withstand being dropped. Drop resistance is important for product functionality and user safety and satisfaction.

a) Class A Test procedure(s): Appendix X: mechanical durability test

b) Class B Test procedure(s): n/a

c) Result: Pass/fail for functionality, damage, and the presence of user safety hazards.

d) Units: A pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: When dropped, the product stopped working and its glass LED cover shattered, presenting a safety hazard to the user. Functional: Fail, Damage: Fail, Safety hazard: Fail.

4.2.2.5 Gooseneck durability

This provides an evaluation of a product's gooseneck's robustness and ability to withstand being torqued through its expected range of motion. Gooseneck durability is important for product functionality and user safety and satisfaction.

a) Class A Test procedure(s): Appendix X: mechanical durability test

b) Class B Test procedure(s): n/a

c) Result: Pass/fail for functionality, damage, and the presence of user safety hazards.

d) Units: A pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: After the gooseneck test, the LEDs worked properly but there was visible damage (a cracked housing) that did not pose a hazard. Functional: Pass, Damage: Fail, Safety: Pass.

4.2.2.6 Connector durability

This provides an evaluation of a product's connectors' robustness and ability to withstand plug cycling. Connector durability is important for product functionality and user safety and satisfaction.

a) Class A Test procedure(s): Appendix X: mechanical durability test

b) Class B Test procedure(s): n/a

c) Result: Pass/fail for functionality, damage, and the presence of user safety hazards.

d) Units: A pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: After 400 cycles in the connector test, the PV module's barrel plug socket detached from the DUT enclosure, rendering the PV module connector unusable. Functional: Fail, Damage: Fail, Safety: Pass.

4.2.2.7 Switch durability

This provides an evaluation of a product's switches' robustness and ability to withstand switch cycling. Switch durability is important for product functionality and user safety and satisfaction.

a) Class A Test procedure(s): Appendix X: mechanical durability test

b) Class B Test procedure(s): n/a

c) Result: Pass/fail for functionality, damage, and the presence of user safety hazards.

d) Units: A pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: After 600 cycles in the switch test, the DUT's light switch stopped turning on the DUT. Functional: Fail, Damage: Fail, Safety: Pass.

4.2.2.8 Strain relief durability

This provides an evaluation of a product's strain reliefs' robustness and ability to withstand being pulled. Strain relief durability is important for product functionality and user safety and satisfaction.

a) Class A Test procedure(s): Appendix X: mechanical durability test

b) Class B Test procedure(s): n/a

c) Result: Pass/fail for functionality, damage, and the presence of user safety hazards.

d) Units: A pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: The DUT's strain reliefs all withstood the strain relief test without incurring any damage. Functional: Pass, Damage: Pass, Safety: Pass.

4.2.2.9 Wiring quality

This provides a qualitative evaluation of a product's wiring quality, including (but not limited to) neatness and connection quality.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): n/a

c) Result: Description of wiring quality.

d) Units: Qualitative description and number of failures with respect to key indicators.

Example: The DUT's wires are neatly arranged (i.e., not tangled or wrapped around one another) and the solder joints are of good quality. No bad joints, pinched wires, or other poor wiring indicators.

4.2.2.10 Battery protection strategy

This provides a quantitative evaluation of a product's battery discharge-recharge protection strategy / algorithm, which is important for battery longevity as well as user safety.

a) Class A Test procedure(s): Appendix T: charge controller behaviour test

b) Class B Test procedure(s): Appendix E: manufacturer self-reported information

c) Result: Deep discharge and overvoltage protection voltages.

d) Units: Quantitative description

Example: The DUT has a deep discharge protection voltage of 1,92 V/cell and an overvoltage protection voltage of 2,4 V/cell.

4.2.3 Lighting durability aspects

4.2.3.1 500 hour lumen maintenance

This is a measure of the amount of light degradation after 500 h of operation at a constant voltage, which can provide valuable insight into the quality of the LEDs and/or the DUT's circuitry.

a) Class A Test procedure(s): Appendix K: lumen maintenance test

b) Class B Test procedure(s): n/a

c) Result: Percentage of lumen output maintained after 500 h of constant operation.

d) Units: Percentage (%)

e) Example: The DUT maintained 96 % of its original lumen output after 500 h of operation.

4.2.3.2 2 000 hour lumen maintenance

This is a measure of the amount of light degradation after 1 000 h and 2 000 h of operation at a constant voltage, which can provide valuable insight into the quality of the LEDs and/or the DUT's circuitry.

a) Class A Test procedure(s): Appendix K: lumen maintenance test

b) Class B Test procedure(s): n/a

c) Result: Percentage of lumen output maintained after 1 000 h and 2 000 h of constant operation.

d) Units: Percentage (%)

e) Example: The DUT maintained 96 % and 93 % of its original lumen output after 1 000 h and 2 000 h of operation, respectively.

4.2.3.3 Fluorescent light durability

These are additional checks of durability for fluorescent lights that account for their unique characteristics.

a) Class A Test procedure(s): PVRS 7A

b) Class B Test procedure(s): n/a

c) Result: pass / fail durability tests in PVRS 7A

d) Units: pass/fail

e) Example: The DUT passed the durability tests in PVRS 7A.

4.2.4 Battery performance aspects

4.2.4.1 Battery capacity

This is a measure of the amount of charge that can be stored in a battery, which effects the run time of products.

a) Class A Test procedure(s): Appendix L: battery test

b) Class B Test procedure(s): Reference component rating

c) Result: Charge-carrying capacity of the battery at a particular discharge rate.

d) Units: Milliampere-hours (mAh) at a discharge rate expressed as the fraction of the battery capacity that is used each hour (I_t A)

e) Example: 3 500 mAh at 0,2 I_t A

4.2.4.2 Battery voltage

This is important for matching to the other components and determines, along with the battery ampere-hour capacity, the energy capacity of the battery. It depends on the battery chemistry (what materials are used to store energy) and the number of electrochemical cells that are in series.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Reference component rating

c) Result: Nominal voltage of the battery pack.

d) Units: Volts (V)

e) Example: 3,6 V

4.2.5 Solar module aspects

4.2.5.1 Solar I-V curve parameters

These are the key parameters describing solar module performance at standard test conditions (“STC” -AM 1,5, 25 °C, 1 000 W/m^2) and Normal operating cell temperature (“NOCT” - same as STC except cell temperature of 50 °C)

a) Class A Test procedure(s): IEC 60904-1

b) Class B Test procedure(s): Appendix R: outdoor photovoltaic module I-V characteristics test

c) Result (for both STC and NOCT):

1) Open circuit voltage (V_{oc})
2) short circuit current (I_{sc})
3) maximum power voltage (V_{mpp})
4) maximum power current (I_{mpp})
5) peak power (P_{mpp})
6) Voltage temperature coefficient (not dependent on STC nor NOCT)

d) Units: Volts (V), amperes (A), watts-peak (W_p), per degree Celsius (1/°C)

e) Example: 7,5 V_{oc}, 0,55 A I_{sc}, 5,8 V_{mpp}, 0,50 A I_{mpp}, and 2,9 W_p at STC. The module's voltage temperature coefficient is -0,0042/°C.

4.2.5.2 Solar module cable length

The length of solar module cables is important because it is one aspect that determines the product category; a minimum length is typically specified for products to "qualify" as having separate PV modules to ensure that a user can place the solar module outdoors in a location with good solar access while the other components remain indoors. This has implications for the degree of water protection in quality standards.

a) Class A Test procedure(s): Appendix G: visual screening

b) Class B Test procedure(s): Self-reported by manufacturer

c) Result: The length of a solar module cable that is useful for separating the solar module from the enclosure that contains the battery being charged.

d) Units: meters (m)

e) Example: 3,5 m

4.2.6 Run time aspects

Run time is a key element of performance for lighting products. Each of the run time aspects listed below will be different for different light settings.

4.2.6.1 Full-battery run time

The full-battery run time is the duration of service provided to end-users from a fully charged battery and depends on the system-level performance for a particular setting. Regardless of the charging method, the full-battery run time is a relevant metric. For products that recharge centrally, it represents their hours of autonomy until the product must be returned to a charging station (and potentially a fee must be paid). For solar-charged products, it represents the ability store excess energy for a rainy day. For mechanically charged products, it represents the maximum period the product can be operated in between charges.

a) Class A Test procedure(s): Appendix N: full-battery run time test

b) Class B Test Standards(s): n/a

c) Result: Hours of operation to 70 % of the initial brightness when beginning with a fully charged battery; sometimes also known as "autonomous run time."

d) Units: hours (h)

e) Example: 9,3 h

4.2.6.2 Solar-day run time

The solar day run time is the duration of service provided to end-users from a one day of solar charging and depends on the system-level performance for a particular setting. The standard solar charging day is defined as an incident solar resource of 5 kWh/m^2. This is an important metric because it is an estimate of the day-to-day services users can expect in ideal charging conditions. It is important to note that variations in available solar energy (due to climate, weather, or user behaviour) will result in commensurate differences in actual run time from solar charging.

a) Class A Test procedure(s): Appendix S: solar charge test

b) Class B Test procedure(s): n/a

c) Result: Hours of operation to 70 % of the initial brightness after the battery is charged from empty for one standard solar day (defined above).

d) Units: hours (h)

e) Example: 4,5 h

4.2.6.3 Grid-charge run time

The grid-charge run time is the run time for DUTs that are centrally charged (i.e., with a central charging station or the grid). This is an important metric because it provides the expected run time after a full day of grid charging.

a) Class A Test procedure(s): Appendix P: grid charge test

b) Class B Test procedure(s): n/a

c) Result: Hours of operation to 70 % of the initial brightness after the battery is grid charged from empty.

d) Units: hours (h)

e) Example: 6,3 h

4.2.6.4 Mechanical charge ratio

The mechanical charge ratio is the response factor for electromechanical (i.e., dynamo) charging—a ratio of run time to charging time (i.e., with a mechanical charger that is included with the device and not at a central mechanical charging station). The mechanical charging is done at a controlled rate. This is an important metric because it allows one to estimate the duration of user effort required each day for a given level of service.

a) Class A Test procedure(s): Appendix Q: mechanical charge test

b) Class B Test procedure(s): n/a

c) Result: Ratio of time of operation to charging time.

d) Units: unitless

e) Example: 12 minutes run time per minute of charging time

4.2.7 Light output aspects

4.2.7.1 Average luminous flux output

Average luminous flux output is the light output of a DUT when it is operated at the average operating point from the full-battery run time test. This is a key metric that compares the overall light output of DUTs.

a) Class A Test procedure(s): CIE084, CIE127, IESNA LM-78-07, or IESNA LM-79-08

b) Class B Test procedure(s): Appendix J: light output test

c) Result: Average luminous flux.

d) Units: Lumens (lm)

e) Example: 95,6 lm

4.2.7.2 Full width half maximum (FWHM) angles

The full width half maximum angle is a metric used to understand the light distribution of a DUT and is the angle within which illuminance values are greater than or equal to half of the DUT's maximum illuminance measurement.

a) Class A Test procedure(s): CIE084, CIE127, IESNA LM-79-08

b) Class B Test procedure(s): Appendix U: light distribution test

c) Result: Vertical and horizontal FWHM angles.

d) Units: Degrees (°)

e) Example: The DUT's horizontal and vertical FWHM angles are both 65°.

4.2.7.3 Average light distribution characteristics

A light distribution is the illuminance "map" of a DUT. This metric is useful for determining the utility with respect to task lighting. The test is done with the DUT operating at the average operating point from the full-battery run time test.

a) Class A Test procedure(s): CIE084, CIE127, IESNA LM-79-08

b) Class B Test procedure(s): Appendix U: light distribution test

c) Result: Constant-voltage useable area at a specified distance.

d) Units: Square meters (m^2)

e) Example: The DUT's useable area at a distance of 0,5 m is 0,76 m^2.

4.2.7.4 Colour characteristics

The colour characteristics of light determine how accurately the light renders colours (CRI) and the colour of the light expressed as a temperature in kelvin.

a) Class A Test procedure(s): Appendix J: light output test

b) Class B Test procedure(s): n/a

a) Result: CRI value and colour temperature

b) Units: CRI is unitless and the colour temperature is in kelvin (K)

c) Example: The CRI is 80 and the colour temperature is 7 000 K.

4.2.8 Circuit efficiency aspects

4.2.8.1 Input to battery circuit efficiency

The input to battery circuit efficiency, or generator-to-battery charging efficiency, is a measure of how efficient the DUT electronics are at feeding generated energy into the battery.

a) Class A Test procedure(s): IEC 62509

b) Class B Test procedure(s): Appendix S: solar charge test

c) Result: generator-to-battery charging efficiency.

d) Units: Percentage (%)

e) Example: 90 %

4.2.9 Self-certification aspects

4.2.9.1 Product and manufacturer information

Manufacturer-reported product and manufacturer information is important for tracking purposes as well as for ensuring the test lab has up-to-date product information.

a) Class A Test procedure(s): Appendix E: manufacturer self-reported information

b) Class B Test procedure(s): n/a

c) Result: Various qualitative and quantitative information

d) Units: Qualitative and quantitative

Example: The product's free-on-board price is 30 $USD, it is sold in Kenya and India, etc.

4.2.9.2 Warranty coverage

Warranty coverage goes beyond the terms of a warranty and provides detail on coverage in a particular location. It is typically only provided in cases where it is necessary to verify coverage in a particular town or region.

a) Class A Test procedure(s): Appendix E: manufacturer self-reported information

b) Class B Test procedure(s): n/a

c) Result: Qualitative description

d) Units: Qualitative description

e) Example: The support in [region name] is provided by a small network of technicians who have been trained to repair products by [manufacturer or distributor name]. For repairs that are beyond the scope of their capabilities, replacement products are provided. The consumers in [region name] can access warranty service by dialling a phone number that is on a sticker placed on the original packaging.

4.2.9.3 Third-party marks and certifications

Third-party marks and certifications (e.g., UL) can be an important aspect in the eyes of consumers and investors, alike.

a) Class A Test procedure(s): Appendix E: manufacturer self-reported information

b) Class B Test procedure(s): n/a

c) Result: Qualitative marks and certifications

d) Units: Qualitative type

e) Example: ISO9001-certified.

4.2.10 Integrated assessment

4.2.10.1 Water protection integrated assessment

This combines the protection afforded by the enclosure, circuit protection, and consumer labelling to assess the overall protection from water exposure.

a) Class A Test procedure(s): Appendix W: level of water protection

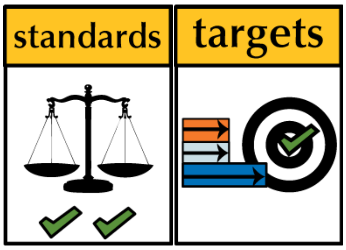
b) Class B Test procedure(s): n/a

c) Result: descriptive assessment of exposure protection by enclosure only, technical means, and overall system. The assessment categories are "no protection," "occasional rain," and "frequent rain."

d) Units: Qualitative type

e) Example: Enclosure only: no protection, technical means: occasional rain, overall: frequent rain

5 Product specification



5.1 General

Quality standards, warranty requirements, and performance targets are used to interpret the measurements and observations made about a product. Together they form a product specification.

- **Quality standards** set a minimum level of durability and protect buyers and users from false advertising claims.
- **Warranty requirements** set a minimum level of user protection from early failure.
- **Performance targets** set a recommended level of service and features.

Each criterion in a specification refers to a particular aspect of the product, as listed in section 4.2 (system measurements and observations) and requires a minimum level of quality, service, or performance.

The standards, requirements, and targets should be appropriate for the goals of the organization or individual who is using them as a framework for quality assurance and should consider the following factors:

- Availability of products on the market with the necessary quality and performance
- Ability of buyers to pay for the products
- Diversity of end-user needs
- Tolerance for manufacturing variation

This section describes the framework for standards, requirements, and targets in general and offers insights on the best practices for creating a product specification. It includes a "blank" product specification followed by guidance on "filling in" each section. Appendix A presents an example specification for off-grid lighting market support programme qualification. Appendix C presents another example, for bulk procurement.

5.2 Applications

Product specifications that include some combination of quality standards, warranty requirements, and performance targets can support a broad range of quality assurance needs. The table below lists examples of how they are applied depending on the type of quality assurance framework:

Table 1 – Applications of product specifications

Type of QA framework	Example(s) of applying this section
General market support	Use quality standards and general warranty requirements to qualify for market support; provide additional services if performance targets are also met. Use quality standards to qualify for a business-to-business seal.
Manufacturing / distribution	For manufacturers: incorporate quality standards and performance targets from market support programmes or distributors in the design and production QC processes. For distributors: set minimum quality standards, warranty requirements, and/or performance targets for products to identify suppliers.
Bulk procurement	Set minimum quality standards, warranty requirements, and/or performance targets for products to qualify in a request for offers. If the project is in a specific location, the warranty requirements may also include specific levels of service in that particular area.
Trade regulation	Set minimum quality standards for tax exemption or customs.

5.3 Quality assurance principles

The framework for considering quality standards, warranty requirements, and performance targets presented in this document is designed to support broad types of programmes and institutions in the off-grid lighting market. The following key principles guide the framework:

- Balance quality and affordability for price-sensitive buyers—it does not matter how well products perform if the target users cannot afford them.
- Encourage innovation and technological diversity. Wherever possible, be open-ended in the technical approaches that are allowed.
- Empower buyers to choose the right product for their needs and budget by focusing product specifications and communication on outcomes for end-users.
- Use low-cost, rigorous, targeted tests to match the general affordability requirements for the market and accommodate both incremental and innovative changes to product design. The tests should be feasible for use by a broad set of potential users.
- Focus quality standards on elements of a product that are difficult for typical buyers to assess themselves, like truth-in-advertising and durability.
- Focus warranty requirements on providing a baseline of support.
- Focus performance targets on bottom-line user experience metrics like run time and brightness.

5.3.1 Rationale for dividing quality, warranty, and performance

Quality standards, warranty requirements, and performance targets are considered separately for two reasons:

- Allows programmes and institutions have the flexibility to establish targets with their goals in mind:
  - Quality standards deal with basic consumer protection (from early product failure, unsafe operation, or false advertising) and typically are a "baseline" or minimum level.
  - Warranty requirements deal with aspects of the product that are not controlled at the factory—the service available for products is typically very dependent on the supply chain and geography.

  - Performance targets are typically in addition to quality standards and define service levels that should be met. It is necessary to know the diversity of needs and ability to pay of end-users to properly set performance targets.
- Enables tiered service offerings for market support programmes. For instance, it is possible to have a tiered support system in which certain services only require meeting quality standards and warranty requirements while others also require performance targets.

5.4 Product specification framework description

This section describes the framework for creating a product specification for off-grid lighting. First, a blank specification is provided that lists all the pieces that can be specified. It is followed by a section describing guidelines for setting tolerances in a product specification. Finally, the main sections in a specification are described in more detail with notes and guidance.

There are example product specifications in Appendix A and Appendix C; one is for general market support programmes and the other is a "sample tender" for bulk purchasing.

A product specification has six parts:

1) **Scope:** defines the applicability and use of the quality standards and performance targets
2) **Test requirements:** defines requirements for test result validity
3) **Product category requirements**: unambiguously defines the categories that may be referenced later
4) **Quality standards:** lists quality-related aspects and minimum or required results for each aspect with a tolerance; may be subdivided by product category
5) **Warranty requirements:** lists requirements for minimum levels of warranty support
6) **Performance targets:** lists performance-related aspects and minimum or required results for each aspect with a tolerance; may be subdivided by product category

5.4.1 Blank Product Specification Document

This section is a blank framework for setting quality standards, warranty requirements, and performance targets to support the goals of a programme or institution. Note that in many applications certain criteria or entire categories of criteria may not apply and should be removed. Text in *italics with grey highlights* is intended for replacement and describes what should go in each space.

5.4.1.1 Scope

Describe the intended use of the product specification. Describe the contents in general and provide guidance on how to use the document.

5.4.1.2 Test Requirements

Specify the level of testing that is required. Typically this is Quality Test Method (QTM) testing (see section 6).

5.4.1.3 *Product Category Requirements*

Describe which product categories (see section 4.1.2) are covered / allowed.

Describe any other requirements for products that are categorical (e.g., must be solar charged).

Qualification as a "separate" PV module requires meeting the criteria listed below:

Table 2 – Qualification as separate PV module

Criterion	Aspect(s)	Required value
PV module cable length	4.2.5.2 Solar module cable	*Define the length in meters that is required for qualification as a separate PV module.*

5.4.1.4 Quality standards

The product must meet each of the criteria listed in the truth-in-advertising, safety and durability, and end-user support tables below.

Table 3 – Truth-in-advertising tolerance

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
System performance tolerance – numeric ratings	4.2.6 Run time 4.2.7 Light output Others, if applicable	*Define the tolerance for deviation from ratings.*
System components tolerance – numeric ratings	4.2.5 Solar module 4.2.4 Battery performance aspects Others, if applicable	*Define the tolerance for deviation from ratings.*
Other numeric ratings tolerance	Multiple	*Define the tolerance for deviation from ratings.*
Overall truth–in-advertising statement	Multiple	*Include an overall description of the requirements for truth-in-advertising that may not be covered by the requirements above.*

Table 4 – Safety and durability standards

Safety or durability criterion	Aspect(s) considered in assessment	Product category (form factor and/or technology)	Requirement
Level of water exposure protection (*overall, technical, or enclosure-only*)	4.2.10.1 Water protection integrated assessment 4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage 4.2.9.1 Product and manufacturer information 4.2.1.7 Packaging and user's manual information	Category 1	Define level of protection in terms of water protection integrated assessment: No protection, occasional rain, frequent rain, or permanent outdoor exposure.
		Category 2…	Define level of protection in terms of water protection integrated assessment.
Physical ingress protection	4.2.2.3 Physical ingress protection	Category 1	Define level of protection in terms of IP class.
		Category 2…	Define level of protection in terms of IP class.
Mechanical durability – drop test	4.2.2.4 Drop resistance	Category 1	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
		Category 2…	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Mechanical durability – goosenecks	4.2.2.5 Gooseneck durability	Products with goosenecks	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Mechanical durability – connectors	4.2.2.6 Connector durability	Products with connectors	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Mechanical durability – switches	4.2.2.7 Switch durability	All products	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Workmanship	4.2.2.9 Wiring quality	All products	Define maximum number of samples with bad solder joints, poor wiring, etc. out of the number that are tested.
Battery durability	4.2.2.10 Battery protection strategy	All products	Define a minimum level of battery protection that will protect the product's battery and the user.
Lumen maintenance	4.2.3.2 2 000 hour lumen maintenance	All products	Define maximum number of samples that can fail specified lumen maintenance criteria out of the number that are tested.
Fluorescent light durability	4.2.3.3 Fluorescent light durability	Products with fluorescent lights	Define maximum number of failures out of the number that are tested.

Table 5 – End-user support standards

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
Information on product design, utilization, and care	4.2.1.7 Packaging and user's manual information	*Define if there are requirements for consumer-facing information on packaging or in a user's manual, such as end-of-life disposal instructions.*
Other	4.2.1.10 Other visual screening results	*Define other product requirements that support end-users to maintain the quality of the product.*

5.4.1.5 Warranty requirements

The product must meet each of the criteria listed in the end-user support table below.

Table 6 – End-user support requirements

Support type	Aspect(s)	Requirement
Maintenance and warranty terms	4.2.1.8 Warranty information	*Define minimum warranty requirements (length, components covered, etc.)*
Service capabilities	4.2.9.2 Warranty coverage	*Define "on the ground" requirements for warranty service (typically only for projects in a specific location)*

5.4.1.6 Performance targets

In addition to meeting the quality standards and warranty requirements, at least one product setting must meet one of the run time criteria and one of the lighting service criteria listed in the tables below. The product must also meet the additional features criteria.

Table 7 – Run time criteria for performance targets

Run time criterion	Aspect(s)	Requirement
Central charged product full-battery run time	4.2.6.3 Grid-charge run time 4.2.6.1 Full-battery run time	*Define minimum full-battery run time in hours (h) and compliance tolerance (%).*
Independently solar charged product – solar-day run time	4.2.6.2 Solar-day run time	*Define minimum solar day run time in hours (h) and compliance tolerance (%).*
Independently mechanically charged product – mechanical run time characteristics	4.2.6.4 Mechanical charge ratio 4.2.6.1 Full-battery run time	*Define minimum mechanical charge run time ratio (unitless) and full-battery run time in hours (h) with compliance tolerances (%).*

Table 8 – Lighting service criteria for performance targets

Light output criterion	Aspect(s)	Requirement
General illumination service	4.2.7.1 Average luminous flux output	*Define minimum average lumen output (lm) through the product's discharge and compliance tolerance (%).*
Task lighting service	4.2.7.3 Average light distribution characteristics	*Define minimum average useable area (m^2) at a specified distance through the product's discharge and compliance tolerance (%).*

Table 9 – Additional features criteria for performance targets

Support Type	Aspect(s)	Requirement
Mobile phone charging	4.2.1.9 Auxiliary features information	*Define minimum included auxiliary features (e.g., mobile phone charging with at least three different connectors).*
Other	4.2.1.9 Auxiliary features information	*Define other required features.*

5.4.2 Tolerances

Tolerances are an allowable deviation from the target value for a particular criterion in a product specification and are part of the product specification. In the case of truth-in-advertising the target value is what is advertised. For performance targets, the target value is the minimum performance level. Durability tests and other pass/fail criteria also have a target—passing the test.

Tolerances should be set carefully, considering how the measured or observed values from a test (with a limited number of samples) characterize the true quality or performance aspects of every product in the market. The sample size, expected manufacturing tolerance, and testing uncertainty should each be considered.

There are trade-offs between protecting buyers/end-users and suppliers from "false positive" and "false negative" results, respectively. Tighter tolerance tends to protect buyers/end-users better from poor quality or performance products but will also result in a higher number of good quality or performance products being excluded based on non-representative sampling or test results. The dynamic is reversed for looser tolerances.

The type of tolerance depends on the aspect being specified:

a) Qualitative: aspects that are descriptive (e.g., type of light source) do not typically have a tolerance.

Numeric: aspects that are described with a measured value (e.g., battery capacity) should have a tolerance defined in terms of percent deviation of the average DUT measurement from a particular value. Often it is allowable for the test result to deviate in one "direction" but not the other. For instance, it is allowable to over-perform on the run time but not underperform. There may also be a tolerance defined for the variance in results of the DUT.

In general, the percent deviation from a target value is calculated by the following equation:

$$D = 100\ \% \times \frac{x_{\text{target}} - x_{\text{meas}}}{x_{\text{target}}}$$

where:

D	is the percent deviation in a numeric value;
x_{ad}	is the target value;
x_{meas}	is a measured value or the average of the measured values for each sample.

b) Boolean: aspects that are described in terms of "pass/fail" (e.g., drop test) should have a tolerance defined in terms of the number of allowable failures out of a set number of trials or tests. Note that the statistical power of Boolean results for predicting population pass/fail rates is not very high with small sample sizes. The implication is that it is not possible to accurately predict population failure rates for a particular aspect from a small sample size, and it is often appropriate to allow some small but reasonable failure rate to avoid false negative results.

5.4.3 Quality standards criteria

The following sections describe the quality standards aspects and give guidance on how to implement a quality standard.

There are several categories of quality criteria listed below. For each category, it is important for a set of quality standards to specify:

- Which aspects are referenced by the criteria
- What level of failure or minimum quality level is acceptable for each aspect
- Which product categories are subject to each criterion if there are differences across categories

5.4.3.1 Truth-in-advertising

The goal of a Truth-in-advertising standard is to protect buyers and end-users from false advertising claims. It is particularly important to ensure that the description of advertised values corresponds with test results in cases where end-users will make product purchasing decisions based partly or solely on advertising and packaging.

In practice it is ideal to check **any** advertised quality or performance statements against the test results, keeping in mind that often the framing or messaging for advertised statements is different from test conditions and that there is inherent uncertainty in the test result. In those cases where the advertised values will not be directly comparable to test results, care should be taken to avoid wrongly identifying false advertising.

For aspects that are described with numeric information, a tolerance should be defined for truth-in-advertising.

For aspects that are described with qualitative or Boolean information, judgement is required to discern if the test results match advertised values.

Table 10 – Truth-in-advertising criteria for quality standards

Truth-in-advertising criterion	Aspect(s) considered in assessment	Standard specification	Notes
System performance tolerance – numeric ratings	4.2.6 Run time 4.2.7 Light output Others, if applicable	The tolerance between the rated performance and measured performance.	These are key aspects for end-user experiences with the product, but also tend to have test results with higher uncertainty due to a combination of intrinsic manufacturing variation and test uncertainty due to the system-level nature of the aspects.
System components tolerance – numeric ratings	4.2.5 Solar module 4.2.4 Battery performance aspects Others, if applicable	The tolerance between the rated performance and measured performance.	These aspects, while important, have less impact on the overall user experience in general. They are more important for identifying replacement parts.
Other numeric ratings tolerance	Multiple	The tolerance between the rated performance and measured performance.	n/a
Overall truth-in-advertising statement	Multiple	Describe the general policy for interpreting truth-in-advertising requirements. Suggested statement: "Each description of the product that appears on the packaging, inside the package, and in any other media should be truthful and accurate. No statements should mislead buyers or end users about the features or utility of the product."	It is important to lay out a broad expectation of truth-in-advertising and to interpret it on a case-by-case basis.

Table 11 includes notes with guidance on aspects that are often part of a truth-in-advertising check because they are commonly advertised.

Table 11 – Notes on common truth-in-advertising aspects

Aspect(s)	Notes
4.2.6.1 Full-battery run time	Depends on the setting.
4.2.6.2 Solar-day run time	Depends on the setting and often depends on the assumptions about solar resource, which can be location-dependent.
4.2.6.3 Grid-charge run time	Depends on the setting.
4.2.6.4 Mechanical charge	Depends on the setting.
4.2.7.1 Average luminous flux output	Normally listed as peak luminous flux instead, but other times as the average during discharge, which is more representative of typical service levels.
4.2.1.6 Battery general aspects 4.2.4 Battery performance aspects 4.2.1.5 Battery easy replaceability	Package type, nominal voltage, capacity are all important for understanding if spares will be available; the replaceability determines if it is easy to service.
4.2.4 Battery performance aspects 4.2.1.4 Energy storage system information 4.2.1.6 Battery general aspects	This information is useful for ensuring the correct replacement battery can be obtained.
4.2.7.3 Average light distribution characteristics	Peak illuminance at a specified distance is often advertised in lieu of luminous flux. It is important to carefully adjust the test result to match the distance specified in the advertised value using known light propagation relationships ("inverse square law").
4.2.5 Solar module	Peak power capacity and type are often listed.
4.2.1.9 Auxiliary features information	The presence of functional auxiliary features (e.g., a mobile phone charger or USB power source) may be very important to some end-users.
4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage	Ensure that there is no information that misleads consumers about the level of protection afforded them by the combination of the enclosure and other water protection systems.
4.2.3.2 2 000 hour lumen maintenance	Lifetime is often given for much longer durations (e.g., 20 000 h). These can be compared to the 2 000 h lifetime to ensure the claim is possible.

5.4.3.2 Safety and durability

Safety and durability criteria protect the user from harm and the product from early failure during typical use. It is important to balance the safety and durability requirements with cost implications and reasonable expectations of consumer care, or the safety and durability criteria risk being over-prescribed. It is helpful to consider the expected minimum product lifetime when determining durability-related criteria.

For pass/fail tests, tolerances for failure rates should be specified.

Table 12 – Safety and durability criteria for quality standards

Safety or durability criterion	Aspect(s) considered in assessment	Standard specification	Notes
Level of water exposure protection (overall, technical, or enclosure-only)	4.2.10.1 Water protection integrated assessment 4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage 4.2.9.1 Product and manufacturer information 4.2.1.7 Packaging and user's manual information	The required level of water protection (see list below) and which aspects can contribute to protection. Levels of water protection: No protection Occasional rain Frequent rain Permanent outdoor exposure	The degree of protection should include consideration of product category and expected exposure. Specify the aspects that can contribute to the level of water exposure protection by choosing an overall, technical, or enclosure-only criterion.
Physical ingress protection	4.2.2.3 Physical ingress protection	The required level of physical ingress protection in terms of the minimum IP Class.	Degree of protection should include consideration of product category and expected exposure. Also, consider how connectors will be incorporated. Most external power connectors are not protected above IP2x.
Mechanical durability – drop test	4.2.2.4 Drop resistance	The required success rates in the drop test for functionality and safety (two success rates).	Failure allowance should consider Boolean nature of results and consider product category (i.e., fixed products are unlikely to be dropped compared to portable products).
Mechanical durability – goosenecks	4.2.2.5 Gooseneck durability	The required success rates in the gooseneck durability test for functionality and safety (two success rates).	Only applies to lamps with a gooseneck.
Mechanical durability - - connectors	4.2.2.6 Connector durability	The required success rates in the connector test for functionality and safety (two success rates).	Failure allowance should consider Boolean nature of results.
Mechanical durability - - switches	4.2.2.7 Switch durability	The required success rates in the switch test for functionality and safety (two success rates).	Failure allowance should consider Boolean nature of results.
Workmanship	4.2.2.9 Wiring quality	The required success rate for each aspect of the wiring quality inspection.	Failure allowance should consider the prevalence of each fault type.
Battery durability	4.2.2.10 Battery protection strategy	The guidelines for determining if batteries are well protected from early failure and if users are protected from potential harm due to battery failure.	Be careful not to over-prescribe the requirements, since there are a wide range of battery protection strategies that may provide satisfactory results—particularly for emerging chemistries.
Lumen maintenance	4.2.3.2 2 000 hour lumen maintenance	The minimum average level of lumen maintenance after 2 000 h and the required success rate on a sample-to-sample basis.	Consider the expected rate of use and desired product lifetime.
Fluorescent light durability	4.2.3.3 Fluorescent light durability	The required success rate for each sample in additional tests for fluorescent light durability.	Failure allowance should consider Boolean nature of results.

5.4.3.2.1 Water exposure protection considerations

The specifying organization should consider several factors when establishing water exposure protection requirements for solar lighting products. The product category (as outlined in section 4.1.2) is primarily responsible for determining these requirements, as some products are more likely than others to be exposed to water based on the product design. Cost is also a consideration, as products designed to be resistant to higher levels of water exposure are often more expensive because of the additional manufacturing costs associated with sealing the enclosure or internal circuit elements.

Table 13 describes how various levels of water protection are determined based on a combination of laboratory test results, product design and manufacturing information, and consumer information. The levels of protection are:

- No protection
- Occasional rain
- Frequent rain
- Permanent outdoor exposure

The results of an assessment will include several "types" of water protection level. A quality standard will need to specify which type is applicable. The types are:

- Overall protection: water protection by all the potential sources, including user behaviour
- Technical protection: protection from all product design and manufacturing aspects
- Enclosure-only protection: protection from the enclosure only

Table 13 – Recommended level of water protection by product category

Product category	Recommended level of water protection	Notes
Fixed separate (indoor)	No protection	Products intended for indoor use are unlikely to be exposed to water and do not require water protection.
Portable separate	Occasional rain	Portable products may experience occasional water exposure in service and should have some degree of water protection.
Portable integrated	Frequent rain	Portable integrated products are likely to be exposed to water when left outside to solar charge and should have good water exposure protection.
Fixed integrated (outdoor)	Permanent outdoor exposure	Outdoor products are certain to be exposed to rain and should have a high degree of water exposure protection.

5.4.3.3 End-user support

End-user support criteria describe the information (labelling, instructions, and built-in indicators) that enables end-users to maintain and fully realize the potential of a device.

Table 14 – End-user support criteria for quality standards

End user support criterion	Aspect(s) considered in assessment	Standard specification	Notes
Information on product design, utilization, and care	4.2.1.7 Packaging and user's manual information	Requirements for end-user information.	Define if there are requirements for consumer-facing information on packaging or in a user's manual. **This may be more appropriate for specific, targeted programmes than general market support or market offerings, since it is unlikely that a broad set of products will be available that meet any particular set of guidelines.** In some cases, a specific piece of information may have implications for the required level of quality in another criterion (e.g., advising the user to protect the device from exposure to water on the packaging or in the user's manual may warrant a reduction in the requirements for water protection defined by 4.2.2.1 Water protection – enclosure and 4.2.2.2 Water protection – circuit protection and drainage)
Other	4.2.1.10 Other visual screening results	Requirements for particular aspects of the visual screening.	Define if there are requirements for other aspects of end-user support (e.g., indicator lights). As with requirements for consumer-facing information, these requirements should be added with care to avoid over-prescribing.

5.4.4 Warranty requirements criteria

Warranty requirements are generally narrow in scope, focusing on the minimum duration and coverage for product warranties. In situations where there is a specific need for service in a particular location, service capabilities may be added to the warranty requirements. The table below lists criteria that are included in a warranty standard.

Table 15 – Criteria for warranty standards

End user support criterion	Aspect(s) considered in assessment	Standard specification	Notes
Maintenance and warranty terms	4.2.1.8 Warranty information	Minimum warranty duration and coverage.	Define the minimum warranty terms with consideration for the implications on availability of service and reasonable expectations for guaranteed lifetime.
Service capabilities	4.2.9.2 Warranty coverage	Minimum availability of service to end-users in a particular location	These requirements are very specific to "local" projects typically.

5.4.5 Performance targets criteria

The following sections describe aspects that are appropriate for use as performance targets and gives guidance on implementing a set of targets.

There are several categories of performance criteria listed below. For each category, it is important for a set of performance targets to specify:

- What level of performance is acceptable for each aspect
- Whether minimum levels of performance are contingent on also meeting others (e.g., a combination of run time and brightness)
- How many product settings must meet the criteria[1)]
- Which product categories are subject to each criterion if there are differences across categories

5.4.5.1 Combined run time and lighting service targets

Each product setting ("brightness level") can be described by a set of run times and lighting service. A set of performance targets includes a "combined" target to meet minimum run time(s) at a minimum lighting service level(s), and if at least one setting meets the combined target the product is in compliance. There may be more than one combined target.

5.4.5.1.1 Run time

Run time is a key performance indicator for lighting products; the duration of lighting service is directly related to end-user utility.

It is important to consider the range of charging options (see section 4.2.1.2) available to end-users and their likely service needs when setting run time criteria. Often, an "or" requirement is appropriate that allows compliance with any one of the criteria to pass an overall run time assessment.

1) It is generally appropriate to set performance targets that should be met by one setting or more, but allow flexibility for the remaining settings.

Table 16 – Run time criteria for performance targets

Run time criterion	Aspect(s) considered in assessment	Target specification	Notes
Central charged product full-battery run time	4.2.6.1 Full-battery run time 4.2.6.3 Grid-charge run time	The minimum full-battery run time and grid run time.	Set the target high enough to meet 1 day to 2 days of lighting service requirements for the end-user who will charge via centralized means. Note that many products with solar charging can also be charged via centralized means if they have an input port.
Independently solar charged product – solar-day run time	4.2.6.2 Solar-day run time	The minimum solar run time for a given solar resource.	Set the target high enough to meet typical daily needs given a standard or specific solar resource. Typically based on the standard solar day (5 kWh/m^2)
Independently mechanically charged product – mechanical run time characteristics	4.2.6.1 Full-battery run time 4.2.6.4 Mechanical charge	The minimum full-battery run time and mechanical run time.	Set a mechanical charge run time that is reasonable in terms of user effort and a Full-battery run time that ensures the user can use a product for sufficiently long periods of time between charging.

The table below lists some benchmarks for run time requirements that may be helpful for setting performance targets:

Table 17 – Run time benchmarks

Service type / context	Service level	Notes and source
2008 evening / night time illumination in off-grid Sub-Saharan Africa using fuel-based lighting	Median 3,5 h - 4 h, range of 2 h - 6 h.	From a set of market research surveys across five countries in Sub-Saharan Africa (Lighting Africa). Note this does not include early morning illumination needs, which may be an hour or more.
2007 night fishing in India	4 h - 6 h for fish sorting; 10 h for night fishing; 1,5 h for household uses.	From a small-sample survey in a fishing village (*Improved Lighting for Indian Fishing Communities,* ER291-3 Final Report May 16, 2007)

5.4.5.1.2 Lighting service

Lighting service levels determine the usefulness of a device for particular activities.

It may be important to consider the form factor (i.e. task, ambient, etc.) of the product or the needs of a particular target set of users (in the case of a targeted project) when setting lighting service level requirements.

Table 18 – Lighting service criteria for performance targets

Lighting service criterion	Aspect(s) considered in assessment	Target specification	Notes
General illumination service	4.2.7.1 Average luminous flux output	Minimum luminous flux.	Set the target high enough to meet general illumination needs, considering the affordability trade-offs and the size of spaces typically lit in off-grid households.
Task lighting service	4.2.7.3 Average light distribution characteristics	Minimum illuminance level and minimum area served with at least the minimum illuminance level. Specify the allowable orientations of the light (suspended from a fixed distance, suspended from an arbitrary distance, etc.).	Set the target high enough to meet the task lighting needs of a range of consumers, considering the affordability trade-offs.

The table below lists some benchmarks for lighting service requirements that may be helpful for setting performance targets:

Table 19 – Lighting service benchmarks

Service type / context	Service level	Notes and source
General illumination expectations in off-grid Sub-Saharan Africa	20 lm	A set of focus groups in 2010-2011 across five countries in Sub-Saharan Africa established that 20 lm is generally favourable for a variety of end-users in terms of meeting their expectations (Lighting Africa).
General illumination from typical fuel based lighting	10 lm - 30 lm	Unpressurized fuel based lighting (candles, "wick" lamps, and hurricane lamps) provide a range of lighting service from 10 lm - 30 lm.
General illumination from a 60 W incandescent light bulb (or 15 W CFL)	900 lm	This is representative of typical minimum lighting service levels in grid-connected homes and businesses.
Reading (children in off-grid village)	25 lux	This is based on a review of lighting needs in Nepali villages. (Bhusal et al 2007 doi: 10.1582/LEUKOS.2007.03.04.003).
General illumination in public buildings (industrialized country standards)	100-700 lux	From a review of lighting standards (Mills, E. and N. Borg, 1999. Trends in Recommended Illuminance Levels: An International Comparison Journal of the Illuminating Engineering Society, Winter 1999)
General detail-oriented work (industrialized country standards)	1 000 lux	From a review of lighting standards (Mills and Borg 1999)

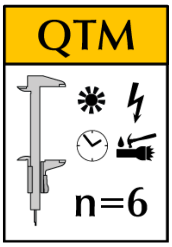
5.4.5.2 Additional functions

Additional functions may be required for particular programmes or offers if the end-users have specific needs beyond lighting service. These requirements are not normally used for general market support programmes focused on off-grid lighting that serve users with a variety of needs.

Table 20 – Additional function criteria for performance targets

Additional function criterion	Aspect(s) considered in assessment	Target specification	Notes
Mobile phone charging	4.2.1.9 Auxiliary features information	Specify if mobile charging is required and whether there are requirements for number and type of connectors, etc.	Mobile phone charging is a key function for many consumers, but is one that is easily described by advertising or on packaging. Consider a truth-in-advertising quality standard in this area for market support programmes. For bulk purchase or specifically targeted programmes it may be appropriate to specify mobile phone charging functions as a performance target.
Other	4.2.1.9 Auxiliary features information	Specify if there are additional required services.	Other services sometimes offered include integrated radios, fans, and more. It is critical to be careful not to over-specify feature requirements.

6 Quality test method



6.1 General

The Quality Test Method (QTM) is a rigorous set of tests with a relatively large sample size that uses randomly procured samples. It is the most stringent set of tests in this technical specification and is appropriate for several uses:

- Qualification for market support programmes
- Generating information for third-party verified specifications sheets

6.2 Applications

QTM tests can support a broad range of quality assurance needs where rigorous, unbiased test results are required. The table below lists examples of how they are applied depending on the type of quality assurance framework:

Table 21 – Applications of product specifications

Type of QA framework	Example(s) of applying this section
General market support	Require QTM results for qualifying for market support. Accept QTM results from any accredited laboratory. Use QTM results to produce standardized specifications sheets.
Manufacturing / distribution	Use QTM results to assess the full production / supply chain. Require QTM results for assessing potential business partners. Accept QTM results from any accredited laboratory.
Bulk procurement	Require QTM results for assessing potential suppliers. Accept QTM results from any accredited laboratory.
Trade regulation	Require QTM results for qualifying for tax exemption. Accept QTM results from any accredited laboratory.

6.3 Sampling requirements

The product samples should be selected and shipped to the test lab according to the random sampling guidelines outlined in Appendix F.

The recommended number of samples to procure for QTM testing is 18: six each for two parallel batches plus six spares.

6.4 Laboratory requirements

The test laboratory should be properly trained to undertake the test methods described below and accredited by an international or national standards body (e.g., ILAC using ISO 17025). The measurement equipment should be calibrated against reference instruments annually, or as directed by the equipment manufacturer or laboratory accreditation organization.

6.5 Testing requirements

Each of the aspects listed in the table below should be measured where they are applicable to a product. It is not necessary that each aspect be measured on each sample under test, but it is important to note in the test results which samples were the source of each result in an unambiguous way. A general description of the test method family for each aspect is listed for informative purposes only.

For products with multiple settings, at least one set of test results should fully characterize the performance on the highest light output setting. At least one other set of test results should characterize a setting with lower output. Additional settings can be measured at the discretion of the test laboratory.

Table 22 (1 of 2) – QTM testing requirements

Aspect	Reference	Applicability	Sample size	Test classes	Test method family
Product design, manufacture, and marketing aspects	**4.2.1**				
Arrangement of components	4.2.1.1	All products	1	A	Visual screening
Charging system information	4.2.1.2	All products	1	A	Visual screening
Lighting system information	4.2.1.3	All products	1	A	Visual screening
Energy storage system information	4.2.1.4	All products	1	A	Visual screening
Battery easy replaceability	4.2.1.5	All products	1	A	Visual screening
Battery general aspects	4.2.1.6	All products	1	A	Visual screening
Packaging and user's manual information	4.2.1.7	All products	1	A	Visual screening
Warranty information	4.2.1.8	All products	1	A	Visual screening
Auxiliary features information	4.2.1.9	All products	1	A	Visual screening
Other visual screening results	4.2.1.10	All products	6	A	Visual screening
Product durability and workmanship aspects	**4.2.2**				
Water protection – enclosure	4.2.2.1	All products	6	A,B	IP class assessment
Water protection – circuit protection and drainage	4.2.2.2	At the request of the testing client	6	A	n/a
Physical ingress protection	4.2.2.3	All products	6	A,B	IP class assessment
Drop resistance	4.2.2.4	All products	6	A,B	Durability
Gooseneck durability	4.2.2.5	Products with a gooseneck	6	A	Durability
Connector durability	4.2.2.6	All products	6	A	Durability
Switch durability	4.2.2.7	All products	6	A	Durability
Strain relief durability	4.2.2.8	All products	6	A	Durability
Wiring quality	4.2.2.9	All products	6	A	Visual screening
Battery protection strategy	4.2.2.10	All products	6	A	Charge controller testing
Lighting durability aspects	**4.2.3**				
2 000 hour lumen maintenance	4.2.3.2	All products	6	A	Lumen maintenance
Fluorescent light durability	4.2.3.3	Products with fluorescent light	6	A	Extra tests for fluorescent lights

Table 23 (2 of 2) – QTM testing requirements

Aspect	Reference	Applicability	Sample size	Test classes	Test method family
Battery performance aspects	**4.2.4**				
Battery capacity	4.2.4.1	All products	6	A	Battery tests
Battery voltage	4.2.4.2	All products	6	A	Battery tests
Solar module aspects	**4.2.5**				
Solar I-V curve parameters	4.2.5.1	All products	6	A, B	Solar module tests
Solar module cable length	4.2.5.2	All products	6	A	Visual screening
Run time aspects	**4.2.6**				
Full-battery run time	4.2.6.1	All products	6	A	Run time
Solar-day run time	4.2.6.2	Solar charged products	6	A	Run time
Grid-charge run time	4.2.6.3	Grid charged products	6	A	Run time
Mechanical charge ratio	4.2.6.4	Mechanical charged products	6	A	Run time
Light output aspects	**4.2.7**				
Average luminous flux output	4.2.7.1	All products	6	A	Luminous flux
Full width half maximum (FWHM) angles	4.2.7.2	All products	6	A	Light distribution
Average light distribution characteristics	4.2.7.3	All products	6	A	Light distribution
Colour characteristics	4.2.7.4	All products	6	A	Luminous flux
Circuit efficiency aspects	**4.2.8**				
Input to battery circuit efficiency	4.2.8.1	All products	6	A	Circuit efficiency
Self-certification aspects	**4.2.9**				
Product and manufacturer information	4.2.9.1	All products	n/a	A	Self-reported
Warranty coverage	4.2.9.2	As required for programmes	n/a	A	Self-reported
Third-party marks and certifications	4.2.9.3	All products	n/a	A	Self-reported
Integrated assessment	**4.2.10**				
Water protection integrated assessment	4.2.10.1	As requested by the manufacturer	n/a	A	Integrated assessment

6.6 Recommended tests programme

The following programme is one strategy to accomplish all the tests in a timely manner. The figure below illustrates the recommended flow for the programme of tests.

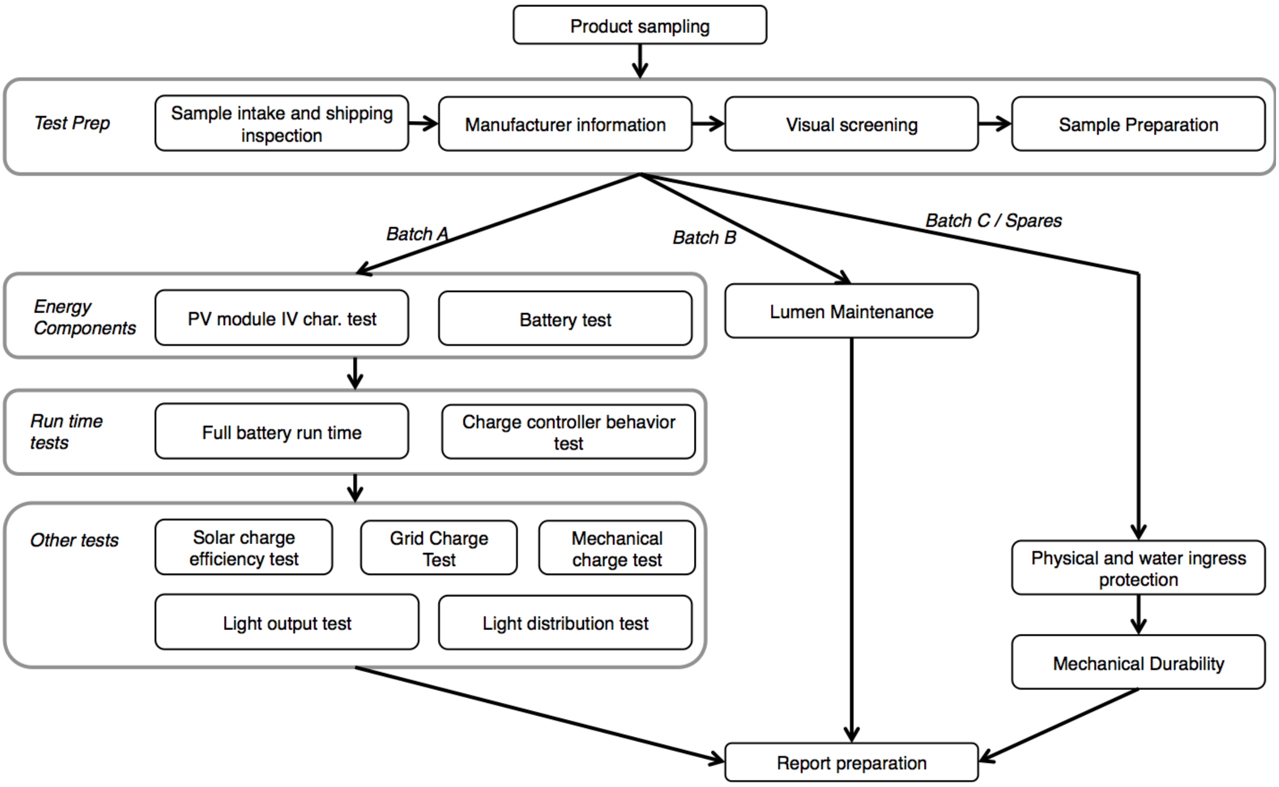


Figure 6 – Recommended sequence of testing for QTM

6.6.1 Product sampling

Samples are randomly procured in the supply chain or market and shipped to the test centre. The product sampling procedure is presented in Appendix F.

6.6.2 Test preparation

The initial intake steps involve ensuring the samples are intact, preparing them for further tests, and requesting self-certification information from the manufacturer.

6.6.2.1 Test sample intake and shipping inspection

The samples should all be inspected for shipping damage, unambiguously labelled for identification during the testing process, and placed into batches.

6.6.2.2 Manufacturer self-reported information

If it has not already been done, the manufacturer (or their proxy) should be contacted to ask for self-certification information that is outlined in Appendix E and to inform them the test samples were received.

6.6.2.3 Visual screening

The visual screening should be done before any other tests and before the samples are altered to prepare them for other tests. The visual screening procedure is presented in Appendix G.

6.6.2.4 Sample preparation

After the visual screening it is necessary to prepare the samples for further testing by partially disassembly to provide easy access to various components. Sample preparation recommendations are presented in Appendix H. All samples, except for spares, need to be prepared.

6.6.3 Batch A tests

Batch A undergoes the main set of tests.

6.6.3.1 Energy Component tests

Energy component tests can generally be done independently of each other on an ad-hoc basis. The recommendation is to complete them before running system-level tests, or complete them opportunistically as is appropriate.

6.6.3.1.1 Battery test

The battery tests (in particular capacity measurements) should be done before any system-level run time tests to ensure the batteries are "refreshed" from any time they spent in storage before testing. The battery test procedure is presented in Appendix L.

6.6.3.1.2 Photovoltaic module I-V characteristics test

Since outdoor solar module testing is subject to the availability of a clear "solar window" they are often the most "opportunistic" of the tests in the programme. The outdoor photovoltaic module I-V characteristics test procedure is presented in Appendix R.

For amorphous solar modules, it is important to begin sun soaking the modules immediately after they are received since at least 30 days of outdoor exposure are needed before the tests can commence.

6.6.3.2 Run time tests

The full-battery run time test should be carried out prior to the additional run time related tests. The additional run time related tests require using measured values during the test to determine the specified run time.

6.6.3.2.1 Full-battery run time

It is often convenient to do the full-battery run time test directly after the battery capacity measurements. It is necessary to cycle the batteries (as is done in the battery capacity measurements) and fully charge them before this test. The full-battery run time test procedure is presented in Appendix N.

6.6.3.3 Charge controller behaviour test

The deep-discharge protection charge controller measurement can be incorporated into the full-battery run time. The overcharge protection charge controller measurement requires independent testing. The charge controller behaviour test procedure is presented in Appendix T.

6.6.3.4 Other tests

6.6.3.4.1 Solar charge efficiency test

Solar charging efficiency testing must be commenced after the sample is fully discharged according to the full discharge preparation in Appendix O. The solar charge efficiency value is used to determine the solar run time. The solar charge test procedure is presented in Appendix S.

6.6.3.4.2 Grid charge test

Grid charge testing must be commenced after the sample is fully discharged according to the full discharge preparation in Appendix O. The grid charge efficiency value determined by the grid charge test is used to determine the grid run time. The grid charge test procedure is presented in Appendix P.

6.6.3.4.3 Electromechanical charge test

Electromechanical charge testing must be commenced after the sample is fully discharged according to the full discharge preparation in Appendix O. The mechanical charge efficiency value determined by the electromechanical charge test is used to determine the mechanical charging ratio. The electromechanical charge test procedure is presented in Appendix Q.

6.6.3.4.4 Light output test

The light output test is not strictly on components, but of a system including a driver, light source, and optical components. However, the system can often be treated as a single component if it is separable from the other main components while maintaining the same electrical and thermal characteristics that are present when the product is fully assembled. The light output test procedure should be done after the full-battery run time test and is presented in Appendix J.

6.6.3.4.5 Light distribution test

Like the light output test, the light distribution test is not strictly on components, but of a system including a driver, light source, and optical components. However, the system can often be treated as a single component if it is separable from the other main components while maintaining the same electrical and thermal characteristics that are present when the product is fully assembled. The light distribution test procedure should be done after the full-battery run time test and is presented in Appendix U.

6.6.4 Batch B tests

Batch B undergoes long-term lumen maintenance testing in parallel with Batch A testing.

6.6.4.1 Lumen maintenance test

The batch B samples must not have undergone any other testing prior to lumen maintenance testing. This test is long-term and is carried out in parallel with those tests undergone by batch A samples. The lumen maintenance test procedure is presented in Appendix K.

6.6.5 Batch C / Potentially destructive tests

In general it is best to save destructive testing to the end of the test programme to ensure sufficient samples are available in other tests. These tests can be performed on spare samples or batch A or B samples that have finished all other testing.

6.6.5.1 Physical and water ingress protection test

It is necessary that physical and water ingress protection be assessed on samples that have the least amount of impact or adulteration from the testing process. Unused spares should be the preferred samples for this assessment. The physical and water ingress protection test procedure is presented in Appendix V. It is also possible for product to be assessed for water protection with the level of water protection procedure, which is presented in Appendix W.

6.6.5.2 Mechanical durability test

It is preferable to do durability testing (switches, connectors, gooseneck, and drop test) on the "spare" samples that have not been altered for testing. However, it is often infeasible to accomplish this if the unadulterated spares are required for other tests and in the best case there will be five unadulterated spares out of the original 18. In this case, the "least modified" samples from Batch A or Batch B should be used. The mechanical durability test procedure is presented in Appendix X.

6.6.6 Report preparation

After testing is complete and the results are validated, a report is generated and checked for accuracy before submission to the client.

6.7 Reporting

The report for ISM testing should support any activities that depend on the information from ISM testing. Templates for test results reporting are provided in Appendix Y.

At a minimum the report should include the following elements:

a) Informative cover page

a) Summary page(s) as described in Appendix Y.

b) Detailed test reports that include results for the aspects described in section 6.5 that were measured at the primary test lab.

c) Detailed test reports for tests performed at other labs (e.g. ingress protection test results done at a specialty IP test lab).

d) Appendices that include supplementary images and/or other supporting information.

e) Appendices that indicate manufacturer-provided information and self-certification evidence (e.g., certificates of compliance)

7 Market check method

7.1 General

The Market Check Method (MCM) is a flexible set of tests that is designed for targeted retesting or checking of an aspect or set of aspects. The tests are designed for use in situations where only partial retesting is required but with rigor equal to QTM testing, such as:

- when a product is partially updated and an update is required for a standardized specifications sheet
- when there is suspicion that products on the market are substandard compared to those that were originally tested for programme qualification or the production of a standardized specifications sheet

7.2 Applications

MCM tests have a narrower focus than QTM results—they are targeted for establishing if a deviation has occurred from previous QTM results for particular aspects (but not every aspect). The table below lists examples of how they are applied depending on the type of quality assurance framework:

Table 24 – Applications of product specifications

Type of QA framework	Example(s) of applying this section
General market support	Use MCM results for market monitoring and enforcement. Use MCM results to update standardized specifications sheets.
Manufacturing / distribution	Use MCM results for market monitoring.
Bulk procurement	N/A
Trade regulation	N/A

7.3 Sampling requirements

The test samples should be randomly procured from the market according to procedures in Appendix F. In select cases it may be appropriate to accept samples directly submitted by the manufacturer (e.g., if the MCM testing is to confirm the existence of an aspect that does not depend on manufacturing QC and tolerances).

Enough samples should be provided or selected so it is possible to complete the tests in a timely manner and account for unforeseen needs of additional samples.

The recommended number of samples for MCM testing is six per batch plus at least one spare. If there are several tests to be undertaken it may be appropriate to use more than one batch.

7.4 Laboratory requirements

The test laboratory should be properly trained to undertake the test methods described below and accredited by an international or national standards body (e.g., ILAC using ISO 17025). The measurement equipment should be calibrated against reference instruments annually, or as directed by the equipment manufacturer or laboratory accreditation organization.

7.5 Testing requirements

Most of the specific test requirements for MCM tests will depend entirely on the aspects that are suspected to have changed since the previous testing.

The required sample size and allowable test classes for MCM tests should be the same as those required for QTM testing of the same aspect (see section 6.5).

The particular test plan for a MCM is case dependent and up to the judgement of the organization or institution who initiates the testing. The following recommendations should be kept in mind when creating MCM test plans:

- Always include a visual screening test to uncover any unexpected changes to the product; be ready to augment the original test plan pending the visual screening results.
- Consider system-level impacts of component changes.

The table below lists recommended aspects to test or measure in the case of three typical changes to a product: updates to the light source, battery, and PV module.

Table 25 (1 of 2) – Typical MCM testing guidelines

Aspect	Reference	Different light source	Different battery	Different PV module
Product design, manufacture, and marketing aspects	**4.2.1**			
Arrangement of components	4.2.1.1	Yes	Yes	Yes
Charging system information	4.2.1.2	No	Yes	No
Lighting system information	4.2.1.3	Yes	No	No
Energy storage system information	4.2.1.4	No	Yes	No
Battery easy replaceability	4.2.1.5	No	Yes	No
Battery general aspects	4.2.1.6	No	Yes	No
Other visual screening results	4.2.1.10	Yes	Yes	Yes
Product durability and workmanship aspects	**4.2.2**			
Drop resistance	4.2.2.4	Yes	Yes	Yes
Strain relief durability	4.2.2.8	No	No	Yes
Wiring quality	4.2.2.9	Yes	Yes	Yes
Battery protection strategy	4.2.2.10	No	Yes	No
Lumen maintenance aspects	**4.2.3**			
2 000 hour lumen maintenance	4.2.3.1	Yes	No	No
Battery performance aspects	**4.2.4**			
Battery capacity	4.2.4.1	No	Yes	No
Battery voltage	4.2.4.2	No	Yes	No
Solar module aspects	**4.2.5**			
Solar I-V curve parameters	4.2.5.1	No	No	Yes
Solar module cable length	4.2.5.2	No	No	Yes

Table 25 (2 of 2) – Typical MCM testing guidelines

Aspect	Reference	Different LED	Different battery	Different PV module
Run time aspects	**4.2.6**			
Full-battery run time	4.2.6.1	Yes	Yes	No
Solar-day run time	4.2.6.2	Yes	Yes	Yes
Grid-charge run time	4.2.6.3	Yes	Yes	No
Mechanical charge run time	4.2.6.4	Yes	Yes	No
Light output aspects	**4.2.7**			
Average luminous flux output	4.2.7.1	Yes	No	No
Full width half maximum (FWHM) angles	4.2.7.2	Yes	No	No
Average light distribution characteristics	4.2.7.3	Yes	No	No
Colour characteristics	4.2.7.4	Yes	No	No
Self-certification aspects	**4.2.9**			
Third-party marks and certifications	4.2.9.3	Yes	Yes	Yes

7.6 Recommended tests programme

See section 6.6.

7.7 Report requirements

The report for MCM testing should support any activities that depend on the information from MCM testing. Templates for test results reporting are provided in Appendix Y.

At a minimum the report should include the following elements:

a) Informative cover page

b) Table of contents

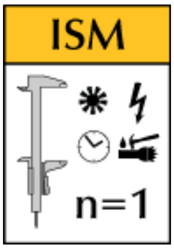
c) Summary page(s) as described in Appendix Y.

d) Detailed test reports that include results for the aspects described in section 7.5.

e) Appendices that include images and other supporting information.

f) Appendices that indicate manufacturer-provided information and self-certification evidence (e.g., certificates of compliance)

8 Initial screening method



8.1 General

The Initial Screening Method (ISM) is appropriate for preliminary testing and providing quick feedback on product design and performance in absolute terms.

8.2 Applications

ISM tests should be used for obtaining quick, preliminary results to help inform subsequent rounds of testing that confirm the preliminary results. The table below lists examples of how they are applied depending on the type of quality assurance framework:

Table 26 – Applications of product specifications

Type of QA framework	Example(s) of applying this section
General market support	Use ISM results to filter potential organizations / products for targeted support, followed up by QTM testing for those with promise. Use ISM results to trigger MCM testing when there is suspicion of a change in the quality or performance or products in the market.
Manufacturing / distribution	Use ISM results for batch to batch monitoring of production runs of shipments.
Bulk procurement	Use ISM results for batch to batch monitoring shipments.
Trade regulation	Use ISM results to make preliminary decisions, followed up with QTM testing to confirm results.

8.3 Sampling requirements

The test samples can be provided directly by a manufacturer (or their proxy) or can be randomly procured from the market according to procedures in Appendix F.

Enough samples should be provided or selected so it is possible to complete the tests in a timely manner and account for unforeseen needs of additional samples.

The recommended number of samples for ISM testing is three: one each for two parallel batches and one spare.

8.4 Laboratory requirements

The test laboratory should be properly trained to undertake the test methods described below. The measurement equipment should be calibrated against reference instruments annually, or as directed by the equipment manufacturer.

8.5 Testing requirements

Each of the aspects listed in the table below should be measured where they are applicable to a product. It is not necessary that each aspect be measured on each sample under test, but it is important to note in the test results which samples were the source of each result in an unambiguous way. A general description of the test method family for each aspect is listed for informative purposes only.

For products with multiple settings, at least one set of test results should fully characterize the performance on the highest light output setting. At least one other set of test results should characterize a setting with lower output. Additional settings can be measured at the discretion of the test laboratory.

Table 27 (1 of 2) – ISM testing requirements

Aspect	Reference	Applicability	Sample size	Test classes allowed	Test method family
Product design, manufacture, and marketing aspects	**4.2.1**				
Arrangement of components	4.2.1.1	All products	1	A	Visual screening
Charging system information	4.2.1.2	All products	1	A	Visual screening
Lighting system information	4.2.1.3	All products	1	A	Visual screening
Energy storage system information	4.2.1.4	All products	1	A	Visual screening
Battery easy replaceability	4.2.1.5	All products	1	A	Visual screening
Battery general aspects	4.2.1.6	All products	1	A	Visual screening
Packaging and user's manual information	4.2.1.7	All products	1	A	Visual screening
Warranty information	4.2.1.8	All products	1	A	Visual screening
Auxiliary features information	4.2.1.9	All products	1	A	Visual screening
Other visual screening results	4.2.1.10	All products	1	A	Visual screening
Product durability and workmanship aspects	**4.2.2**				
Water protection – enclosure	4.2.2.1	All products	1	A,B	IP class assessment
Water protection – circuit protection and drainage	4.2.2.2	At the request of the testing client	0	A	n/a
Physical ingress protection	4.2.2.3	All products	1	A,B	IP class assessment
Drop resistance	4.2.2.4	All products	1	A,B	Durability
Gooseneck durability	4.2.2.5	Products with a gooseneck	1	A	Durability
Connector durability	4.2.2.6	All products	1	A	Durability
Switch durability	4.2.2.7	All products	1	A	Durability
Strain relief durability	4.2.2.8	All products	1	A	Durability
Wiring quality	4.2.2.9	All products	1	A	Visual screening
Battery protection strategy	4.2.2.10	All products	1	A	Charge controller testing
Lumen maintenance aspects	**4.2.3**				
500 hour lumen maintenance	4.2.3.1	All products	1	A	Lumen maintenance
Battery performance aspects	**4.2.4**				
Battery capacity	4.2.4.1	All products	1	A	Battery tests
Battery voltage	4.2.4.2	All products	1	A	Battery tests

Table 27 (2 of 2) – ISM testing requirements

Aspect	Reference	Applicability	Sample size	Test classes allowed	Test method family
Solar module aspects	**4.2.5**				
Solar I-V curve parameters	4.2.5.1	All products	1	A, B	Solar module tests
Solar module cable length	4.2.5.2	All products	1	A	Visual screening
Run time aspects	**4.2.6**				
Full-battery run time	4.2.6.1	All products	1	A	Run time
Solar-day run time	4.2.6.2	Solar charged products	1	A	Run time
Light output aspects	**4.2.7**				
Average luminous flux output	4.2.7.1	All products	1	A,B	Luminous flux
Full width half maximum (FWHM) angles	4.2.7.2	All products	1	A	Light distribution
Average light distribution characteristics	4.2.7.3	All products	1	A	Light distribution
Colour characteristics	4.2.7.4	Optional	1	A,B	Luminous flux
Circuit efficiency aspects	**4.2.8**				
Input to battery circuit efficiency	4.2.8.1	Optional	1	A	Circuit efficiency
Self-certification aspects	**4.2.9**				
Product and manufacturer information	4.2.9.1	All products	1	A	Self-reported
Warranty coverage	4.2.9.2	All products	1	A	Self-reported
Third-party marks and certifications	4.2.9.3	Optional	1	A	Self-reported
Integrated assessment	**4.2.10**				
Water protection integrated assessment	4.2.10.1	As requested by the manufacturer	n/a	A	Integrated assessment

8.6 Recommended tests programme

See section 6.6.

8.7 Reporting

The report for ISM testing should support any activities that depend on the information from ISM testing. Templates for test results reporting are provided in Appendix Y.

At a minimum the report should include the following elements:

a) Informative cover page

b) Table of contents

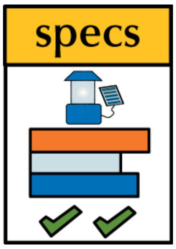
c) Summary page(s) as described in Appendix Y.

d) Detailed test reports that include results for the aspects described in section 8.5.

e) Appendices that include images and other supporting information.

f) Appendices that indicate manufacturer-provided information and self-certification evidence (e.g., certificates of compliance)

9 Standardized specifications sheets



9.1 General

Standardized Specifications Sheets (SSS) are a way to communicate quality assurance information to the market. They include key information for potential buyers of off-grid lighting products. The information in SSS is based on standardized test results from QTM testing.

9.2 Applications

SSS requirements are useful to understand for the broad market, since they are typically the primary way to communicate and share QTM test results. The table below lists examples of how they are applied depending on the type of quality assurance framework:

Table 28 – Applications of product specifications

Type of QA framework	Example(s) of applying this section
General market support	Administer a SSS third-party verification programme.
Manufacturing / distribution	Use SSS to advertise products.
Bulk procurement	Use SSS from third-party verified sources to screen potential products for purchase.
Trade regulation	Use SSS from third-party verified sources to screen applicants for import / tax programmes.

9.2.1 Guidance

A SSS guidelines document should provide a framework for providing clear information to buyers to enable fair comparisons to be made between different products. In general, the following are best practices for designing an SSS programme:

- Focus on specifications for system level performance (as opposed to component performance) wherever possible.
- Keep the required element list as short as possible for simplicity and clarity while still providing key information to the target buyers for the SSS programme.
- Reach out to the people who use SSS to make decisions and ask their opinion on them.
- Use graphics to convey key points.

9.2.2 Framework for SSS guidelines document

The key elements of a guidelines document for an SSS programme are:

- **Qualification requirements**, that is, the quality standards and/or performance targets that must be met to use the SSS.
- **Test result requirements** including the type of testing required and requirements for updating the results in the SSS.

- **Style and format requirements** to ensure easy comparison of information across SSS.
- **Reporting precision** that guides the level of rounding that is allowed from measured test results.
- **Results verification** mechanisms to reduce the incidence of counterfeit SSS.
- **Required elements** that must be in every SSS.
- **Optional elements** that can be included at the discretion of the manufacturer or their proxy.
- **An example** of the style, format, and contents in a fully implemented SSS.

An example framework document is included in Appendix D.

9.2.2.1 Qualification standards and targets

This defines if there are qualification criteria for participating in the SSS programme and generally references a product specification (see section 5).

9.2.2.2 Test result requirements

Details on the test result requirements for information presented in the SSS. The details should be specific about the requirements both when SSS are originally made and when they are updated.

9.2.2.2.1 Original testing

Typically QTM test results are used as the basis for the original SSS of a particular product. In some cases the results may come from other sources. It is important to specify how long results are valid before retesting is required.

9.2.2.2.2 Retesting and updates

This section describes the test requirements for several situations:

- Full retesting after the original results have expired
- Partial retesting when the product is updated and the tolerance for changes in the specification that triggers retesting
- Partial retesting when a market check indicates there are discrepancies between the SSS and products available in the market

9.2.2.3 Style and format

The style and format of SSS is generally uniform across all the SSS in a particular programme to make them useful for buyers or other stakeholders who rely on them as an information resource.

Style and formatting guidelines should generally specify the following:

- Character font and size
- Use of colour
- General guidelines for language and style

The style and format guidelines are typically supplemented by an example SSS.

9.2.2.4 Reporting precision

Reporting precision guidelines describe the process to round quantitative test results so the information in each element of the SSS reflects the degree of significance for test results and is easy to read. For example, an average measurement of 52,3 lumens across several samples might be rounded to 50 lumens for placement on the SSS.

The guidelines should define three rounding rules for each SSS element that is covered:

a) Maximum precision of reporting: The highest number of significant figures allowed in the display on the SSS.

b) Minimum precision of reporting: The fewest number of significant figures allowed in the display on the SSS.

c) Maximum adjustment before additional rounding: If an element is going to be displayed with fewer significant figures than specified in 9.2.2.4 (b), the maximum percentage a measured value can be adjusted up or down before additional rounding. Typically this is a very low number (⩽ 5 %).

d) Allowable direction for additional rounding: If an element is going to be displayed with fewer significant figures than specified in 9.2.2.4 (b), this specifies the allowable direction for additional rounding. Often this is the direction towards "worse" performance or quality.

The table below lists several elements that might be included in a SSS and provides recommended rounding rules for each. A similar table should be included in SSS guidelines documents.

Table 29 – Recommended precision requirements for metrics on a continuous scale

Metric	Maximum precision of reporting	Minimum precision of reporting	Maximum adjustment before rounding	Allowable direction for additional rounding	Example(s)
Run time	2 s.f.*	1 s.f.	5 %	Down	4,33 h → 4,3 h or 4 h 36,6 h → 37 h or 30 h
Light output (lm)	2 s.f.	1 s.f.	5 %	Down	19,2 lm → 19 lm or 20 lm
Colour rendering (CRI) (R_a)	2 s.f.	2 s.f.	n/a	n/a	83,2 → 83
Colour temperature (CCT) (K)	2 s.f.	2 s.f.	n/a	n/a	4 678 K → 4 700 K
Light distribution (FWHM)	2 s.f.	2 s.f.	n/a	n/a	87°→87° 178°→180°
Battery capacity (mAh)	2 s.f.	2 s.f.	n/a	n/a	1 432 mAh → 1 400 mAh or 1 000 mAh
Other information	2 s.f.	1 s.f.	5 %	Varies	n/a

* s.f. = "significant figures"

9.2.2.5 Results verification

Describe any features of the SSS that will facilitate verification of the contents. This can be via an online check, holograms, or any other security feature.

9.2.2.6 Section descriptions

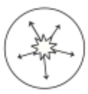
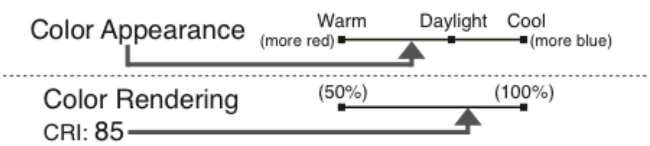
Each section in the SSS should include a heading name and list the required and optional elements in the section. Each element should include a description of which aspects from the test results are referred to and a note on how to format the information. If graphics are used, a general format should be defined.

9.2.2.7 Example sheet

An illustrative example standardized specifications sheet is provided below.

Example Product

Verify specifications at:
www.lightingafrica.org/specs/EX_01

Overall Performance	
"High" setting: 25 lumens for 4 hours after one day of solar charging	
General Information	
Manufacturer	Example Corporation, Inc.
Product Name	Example Lamp 3000+
Model Number	ABC12345
Contact	janedoe@examplecorp.com
Website	www.examplecorp.com
Warranty	6 months for lamp, 1 year for solar module; see detailed terms for more information.
Run Time	
Autonomous Run Time (full battery)	6.0 hours on "high" setting
Lighting hours per solar day (PV only)	4.0 hours on "high" setting
Lighting System	
Lamp type	LED
Light output	25 lumens on "high" setting
Light output at 2000 hours	23 lumens on "high" setting
Light Distribution Omni 	
Charging System	
Charge type(s)	Solar PV
Storage System	
Storage Type	Rechargeable NiMH (3x AA in package)
Nominal Battery Voltage	3.6 volts DC
Battery Capacity	650 milliamp hours
Battery Protection	Active HVD and LVD
Easily Replaceable Battery?	No
Additional Information & Special Features	
Lamp Housing: Injection molded ABS **Standard feature:** Mobile phone charging with six connectors **Factory Certification**: ISO9001	
Date of Sample Procurement for Testing	January 2011
	Revision 2011.01

Appendix A
(normative)
LIGHTING GLOBAL Minimum Quality Standards

A.1 Scope

These quality standards and warranty requirements are the minimum for participation in Lighting Global program activities.

The aim of these quality standards is to protect end-users from early failure and ensure that advertised information is valid. The warranty requirements provide a baseline of support.

A.2 Test Requirements

Initial qualification under these standards and targets requires QTM test results (section 6). On-going qualification is subject to successful market checks according to the market check method (section 7). Full re-testing with QTM is required after two years.

A.3 Product Category Requirements

This document applies to fixed separate (indoor), portable separate, portable integrated and fixed integrated (outdoor) products. It is generally applicable only to products with an FOB wholesale price of 100 $USD or lower but may also be applied to higher cost products that fit the general scope.

Qualification as a "separate" PV module requires meeting the criteria listed below:

Table A.1 – Qualification as separate PV module

Criterion	Aspect(s)	Required value
PV module cable length	4.2.5.2 Solar module cable	≥ 3 m to qualify as a "separate" PV module with 10 % tolerance

A.4 Quality standards

The product must meet each of the criteria listed in the tables below to meet the quality standards:

Table A.2 – Truth-in-advertising tolerance

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
System performance tolerance – numeric ratings	4.2.6 Run time 4.2.7 Light output Others, if applicable	≤ 15 % deviation from ratings (always ok if actual performance is better than advertised).
System components tolerance – numeric ratings	4.2.5 Solar module 4.2.4 Battery performance aspects Others, if applicable	≤ 15 % deviation from ratings (always ok if actual performance is better than advertised).
Other numeric ratings tolerance	Multiple	≤ 15 % deviation from ratings (always ok if actual performance is better than advertised).
Overall truth-in-advertising statement	Multiple	Any description of the product that appears on the packaging, inside the package, and in any other media should be truthful and accurate. No statements should mislead buyers or end users about the features or utility of the product.

Table A.3 – Safety and durability standards

Safety or durability criterion	Aspect(s) considered in assessment	Product category	Requirement
Overall water exposure protection	4.2.10.1 Water protection integrated assessment 4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage 4.2.1.7 Packaging and user's manual information	Fixed separate (indoor)	No protection required.
		Portable separate	Protection from occasional exposure to rain.
		Portable integrated	Protection from frequent exposure to rain.
		Fixed integrated (outdoor)	Protection from permanent outdoor exposure.
Physical ingress protection	4.2.2.3 Physical ingress protection	All except below	Minimum of IP 2x protection.
		Fixed integrated (outdoor)	Minimum of IP 5x protection
Mechanical durability – drop test	4.2.2.4 Drop resistance	Fixed separate (indoor) and fixed integrated (outdoor)	None result in safety hazards. There is no requirement that the lighting kits are still functional after a drop.
		Portable separate	Maximum failure rate for functionality is 1/6; none result in safety hazards.
		Portable integrated	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – goosenecks	4.2.2.5 Gooseneck durability	Any with gooseneck	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – connectors	4.2.2.6 Connector durability	All products	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – switches	4.2.2.7 Switch durability	All products	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Workmanship	4.2.2.9 Wiring quality	All products	Maximum prevalence of bad solder joints is 1/6 samples; maximum prevalence of poor wiring is 1/6 samples; maximum prevalence of overall workmanship failure is 1/6
Battery durability	4.2.2.10 Battery protection strategy	All products	An appropriate battery protection strategy is used that will protect batteries from early failure and end-users from harm.
Lumen maintenance	4.2.3.2 2 000 hour lumen maintenance	All products	L_{70} time is greater than 2 000 h for the average sample. No more than 1/6 samples fails (defined as being more than 10 % below L_{70} at 2 000 h).
Fluorescent light durability	4.2.3.3 Fluorescent light durability	Products with fluorescent lights	Maximum failure rate for functionality is 1/6.

A.5 Warranty requirements

The product must meet each of the criteria listed in the table below to meet the warranty requirements:

Table A.4 – End-user support requirements

Support type	Aspect(s)	Requirement
Maintenance and warranty terms	4.2.1.8 Warranty information	End-users are provided at least six months of warranty coverage from the point of purchase; it should cover manufacturing defects that impede operation under normal use and protection from early component failure, including coverage on the battery.

Appendix B (informative)
Recommended quality standards and performance targets for off-grid lighting market support programme qualification.

B.1 Scope

These quality standards, warranty requirements, and performance targets are appropriate for qualification for market support programmes that support energy access for broad sets of end-users with low to middle incomes who are off-grid in the developing world.

The target end-users are typically cash-poor and will be expected to purchase qualifying products outright or under financing terms.

This is a bi-level qualification document. Meeting only the quality standards and warranty requirements provides access to basic programme services and incentives. Extended services and incentives are available if the performance targets are met.

The aim of these quality standards is to protect end-users from early failure and ensure that advertised information is valid. The warranty requirements provide a baseline of support. The goal of the performance targets is to ensure users receive service levels that are at least as good as the incumbent technology—fuel based lighting.

B.2 Test Requirements

Initial qualification under these standards and targets requires QTM test results (section 6). On-going qualification is subject to successful market checks according to the market check method (section 7). Full re-testing with QTM is required after two years.

B.3 Product Category Requirements

This document applies to fixed separate (indoor), portable separate, portable integrated and fixed integrated (outdoor) products. It is generally applicable only to products with an FOB wholesale price of 100 $USD or lower.

Qualification as a "separate" PV module requires meeting the criteria listed below:

Table B.5 – Qualification as separate PV module

Criterion	Aspect(s)	Required value
PV module cable length	4.2.5.2 Solar module cable	≥ 3 m to qualify as a "separate" PV module with 10 % tolerance

B.4 Quality standards

See Lighting Global Quality Assurance Protocols Appendix A.

B.5 Warranty requirements

See Lighting Global Quality Assurance Protocols Appendix A.

B.6 Performance targets

In addition to meeting the quality standards, at least one product setting must meet one of the run time criteria and one of the lighting service criteria listed in the tables below to meet the performance targets. The tolerance for all targets is: The average DUT should be no worse than 10 % below the target. No DUT should fall more than 20 % below the target.

Table B.6 – Run time criteria for performance targets

Run time criterion	Aspect(s)	Requirement
Central charged product full-battery run time	4.2.6.3 Grid-charge run time 4.2.6.1 Full-battery run time	≥ 8 h
Independently solar charged product – solar-day run time	4.2.6.2 Solar-day run time	≥ 4 h from a standard solar day (5 kWh/m^2)
Independently mechanically charged product – mechanical run time characteristics	4.2.6.4 Mechanical charge ratio 4.2.6.1 Full-battery run time	Mechanical run time ratio ≥ 10:1 and full-battery run time ≥ 2 h

Table B.7 – Lighting Service criteria for performance targets

Light output criterion	Aspect(s)	Requirement
General illumination service	4.2.7.1 Average luminous flux output	≥ 20 lm
Task lighting service	4.2.7.3 Average light distribution characteristics	≥ 0,1 m^2 area of illumination ≥ 25 lux when the lamp is self-supported on the task surface or suspended from a 0,75 m distance from the surface.

Appendix C
(informative)
Example quality standards, warranty requirements, and performance targets for bulk procurement qualification (“sample tender”)

C.1 Scope

These quality standards, warranty requirements, and performance targets are appropriate for qualification to provide products for a bulk procurement programme where products will be offered to end-users at a substantially discounted rate.

There are two classes of product that qualify for this procurement:

Table C.1 – Product classes qualified for bulk procurement

Product class	Basic requirements	Product categories allowed
Desk lamp	Meet quality standards, warranty requirements, and “desk lamp” performance requirements	Fixed separate (indoor), portable separate, or portable integrated
Multipoint lighting system	Meet quality standards, warranty requirements, and “multipoint lighting system” performance targets	Fixed separate (indoor), portable separate

C.2 Test requirements

Qualification requires QTM test results (section 6).

The test results and/or other information should be presented for each of the criteria listed in the quality standards, warranty requirements, and performance targets in support of the offer.

C.3 Product category requirements

This document applies to fixed separate (indoor), portable separate, and portable integrated products. It does not apply to products that only have fixed integrated (outdoor) lighting options.

This document applies only to solar charged products.

Qualification as a “separate” PV module requires meeting the criteria listed below:

Table C.2 – Qualification as separate PV module

Criterion	Aspect(s)	Required value
PV module cable length	4.2.5.2 Solar module cable	$\geq$ 3 m to qualify as a “separate” PV module with 10 % tolerance.

C.4 Quality standards

The product must meet each of the criteria listed in the tables below:

Table C.3 – Truth-in-advertising tolerance

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
System performance tolerance – numeric ratings	4.2.6 Run time 4.2.7 Light output Others, if applicable	≤ 15 % deviation from ratings.
System components tolerance – numeric ratings	4.2.5 Solar module 4.2.4 Battery performance aspects Others, if applicable	≤ 15 % deviation from ratings.
Other numeric ratings tolerance	Multiple	≤ 15 % deviation from ratings.
Overall truth-in-advertising statement	Multiple	Any description of the product that appears on the packaging, inside the package, and in any other media should be truthful and accurate. No statements should mislead buyers or end users about the features or utility of the product.

Table C.4 – Safety and durability standards

Safety or durability criterion	Aspect(s) considered in assessment	Product category	Requirement
Overall water exposure protection	4.2.10.1 Water protection integrated assessment 4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage 4.2.1.7 Packaging and user's manual information	Fixed separate (indoor)	No protection required
		Portable separate	Protection from occasional exposure to rain
		Portable integrated	Protection from frequent exposure to rain
Physical ingress protection	4.2.2.3 Physical ingress protection	All products	Minimum of IP 2x protection
Mechanical durability – drop test	4.2.2.4 Drop resistance	Fixed separate (indoor)	No resistance required
		Portable separate	Maximum failure rate for functionality is 1/6; none result in safety hazards.
		Portable integrated	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – goosenecks	4.2.2.5 Gooseneck durability	Any with gooseneck	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – connectors	4.2.2.6 Connector durability	All products	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – switches	4.2.2.7 Switch durability	All products	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Workmanship	4.2.2.9 Wiring quality	All products	Maximum prevalence of bad solder joints is 1/6 samples; maximum prevalence of poor wiring is 1/6 samples; maximum prevalence of overall workmanship failure is 1/6
Battery durability	4.2.2.10 Battery protection strategy	All products	An appropriate battery protection strategy is used that will protect batteries from early failure and end-users from harm.
Lumen maintenance	4.2.3.2 2 000 hour lumen maintenance	All products	L_{70} time is greater than 2 000 h for the average sample. No more than 1/6 samples fails (defined as being more than 10 % below L_{70} at 2 000 h).
Fluorescent light durability	4.2.3.3 Fluorescent light durability	Products with fluorescent lights	Maximum failure rate for functionality is 1/6.

C.5 Warranty requirements

The product must meet each of the criteria listed in the table below:

Table C.5 – End-user support requirements

Support Type	Aspect(s)	Requirement
Maintenance and warranty terms	4.2.1.8 Warranty information	End-users are provided at least six months of warranty coverage from the point of purchase; it should cover manufacturing defects that impede operation under normal use and unambiguously include coverage on the battery.

C.6 Performance targets for desk lamps

Desk lamps should meet the requirements in both of the tables below with at least one light point.

Table C.6 – Run time criteria for performance targets

Run time criterion	Aspect(s)	Requirement
Independently solar charged product – solar-day run time	4.2.6.2 Solar-day run time	≥ 4 h from a standard solar day (5 kWh/m^2).

Table C.7 – Lighting service criteria for performance targets

Light output criterion	Aspect(s)	Requirement
Task lighting service	4.2.7.3 Average light distribution characteristics	≥ 0,1 m^2 area of illumination ≥ 25 lux when the lamp is self-supported on the task surface or suspended from a 0,75 m distance from the surface.

C.7 Performance targets for multipoint lighting system

Multipoint lighting systems should have two or more light points that can each meet the following criteria every day:

Table C.8 – Run time criteria for performance targets

Run time criterion	Aspect(s)	Requirement
Independently solar charged product – solar-day run time	4.2.6.2 Solar-day run time	≥ 4 h from a standard solar day (5 kWh/m^2) for each lighting point.

Table C.9 – Lighting service criteria for performance targets

Light output criterion	Aspect(s)	Requirement
General illumination service	4.2.7.1Average luminous flux output	≥ 20 lm for each lighting point.

Multipoint lighting systems should also include the additional features listed below:

Table C.10 – Additional features criteria for performance targets

Support type	Aspect(s)	Requirement
Mobile phone charging	4.2.1.9 Auxiliary features information	Product should have an auxiliary output for charging mobile phones with at least 3 connector options: mini-USB, "Nokia small barrel connector", and "Nokia large barrel connector".

C.8 Performance Target Tolerance

The tolerance for all performance targets is: The average DUT should be no worse than 10 % below the target. No DUT should fall more than 20 % below the target.

Appendix D
(informative)
Recommended SSS guidelines

D.1 Scope

These guidelines apply to creating SSS for market support programmes. The goal of the SSS is to provide clear, verifiable, and accurate information on quality and performance to potential buyers, with a focus on distributors and bulk purchasing agents.

D.2 Qualification standards and targets

To qualify for the SSS programme, a product must meet the quality standards and warranty requirements listed in Appendix A. It is not necessary to meet the performance targets.

D.3 Test result requirements

D.3.1 Original testing

QTM test results, obtained in accordance with section 6, are required for initial SSS qualification and creation.

D.3.2 Retesting and updates

Table D.1 – Requirements for retesting to update SSS

Trigger for testing	Scope of testing	Test requirements	Notes
Two years since previous QTM or MCM testing	Any element on SSS	QTM (section 6)	--
Product update with changes in performance aspects lower than ±10 %	None required	Self-declaration allowed	Performance aspects include light output and run time aspects.
Product update with changes in performance aspects greater than ±10 %	Elements that are different	Aspects related to element that is changing tested according to MCM (section 7) using randomly procured samples	--
Product update with changes in quality or durability aspects	Elements that are updated	Aspects related to element that is changing tested according to MCM (section 7) using randomly procured samples	Quality aspects include water protection, lumen maintenance, drop test, etc.
Product update with new, non-lighting features	Elements that are new	Aspects related to element that is changing tested according to MCM (section 7) using manufacturer-provided samples	--
A programme-initiated market check test (in accordance with MCM (section 7) indicates an **improvement** in quality or performance	None required	Accept new results	--
A programme-initiated market check test (in accordance with MCM (section 7) indicates an **decline** in quality or performance	Any element that is shown to decline	Aspects related to element that is changing tested according to MCM (section 7) using randomly procured samples	This essentially means that there is a chance to prove that programme-initiated market check results were an anomaly in cases where they indicate a reduction in quality or performance.

D.4 Style and format

Following are the style guidelines for SSS:

a) Dominant colours: black and white

b) Secondary colours should be consistent and harmonized (e.g., on graphs); the base colour can be from the product packaging or corporate branding from the product marketer.

c) Product images: colour image on a white background

d) Font: Helvetica; 12 pt for most text, 16 pt for product name on headline, 10 pt for notes and graphics

e) Language: English (optional to create translations in other languages)

f) Style: Write in a way that is clear and understandable by a broad set of potential readers.

D.5 Reporting precision

The qualitative parts of the specification sheet (warranty, manufacturer name, lighting type, etc.) should always be accurate and updated.

Quantitative parts of the specification sheet that are reported on a continuous scale can be rounded for ease of interpretation. The rounded specification must be reported so that it meets the precision guidelines presented in the Table below. The guidelines are in terms of significant figures of reporting (s.f.). If one is rounding to the maximum precision, the rounding should be according to standard conventions ($\geqslant$ 0,5 = 1; < 0,5 = 0). Alternatively, if the minimum precision requirements are lower than the maximum, one can round further (to fewer significant figures than the maximum) but any further rounding must be in the "Allowable direction" as defined in the table, starting from the original measured value plus of minus the percentage adjustment that is allowed before additional rounding (i.e. the standard rounding convention does not apply in that case).

Table D.2 – Recommended precision requirements for metrics on a continuous scale

Metric	Maximum precision of reporting	Minimum precision of reporting	Maximum adjustment before rounding	Allowable direction for additional rounding	Example(s)
Run time (h)	2 s.f.*	1 s.f.	5 %	Down	4,33 h → 4,3 h or 4 h 36,6 h → 37 h or 30 h
Light output (lm)	2 s.f.	1 s.f.	5 %	Down	19,2 lm → 19 lm or 20 lm
Colour rendering (CRI) (R_a)	2 s.f.	2 s.f.	n/a	n/a	83,2 → 83
Colour temperature (CCT) (K)	2 s.f.	2 s.f.	n/a	n/a	4 678 K → 4 700 K
Light distribution (FWHM)	2 s.f.	2 s.f.	n/a	n/a	87°→87° 178°→180°
Battery capacity (mAh)	2 s.f.	2 s.f.	n/a	n/a	1 432 mAh → 1 400 mAh or 1 000 mAh
Other information	2 s.f.	1 s.f.	5 %	Varies	n/a

* s.f. = "significant figures"

D.6 Results verification

Each SSS includes a unique Internet URL that is directed towards a web page that is managed by [programme name]. If one goes to the web page, it is possible to download a verified copy of the SSS to ensure the veracity and validity of the SSS.

D.7 Section descriptions

The following sections should be included in the SSS. Each section should begin with a grey bar with the section name in bold, black type. The elements in each section should be black type on a white background with thin grey lines separating the elements.

D.7.1 Header / overall performance

This section includes the name of the product in the header area and a link to verify the SSS. The header elements are white text on a black background.

Below that is a description of the overall performance—brightness and run time—for up to two settings. For each of the settings listed, the lumen output and hours of run time should be described using plain language phrasing. The run time should be "on a full battery charge" for AC charged or central charging model products, "after one day of solar charging" for solar-charged products and "after XX minutes/hours of cranking" for mechanically charged products.

Next to the key performance indicator description is a "thumbnail" image of the product, only including items that are included in the package.

In this section, only the content is displayed (the element names are not indicated).

Table D.3 – Elements in the header / overall performance section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Product name	Text	Required	4.2.9.1 Product and manufacturer information	The product name should be "complete" enough to differentiate it from other similar products in the same manufacturing line. Example: Sunshine Lamp
Verification link	Text	Required	Generated by SSS programme website developer	This unique link should point to a webpage where the original, up-to-date SSS is available for verification. Example: www.example.org/sss/sunshine-lamp
Results summary statement	Text	Required	4.2.6 Run time 4.2.7.1 Average luminous flux output 4.2.7.3 Average light distribution characteristics	This is text that describes the run time and light output from the product for up to two settings. The exact language is flexible as long as the results are characterized accurately. Example: High Setting: 100 lumens for 5 hours after one day of solar charging.
Thumbnail image	Image	Required	Provided directly by manufacturer or from 4.2.1.10 Other visual screening results.	The image should show the product against a white background.
Graphical summary	Graphic	Required	4.2.6 Run time 4.2.7.1 Average luminous flux output 4.2.7.3 Average light distribution characteristics	This is a graphical summary of the run time and brightness as described in the Results Summary Statement. It also includes an iconographic summary of features, quality standards, and performance targets.

D.7.1.1 Graphical summary instructions:

The graphical summary should include two elements:

- Bar graph(s) showing the run time and light output (or light distribution characteristic area) for each of the key settings
- Icons indicating successful passing or presence of features:
  - Overall workmanship pass
  - Mobile charging feature
  - Number of light points

D.7.2 General information

Table D.4 – Elements in the general information section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Manufacturer	Text	Required	4.2.9.1 Product and manufacturer information	The name of the manufacturer or "official" marketing firm for the product. Example: Sirius Lighting Corporation
Product name	Text	Required	4.2.9.1 Product and manufacturer information	The product name should be "complete" enough to differentiate it from other similar products in the same manufacturing line. Example: Sunshine Lamp
Model number	Text	Required	4.2.9.1 Product and manufacturer information	Often more detailed than the product name; may include version number.
Contact	Text	Required	4.2.9.1 Product and manufacturer information	An email or phone contact at the manufacturer
Website	Text	Optional	4.2.9.1 Product and manufacturer information	A URL for the manufacturer web page.
Warranty	Text	Required	4.2.9.2 Warranty coverage	A short (≤ 200 character) description of the warranty coverage that highlights the duration of coverage; this should match with the detailed information provided to consumers and documented in 4.2.1.8 Warranty information.

D.7.3 Run time

Table D.5 – Elements in the run time section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Full-battery run time	Text / graphics	Required	4.2.6.1 Full-battery run time	Specify a full-battery run time for each setting included in any other part of the SSS. The graphics include a stacked horizontal bar graph that indicates run time at various settings with the same axis as other run time graphs.
Run time per day of solar charging	Text / graphics	Required for solar products	4.2.6.2 Solar-day run time	Specify a solar run time for each setting included in any other part of the SSS. The graphics include a stacked horizontal bar graph that indicates run time at various settings with the same axis as other run time graphs.
Run time after cranking for five minutes	Text	Required for mechanical charged products	4.2.6.4 Mechanical charge ratio 4.2.6.1 Full-battery run time	Specify a mechanical run time for each setting included in any other part of the SSS.

D.7.4 Light output

Table D.6 – Elements in the light output section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Lamp type	Text	Required	4.2.1.3 Lighting system information	Include number and type of light sources.
Light output	Text / graphics	Required	4.2.7.1Average luminous flux output	Include for each setting
Task surface brightness	Text / graphics	Optional	4.2.7.3 Average light distribution characteristics	Include for each setting
Colour Characteristics	Text / graphics	Required	4.2.7.4 Colour characteristics	Include for highest setting; use "slider" graphics to display
Distribution category	Graphics	Required	4.2.7.2 Full width half maximum (FWHM) angles	Place in category based on FWHM angle: Narrow (<15°), Wide (15°< -- < 270°), Omni (>270°)
Lumen Maintenance	Text	Required	4.2.3.2 2 000 hour lumen maintenance	Indicate fraction of original light output remaining at 2 000 hours of operation.

D.7.5 Special features

Table D.7 – Elements in the special features section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Mobile Charging	Text	Optional	4.2.1.9 Auxiliary features information	Specify if a mobile charging feature is available
Other features	Text	Optional	4.2.1.9 Auxiliary features information	Specify other features, such as housing material.

D.7.6 Durability

Table D.8 – Elements in the durability section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Overall durability and workmanship	Text and graphics	Required	Multiple	Indicate pass with graphic indicator (all products must pass this requirement to use the SSS).
Water protection	Text	Required	Water exposure protection as defined in Appendix V: physical and water ingress protection test	Specify the overall level of water protection and the elements of the product that contribute to the level of protection (enclosure, product design, user information)
Physical ingress protection	Text	Required	4.2.2.3 Physical ingress protection	Indicate pass or fail
Drop test	Text	Required	4.2.2.4 Drop resistance	Indicate pass or fail for damage, functionality, and safety.
Switches, connectors, strain relief, and goosenecks	Text	Required	4.2.2.5 Gooseneck durability 4.2.2.6 Connector durability 4.2.2.7 Switch durability	Indicate pass or fail for damage, functionality, and safety.

D.7.7 Solar module details

Table D.9 – Elements in the solar module details section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
PV module type	Text	Optional	4.2.1.2 Charging system information	Indicate PV chemistry (e.g., mono-Si)
PV maximum power	Text	Optional	4.2.5.1 Solar I-V curve parameters	Specify the overall level of water protection and the elements of the product that contribute to the level of protection (enclosure, product design, user information)

D.7.8 Battery details

Table D.10 – Elements in the battery details section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Battery replaceability	Text	Required	4.2.1.5 Battery easy replaceability	Either "easily replaceable" or "requires specialized technician"
Battery chemistry	Text	Required	4.2.1.4 Energy storage system information	Indicate chemistry
Battery package type	Text	Required if battery is easily replaceable, otherwise optional	4.2.1.4 Energy storage system information 4.2.4.1 Battery capacity	Specify the package, capacity, and voltage

D.7.9 Marks and certifications

Table D.11 – Elements in the marks and certifications section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Factory certification	Text	Optional	4.2.9.3 Third-party marks and certifications	ISO 900x, etc.
LED / CFL certification	Text	Optional	4.2.9.3 Third-party marks and certifications	UV free LEDs, etc.
Safety certification	Text	Optional	4.2.9.3 Third-party marks and certifications	UL, etc.
Durability certification	Text	Optional	4.2.9.3 Third-party marks and certifications	UV resistant plastics used, etc.
Other certifications	Text	Optional	4.2.9.3 Third-party marks and certifications	Allowed if they pertain to the particular product and are relevant. E.g., CE, etc.

D.7.10 SSS information

Table D.12 – Elements in the SSS information section

Element	Display type	Optional or required	Aspect(s) involved / origin of information	Notes
Expiration date	Text	Required	From QTM report	Indicate a date two years after the completion of the QTM test report that is the foundation for the SSS.
Revision	Text	Required	n/a	Indicate an internal SSS revision tracking number.

D.8 Example sheet

An example standardized specifications sheet is provided below.

Example Product

Verify specifications at:
www.lightingafrica.org/specs/EX_01

Overall Performance

"High" setting: 25 lumens for
4 hours after one day of solar charging

General Information	
Manufacturer	Example Corporation, Inc.
Product Name	Example Lamp 3000+
Model Number	ABC12345
Contact	janedoe@examplecorp.com
Website	www.examplecorp.com
Warranty	6 months for lamp, 1 year for solar module; see detailed terms for more information.
Run Time	
Autonomous Run Time (full battery)	6.0 hours on "high" setting
Lighting hours per solar day (PV only)	4.0 hours on "high" setting
Lighting System	
Lamp type	LED
Light output	25 lumens on "high" setting
Light output at 2000 hours	23 lumens on "high" setting
Light Distribution: Omni	Color Appearance: Warm (more red) – Daylight – Cool (more blue); Color Rendering: (50%) – (100%), CRI: 85
Charging System	
Charge type(s)	Solar PV
Storage System	
Storage Type	Rechargeable NiMH (3x AA in package)
Nominal Battery Voltage	3.6 volts DC
Battery Capacity	650 milliamp hours
Battery Protection	Active HVD and LVD
Easily Replaceable Battery?	No

Additional Information & Special Features

Lamp Housing: Injection molded ABS

Standard feature: Mobile phone charging with six connectors
Factory Certification: ISO9001

Date of Sample Procurement for Testing January 2011

Revision 2011.01

Appendix E
(normative)
Manufacturer self-reported information

E.1 Background

Having proper manufacturer information is important for communication throughout the testing process as well as for understanding key product information and any certifications the manufacturer's lab or product may have. To this end, there are three categories of self-reported information: manufacturer information, product information, and manufacturer self-certification regarding either the manufacturing lab or product.

E.2 Outcomes

The manufacturer self-reported information outcomes are listed in Table E.1.

Table E.1 – Manufacturer self-reported information outcomes

Metric	Reporting units	Related aspects	Notes
Manufacturer information	Varied	4.2.9.1 Product and manufacturer information	Record all provided manufacturer information
Product information	Varied	4.2.9.1 Product and manufacturer information	Record all provided product information
Self-certification information	Varied	4.2.9.3 Third-party marks and certifications	Record all manufacturer or product certifications

E.3 Solicited information

E.3.1 Confidential information (not released publicly)

E.3.1.1 Manufacturer information

a) Manufacturer company physical address

b) Contact person name

c) Contact person position at company (i.e., job title)

d) Contact telephone number

e) Contact fax number

f) Contact e-mail address

E.3.1.2 Product information

a) Markets in which the product is for sale (e.g., Kenya, India, China, etc.)

b) Free on board (FOB) product price for at least 1 000 units ($)

c) Typical product shipping point of origin

d) Product driver type (e.g., resistor, pulse-width modulation, etc.)

e) Battery charge control methods (i.e., deep discharge protection and/or overcharge protection)

f) Description of battery charge control methods

E.3.2 Public information (may be released publicly)

E.3.2.1 Manufacturer information

a) Manufacturer company name

b) Manufacturer company physical address

c) Contact person name

d) Contact person position at company (i.e., job title)

e) Contact telephone number

f) Contact fax number

g) Contact e-mail address

h) Manufacturer company website

E.3.2.2 Product information

a) Product name

b) Product model number

c) All product lighting technologies used (e.g., fluorescent tube, LED, etc.)
   1) If the product uses LEDs, are the LEDs high-power or low-power?

d) Battery chemistry (SLA, NiMH, etc.)

e) Battery package type

f) All product charging system types (e.g., solar module, AC power, dynamo, etc.)
   1) If the product has AC power charging, is an adapter included?
   2) If the product has solar charging, what active material is used in the PV module (e.g., mono-Si, poly-Si, CIS, etc.)

g) All included product features (e.g., mobile phone charging, radio, etc.)

h) All optional product features (e.g., mobile phone charging, radio, etc.)

i) Description of product warranty terms, including duration

E.3.2.3 Manufacturer certifications

These certifications should be accompanied with supporting documentation, such as copies of the original certifications, letters from an appropriate organization, or self-certification.

a) All manufacturer company certifications and markings (e.g., ISO 9000, UL, CE, etc.)

b) All product certifications and markings (e.g., UV-resistant plastic, UV-free LEDs, high-temperature batteries, etc.)

E.4 Reporting

Report the following in the product manufacturer self-reported information report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Product manufacturer
  - Product name
  - Product model number
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Confidential information
  - Manufacturer company physical address
  - Contact person name
  - Contact person position at company
  - Contact telephone number
  - Contact fax number
  - Contact e-mail
  - Product markets
  - Product FOB price ($)
  - Product shipping point of origin

- Public information
    - Manufacturer company name
    - Manufacturer company physical address
    - Contact person name
    - Contact person position at company
    - Contact telephone number
    - Contact fax number
    - Contact e-mail
    - Manufacturer company website
    - Product name
    - Product model number
    - Product lighting technologies
    - Product charging systems
    - Included product features
    - Optional product features
    - Description of product warranty terms
    - Manufacturer company certifications
    - Product certifications

Appendix F
(normative)
Product sampling

F.1 Background

Proper product sampling is the first step in the testing process, and it is critical to maintaining the test method's fairness and credibility.

F.2 Test outcomes

The product sampling outcomes are listed in Table F.1.

Table F.1 – Product sampling outcomes

Metric	Reporting units	Related aspects	Notes
Sample type	Retail/warehouse	n/a	--
Sample procurement agency	Agency name	n/a	The third-party agency that procures the samples
Sample procurement agent	Name	n/a	The name of the person that procures the samples
Sample procurement date	Date	n/a	--
Sample procurement address(es)	Address(es)	n/a	--
Sample shipping date	Date	n/a	The date the samples are shipped to the test lab(s) from the third-party sampling agency
Test lab(s)	Test lab name(s)	n/a	--
Test lab address(es)	Address(es)	n/a	--
Sample delivery date(s)	Date(s)	n/a	The date the samples are received by the test lab(s)

F.3 Related tests

Testing is predicated upon the product samples already being procured, shipped, and received at the test lab(s).

F.4 Procedure

F.4.1 Retail sampling

For retail sampling, third-party agents will procure product samples from a variety of retail outlets in the market.

F.4.1.1 Equipment requirements

No equipment is required for retail sampling.

F.4.1.2 Test prerequisites

Samples must be procured from a geographically-diverse set of retail outlets.

F.4.1.3 Apparatus

No apparatus is required for retail sampling.

F.4.1.4 Procedure

a) The third party sampling agency identifies a specified number of retail outlets in the market from various geographic locations.

b) The sampling agency selects a subset of the retail outlets to procure samples from, ensuring that the subset of retail outlets is geographically diverse (e.g., each retail outlet is in a different city and/or country than the rest of the subset).

c) The sampling agency procures the product samples from the various retail outlets, ensuring that no more than 40 % of the overall number of procured samples comes from any single retail outlet.

d) The date, locations, sampling agent, and number of samples procured from each location should be documented by the sampling agency.

e) The sampling agency ships the products to one or more test labs and reports the shipment tracking number(s), when available.

f) Once received at the test lab(s), the date(s) of reception, test lab name(s), and test lab location(s) should be documented.

F.4.1.5 Calculations

There are no calculations for retail sampling.

F.4.2 Warehouse sampling

For warehouse sampling, third-party agents will procure samples from a warehouse, distributorship, factory, or other bulk storage location.

F.4.2.1 Equipment requirements

No equipment is required for warehouse sampling.

F.4.2.2 Test prerequisites

The sampling location should be the main bulk storage location in the region, and there must be enough products available that the procured samples account for no more than 3,5 % of the total product stock. Furthermore, the sampling agent must be able to sample from the bulk storage location's entire stock.

F.4.2.3 Apparatus

No apparatus is required for warehouse sampling.

F.4.2.4 Procedure

a) At least 24 h before the sampling takes place, the sampling agency must make contact (via email or telephone) with representatives at the sampling location to provide proper notice and ensure that the number of samples procured will not exceed 3,5 % of the sampling location's total product stock.

b) The sampling agency randomly procures the product samples from the entire bulk storage location's stock (i.e., the entire product stock must be available to sample from).

c) The date, location, sampling agent, and number of samples procured should be documented by the sampling agency.

d) The sampling agency ships the products to one or more test labs and reports the shipment tracking number(s), when available.

e) Once received at the test lab(s), the date(s) of reception, test lab name(s), and test lab location(s) should be documented.

F.4.2.5 Calculations

There are no calculations for warehouse sampling.

F.5 Reporting

Report the following in the product sampling test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - Product manufacturer
  - Product name
  - Product model number
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Sampling instructions
- Sampling and shipping information
  - Name of sampling agency
  - Name(s) of sampling agent(s)
  - Sampling location name(s), address(es), and description(s)
  - Number of samples procured (at each location)
  - Name of shipping agency
  - Shipment tracking number(s)
  - Date samples are shipped to test lab(s)
  - Date samples are received at test lab(s)

Appendix G
(normative)
Visual screening

G.1 Background

The visual screening process covers DUT specifications, properties (such as external DUT measurements), functionality, observations, and internal/external construction quality.

The DUT's components, materials, and utilities are categorized and, in some cases, evaluated. This test provides a thorough qualitative and quantitative assessment of the DUT as received from the manufacturer and serves to uniquely identify a DUT. The DUT's operation out of the packaging is documented before any modifications are made for subsequent tests.

G.2 Test outcomes

The test outcomes of the visual screening process are listed in Table G.1.

Table G.1 – Visual screening test outcomes

Metric	Reporting units	Related aspects	Notes
DUT specifications	Varied	4.2.1 Product design, manufacture, and marketing aspects	Record all provided specifications
DUT information	Varied	4.2.1 Product design, manufacture, and marketing aspects 4.2.9.1 Product and manufacturer information	Record dimensions and qualitative descriptors
Internal DUT inspection	Varied	4.2.2 Product durability and workmanship aspects	Describe/document wiring and electronics fixtures
Internal DUT inspection	Number of defects	4.2.2 Product durability and workmanship aspects	Record the number of soldering and/or electronics quality defects

G.3 Related tests

Appendix G is not related to any of the other appendices.

G.4 Procedure

G.4.1 Properties, features, and information

Relevant DUT information, such as external DUT measurements and observations, are recorded to capture the DUT's characteristics. Sufficient comments should be provided to thoroughly describe the DUT's characteristics. This part of the procedure can be completed on a single sample.

G.4.1.1 Equipment requirements

- Callipers and/or ruler
- Balance (scale)
- Bright task light with good colour rendering (≥ 700 lux and ≥ 85 CRI recommended)

- Camera

G.4.1.2 Test prerequisites

The DUT should be new, unaltered, and in its original packaging. Read the DUT's box and documentation for instructions on using the DUT. Consult the manufacturer for missing information pertaining to the required observations.

G.4.1.3 Apparatus

The DUT may be positioned under a bright task light in the examination, if necessary.

G.4.1.4 Procedure

a) Provide the following:

   3) Note all available manufacturer contact information (e.g., name, address, phone number, email, website, etc.)

   4) Photograph all sides of the DUT's retail box and describe the box's quality, if available.

   5) Note if a user's manual is included with the DUT. If so, report the type of manual it is (e.g. booklet, sheet, etc.), report the language(s) in which it is written, and photograph each page.

   6) If a warranty is available for the DUT, record the warranty duration, in months, describe the terms and conditions, and photograph the warranty material.

b) Measure the following (in the specified units) without disassembling the DUT:

   1) Measure the DUT's mass, in grams (g), as it would typically be used in a lighting application (not including any external solar modules or mobile phone charging connectors) and indicate the specific components included in mass measurement.

   2) Measure and describe the length, in meters (m), of any cables connecting the control box to the batteries or the control box to the lamp units.

   3) Measure the length, width, and height, in centimetres (cm), of the DUT's lamp unit(s) and any additional components or interconnected parts, separately. Do not include dimensions of an external PV module or any mobile phone charging accessories.

c) Observe the following (consult the documentation for any explanations; see 4.1.3 Lighting kit parts for details on the terminology in this section):

   1) Note the DUT's total number of unique lighting units, indicate the technology used in each (LED, fluorescent, incandescent, etc.), and provide a description and photographs of each.

   2) Note the number of light points in each lighting unit.

   3) Note the number of arrays contained in each light point (e.g., a group of LEDs that function as a single unit is an array).

      - By example: If a lamp unit contains 10 LEDs and 5 LEDs illuminate for one DUT setting, and all 10 LEDs illuminate for the DUT's only other setting, this lamp unit contains two arrays (5-LED and 10-LED).

   4) Note the number of independent light sources (i.e., the total number of LEDs or other bulb types) in each array.

   5) Determine the number of DUT light output settings. Use the setting descriptions provided by the DUT's literature. If no setting descriptions are provided, use appropriate descriptions (e.g., high, medium, low, 1 high-power LED, 3 low-power LEDs, etc.).

6) Describe and photograph the arrangement of lamp units, battery(-ies), and energy source(s) in terms of housing/cases.
   - By example: There are two housings. In the main housing there is a battery with a gooseneck lamp protruding from the housing. The other housing is a remote lamp unit with no battery; it is connected to the main housing with a 4 m cable that has an inline switch. The PV module is external and connects to the main housing with a cable.
7) Describe the materials that compose the DUT's lamp units, battery housing, charge controller housing, and/or any other housings (e.g., plastic, metal, glass, or other).
8) Note if the DUT has any indicators (e.g., charge indicators) and, if so, include descriptions of indication meanings and photographs of the indicators.
9) Note and photograph any other features present on or included with the DUT (e.g., handles, mounting brackets, stands, etc.).
10) Note if the DUT has a radio or mobile phone charging capabilities. If so, photograph the connectors.
11) Describe and photograph any other included accessories or connectors not yet documented (excluding those associated with a DUT's PV module).
12) Indicate if the DUT provides central (e.g., grid, central station, etc.) or independent (e.g., mechanical, solar PV, etc.) charging and the specific charging means and describe the robustness of each included charging mechanism.

d) Measure and observe the following (in the provided units) for the DUT's PV module:
   1) Measure the PV module's overall length and width, in centimetres (cm), including the frame.
   2) Measure the active solar material's overall area, in square centimetres (cm^2).
   3) Note if the PV module is external or integrated into the DUT's housing.
   4) Measure the PV module's cable length, in meters (m), in the case of external PV modules.
   5) Note the PV module's solar material (e.g., poly-Si, mono-Si, CIS, amorphous, etc.).
   6) Note the PV module's encasing (e.g., lamination, glass, epoxy, etc.)
   7) Describe the quality of workmanship in the PV module's junction box, if present.
   8) Note any additional information about the PV module (e.g., number of individual cells).
   9) Photograph the PV module.

e) Note if the DUT can be turned on while it is being charged with its PV module.

f) Note the DUT's primary form factor (fixed indoor, fixed outdoor, portable separate, portable integrated, or other) and also note any secondary form factors.

g) Note the DUT's expected use(s) (e.g., ambient, torch, task, etc.).

h) Provide any general comments regarding the DUT's properties, features, and/or information.

G.4.2 Specifications

All relevant DUT specifications are recorded for later comparison in testing results. This part of the procedure can be completed on a single sample.

G.4.2.1 Equipment requirements

No equipment is required for this part of the visual screening procedure.

G.4.2.2 Test prerequisites

The DUT should be new, unaltered, and in its original packaging. Read the DUT's box and documentation for instructions on using the DUT. Consult the manufacturer for missing information pertaining to the required observations.

G.4.2.3 Apparatus

No apparatus is required for this part of the visual screening procedure.

G.4.2.4 Procedure

Examine the DUT's packaging, user's manual, and components for battery, lamp, charge controller, and PV module specifications. While obtaining the specifications, the DUT should not be opened or otherwise tampered with in any way. The internal inspection of G.4.3 may reveal more product specifications, which should be included with the specifications from this section and noted accordingly.

a) When provided, note the following specifications (in the specified units), indicate and photograph the source(s) of each, and comment on any specification discrepancies. Indicate if the specification is not provided but can be ascertained by observation (e.g., battery chemistry and nominal battery voltage):
   1) Battery chemistry (SLA, NiCd, NiMH, Li-Ion, $LiFePO_4$, or specify other)
   2) Rated battery capacity, in milliamp hours (mAh)
   3) Nominal battery voltage, in volts (V)
   4) Lamp type (LED, compact fluorescent, linear fluorescent, incandescent, or specify other)
   5) Lamp driver (constant voltage source, constant current source, pulse width modulation, resistor, or specify other)
   6) Charge controller present (yes/no)
   7) Charge controller deep discharge protection voltage, in volts (V)
   8) Charge controller overcharge protection voltage, in volts (V)
   9) PV module maximum power point power (P_{mpp}), in watts-peak (W_p)
   10) PV module open circuit voltage (V_{oc}), in volts (V)
   11) PV module short circuit current (I_{sc}), in milliamps (mA)
   12) PV module maximum power point voltage (V_{mpp}), in volts (V)
   13) PV module maximum power point current (I_{mpp}), in milliamps (mA)

b) When provided, record the following run time specifications, in hours (h), indicate and photograph the source(s) of each, and comment on any discrepancies:
   1) Note the number of hours of operation on a full battery charge for all lamp settings (full-battery run time).
   2) Note the number of hours of operation on a battery charge from a day of solar charging for all lamp settings (daily solar run time).
   3) Note the number of hours of operation after a specified mechanical charge period for all lamp settings (mechanical run time).
   4) Note the number of hours of operation after a specified AC/DC adapter charge period for all lamp settings (grid run time).

5) Note and describe any specified run times that do not fit into the previous four categories.

c) Where available, note any light output specifications, in lumens (lm), indicate and photograph the source(s) of each, the corresponding lamp setting(s), and comment on any discrepancies.

G.4.3 Functionality and internal inspection

An internal inspection is performed to assess the electronics and soldering workmanship. The DUT can fail the inspection if poor internal workmanship inhibits the DUT from properly functioning. This part of the procedure should be completed for every sample being tested.

G.4.3.1 Equipment requirements

- Bright task light with good colour rendering (≥ 700 lux and ≥ 85 CRI recommended)
- Miscellaneous hand tools (screwdrivers, wrenches, etc.) to disassemble DUT
- Camera to document DUT characteristics with particular attention to potential points of failure (e.g., cold solder joints)
- Volt meter or multi-meter for conducting basic electronic integrity and functionality tests

G.4.3.2 Test prerequisites

The DUT should be new, unaltered, and in its original packaging. Read the DUT's box and documentation for instructions on using the DUT. Consult the manufacturer for missing information pertaining to the required observations. If the DUT's instructions require it to be fully charged prior to operation, do so prior to conducting this test.

G.4.3.3 Apparatus

The DUT should be positioned under a bright task light for examination.

G.4.3.4 Procedure

a) Check the DUT's functionality before disassembling:

1) Does the DUT work as described with provided documentation?
2) Do all of the DUT's switches and connectors function as they should?
3) Comment on any faulty operation and provide photographs, if necessary.

b) Disassemble the DUT so the following internal observations can be made:

1) Indicate whether the DUT uses cable strain reliefs and, if so, which cables have strain reliefs. Document with photographs.
2) Inspect the electronic components' quality and workmanship. Note any poor solder joints, such as cold joints or joints with little solder. Document the workmanship with comments and photographs.
3) Indicate methods used to secure parts inside the DUT (e.g., screws, glue, tape, clamps/straps, or other) and document with photographs.
4) Indicate methods used for securing wire and cable connections (e.g., solder, harness, terminal junction, etc.) and document with photographs.
5) Note if the DUT has an easily replaceable battery and/or printed circuit board (PCB). The battery and PCB are easily replaceable if they can be interchanged without any tools other than screwdriver(s) (i.e., no soldering or splicing).
6) Examine the internal components, especially the battery, and note any specifications that were not apparent in the previous procedure (G.4.2.4).

7) Note if the battery has an integrated battery circuit. This type of circuit is typically beneath a plastic jacket encasing the battery. Document with photographs.
8) Note the DUT's overall internal workmanship quality. Document the internal workmanship with descriptions and photographs.

G.5 Reporting

Report the following in the visual screening test report (a sample template is provided in Appendix Y):

- Metadata
    - Report name
    - Procedure(s) used
    - DUT manufacturer
    - DUT name
    - DUT model number
    - Name of test laboratory
    - Approving person
    - Date of report approval
- Manufacturer contact information (e.g., website, email address, phone number, etc.)
- Retail box description, if available
- User's manual information
    - Included with DUT (yes/no)
    - Type (e.g., booklet, pamphlet, sheet, etc.)
    - Language
    - Comments
- Warranty information, if available
    - Length (months)
    - Description of terms and conditions
- Complete DUT information (e.g., battery unit, lamp units, control unit, etc.)
    - Mass (g)
    - List of components included in mass measurement
- DUT cable information
    - Length of all cables except those used to connect PV modules (m)
    - Description of all cables except those used to connect PV modules
- DUT component information
    - Length of each component (cm)
    - Width of each component (cm)

    - Height of each component (cm)
    - Number of each component included with DUT
    - Description of each component
- DUT lamp unit technology information
    - Type of each unique lamp unit variety (e.g., LED, CFL, incandescent, etc.)
    - Number of light points in each unique lamp unit variety
    - Number of arrays in each unique lamp unit variety
    - Description of each unique lamp unit variety's technology use
- Description of DUT arrangement in expected typical use
- DUT setting information
    - Name of all individual light output settings
    - Description of each individual light output setting
- DUT materials information
    - List of all materials used to construct each DUT component (e.g., glass, balsa wood, plastic, etc.)
    - Description of all DUT construction materials
- DUT indicators information
    - List of all indicators present on each DUT component (e.g., battery charge indicators)
    - Description of all DUT indicators
- DUT features information
    - List of all features present on each DUT component (e.g., handles, mounting brackets, stand, etc.)
    - Description of all DUT features
- DUT auxiliary accessories information
    - Radio included (yes/no)
    - Mobile phone charging capability (yes/no)
    - Descriptions of other included DUT accessories and connectors
- DUT charging mechanism information
    - Grid charging supported (yes/no)
    - Mechanical charging supported (yes/no)
    - Solar charging supported (yes/no)
    - Description of each included charging mechanism

- DUT PV module information
  - Length of each PV module (cm)
  - Width of each PV module (cm)
  - Active area of each PV module (cm^2)
  - Form of each PV module (external or integrated)
  - Cable length of each PV module (m)
  - Active solar material of each PV module (e.g., mono-Si, amorphous, CIS, etc.)
  - Encasing of each PV module (e.g., lamination, glass, etc.)
  - Description of the robustness of each PV module
  - Description of PV module junction box workmanship
  - Other PV module information
- DUT form factor and use information
  - DUT's primary form factor (e.g., fixed indoor, fixed outdoor, etc.)
  - DUT's secondary form factor(s)
  - DUT's expected use(s) (e.g., ambient, torch, task, etc.)
- Overall comments based on the visual inspection
- Provided DUT specification information, if available
  - Battery chemistry and source of information
  - Rated battery capacity (mAh) and source of information
  - Nominal battery voltage (V) and source of information
  - Lamp type(s) and source of information
  - Lamp driver and source of information
  - Presence of charge controller (yes/no) and source of information
  - Charge controller deep discharge protection voltage (V) and source of information
  - Charge controller overcharge protection voltage (V) and source of information
  - PV module P_{mpp} (W_p) and source of information
  - PV module V_{oc} (V) and source of information
  - PV module I_{sc} (A) and source of information
  - PV module V_{mpp} (V) and source of information
  - PV module I_{mpp} (A) and source of information
- Description of any provided DUT specification discrepancies

- Provided DUT run time information, if available
  - Full-battery run time (h) for each setting and source of information
  - Daily solar run time (h) for each setting and source of information
  - Mechanical run time (h) for each setting and source of information
  - Grid run time (h) for each setting and source of information
  - Other run time (h) for each setting and source of information
- Description of any provided run time discrepancies
- Provided light output (lm) for each setting and source of information
- Description of any light output discrepancies
- DUT functions out of box (yes/no)
- All switches and connectors function for each DUT sample with comments as necessary (yes/no)
- Description of cable strain relief methods used and for which connections, if applicable
- Number of poor solder joints and workmanship deficiencies for each DUT sample with comments as necessary
- Means (e.g., screws, glue, tape, etc.) used to secure parts in each DUT component (e.g., lamp unit(s), charge controller, PV module(s), etc.)
- General fixture of parts comments
- Easily replaceable battery and PCB (yes/no)
- Comments on ease of battery and/or PCB replacement
- Overall description of internal workmanship
- Figures
  - Properties, features, and information photographs
  - Specifications photographs
  - Functionality and internal inspection photographs

Appendix H
(normative)
Sample preparation

H.1 Background

The product must be prepared before starting the tests. The preparation includes breaking the connections between the product's battery and circuit in order to facilitate charging the product, powering the product with a laboratory power supply, as well as taking measurements.

H.2 Test outcomes

There are no sample preparation outcomes.

H.3 Related tests

The sample preparation procedures must be performed on all DUTs prior to conducting the full-battery run time test (Appendix N), solar charge test (Appendix S), grid charge test (Appendix P), mechanical charge test (Appendix Q), light output test (Appendix J), lumen maintenance test (Appendix K), light distribution test (Appendix U), charge controller behaviour test (Appendix T), and battery test (Appendix L).

H.4 Procedure

H.4.1 Sample preparation

The DUT is rewired in order to make measurements of current and voltage during selected tests, charge the DUT's battery via a battery analyser, and simulate a specified battery voltage during selected tests.

H.4.1.1 Equipment requirements

- Wire (0,52 mm^2 or thicker)[2)]
- Wire cutters
- Wire strippers
- Soldering iron and solder
- Heat shrink and heat gun, or electrical tape
- Screw drivers and/or other appropriate tools for opening the DUT
- May be required depending on the DUT: a power drill with an appropriately sized drill bit to make a hole in the DUT's enclosure to fit four extension wires
- Optional: connectors (e.g., Molex)

H.4.1.2 Test prerequisites

The DUT's visual screening must be completed prior to performing the sample preparation procedures.

2) It is recommended that four different colours of wire be used when rewiring the DUT.

H.4.1.3 Procedure

a) Open the DUT, without incurring damage, such that its battery is exposed.

b) Identify the positive and negative terminals or leads on the DUT's battery.

c) With wire cutters, cut the positive and negative wires individually where the DUT's battery connects with the rest of the DUT circuit. Cutting the wires together could cause an electric shock.

NOTE in some cases, a third wire is attached between the DUT's battery and circuit for battery temperature monitoring – do not cut this wire, leave it as is.

NOTE in some cases, more than one wire is connected to the DUT's positive battery terminal and/or more than one wire is connected to the DUT's negative battery terminal – keep the wires attached to each terminal together and treat them as one wire end for the remainder of the procedure.

d) Extend the four wire ends (two connected to the battery terminals, two connected to where the original battery terminal wires intertied with the PCB) by soldering on additional wires. Make the wire extensions long enough to be extended approximately 6 cm outside the DUT's enclosure. Be sure to cover the wire solder connections with heat shrink.

NOTE When working with the extension wires, be sure to keep the battery positive and negative extensions separate when bare to avoid electrical shock.

e) Close the DUT such that the wires can extend outside the DUT's enclosure without being pinched.

  1) Some products are designed with openings in their enclosures such that the wires can fit through these openings without physically changing the DUT's enclosure.

  2) Some products do not have openings for wire extensions to fit through, in which case a hole must be drilled into the side of the DUT's enclosure. A drill bit with a diameter slightly greater than the combined diameter of all four extension wires should be used. Choose a location on the DUT's enclosure to minimize the extension wire length and minimize changes to the DUT's enclosure. Be sure that the extension wires do not interfere with the DUT's light output.

f) Attach optional connectors (e.g., Molex) to the ends of the extension wires for easy use during testing. Attach the two battery positive and negative extension wires in one half of the connector pair and the other two mating wires in the other half of the connector pair. If no connectors are used, be sure to keep the battery positive and negative extensions separate when bare to avoid electrical shock. Covering the ends of the wires with electrical tape is one method to keep the extensions separate.

g) To ensure the DUT still works after it has been rewired, connect the wire pairs (with connectors or electrical tape) so the original, unaltered circuit is replicated and turn the DUT on. If the DUT does not turn on, check that the wires are connected correctly and that the solder joints connecting wires are good.

NOTE Some products require having their PV modules attached with light shining on the PV module to get the product to turn on; afterwards the PV module can be removed and the product will continue working until its circuit is broken again.

H.4.1.4 Calculations

No calculations are required with the sample preparation procedures.

H.5 Reporting

No reporting is required with the sample preparation procedures.

Appendix I
(normative)
Power supply setup procedure

I.1 Background

Several of the photometric test procedures replace the battery with an external laboratory (bench) power supply to provide electrical power to the DUT for the duration of the test. This appendix specifies the power supply equipment requirements and setup procedure for these tests.

In order to correctly simulate the battery and provide the DUT accurate direct current (DC) power, the power supply must be configured properly to eliminate errors that can occur from:

- Voltage drops from the resistance of the lead wires
- Electronic noise in the lead wires from either the DUT or the test environment.

These errors can (in most cases) be eliminated with a 4-wire test configuration and input filter capacitors.

I.2 Related tests

This appendix is related to the light output test, light distribution test, lumen maintenance test, charge controller behaviour test, and solar run time test.

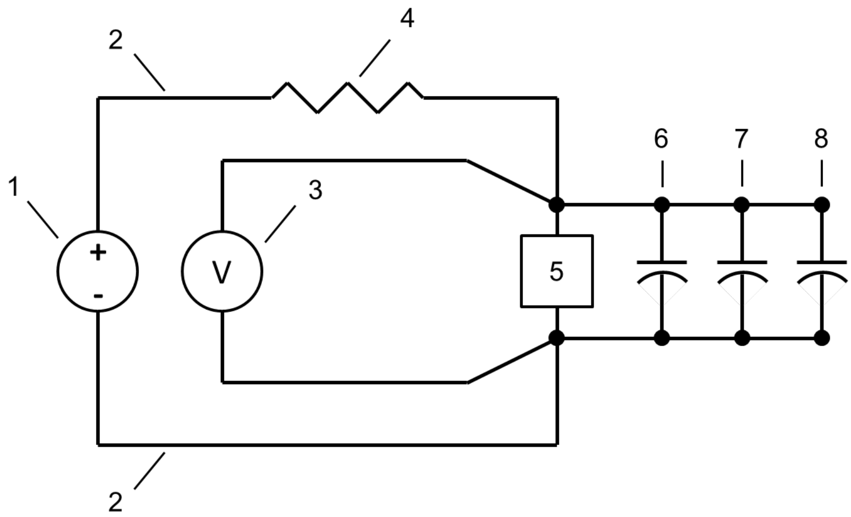
I.3 Equipment requirements

The DC power supply must be capable of delivering a stable, accurate DC input to the DUT. The power supply should have a voltage readout resolution of at least 0,01 V and a current readout resolution of at least 0,001 A. The voltage applied to the DUT should be regulated to within ± 0,2 % during photometric measurements, charge controller tests, and solar charging tests and ± 3 % for the duration of lumen maintenance tests.

Some test configurations may use power supplies without voltage and current readouts capable of measuring voltage and current values according to Table I.1. For example, a single power supply can be used to run concurrent lifetime tests on multiple DUT's (the DUT's are run in parallel from a single DC voltage rail). For these configurations, voltage measurements can be made at each DUT input using a voltmeter or multimeter and current measurements can be made using a voltage drop measurement on a series shunt resistor using Ohm's Law.

I.4 Setup procedure for photometric measurements and lumen maintenance tests

a) The power supply and DUT are configured according to Figure I.1.
   1) (optional) Input filter capacitors are placed at the device input according to section I.4.4.
b) The voltage level is set according to I.4.1 and measured according to I.4.3.
c) The DUT is powered on and allowed to stabilize for ≥ 20 min according to I.4.2.
d) Tests are performed on the DUT.
e) During testing, monitor the DUT for erratic behaviour that may indicate a problem with the test setup. This can include light output flickering, voltage and current instability, and difficulty in device start-up.



Key

1	DC power supply
2	Lead wire
3	Voltage sense
4	Series shunt resistor (optional)
5	DUT
6	1 µF capacitor
7	10 µF capacitor
8	100 µF capacitor

Figure I.1 – 4-wire test configuration with input filter capacitors

I.4.1 DC voltage and current levels

The constant DC voltage level for testing a product sample is based on the test requirements and battery characteristics.

For light output and distribution tests, the **average operating voltage** (corresponding to the voltage at the average light output operating point found during the run time test, Appendix N) is used to set the drive voltage for a DUT. For the lumen maintenance test, a **standard operating voltage** is used.

The standard operating voltage depends on the type and number of cells of the battery pack. This is typically provided by the manufacturer but may be determined by testing the discharge profile (Appendix L) and inspecting the battery.

The standard operating voltages for several battery chemistries are listed below.

Table I.1 – Standard operating voltage for several common battery types

Battery Type	Standard voltage (V/cell)
Sealed Lead-acid	2,05
NiMH and NiCd	1,25
Lithium Iron Phosphate	3,2
Other Lithium Ion	3,7

NOTE for unknown or new types of batteries, it is possible to estimate a standard operating voltage using the typical operating point voltage—the average voltage during a run time test (Appendix N).

During testing, some DUTs may not start up at the desired voltage and may require an input slightly greater than the desired battery voltage. In this case, incrementally increase the power supply voltage by 0,05 V until the DUT is operational at the desired light setting. After start up, reduce the voltage back to the desired battery voltage and allow the DUT to stabilize. If the DUT will not remain on when the voltage is reduced, repeat this step and run the DUT as close to the desired battery voltage as possible, making note of the issue.

The current level of a DUT powered with an external power supply should be at or near the current level measured in the full-battery run time test for the desired setting (see section N.4.2.4 of Appendix N). Variations greater than 5 % may indicate a problem with the power supply setup and should be noted in the test report.

I.4.2 Stabilization period

A DUT must be allowed to stabilize (warm up) before light output measurements are made. There are two approved stabilization procedures in this appendix:

1) The DUT is powered on and allowed to stabilize for 20 min.
2) The DUT is powered on and is considered stable when three consecutive output measurements, taken 15 min apart, have a variation of ≤ 0,5 % (IES LM-79-08).

In order to facilitate testing of multiple samples, 20 min is specified as the minimum stabilization time and is adequate for most products. Longer times may be necessary for DUT's with large heatsinks or high-powered LEDs. Voltage, current, and light output for a DUT should be monitored to determine if 20 min is an adequate stabilization time. If a longer stabilization time is necessary, the IES LM-79-08 procedure can be used to determine the stabilization time for a single DUT sample, and this time can then be used to test additional DUT samples of the same type.

I.4.3 4-wire power supply measurements

Current carrying lead wires used to provide power to the DUT should be appropriately sized and as short as possible, and must be separate from the wires used to measure the device voltage (Figure I.1). This is typically referred to as a 4-wire test measurement, and eliminates the voltage drop associated with the resistance of the test leads because very little electric current is carried in the voltage sensing wires. Many power supplies are equipped to handle this measurement automatically (also known as remote sensing), although test personnel may make corrections by adjusting the sense voltage manually.

I.4.4 Filtering electronic noise

Electromagnetic interference (EMI) generated by the DUT or the test environment may interfere with voltage and current measurements. This can occur from switching power supplies found in some electronic devices and is exacerbated by using long lead wires from the power supply to the DUT. Problems with EMI will typically cause input voltage and current instability, and often can result in light output variation in the DUT.

In cases where EMI problems are known or suspected, input capacitors should be placed at the DUT input connections, between supply positive and negative leads, as close to the device as possible. The capacitors should be ceramic chip or tantalum types and have 1 μF, 10 μF, and 100 μF values. These three capacitor values, used in parallel, will effectively mitigate most EMI problems.

I.5 Reporting

The voltage and current for tests using an external power supply should be reported according to Table I.2.

Table I.2 – Voltage and current reporting requirements

	Notes
DC Voltage	Regulated to within ± 0,2 % during photometric measurements and ± 3 % for the duration of lifetime tests
DC Current	Measured using the power supply readout or series shunt resistor. Readout resolution should be ≥ 0,001 mA

Appendix J
(normative)
Light output test

J.1 Background

The light output of a solar LED light is a key parameter as products that do not provide a sufficient amount of light have limited value.

Light output measurements (total luminous flux or lumen output) typically require the use of an integrating sphere or goniophotometer. An additional luminous flux measurement technique, referred to as the multi-plane method, involves conducting illuminance measurements on six planes that define a "box" around a test product and uses these measurements to calculate luminous flux. The multi-plane method is described in section J.4.2.

Laboratories can measure total luminous flux using an integrating sphere, goniophotometer, or the multi-plane method.

J.2 Test outcomes

The test outcomes of the light output test are listed in Table J.1.

Table J.1 – Light output test outcomes

Metric	Reporting units	Related aspects	Notes
Luminous flux	Lumens (lm)	4.2.7.1 Average luminous flux output	Measured using a DC power supply
Correlated colour temperature (CCT)	Kelvin (K)	4.2.7.4 Colour characteristics	Measured using equipment capable of characterizing spectral distribution
Colour rendering index (CRI)	0-100 (unitless)	4.2.7.4 Colour characteristics	Measured using equipment capable of characterizing spectral distribution

J.3 Related tests

This module is related to the light distribution test (Appendix U) and the full-battery run time test (Appendix N).

The light output test allows three alternatives for determining light output. The multi-plane method described in section J.4.2 and a goniophotometer can be used to generate information on the distribution of the device (needed for Appendix U) as well as information on light output. When these methods are utilized, data may also be used by Appendix U to calculate illuminance on a plane, illuminance about an axis, and/or full width half maximum (FWHM) angles as described in section U.4.1.2.5 of Appendix U.

J.4 Luminous flux measurement techniques

General procedure

a) Prerequisite: Find the average operating voltage as described in Appendix N.

b) Prepare the test sample for lighting evaluation as described in Appendix H. Set up a power supply to drive the DUT as described in Appendix I. Note that each test sample will have a unique average operating voltage.

c) The DUT shall operate undisturbed for at least 20 min before any flux measurements are made.

NOTE Refer to Appendix I for a complete description of the electronic power supply setup procedure.

J.4.1 Luminous flux measurements with an integrating sphere or goniophotometer

Refer to the following standard test methods for the measurement of luminous flux with an integrating sphere or goniophotometer:

- CIE084: The measurement of luminous flux
- CIE127: Measurement of LEDs
- IESNA LM-78-07: IESNA approved method for total luminous flux measurement of lamps using an integrating sphere photometer
- IESNA LM-79-08: Electrical and photometric measurement of solid state lighting products

J.4.2 Luminous flux measurements using the multi-plane method

1 lux is one lumen per square meter. This relationship is used in this method to obtain total lumen output by determining the average illuminance (lux) on a 1 m^2 surface at six surfaces (left, right, front, back, top, and bottom) that completely encompass the DUT and summing up the zonal lumen output from each of these six surfaces—approximating a manual goniophotometer measurement.

J.4.2.1 Equipment requirements

- Illuminance meter (cosine-corrected, ≤ 0,1 lux precision, V(λ) corrected)
- Multi-plane test apparatus (described below)
- DC power supply
- DC voltmeter or multimeter
- DC ammeter

J.4.2.2 Test prerequisites

See general procedure (J.4)

J.4.2.3 Apparatus

This test method measures the light distribution characteristic of a DUT on six surfaces to capture all the light emitted by the DUT. The luminous flux is estimated from the six surfaces of data.

The test requires a lighting distribution grid surface that can hold an illuminance meter over a 1 m^2 surface with 0,1 m spacing—an 11 x 11 grid with 121 points (Figure J.1). The 81 interior points each represent 10 cm^2 of surface area. The 36 edge points each represent 5 cm^2 of surface area. The four corner points represent 2,5 cm^2 of surface area. The light is fixed 0,5 m away from the centre of the grid surface (the 0,5 m is measured from the centre of the light source itself).

The light should be situated so the first surface that is measured is the one that contains the peak of the overall light distribution. Subsequently, the light is carefully rotated to capture the other five surface measurements. Three of the remaining five positions are achieved by rotating the lamp exactly 90° about the vertical (Z) axis between each measurement. The remaining two positions are achieved by rotating the light about the horizontal (X) axis (see Figure J.1). After every rotation, the centre point of the light should be exactly 0,5 m from the light meter's sensor when it is placed in the centre of the measurement plane. A rotary disk may be helpful for some lighting products; otherwise a clamping system must be used.

Be sure no stray light hits the photometer and no reflections from other surfaces in the room interfere with the readings. Installing a black curtain around the test setup and having the test operator wear all black are recommended.

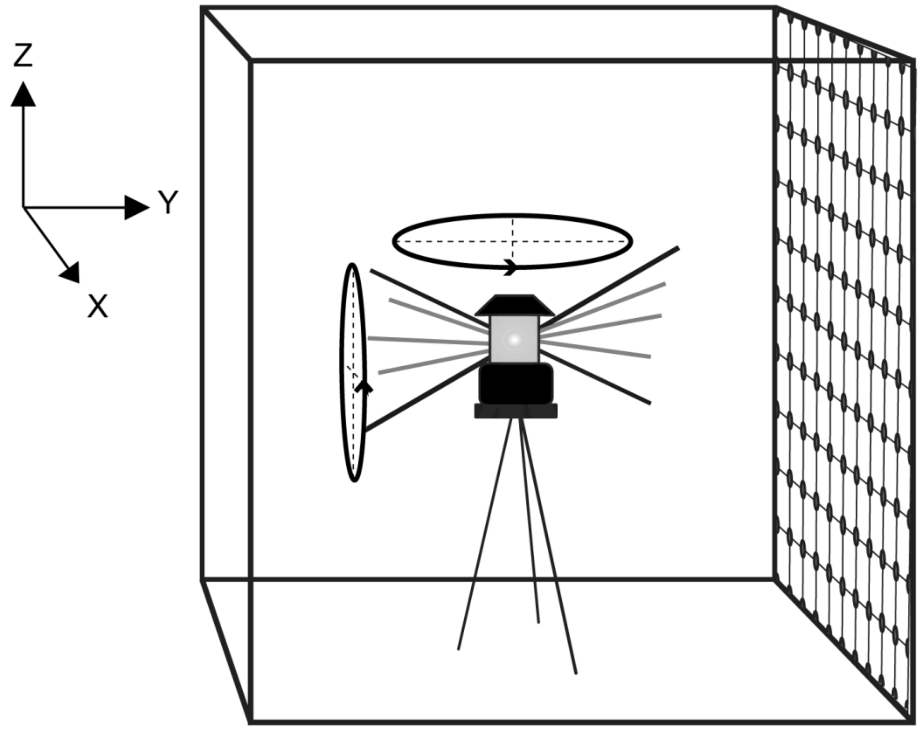


Figure J.1 – Conceptual schematic of the light output test setup, including the 11 x 11 grid, Cartesian coordinate axes for rotation reference, and the DUT

J.4.2.4 Procedure

a) Arrange the room and prepare the DUT, ensuring the stand can hold the DUT steadily and enables precise rotation.

b) Operate the DUT for at least 20 min before the first measurement is taken using an external power supply (Appendix I).

c) Position the DUT such that the centre of its light output is 0,5 m away from the centre of the grid surface as shown in Figure J.1.

d) The centre of the grid surface must read the highest light output provided by the DUT at a 0,5 m distance.

e) Measure illuminance levels at every 0,1 m distance on the grid surface.

f) Rotate the DUT 90° clockwise, repositioning the DUT, if necessary, such that the centre point of the light output is exactly 0,5 m from the light meter's sensor.

g) Measure illuminance levels for the grid points that read a lux value greater than the resolution of the light meter and greater than 0,2 % of the maximum lux reading from the first surface measured.

h) Repeat step 5 and step 6 for the two remaining side faces until reaching the DUT's initial position.

i) Tilt the DUT 90° down (about the X axis) and reposition the DUT, if necessary, such that the centre point of the light output is exactly 0,5 m from the light meter's sensor.

j) Measure illuminance levels for the grid points that read a lux value greater than the resolution of the light meter and greater than 0,1 % of the maximum lux reading from the first surface measured.

k) Tilt the DUT 180° up (about the X axis) and reposition the DUT, if necessary, such that the centre point of the light output is exactly 0,5 m from the light meter's sensor.

l) Measure illuminance levels for the grid points that read a lux value greater than the resolution of the light meter and greater than 0,1 % of the maximum lux reading from the first surface measured.

J.4.2.5 Calculations

The illuminance data can be used to estimate the DUT's luminous flux output. The six measured sides have virtually enclosed the DUT's light output within a box. All the illuminance values over the virtual surfaces will be integrated to calculate an estimate for luminous flux.

a) Estimate the luminous flux incident on the first measured surface.

   1) Multiply the illuminance values by the appropriate area each one represents (0,01 m^2 for interior points, 0,005 m^2 for edge points, and 0,0025 m^2 for corner points) to obtain the luminous flux (lm) represented by each illuminance measurement.

   2) Sum the luminous flux measurements over the entire surface.

b) Repeat step (a) to calculate the luminous flux for the remaining five sides.

c) Total the luminous flux estimates over all six sides to obtain an estimated constant-voltage total luminous flux emitted from the DUT.

J.5 Correlated colour temperature (CCT) measurement

Measurement of correlated colour temperature shall be made in accordance to IEC 60081, Annex D (which references CIE 15:2004).

J.6 Colour rendering index (CRI) measurement

Measurement of colour rendering index (R_a) shall be made in accordance to CIE 13.3 and CIE 177.

J.7 Reporting

Report the following in the light output test report (a sample template is provided in Appendix Y):

- Metadata
    - Report name
    - Procedure(s) used
    - DUT manufacturer
    - DUT name
    - DUT model number
    - DUT setting
    - Test room temperature (°C)
    - Name of test laboratory
    - Approving person
    - Date of report approval

- Results for tested DUT aspects for samples 1 through n
  - Drive current (A)
  - Drive voltage (V)
  - Waiting time (min)
  - Total constant-voltage luminous flux (lm)
  - Average luminous flux during discharge (lm)
  - Correlated colour temperature
  - Colour rendering index
- Average of n sample results for each DUT aspect tested
- Coefficient of variation of n sample results for each DUT aspect tested (%)
- DUT's rating for aspects tested, if available
- Deviation of the average result from the DUT's rating for each aspect tested, if available (%)
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n

Appendix K
(normative)
Lumen maintenance test

K.1 Background

An important performance metric for LED lights is consistent luminous flux over the product's lifetime. The lifetime of LEDs is mainly influenced by electrical operating conditions and thermal management. Further criteria, which accelerate degradation, include the quality of the phosphor used in white LEDs and the UV resistance of the housing. Assuming that an overall lifetime of 5 years and a daily burn time (DBT) of 4 h are achieved, this results in a total operation time of 7 300 h.

Examination of the lumen maintenance is performed in a long-term test. Because of time constraints, it is generally not practical to measure degradation over the entire expected lifespan of a product. The test methods described in this module monitor light output over a fixed period of operation in order to identify and flag products that are found to suffer significant lumen depreciation. An initial screening method is described which monitors light output for 500 h (approximately 3 weeks) as well as a longer term evaluation in which light output is monitored for 2 000 h (approximately 12 weeks).

For the 2 000 h test, a provisional L_{70} judgment can be made at 1 000 h for products that maintain a 95 % lumen maintenance average across all tested samples. Testing has shown that these products are very likely to have L_{70} greater than 2 000 h.

Several of the tests used to evaluate solar LED products are relatively short-term, thus allowing a single test sample to be used on several different tests. Because the lumen maintenance test requires a sample to be dedicated for such a long period of time (up to 12 weeks), it is recommended that test samples are dedicated to this test and not utilized for other testing.

K.2 Test outcomes

The lumen maintenance test outcomes are listed in Table K.1.

Table K.1 – Lumen maintenance test outcomes

Metric	Reporting Units	Related aspects	Notes
Lumen maintenance at 2 000 h	%	4.2.3.2 2 000 hour lumen maintenance	The percentage of initial light output (time = 0 h) that the product generates at the end of the test (time = 2 000 h)
Luminous flux at 2 000 h	Lumens (lm)	4.2.7.1 Average luminous flux output	--
Lumen maintenance at 1 000 h (provisional results)	%	4.2.3.2 2 000 hour lumen maintenance	A provisional L_{70} rating ($L_{70} \geq 2\ 000$ h) can be given to products with a lumen maintenance of ≥ 95 % at 1 000 h
Lumen maintenance at 500 h	%	4.2.3.1 500 hour lumen maintenance	The percentage of initial light output (time = 0 h) that the product generates at the end of the test (time = 500 h)
Luminous flux at 500 h	Lumens (lm)	4.2.7.1 Average luminous flux output	--

K.3 Related tests

This module is related to the light output test (Appendix J). While the relative lumen maintenance of the DUT can be calculated without the results from the light output test (Appendix J), the absolute luminous flux at the end of the lumen maintenance test is a product of both the initial absolute luminous flux (derived from Appendix J) and the relative lumen maintenance.

K.4 Procedure

There at two tests described in this section: a full lumen maintenance characterization in which DUTs are tested for 2 000 h and a quick screening test in which DUTs are tested for 500 h. For 2 000 h tests, a provisional rating is provided after 1 000 h.

Similar to the full-battery run time test (Appendix N), the lumen maintenance test requires an accurate measurement of relative light output over time. There are four approved methods for making these measurements:

a) Photometer tube method (section K.4.1.1)

b) Fixed geometry method (section K.4.1.2)

c) Photometer box method (section K.4.1.3)

d) Integrating sphere method (section K.4.1.4)

K.4.1 Full screening

K.4.1.1 Photometer tube method

K.4.1.1.1 Equipment requirements

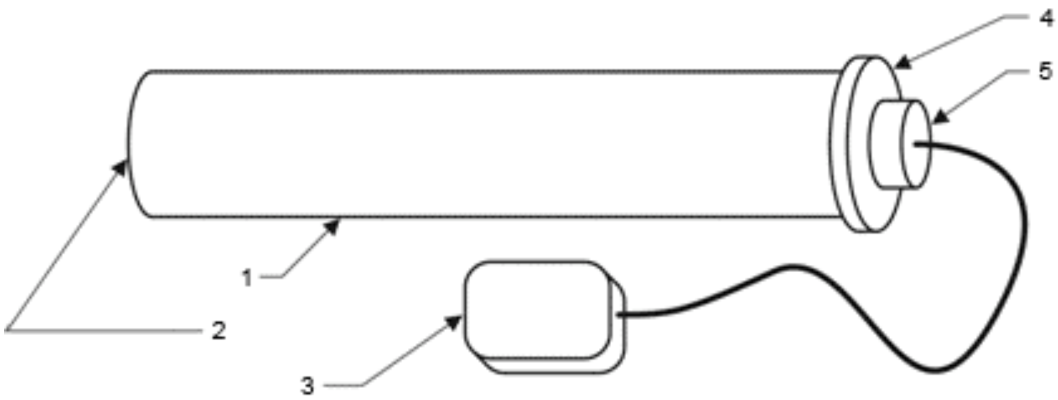
- Photometer tube test apparatus (described below)
- DC power supply
- DC voltmeter
- DC ammeter

K.4.1.1.2 Test prerequisites

Determination of initial luminous flux per the light output test (Appendix J).

K.4.1.1.3 Apparatus

The photometer tube is a self-made device (made from low-cost materials that are readily available in developing countries) for taking measurements of relative luminous flux. A basic rendering of a photometer tube is included in Figure K.1.



Key

1 Tube
2 Open end
3 Photometer
4 End cap
5 Photometer sensor

Figure K.1 – Schematic of a photometer tube

The recommended tube for this application is made of cardboard, often available free of cost from fabric or paper rolls. PVC pipe is also relatively inexpensive and appropriate for use as a photometer tube. The tube inside diameter should be between 5 cm and 7 cm. The tube should be at least 50 cm in length.

An end cap is fit snugly to one end of the tube. The end cap holds the light meter sensor in a fixed position at the end of the tube and restricts stray light from entering. Due to material cost and ease of manufacture, wood is the recommended material for the end cap.

No reflective coating is necessary on the internal surface of the photometer tube.

K.4.1.1.4 Procedure

a) The DUT battery is replaced by a laboratory power supply that is set to deliver the DUT's standard battery voltage according to the power supply setup procedure (Appendix I).
b) Light from the DUT is directed into the open end of the photometer tube.
c) The DUT and the photometer are both fixed to the photometer tube for the duration of the test.[3)]
d) Care must be taken to ensure that the DUT is secured to the photometer tube such that exactly the same alignment is maintained for each measurement. Care must also be taken when securing the DUT to the photometer tube that the DUT does not have its thermal environment altered significantly. If airflow around the DUT is significantly reduced due to the connection to the

[3)] It is recognized that laboratories testing a large number of samples may not be able to dedicate a photometer to each sample that they are testing during the duration of the lumen maintenance test. Thus, it is allowable to have an apparatus in which the DUT or the photometer is installed just prior to the making measurements and then removed afterwards. If such a method is utilized great care must be made to ensure that the photometer and the DUT are placed in precisely the same geometric arrangement for each measurement, as even slight variation in placement can generate significant measurement errors. Also, if a photometer is installed and removed from an apparatus, it is important that the same photometer is used for all measurements (i.e., do not measure some readings with meter A, and subsequent readings with meter B). Using photometers with "max" functions can facilitate replication of the original geometry (i.e., if the original reading is at the peak of the light distribution it is possible to search for the peak using a max function).

photometer tube (i.e., if the entire DUT is placed inside the tube), the test results could show a higher lumen maintenance rate than would actually result from normal use.

e) Refer to Table K.2 for the minimum frequency at which the relative illuminance of the DUT, ambient temperature, DUT voltage, and current are measured and recorded.

f) (Optional) A data logger or a lux meter with a data logging function can be used to record the illuminance every hour.

Table K.2 – Lumen maintenance test minimum frequency of measurement for full screening test

Measurement number	Time interval (h)	Cumulative time (h)
1	0,33 (20 min)	0
2	24	24
3	48	72
4	48	120
5	48	168
6	48	216
7	168	384
8	168	552
9	168	720
10	168	888
(optional)	112	1000
11	168	1056
12	168	1224
13	168	1392
14	168	1560
15	168	1728
16	168	1896
17	104	2000

K.4.1.1.5 Calculations

See section 0.

K.4.1.2 Fixed geometry method

K.4.1.2.1 Equipment requirements

- DC power supply
- DC voltmeter
- DC ammeter

K.4.1.2.2 Test prerequisites

Determination of initial luminous flux per the light output test (Appendix J).

K.4.1.2.3 Apparatus

The apparatus for the method is simply any dedicated space in which the DUT and the photometer are secured so they do not move relative to one another during testing and so no outside light is received.

This could be a dedicated area in a "dark room" in which the photosensor and DUT are secured, or other similar setup.

K.4.1.2.4 Procedure

a) The DUT battery is replaced by a laboratory power supply that is set to deliver the DUT's standard battery voltage (Appendix I).

b) The DUT and the photometer are both place in a fixed locations relative to one another for the duration of the test. Care must be taken to ensure that the DUT and the photometer are secured such that exactly the same alignment is maintained for each measurement. Care must also be taken such that no stray light (i.e., ambient light, light from other test samples, etc.) is able to reach the photosensor.

c) Refer to Table K.2 for the minimum frequency at which the relative illuminance of the DUT, ambient temperature, DUT voltage, and current are measured and recorded.

d) A data logger or a lux meter with a data logging function can be used to record the illuminance every hour.

K.4.1.2.5 Calculations

See section 0.

K.4.1.3 Photometer box method

K.4.1.3.1 Equipment requirements

- Photometer box
- DC power supply
- DC voltmeter
- DC ammeter

K.4.1.3.2 Test prerequisites

Determination of initial luminous flux per the light output test (Appendix J).

K.4.1.3.3 Apparatus

The apparatus for the method is a photometer box, as described in the full-battery run time test (Appendix N).

K.4.1.3.4 Procedure

a) The DUT battery is replaced by a laboratory power supply that is set to deliver the DUT's standard battery voltage (Appendix I).

b) The relative illuminance is measured using the photometer box.

c) The location of the DUT in the photometer box must be accurately noted to ensure exact replication of alignment and orientation for each measurement. A printed photograph of the DUT placement within the box is a useful reference. Alignment marks may also be used to ensure repeatability.

d) For the following measurements, the DUT must be placed in the photometer box with exactly the same alignment and orientation.

e) Refer to Table K.2 for the minimum frequency at which the relative illuminance of the DUT, ambient temperature, DUT voltage, and current are measured and recorded.

f) In the case that the DUT remains in the box throughout the duration of the test, a data logger or a lux meter with a data logging function can be used to record the illuminance every hour.

K.4.1.3.5 Calculations

See section 0.

K.4.1.4 Integrating sphere method

K.4.1.4.1 Equipment requirements

- Integrating sphere
- DC voltmeter
- DC ammeter

K.4.1.4.2 Test prerequisites

Determination of initial luminous flux per the light output test (Appendix J).

K.4.1.4.3 Apparatus

Integrating sphere

K.4.1.4.4 Procedure

a) The DUT battery is replaced by a laboratory power supply that is set to deliver the DUT's standard battery voltage (Appendix I).

b) The luminous flux is measured using an integrating sphere system.

c) Refer to Table K.2 for the minimum frequency at which the luminous flux of the DUT, ambient temperature, DUT voltage, and current are measured and recorded.

K.4.1.4.5 Calculations

See section 0.

K.4.2 Initial screening (500 hour test)

The lumen maintenance initial screening test is identical to the full screening test with the exception of the test duration, which is reduced from 2 000 h to 500 h. All four of the methods described above for the full screening test (photometer tube, fixed geometry, photometer box, and integrating sphere) can be used for the Initial screening test. Table K.3 is to be used for minimum testing duration.

Table K.3 – Lumen maintenance test minimum frequency of measurement for Initial screening test

Measurement number	Time interval (h)	Cumulative time (h)
1	0,33 (20 min)	0
2	24	24
3	48	72
4	48	120
5	48	168
6	48	216
7	168	384
8	116	500

K.5 Calculations

Lumen maintenance is calculated by dividing the final light output reading by the initial light output reading. Lumen maintenance is always reported along with the test duration.

The final luminous flux equals the initial luminous flux (as measured in Appendix J) multiplied by the lumen maintenance.

If the light output of the DUT ever drops below 70 % of the initial reading, then operating hours at which this occurs should be reported as L_{70}. For example, if the initial reading was 1 000 lx, and readings dropped to 700 lx after 720 h, then $L_{70} = 720$ h.

If the light output of the DUT at the end of the 2 000 hour test is greater than 70 % of the initial reading, the L_{70} rating will then be $L_{70} > 2\,000$ h.

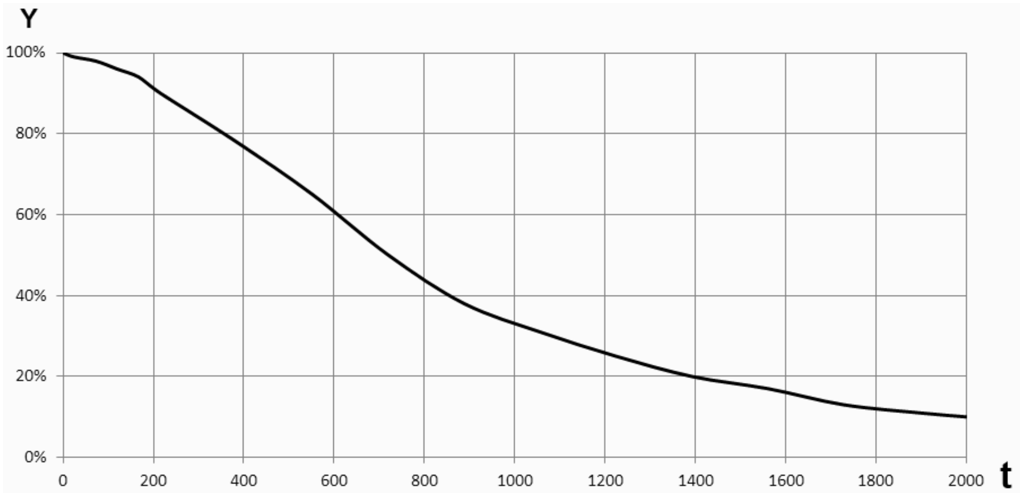
For the 2 000 h test, a provisional $L_{70} > 2\,000$ h rating can be given to products that have a lumen maintenance ≥ 95 % at 1 000 h.

K.6 Reporting

Report the following in the lumen maintenance test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - DUT setting
  - Test room temperature (°C)
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Results for tested DUT aspects for samples 1 through n
  - Drive current (A)
  - Drive voltage (V)
  - Waiting time (min)
  - Initial, constant-voltage luminous flux (lm)
  - Lumen maintenance (note if at 500 h, 1 000, or 2 000 h) (%)
  - Final, constant-voltage luminous flux (lm)
- Average of n sample results for each DUT aspect tested

- Coefficient of variation of n sample results for each DUT aspect tested (%)
- DUT's rating for aspects tested, if available
- Deviation of the average result from the DUT's rating for each aspect tested, if available (%)
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n
- Figures
  - Plot of lumen maintenance (see example in Figure K.2)
- Datasets
  - Table with all illuminance or flux, ambient temperature, DUT voltage, and current measurements



Key

t Time (h)

Y Relative luminous flux

Figure K.2 – Example lumen maintenance plot

Appendix L
(normative)
Battery test

L.1 Background

The battery test is used to determine a DUT's actual battery capacity and storage efficiency. This information is useful to determine if a battery is mislabelled or damaged. During the test the battery is connected to a battery analyser, which performs charge-discharge cycles on the battery. The last charge-discharge cycle data from the battery test is analysed to determine the actual battery capacity and battery storage efficiency.

L.2 Test outcomes

The test outcomes of the battery test are listed in Table L.1.

Table L.1 – Battery test outcomes

Metric	Reporting units	Related aspects	Note
Battery capacity (C_b)	Milliampere-hours (mAh) at a discharge current (0,x I_t A)	4.2.4.1 Battery capacity	--
Battery storage efficiency (η_b)	Percentage (%)	4.2.8.1 Input to battery circuit efficiency	At least two complete charge-discharge cycles are required for the calculation

L.3 Related tests

The battery test results are inputs to the solar charge test (Appendix S) and the full-discharge preparation procedure (Appendix O).

L.4 Procedure

L.4.1 Sealed lead-acid battery test

The DUT's sealed lead-acid battery is cycled on a battery analyser and the data from the final charge-discharge cycle is used to determine the DUT's actual battery capacity and storage efficiency.

L.4.1.1 Equipment requirements

- Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2

L.4.1.2 Test prerequisites

The battery can be taken out of the lighting product for this test, if desired.

L.4.1.3 Procedure

a) Prime the battery using a charge rate of 0,1 I_t A, a discharge rate of 0,1 I_t A, and the information in the battery cycling recommended practices appendix (Appendix M).

   1) Using the battery analyser, continuously cycle the battery until the maximum battery capacity is reached (i.e., until the capacity improvement is less than or equal to 5 % over the previous battery capacity).

b) Ensure the battery is charged using a charge rate of 0,1 I_t A and the information in the battery cycling recommended practices appendix (Appendix M). After charging, the battery shall be stored in an ambient temperature of 20 °C ± 5 °C for not less than 1 h and not more than 4 h.

c) The battery shall be discharged at a rate of 0,1 I_t A, using the information in the battery cycling recommended practices appendix (Appendix M), and the battery capacity shall be measured.

d) Continue cycling the battery until the change in measured battery capacity between subsequent cycles is less than or equal to 15 %, ensuring that the last two charge-discharge cycles have identical charge and discharge rates.

e) If the battery will be stored after undergoing this test, charge the battery using a charge rate of 0,1 I_t A and the information in the battery cycling recommended practices appendix (Appendix M).

L.4.1.4 Calculations

a) Determine the total energy input into the DUT's battery during the final charge cycle (E_c) using the following formula:

$$E_\mathrm{c} = \sum \left(V_\mathrm{c} \times I_\mathrm{c} \times \Delta t\right)$$

where

E_c is the energy entering the battery during the charge cycle, in watt-hours (Wh);
V_c is the voltage recorded during the charge cycle, in volts (V);
I_c is the current recorded during the charge cycle, in amperes (mA);
Δt is the time interval between subsequent data points, in hours (h).

b) Determine the total energy output from the DUT's battery during the final discharge cycle using the following formula:

$$E_\mathrm{d} = \sum \left(V_\mathrm{d} \times I_\mathrm{d} \times \Delta t\right)$$

where

E_d is the battery's energy output during the discharge cycle, in watt-hours (Wh);
V_d is the voltage recorded during the discharge cycle, in volts (V);
I_d is the current recorded during the discharge cycle, in amperes (mA);
Δt is the time interval between subsequent data points, in hours (h).

c) Determine the DUT's battery capacity with data from the final discharge cycle using the following formula:

$$C_\mathrm{b} = \sum \left(I_\mathrm{d} \times \Delta t\right)$$

where

C_b is the measured battery capacity, in milliampere-hours (mAh);
I_d is the current recorded during the discharge cycle, in amperes (mA);
Δt is the time interval between subsequent current data, in hours (h).

d) Determine the DUT's battery efficiency using the following formula:

$$\eta_b = \frac{E_d}{E_c}$$

where

η_b	is the battery storage efficiency;
E_d	is the battery's energy output during the discharge cycle, in watt-hours (Wh);
E_c	is the energy input to the battery during the charge cycle, in watt-hours (Wh).

L.4.2 Nickel-metal hydride battery test

The DUT's nickel-metal hydride battery is cycled on a battery analyser and the data from the final charge-discharge cycle is used to determine the DUT's actual battery capacity and battery storage efficiency.

L.4.2.1 Equipment requirements

- Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2

L.4.2.2 Test prerequisites

The battery can be taken out of the lighting product for this test, if desired.

L.4.2.3 Procedure

a) Prime the battery using the charge-discharge rates specified in section 7.1 of IEC 61951-2 and the information in the battery cycling recommended practices appendix (Appendix M).
   1) Using the battery analyser, continuously cycle the battery until the maximum battery capacity is reached (i.e., until the capacity improvement is less than or equal to 5 % over the previous battery capacity).

b) Follow the discharge performance at 20 °C procedure in section 7.3.2 of IEC 61951-2, using the measured battery capacity from the previous charge-discharge cycle as the target capacity for the next charge-discharge cycle.

c) Continue cycling the battery until the change in measured battery capacity between subsequent cycles is less than or equal to 15 %, ensuring that the last two charge-discharge cycles have identical charge and discharge rates.

d) If the battery will be stored after undergoing this test, charge the battery using the charge rates specified in section 7.1 of IEC 61951-2 and the information in the battery cycling recommended practices appendix (Appendix M).

L.4.2.4 Calculations

Perform the same calculations listed in L.4.1.4.

L.4.3 Lithium-ion battery test

The DUT's lithium-ion battery is cycled on a battery analyser and the data from the final charge-discharge cycle is used to determine the DUT's actual battery capacity and battery storage efficiency.

L.4.3.1 Equipment requirements

- Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2

L.4.3.2 Test prerequisites

The battery can be taken out of the lighting product for this test, if desired.

L.4.3.3 Procedure

a) Follow the discharge performance at 20 °C procedure in section 7.3.1 of IEC 61960, using the measured battery capacity from the previous charge-discharge cycle as the target capacity for the next charge-discharge cycle.

b) Continue cycling the battery until the change in measured battery capacity between subsequent cycles is less than or equal to 15 %, ensuring that the last two charge-discharge cycles have identical charge and discharge rates.

c) If the battery will be stored after undergoing this test, charge the battery using the charge rates specified in section 4 of IEC 61951-2 and the information in the battery cycling recommended practices appendix (Appendix M).

L.4.3.4 Calculations

Perform the same calculations listed in L.4.1.4.

L.4.4 Lithium iron phosphate battery test

The DUT's lithium iron phosphate battery is cycled on a battery analyser and the data from the final charge-discharge cycle is used to determine the DUT's actual battery capacity and battery storage efficiency.

L.4.4.1 Equipment requirements

- Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2

L.4.4.2 Test prerequisites

The battery can be taken out of the lighting product for this test, if desired.

L.4.4.3 Procedure

a) Follow the discharge performance at 20 °C procedure in section 7.3.1 of IEC 61960, using the measured battery capacity from the previous charge-discharge cycle as the target capacity for the next charge-discharge cycle.

b) Continue cycling the battery until the change in measured battery capacity between subsequent cycles is less than or equal to 15 %, ensuring that the last two charge-discharge cycles have identical charge and discharge rates.

c) If the battery will be stored after undergoing this test, charge the battery using the charge rates specified in section 4 of IEC 61951-2 and the information in the battery cycling recommended practices appendix (Appendix M).

L.4.4.4 Calculations

Perform the same calculations listed in L.4.1.4.

L.4.5 Nickel-cadmium battery test

The DUT's nickel-cadmium battery is cycled on a battery analyser and the data from the final charge-discharge cycle is used to determine the DUT's actual battery capacity and battery storage efficiency.

L.4.5.1 Equipment requirements

- Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2

L.4.5.2 Test prerequisites

The battery can be taken out of the lighting product for this test, if desired.

L.4.5.3 Procedure

a) Prime the battery using the charge-discharge rates specified in section 7.1 of IEC 61951-1 and the information in the battery cycling recommended practices appendix (Appendix M).

    1) Using the battery analyser, continuously cycle the battery until the maximum battery capacity is reached (i.e., until the capacity improvement is less than or equal to 5 % over the previous battery capacity).

b) Follow the discharge performance at 20 °C procedure in section 7.2.1 of IEC 61951-1, using the measured battery capacity from the previous charge-discharge cycle as the target capacity for the next charge-discharge cycle.

c) Continue cycling the battery until the change in measured battery capacity between subsequent cycles is less than or equal to 15 %, ensuring that the last two charge-discharge cycles have identical charge and discharge rates.

d) If the battery will be stored after undergoing this test, charge the battery using the charge rates specified in section 7.1 of IEC 61951-1 and the information in the battery cycling recommended practices appendix (Appendix M).

L.4.5.4 Calculations

Perform the same calculations listed in L.4.1.4.

L.5 Reporting

Report the following in the battery test report (a sample template is provided in Appendix Y):

- Metadata
    - Report name
    - Procedure(s) used
    - DUT manufacturer
    - DUT name
    - DUT model number
    - Name of test laboratory
    - Approving person
    - Date of report approval
- Results for tested DUT aspects for samples 1 through n
    - Battery capacity (mAh) at a discharge current (0,x I_t A)
    - Battery storage efficiency (%)
- Average of n sample results for each DUT aspect tested

- Coefficient of variation of n sample results for each DUT aspect tested (%)
- DUT's rating for aspects tested, if available
- Deviation of the average result from the DUT's rating for each aspect tested, if available (%)
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n

Appendix M
(informative)
Battery cycling recommended practices

M.1 Background

During the battery test (Appendix L), a DUT's battery is cycled numerous times in order to determine the battery's actual capacity and storage efficiency. In addition to the charge-discharge guidelines specified in the battery test (Appendix L), the battery cycling recommended practices appendix provides further information to ensure that the battery is not damaged during testing and the person conducting the test is safe.

M.2 Charge-discharge specifications by battery type

Table M.1 contains battery cycling information specific to the five common types (i.e., chemistries) of batteries. This information should be used in conjunction with the charge and discharge rates specified in the battery test procedures (Appendix L).

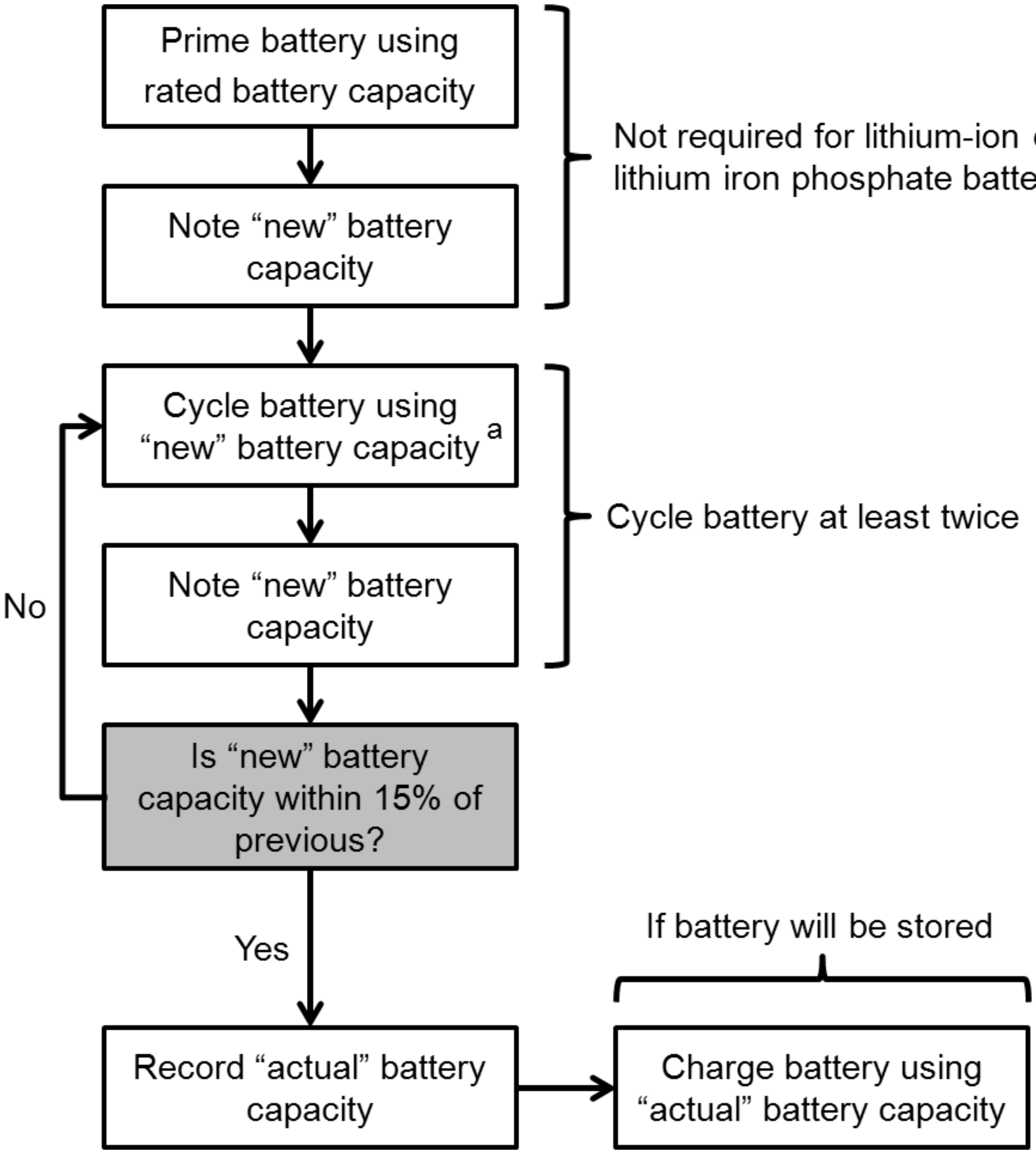
Table M.1 – Recommended battery cycling specifications according to battery chemistry

Battery type	Maximum standby voltage (V/cell)	Maximum charge voltage (V/cell)	End of charge / topping charge rate (A)	End of discharge voltage (V/cell)
Sealed lead-acid	2,25	2,40	0,05 I_t	1,49
Lithium-ion	4,05	4,10	0,05 I_t	3,00
Lithium iron phosphate	3,55	3,60	0,01 I_t	3,00

Battery type	Negative slope (mV/cell)	End of discharge voltage (V/cell)	End of recondition (V/cell)	Charge method
Nickel-metal hydride	8,00	1,00	0,40	Reverse load pulse at 9 %
Nickel-cadmium	8,00	1,00	0,40	Reverse load pulse at 9 %

M.3 Battery cycling process flowchart

The battery testing flowchart below can be used in conjunction with the information provided in section A.2 and the battery test procedures (Appendix L).



Key

a Use the rated battery capacity for the first cycle of lithium-ion and lithium iron phosphate batteries

Figure M.1 – Battery cycling flowchart for battery test (Appendix L)

Appendix N
(normative)
Full-battery run time test

N.1 Background

The full-battery run time captures one of the key system-performance metrics from a user's perspective. It combines the relationship between battery capacity, circuit efficiency, and lighting system power consumption under realistic operating conditions.

In general terms, the full-battery run time test involves operating a DUT with a fully charged battery until the light output has decreased to some pre-defined minimum value (70 % in this case).

$$\Phi_{\mathrm{v,rel}} = \Phi_{\mathrm{v}}(t) / \Phi_{\mathrm{v}}(t_{\mathrm{i}})$$

where

- $\Phi_{\mathrm{v,rel}}$ is the DUT's relative luminous flux, expressed in lumens (lm);
- $\Phi_{\mathrm{v}}(t)$ is the DUT's luminous flux, expressed in lumens (lm), corresponding to 70 % of the DUT's initial luminous flux;
- $\Phi_{\mathrm{v}}(t_{\mathrm{i}})$ is the DUT's initial luminous flux, expressed in lumens (lm).

The full-battery run time is defined as when $\Phi_{\mathrm{v,rel}}$ reaches 70 % of the initial luminous flux $\Phi_{\mathrm{v}}(t_{\mathrm{i}})$.[4)] To ensure that the DUT is measured in its thermal balance and with stabilized battery voltage (after initial voltage drop), the initial luminous flux is measured 20 min into the DUT's discharge.

[4)] This limit was chosen since a decrease of more than 30% is clearly visible for human eyes according to the Alliance for Solid-State Illumination Systems and Technologies (ASSIST).

N.2 Test outcomes

The test outcomes of the full-battery run time test are listed in Table N.1.

Table N.1 – Full-battery run time test outcomes

Metric	Reporting units	Related aspects	Notes
Full-battery run time, to L_{70}	Hours (h)	4.2.6.1 Full-battery run time	Run time to 70 % of initial light output
Average relative light output, through L_{70}	%	4.2.7.1 Average luminous flux output 4.2.7.3 Average light distribution characteristics	The average RLO operating point determines the operating point for making light output measurements.
Average battery voltage and current at average relative light output (i.e., the "average operating point")	Voltage (V) and current (mA)	4.2.7.1 Average luminous flux output 4.2.7.3 Average light distribution characteristics	This operating point is used to make light output measurements.
Average power over the L_{70} run time	Watts (W)	4.2.6.1 Full-battery run time	Average power draw over the run time while light output is over 70 % of initial light output
Energy removed from the battery over the L_{70} run time	Watt-hours (Wh)	4.2.6.1 Full-battery run time	Total energy removed over the run time while light output is over 70 % of initial light output
Deep discharge protection incorporation	Yes/no	4.2.2.10 Battery protection strategy	--
Deep discharge protection voltage	Volts (V)	4.2.2.10 Battery protection strategy	--

N.3 Related tests

Appendix N is related to the charge controller behaviour test (Appendix T). The information about average operating point from this test is used to set up the Light output test (Appendix J) and Light distribution test (Appendix U).

N.4 Procedure

N.4.1 Full-battery run time test

The DUT is set in the measurement cavity and turned on in order to record its light output over the duration of its discharge.

N.4.1.1 Equipment requirements

- Integrating sphere, or other approved measurement cavity
- Data-logging light meter
- Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2
- Data-logging voltage device
- Data-logging current device (e.g. voltage data logger and current transducer)

N.4.1.2 Test prerequisites

Cycle the DUT's battery according to the procedures in the battery test appendix (Appendix L) and the information in the battery cycling recommended practices appendix (Appendix M).

N.4.1.3 Apparatus

The full-battery run time test requires an accurate measurement of relative light output over time. In practice, this means using an integrating sphere or a fixed-geometry measurement cavity to measure the illuminance level[5)] under constant conditions. Three approved measurement cavities are listed below in order of preference.[6)] The lighting measurement is taken indirectly (reflected) in the first two types, while it is taken directly in the last type.

- Integrating sphere
- A self-built photometer box with a baffled measurement of illuminance on a port (i.e., an "integrating cube" as shown in the figure below).[7)]
- A darkened room or cabinet with direct illuminance measurement under fixed geometry.

Figure N.1 – Interior view of photometer box with suspended light

N.4.1.4 Procedure

Before measurement, fully charge the battery according to the procedures in the battery test appendix (Appendix L) and the information in the battery cycling recommended practices appendix (Appendix M). The run time test can be started between 1 h and 10 h after the DUT has finished receiving its full charge.

a) Set and secure the DUT inside the test cavity such that it is stable and cannot be jostled. Position the direction of light indirectly towards the light meter for an integrating sphere or photometer box measurement cavity. Position the direction of light directly towards the light meter for a darkened room/cabinet or tube measurement cavity.

---

5) A measurement of illuminance in a fixed geometry (such as a dark room or isolated box) is always directly proportional in a linear fashion to the luminous flux of a lamp. Therefore, fixed-geometry measurements of illuminance can be used in place of luminous flux measurements for this test, which relies on relative light output to indicate the end of a discharge cycle.

6) Any of these cavities can result in identical estimates for full-battery run time. The preference order is related to the degree of operator care required to maintain a fixed geometry in each, with a preference for cavities whose relative measurement is less sensitive to small changes in the system (e.g., from accidentally bumping into the cavity during a test).

7) The photometer's precision in the range of expected measurements being made is sufficient to provide ≤ 5 min resolution on run time. And the magnitude of stray light's influence on the absolute light output measurements are less than 0,5% of the minimum light output magnitude being measured during the test.

b) Prepare the data logging voltage device to measure voltage across the DUT's battery terminals at intervals of 1 min or less. Prepare the data logging current device to measure the current exiting the DUT's battery at the negative battery terminal at intervals of 1 min or less.

c) The light is switched on at the correct brightness setting and the measurement is started. Light output (luminous flux for the integrating sphere; illuminance for other measurement devices) should be recorded every minute, at a minimum.

d) The initial light output is measured after 20 min (t_i).[8] This defines the point at which relative light output (RLO) is 100 %.

e) The test should be continued until the RLO reaches 10 % or less (i.e., the light output measurement is 10 % of the value at t_i).

N.4.1.5 Calculations

Analyse the time-series light output data to estimate the L_{70} run time, the average relative light output, and the operating characteristics (voltage and current) that correspond to the average relative light output. Analyse the time-series current and voltage data to estimate the average power over the L_{70} run time and the total energy removed from the battery over the L_{70} run time.

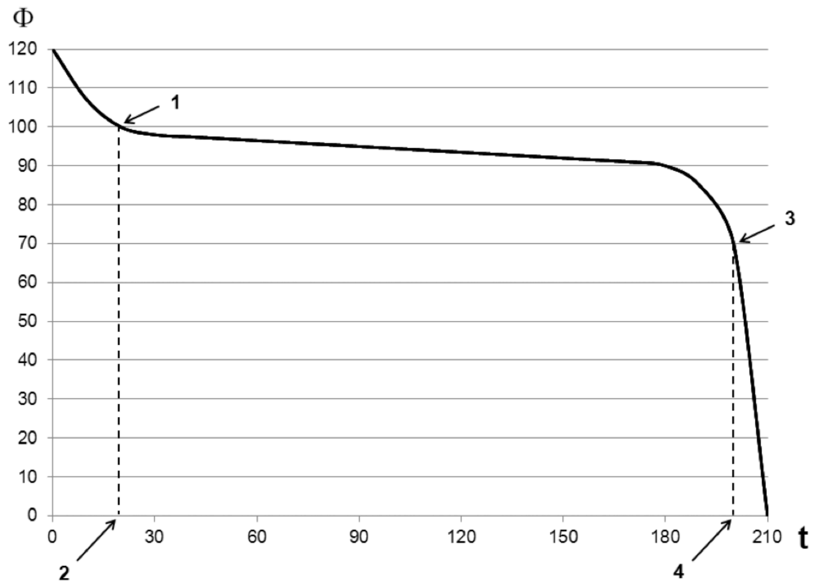
a) The end of the L_{70} discharge period is reached when the RLO is 70 % of the initial value at t_0 (i.e., the light output is 70 %). The result shall be noted, expressed in hours (h).

b) If an integrating sphere was utilized, use the luminous flux averaged over the L_{70} run time.

c) The recorded data should be presented in a graph such as the one shown in the figure below for each brightness level (the figure shows only the result of one brightness level). If more than one brightness level was tested, prepare a separate graph for each test.

NOTE This should include the full discharge, beginning at 0 min, and may include values greater than 100 %.

[8] In the case where the DUT's light output cascades in steps while it discharges and the DUT's light output steps down to a dimmer setting prior to having been on for 20 minutes: the test lab should make a note and adjust the L_{70} discharge period to represent the setting in which the DUT was tested for.



Key

t Time (min)

ϕ Relative light output (%), which is directly proportional to the luminous flux output

1 20 min from point DUT is turned on

2 t_i, time when RLO is defined as 100 %

3 L_{70} reached (RLO is 70 %)

4 t_{70}, time when RLO is 70 %

Figure N.2 – Plot of example results from the full-battery run time test

d) Determine the average power over the L_{70} run time ($P_{b,i}$) using the following formula:

$$P_{b,i} = \frac{\sum_i \left(I_{b,i} \times V_{b,i}\right)}{n}$$

where

$P_{b,i}$	is the average power exiting the battery over the L_{70} run time, in watts (W);
$I_{b,i}$	is the current exiting the battery over the L_{70} run time, in amperes (A);
$V_{b,i}$	is the voltage exiting the battery over the L_{70} run time, in volts (V);
n	is the total number of current and voltage measurements over the L_{70} run time (unit less)

e) Determine the energy removed from the battery over the L_{70} run time ($E_{b,i}$) using the following formula:

$$E_{b,i} = \sum_i \left(I_{b,i} \times V_{b,i} \times t_i \right)$$

where

$E_{b,i}$	is the energy exiting the battery over the L_{70} run time, in watt-hours (Wh);
$I_{b,i}$	is the current exiting the battery over the L_{70} run time, in amperes (A);
$V_{b,i}$	is the voltage exiting the battery over the L_{70} run time, in volts (V);
t_i	is the duration of time associated with each current and voltage point over the L_{70} run time, in hours (h)

f) Determine the average relative light output during the L_{70} run time (RLO_{avg}).

g) Create a table listing the relative light output and current as a function of voltage operating point for the steady-state operating period—defined as the period beginning 20 minutes into the tests (when RLO is defined as 100 %) and ending at the L_{70} point. The table should list each operating voltage during the period in increments of 0,01 V. The average relative light output and average current should be found based on all the steady state points that fall into each voltage "bin."

h) Determine the operating voltage (V_{avg}) and current (I_{avg}) that correspond to the average operating point (RLO_{L70}) based on the table.

N.4.2 Full-battery run time test with low voltage disconnect measurement

The DUT is set in the measurement cavity and switched on to run while recording its light output, battery voltage, and current over the duration of its discharge.

N.4.2.1 Equipment requirements

- Integrating sphere, or other approved measurement cavity
- Data-logging light meter
- Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2
- Data-logging voltage device
- Data-logging current device (e.g. voltage data logger and current transducer)

N.4.2.2 Test prerequisites

Cycle the DUT's battery according to the procedures in the battery test appendix (Appendix L) and the information in the battery cycling recommended practices appendix (Appendix M).

N.4.2.3 Apparatus

The full-battery run time with low voltage disconnect measurement method requires the same apparatus as the full-battery run time test (Appendix N).

N.4.2.4 Procedure

The procedure for the full-battery run time test combined with deep discharge protection measurement is equivalent to the procedure for the full-battery run time test (section N.4.1.4). When performing this procedure, take note of the DUT's operating current, which can be used to ensure the DUT is operating at the same setting during other tests.

N.4.2.5 Calculations

Analyse the time-series light output data to estimate the L_{70} run time and the average relative light output during the period (see section N.4.1.5). Analyse the time-series current and voltage data to estimate the average power over the L_{70} run time, the total energy removed from the battery over the L_{70} run time, the average relative light output during the L_{70} run time, and the operating voltage (V_{avg}) and current (I_{avg}) that correspond to the average operating point (RLO_{L70}) (see section N.4.1.5). Also, determine if the DUT has deep discharge protection incorporated into its charge controller and determine the deep discharge protection voltage:

If the DUT has deep discharge protection, one of two observations may be seen: (1) an abrupt drop will occur in the DUT's light output and current flow will quickly decrease to 0 A, or (2) a relatively quick drop will occur in the DUT's light output and current will ultimately decrease to 0 A. At the instant before the light output reaches zero, if the DUT's battery voltage is greater than or equal to the specified deep discharge protection voltage threshold for the DUT's battery chemistry[9)], then the product has deep discharge protection. Report if deep discharge protection was observed in the DUT.

i) If the DUT has deep discharge protection, report the DUT's deep discharge protection voltage, in volts (V). The battery voltage typically decreases until reaching its deep discharge protection point. After the deep discharge protection point is reached, typically the light turns off and the battery voltage increases. Determine the deep discharge protection voltage by identifying the battery voltage just before the battery voltage increases.

N.5 Reporting

Report the following in the full-battery run time test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - DUT setting
  - Name of test laboratory
  - Approving person
  - Date of report approval

9) Recommended deep discharge protection voltage thresholds according to battery chemistry are: 1,87 V/cell ± 0,05 V/cell for lead-acid, 1,00 V/cell ± 0,05 V/cell for NiMH and NiCd, 3,00 V/cell ± 0,05 V/cell for Li-ion, and 2,00 V/cell ± 0,05 V/cell for $LiFePO_4$.

- Results for tested DUT aspects for samples 1 through n
    - Run time to L_{70} (h)
    - Average relative light output during the run time period (RLO_{avg})
    - Average operating point that corresponds to RLO_{avg} : V_{avg} (V) and I_{avg} (mA)
    - Average power over the L_{70} run time (W)
    - Energy removed from the battery over the L_{70} run time (Wh)
    - Presence of deep discharge protection, if applicable (yes/no)
    - Deep discharge protection voltage, if applicable (V)
- Average of n sample results for each DUT aspect tested
- Coefficient of variation of n sample results for each DUT aspect tested (%)
- DUT's rating for aspects tested, if available
- Deviation of the average result from the DUT's rating for each aspect tested, if available (%)
- Comments
    - Individual comments, as necessary, for samples 1 through n
    - Overall comments, as necessary, for collective set of samples 1 through n
- Figures
    - Plot showing the luminous flux (lm) against the run time (min), as in Figure N.2
- Table showing relative light output and current as a function of operating voltage, as described above.

Appendix O
(normative)
Full discharge preparation

O.1 Background

Prior to starting selected run time tests, a DUT must be fully discharged. When performing the full-battery run time test (Appendix N), a DUT is considered "fully discharged" when it reaches its L_{70}. This is point at which the DUT provides 70 % of the light output provided 20 min into the DUT's full-battery discharge.

The mechanical charge test (Appendix Q) and solar charge test (Appendix S) use a specified charge cycle and the DUT's initial state of charge will influence the DUT's performance during the charge. It is important that that the DUT be set to a prescribed state of charge to simulate a "full discharge" prior to commencing the selected run time tests so the results are repeatable and comparable across products.

O.2 Test outcomes

There are no full discharge preparation procedures outcomes.

O.3 Related tests

The full discharge preparation procedures must be performed on all DUTs prior to conducting the mechanical charge test (Appendix Q) and solar charge test (Appendix S).

O.4 Procedure

O.4.1 Full discharge preparation

Each DUT is "fully discharged" prior to starting selected run time tests.

O.4.1.1 Equipment requirements

One of the following three pieces of equipment is required for the full discharge preparation:

1) Battery analyser with the voltage, current, and capacity measurement tolerances specified in section 4 of IEC 61951-2
2) Low voltage disconnect device that will stop a DUT's discharge when the DUT's battery reaches a specified voltage
3) Digital timer with a precision of at least 2 min and a relay that can break the connection between the DUT's circuit and its battery (e.g., an AC digital timer combined with an AC-actuated mechanical relay)

O.4.1.2 Test prerequisites

Each DUT is fully charged according to the procedures and information in the battery test (Appendix L) and battery cycling recommended practices appendix (Appendix M).

O.4.1.3 Procedure

Products generally have one of four types of discharge curves:

1) A constant light output with a sharp turn-off when the product reaches its low-voltage disconnect

2) A cascade of constant light outputs such that the product steps down in its light setting during its discharge, often reaching a low-voltage disconnect after providing some light in its lowest setting
3) A gradually decreasing light output as the product discharges, reaching a low-voltage disconnect after hitting its L_{70}
4) A gradually decreasing light output as the product discharges with no low-voltage disconnect

If the product discharges as type (1), proceed with procedure A. If the product discharges as type (2), (3), or (4), proceed with either procedure B1, B2, or B3.

O.4.1.3.1 Procedure A

a) Set the DUT in a secure location.
b) Turn the DUT on in the setting that it will be tested in for the selected run time test.
c) Allow the DUT to discharge uninterrupted until its low-voltage disconnect automatically turns it off.
d) After the DUT finishes discharging, wait at least 60 min prior to commencing the selected run time test.

O.4.1.3.2 Procedure B1

a) Calculate the average discharge current measured from the DUT's battery during its full-battery run time test (Appendix N) until it reached its L_{70} in the setting that it will be tested in for the selected run time test.
b) Set the DUT on the battery analyser such that it discharges at the average discharge current calculated in step (a) for the duration of its full-battery run time (Appendix N) until it reached L_{70} in the setting that it will be tested in for the selected run time test.
c) After the DUT finishes, wait at least 60 min prior to commencing the selected run time test.

O.4.1.3.3 Procedure B2

a) Determine the DUT's battery voltage when it reached its L_{70} during its full-battery run time test (Appendix N) in the setting that it will be tested in for the selected run time test.
b) Set the DUT on the low-voltage disconnect device and set the disconnect voltage to the voltage value calculated in step (a).
c) Turn the DUT on in the setting that it will be tested in for the selected run time test.
d) After the DUT finishes, wait at least 60 min prior to commencing the selected run time test.

O.4.1.3.4 Procedure B3

a) Determine the DUT's battery voltage when it reached its L_{70} during its full-battery run time test (Appendix N) in the setting that it will be tested in for the selected run time test.
b) Set the DUT on the low-voltage disconnect device and set the disconnect voltage to the voltage value calculated in step (a).
c) Connect the DUT to the timer device such that the timer's relay will disconnect the DUT's circuit from its battery upon reaching the programmed discharge time.
d) Programme the timer for the duration of its full-battery run time (Appendix N) until it reached L_{70} in the setting that it will be tested in for the selected run time test.
e) Turn the DUT on in the setting that it will be tested in for the selected run time test.

f) After the DUT finishes, wait at least 60 min prior to commencing the selected run time test.

O.4.1.4 Calculations

No calculations are required with the full discharge preparation procedures.

O.5 Reporting

No reporting is required with the full discharge preparation procedures.

Appendix P
(normative)
Grid charge test

P.1 Background

The possibility of grid charging improves the usability of an LED lighting product, even if it is designed for use in remote areas. This module describes the method for measuring the grid-charge run time of the lighting product.

The DUT is grid charged via the provided power adapter for 8 h.

P.2 Test outcomes

The test outcomes of the grid charge test are listed in Table P.1.

Table P.1 – Grid charge test outcomes

Metric	Reporting units	Related aspects	Notes
Grid-charge run time	Hours (h)	4.2.6.3 Grid-charge run time	--

P.3 Related tests

The grid charge test requires the full-battery run time test (Appendix N) to be performed before the test. Also, if the charge controller behaviour test (Appendix T) is performed before the grid charge test and it is determined the DUT has overcharge protection, no overcharge protection device is required during the grid charge test.

P.4 Procedure

P.4.1 Grid charge test

The DUT sample is charged by the grid for 8 h to determine the DUT's grid-charge run times.

P.4.1.1 Equipment requirements

- AC power adapter supplied with the DUT
- Overcharge disconnect device (if necessary)
- Data-logging voltage device
- Data-logging current device (e.g. voltage data logger and current transducer)
- Circuit cutoff device with timer

P.4.1.2 Test prerequisites

a) The DUT should be discharged according to the specifications provided in the battery test (Appendix L) and the battery cycling recommended practices (Appendix M).

b) If it is unknown whether the DUT has an overcharge protection disconnect, an overcharge protection disconnect device should be used to protect the battery during the test.

c) Check that the grid voltage is suitable for the DUT's supplied AC power adapter.

P.4.1.3 Apparatus

A suitable location for the DUT to be undisturbed for 8 h while grid charging is required.

P.4.1.4 Procedure

a) Set up the circuit cutoff device to disconnect the AC power circuit after 8 hours of testing

b) Plug the AC power adapter into the circuit cutoff device.

c) Set up the current and voltage sensors to monitor the charge into the battery and set data logging for one minute intervals or shorter.

d) If an overcharge protection disconnect device is required by P.4.1.2 (b), the battery terminal voltage should be continuously monitored.

e) Enable the circuit and begin the 8 hour charging cycle.

f) After 8 h of grid charging, disconnect the equipment and check for data consistency.

P.4.1.5 Calculations

a) Find the instantaneous power for each data point by multiplying current and voltage.

b) Find the total energy input to the battery during the 8-hour charging cycle by multiplying each instantaneous power by the time step duration and summing the energy.

c) Find the grid-charge run time for each setting with the formula below:

$$t_{\mathrm{grid,s}} = \max\left(\frac{E_{\mathrm{grid}} \times \eta_{\mathrm{batt}}}{P_{\mathrm{FBR,s}}}, t_{\mathrm{FBR,s}}\right)$$

where

$t_{\mathrm{grid,s}}$ is the grid-charge run time on setting "s" in hours (h);

E_{grid} is the total energy input to the battery during the grid charge in watt-hours (Wh);

η_{batt} is the battery efficiency as a fraction;

$P_{\mathrm{FBR,s}}$ is the average power during the full-battery run time for setting "s" in watts (W);

$t_{\mathrm{FBR,s}}$ is the full-battery run time in hours (h).

P.5 Reporting

Report the following in the grid charge test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - Name of test laboratory
  - Approving person
  - Date of report approval

- Results for tested DUT aspects for samples 1 through n
  - Grid-charge run time to L_{70} (h)
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n

Appendix Q
(normative)
Electromechanical charge test

Q.1 Background

A number of lighting products provide mechanical crank-charging as an alternative to grid and/or PV module charging.

This Appendix describes a procedure for measuring the energy generated by mechanical charging under predetermined conditions.

Q.2 Test outcomes

The test outcomes of the mechanical charge test are listed in Table Q.1.

Table Q.1 – Mechanical charge test outcomes

Metric	Reporting units	Related aspects	Notes
Mechanical charger power rating	Watts (W)	4.2.6.4 Mechanical charge	--
Mechanical charging ratio	Unitless (minutes of run time per minute of charging)	4.2.6.4 Mechanical charge	--

Q.3 Related tests

Appendix Q is not related to any other appendices.

Q.4 Procedure

Q.4.1 Electromechanical charge test

The DUT sample is mechanically crank-charged for 5 min at approximately 120 rpm with measurements of the current and voltage available to charge the battery.

Q.4.1.1 Equipment requirements

- Sensors to measure battery current and voltage with data logging
- Stopwatch or clock

Q.4.1.2 Test prerequisites

The DUT battery should be discharged according to full discharge preparation procedure (Appendix O).

Q.4.1.3 Apparatus

No particular apparatus is required. For mechanical chargers that require a fixed position (e.g., bicycle crank chargers) a special apparatus may need to be built or used.

Q.4.1.4 Procedure

a) Attach the voltage and current sensors to the product to measure charge into the battery. Set the data logging interval for 2 s or less and begin logging.

b) Crank-charge the DUT for 5 min at approximately 120 rpm, resulting in approximately 600 total crank rotations.

c) Download the data and check for consistency.

Q.4.1.5 Calculations

a) Find the actual duration of the time series according to the dataset

b) Calculate the instantaneous power input to the battery for each data point in the time series by multiplying current and voltage

c) Find the average power input over the charging period.

d) Estimate the mechanical charging ratio for each product setting with the formula below:

$$R_s = \frac{\eta_{batt} \times P_{FBR,s}}{P_{mech}}$$

where

R_s is the mechanical run time to charging ratio on setting "s";
η_{batt} is the battery efficiency;
$P_{FBR,s}$ is the average power during the full-battery run time for setting "s";
P_{mech} is the average power during the mechanical charging period.

Q.5 Reporting

Report the following in the mechanical charge test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Results for tested DUT aspects for samples 1 through n
  - Mechanical charger power
  - Mechanical charge ratio for each product setting of interest
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n

Appendix R
(normative)
Outdoor photovoltaic module I-V characteristics test

R.1 Background

The purpose of the outdoor photovoltaic (PV) module I-V characteristics test is to validate the DUT manufacturer's PV module data (if available) and determine the PV module's I-V characteristic curve under standard test conditions (STC) and normal operating cell temperatures (NOCT).

Solar LED lamp units are often powered by PV modules having a power range from approximately 0,3 watts-peak (W_p) to 10 W_p.[10)] When selecting a measurement instrument, it is important to ensure that it is able to make accurate measurements of modules in the desired size range. This is particularly important for modules rated at less than 3,0 W_p since most measurement equipment is not designed for very small modules.

The PV module can be measured with a solar simulator in accordance with standard IEC 60904-1 and corrected for NOCT with standard IEC 60891. This is the preferred technique for characterizing PV modules and laboratories with access to a solar simulator should use this procedure.

The test can also be performed with an instrument that is designed to make outdoor performance measurements of small solar modules.

10) This is the nominal power a PV module shows under standard test conditions (STC). Since being at STC is extremely rare in practice, the achieved power is usually lower.

R.2 Test outcomes

The test outcomes of the outdoor PV module I-V characteristics test are listed in Table R.1.

Table R.1 – Outdoor PV module I-V characteristics test outcomes

Metric	Reporting units	Related aspects	Notes
Short-circuit current (I_{sc}) at STC	Amperes (A)	4.2.5.1 Solar I-V curve parameters	Report at STC
Open-circuit voltage (V_{oc}) at STC	Volts (V)	4.2.5.1 Solar I-V curve parameters	Report at STC
Maximum power point power (P_{mpp}) at STC	Watts-peak (W_p)	4.2.5.1 Solar I-V curve parameters	Report at STC
Maximum power point current (I_{mpp}) at STC	Amperes (A)	4.2.5.1 Solar I-V curve parameters	Report at STC
Maximum power point voltage (V_{mpp}) at STC	Volts (V)	4.2.5.1 Solar I-V curve parameters	Report at STC
Short-circuit current ($I_{sc,NOCT}$) at NOCT	Amperes (A)	4.2.5.1 Solar I-V curve parameters	Report at NOCT
Open-circuit voltage ($V_{oc,NOCT}$) at NOCT	Volts (V)	4.2.5.1 Solar I-V curve parameters	Report at NOCT
Maximum power point power ($P_{mpp,NOCT}$) at NOCT	Watts-peak (W_p)	4.2.5.1 Solar I-V curve parameters	Report at NOCT
Maximum power point current ($I_{mpp,NOCT}$) at NOCT	Amperes (A)	4.2.5.1 Solar I-V curve parameters	Report at NOCT
Maximum power point voltage ($V_{mpp,NOCT}$) at NOCT	Volts (V)	4.2.5.1 Solar I-V curve parameters	Report at NOCT
Temperature coefficient	Per degree Celsius (1/°C)	4.2.5.1 Solar I-V curve parameters	Based on temperature variation in V_{oc}.
STC I-V Curve dataset	Volts (V), Amperes (A)	4.2.5.1 Solar I-V curve parameters	Delimited dataset

R.3 Related tests

Appendix R should be completed before the solar charge test (Appendix S).

R.4 Procedure

R.4.1 Test programme using indoor (simulated measurements)

R.4.1.1 I-V curve measurements

Use standard IEC 60904.

R.4.1.2 I-V curve adjustment for NOCT

Use standard IEC 60891.

R.4.2 Outdoor PV module I-V characteristics test

The PV module is tested outdoors to obtain its characteristic I-V curve, from which the maximum power (P_{mpp}), open-circuit voltage (V_{oc}), and short-circuit current (I_{sc}) can be determined.

R.4.3 Equipment requirements

- Outdoor I-V curve analyser[11)]
- Fast-response (i.e., silicon PV-based) pyranometer with less than 5 % error
- Voltage meter or multimeter with a basic measurement uncertainty less than or equal to 0,5 % of the measuring range
- Surface-mounted thermocouple(s) and a thermocouple reader with a precision less than 2 °C

R.4.3.1 Test prerequisites

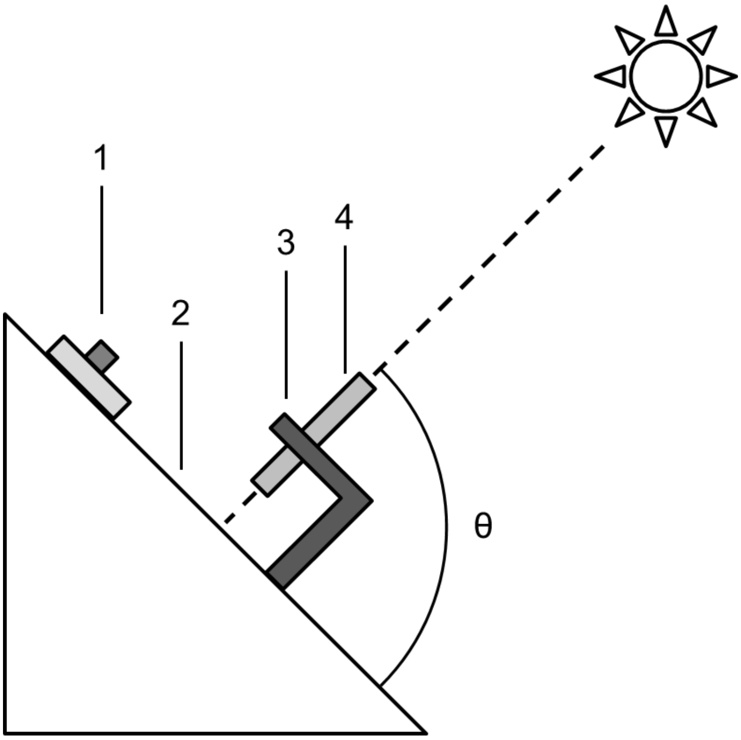
- Constant atmospheric conditions (i.e., a clear, sunny day with no clouds)
- Incident solar radiation between 850 W/m^2 and 1 150 W/m^2 and an ambient temperature between 15 °C and 35 °C
- Air mass less than or equal to 2
- If the PV module is amorphous silicon or otherwise may be subject to degradation (e.g., because it is thin film or of unknown technology), it must sun-soak for 30 days prior to performing this test

---

11) A current measuring range of up to 2 A and a voltage measuring range of up to 60 V is generally acceptable. The basic measurement uncertainty should be less than or equal to 0,5% of the measuring range. The analyser may include an integrated pyranometer, provided it is a fast-response (i.e., silicon PV-based pyranometer with less than 5% error).

R.4.3.2 Apparatus

There should be an appropriate stand to hold the PV module and pyranometer in the same plane, directly normal to the sun. The PV module should be placed as close as possible to the pyranometer to ensure that each device "sees" the same sky view. A sighting tube with bracket can be used to ensure the stand is directly normal to the sun (Figure R.1).



Key

1 Pyranometer

2 Board or other flat surface

3 Bracket

4 Sighting tube

θ 90°

Figure R.1 – PV module I-V curve testing rack

R.4.3.3 Procedure

Determine the appropriate thermocouple mounting technique based on PV panel configuration. If the PV module is separate from the lighting product or can be easily removed without damaging the active PV material and the back of the PV module is accessible, use the back-mounted thermocouple procedure (section R.4.3.3.1). Otherwise, use the front-mounted thermocouple procedure (section R.4.3.3.2).

R.4.3.3.1 Back-mounted thermocouple

a) Before the PV module is exposed to sunlight, do the following:

1) Cut the connector from the end of the PV module cable, leaving as much of the cable connected to the PV module as possible, and strip the wire ends.

2) Connect a voltage meter or multimeter (DC voltage range) to the PV module.

   3) Fix the thermocouple to the back of the PV module near the centre of the active area and affix insulating material (e.g., foil-backed foam tape) over the thermocouple.

b) Expose the PV module to direct normal sunlight and immediately measure and record the open-circuit voltage ($V_{oc,1}$) and the PV module temperature (T_1).

c) Leave the PV module in direct normal sunlight until thermal equilibrium is reached (i.e., the PV module temperature is not changing by more than 1 °C/min).

d) Connect the PV module to the I-V curve analyser per the I-V curve analyser's manufacturer's instructions.

e) Execute the I-V measurement per the I-V curve analyser's manufacturer's instructions and record the PV module temperature (T) and incident solar radiation.

f) After the I-V curve measurement, measure and record the PV module temperature again (T_2).

g) Measure the record the PV module's open-circuit voltage at T_2 ($V_{oc,2}$) using the same instrument that was used in step (a).

h) Connect the PV module to the lighting product and measure and record the typical operating voltage (V_{op}) at the lighting product's PV socket using a voltage meter or multimeter.

NOTE Some re-wiring may be necessary to obtain the typical operating voltage.

R.4.3.3.2 Front-mounted thermocouple

a) Before the PV module is exposed to sunlight, do the following:

   1) Connect a voltage meter or multimeter (DC voltage range) to the PV module.

   2) Fix the thermocouple to the front of the PV module over the active area and affix insulating material (e.g., foil-backed foam tape) over the thermocouple.

b) Expose the PV module to direct normal sunlight and immediately measure and record the PV module temperature (T_1), then quickly remove the thermocouple and insulating material from the front of the PV module, and measure and record the open-circuit voltage ($V_{oc,1}$).

c) After measuring ($V_{oc,1}$), again fix the thermocouple to the front of the PV module over the active area in the same location as before and affix insulating material (e.g., foil-backed foam tape) over the thermocouple.

d) Leave the PV module in direct normal sunlight until thermal equilibrium is reached (i.e., the PV module temperature is not changing by more than 1 °C/min).

e) Connect the PV module to the I-V curve analyser per the I-V curve analyser's manufacturer's instructions.

f) Remove the thermocouple.

g) Measure and record the PV module's open-circuit voltage at T_2 ($V_{oc,2}$) using the same instrument that was used in step (a).

h) Immediately after obtaining $V_{oc,2}$, affix the thermocouple and insulating material to the front of the PV module (i.e., the same place as in step (a)) and measure and record the temperature of the PV module (T_2 & T).

i) Immediately execute the I-V measurement per the I-V curve analyser's manufacturer's instructions.

j) Connect the PV module to the lighting product and measure and record the typical operating voltage (V_{op}) at the lighting product's socket using a voltage meter or multimeter.

NOTE Some re-wiring may be necessary to obtain the typical operating voltage.

R.4.3.4 Calculations

a) Convert all of the current measurements to STC using the following formula:

$$I = I_m \times \frac{1\,000\ \mathrm{W/m^2}}{G}$$

where

I	is the PV module's current at STC, in amperes (A);
I_m	is the PV module's measured current, in amperes (A);
G	is the measured incident solar radiation during the I-V curve measurement, in watts per square meter (W/m²).

b) Determine the temperature coefficient for the voltage ($T_{c,voc}$) using the following formula:

$$T_{c,voc} = \frac{\left(V_{oc,1} - V_{oc,2}\right)/V_{oc,2}}{T_1 - T_2}$$

where

$T_{c,voc}$	is the PV module's temperature coefficient for the voltage, per degree Celsius (1/°C);
$V_{oc,1}$	is the PV module's open-circuit voltage immediately after exposure to sunlight, in volts (V);
$V_{oc,2}$	is the PV module's open-circuit voltage after the I-V measurement is taken, in volts (V);
T_1	is the PV module's temperature immediately before exposure to sunlight, in degrees Celsius (°C);
T_2	is the PV module's temperature after the I-V curve measurement is taken, in degrees Celsius (°C).

c) Convert all of the voltage measurements to STC using the following formula:

$$V = V_m \times \left[1 + T_{c,voc} \times \left(T_{stc} - T\right)\right]$$

where

V	is the PV module's voltage at STC, in volts (V);
V_m	is the PV module's measured voltage, in volts (V);
$T_{c,voc}$	is the PV module's temperature coefficient for the voltage, per degree Celsius (1/°C);
T_{stc}	is the temperature at STC, 25 °C;
T	is the PV module's temperature during the I-V curve measurement, in degrees Celsius (°C).

d) The PV module's short-circuit current at STC (I_{sc}) is the current corresponding to 0 V on the STC-adjusted I-V curve.

e) The PV module's open-circuit voltage at STC (V_{oc}) is the voltage corresponding to 0 A on the STC-adjusted I-V curve.

f) Determine the PV module's measured maximum power point power at STC (P_{mpp}) using the following formula:

$$P_{\text{mpp}} = \max\left(I \times V\right)$$

where

P_{mpp}	is the PV module's measured maximum power point power at STC, in watts-peak (W_p);
I	is the PV module's current at STC, in amperes (A);
V	is the PV module's voltage at STC, in volts (V).

g) The PV module's maximum power point current at STC (I_{mpp}) is the current corresponding to P_{mpp} on the STC-adjusted I-V curve.

h) The PV module's maximum power point voltage at STC (V_{mpp}) is the voltage corresponding to P_{mpp} on the STC-adjusted I-V curve.

i) Repeat steps (c) through (h) for NOCT in place of STC, where NOCT is defined as 50 °C.

R.5 Reporting

Report the following in the outdoor PV module I-V characteristics test report (a sample template is provided in Appendix Y):

- Metadata
    - Report name
    - Procedure(s) used
    - Lighting product manufacturer
    - Lighting product name
    - Lighting product model number
    - Name of test laboratory
    - Description of location of test
    - Approving person
    - Date of report approval
- Results for tested PV module aspects for samples 1 through n
    - Short-circuit current at STC (A)
    - Open-circuit voltage at STC (V)
    - Maximum power point power at STC (W_p)

    - Maximum power point current at STC (A)
    - Maximum power point voltage at STC (V)
    - Short-circuit current at NOCT (A)
    - Open-circuit voltage at NOCT (V)
    - Maximum power point power at NOCT (W_p)
    - Maximum power point current at NOCT (A)
    - Maximum power point voltage at NOCT (V)
    - Temperature coefficient for voltage (1/°C)
- Average of n sample results for each PV module aspect tested
- Coefficient of variation of n sample results for each PV module aspect tested (%)
- PV module's rating for aspects tested, if available
- Deviation of the average result from the PV module's rating for each aspect tested, if available (%)
- Comments
    - Individual comments, as necessary, for samples 1 through n
    - Overall comments, as necessary, for collective set of samples 1 through n
- Figures
    - Single plot showing the I-V and power-voltage curves for every PV module sample
- Datasets
    - Comma-delimited or tabular dataset listing current (A) and voltage (V) adjusted to STC across the full measured I-V curve

Appendix S
(normative)
Solar charge test

S.1 Background

The solar charge test provides estimates for two key sources of energy loss during solar charging: suboptimal operation of the solar module ("solar operation efficiency") and losses from the DUT's internal electronic circuits that charge the battery ("generator-to-battery efficiency"). Along with the battery charge efficiency (Appendix L), these values are used in the solar run time calculation.

A power supply along with two resistors is used to simulate a solar module and charge a DUT's battery. The voltage operating point during the test combined with the solar I-V curve is used to calculate the solar operating efficiency. Measurements of energy input to the DUT solar charging port and DUT battery are used to estimate the generator-to-battery efficiency.

If the DUT is a kit that has multiple batteries that can be charged simultaneously by a single solar module, the test should be done with all the batteries connected at once. This will require additional measurements of battery current and voltage for each battery.

S.2 Test outcomes

The test outcomes of the solar charge test are listed in Table S.1.

Table S.1 – Solar charge test outcome

Metric	Reporting units	Related aspects	Note
Solar operation efficiency ($\eta_{sol\text{-}op}$)	Percentage	4.2.5 Solar module aspects	This is representative of the efficiency with respect to optimal operation of the PV module (where optimal operation is at the maximum power point).
Generator-to-battery charging efficiency ($\eta_{g\text{-}b}$)	Percentage	4.2.8.1 Input to battery circuit efficiency	This is a lump figure for the whole lighting kit and is not disaggregated by lighting unit.
Solar run time (standard solar day)	Hours (h)	4.2.6.2 Solar-day run time	Multiple outcomes will be found—one for each setting on each independent lighting unit.
Solar charging system characteristics	n/a		This describes key features of the solar charging circuit

S.3 Related tests

The solar charge test is related to the battery test (Appendix L), the outdoor photovoltaic module I-V characteristics test (Appendix R), and the full-battery run time test (Appendix N).

S.4 Procedure

S.4.1 Solar charge efficiency test

The current and voltage from an electronics setup that simulates a solar module and into the DUT battery are recorded at one minute intervals after the test setup is left to stabilize for 5 min.

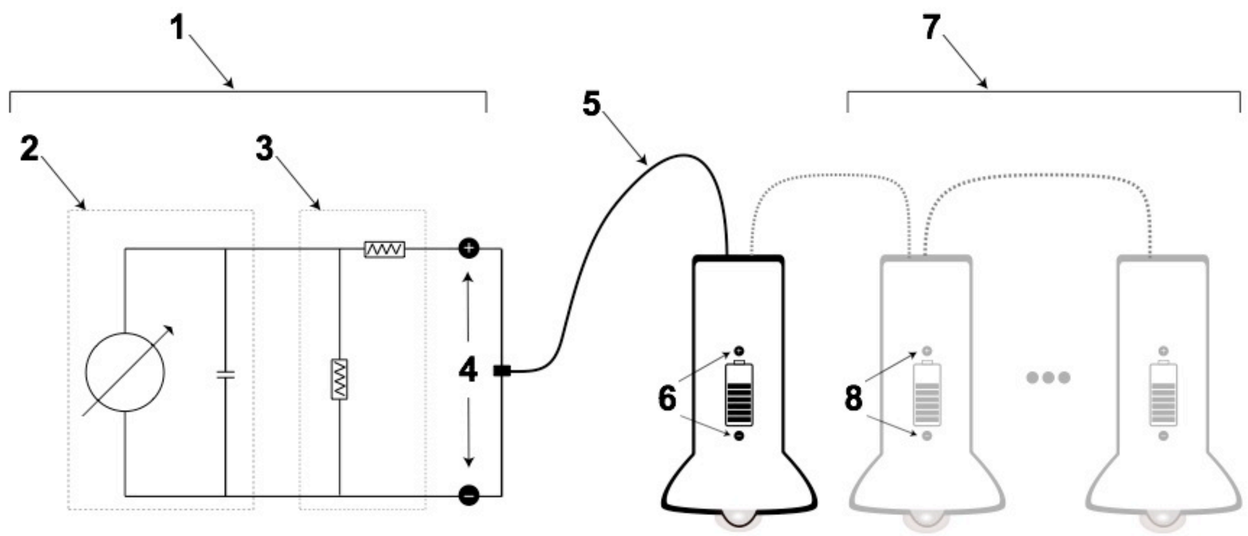
S.4.1.1 Equipment requirements

- Programmable power supply with constant-voltage and constant-current modes and ability to automatically step through a timed programme
- Data-logging voltage devices
- Data-logging current devices (e.g. voltage data logger and current transducer)

S.4.1.2 Test prerequisites

The DUT's battery should be at a state of charge that corresponds to the "end of discharge" which can be accomplished using procedures in Appendix O. Additionally, this test should be performed after completion of the outdoor PV module I-V characteristics measurements (Appendix R), since the I-V curve information from the PV module during that test are needed to set up the inputs to the power supply for the electronics efficiency test. The results from the Battery tests (Appendix L) and full-battery run time tests (Appendix N) are required for the calculations.

S.4.1.3 Apparatus



Key

1 PV simulation circuit

2 Laboratory power supply

3 Series and parallel resistors (or variable resistors)

4 PV simulation circuit output (measure current and voltage here during simulated charging)

5 Connection cable from PV simulation circuit to lighting unit

6 Lighting product battery (measure current and voltage here during simulated charging)

7 [optional] Additional lighting units with separate batteries that are included in the kit

8 [optional] Additional lighting unit battery(-ies) (measure current and voltage here during simulated charging)

Figure S.1 – Schematic of the power supply and DUT connection for the solar charge efficiency test

S.4.1.4 Procedure

Preparation for the test:

a) Use the NOCT I-V curve (from Appendix R) to find appropriate resistor values and power supply set points to simulate the PV module operating at NOCT during the charging cycle. Using a computer spreadsheet is required for this step.

- Use the spreadsheet to estimate the response curve of the PV simulator circuit over the range of voltages that corresponds to the I-V curve.
- The input variables to the spreadsheet should be the following:
  - Series resistance
  - Parallel resistance
  - Voltage setpoint
  - Current setpoints corresponding to each level of simulated solar radiation listed in Table S.2
- The circuit simulation should be based on Ohm's law.
- The spreadsheet should estimate the NOCT current at evenly spaced voltage points by linearly interpolating between points on the measured I-V curve.
- Create a scaled I-V curve for each level of simulated solar radiation listed in table S.2 by multiplying the interpolated current values by the ratio of the desired solar radiation level to 1 000 W/m^2:

$$I_{\mathrm{pv},i,j} = I_{\mathrm{interp},j} \times \frac{G_i}{1\ 000\ \mathrm{W/m^2}}$$

where

$I_{\mathrm{pv},i,j}$	is the scaled, interpolated current at each solar radiation level i and voltage point j, in amperes (A);
$I_{\mathrm{interp},j}$	is the interpolated current at NOCT and 1 000 W/m^2 at each voltage point j, in amperes (A);
G_i	is the simulated solar radiation, in watts per square meter (W/m^2);

- Use a non-linear minimization technique to minimize the weighted sum of the squared residuals between the scaled, interpolated NOCT I-V curve values and the simulated I-V curve of the PV simulator by altering the input variables. To give preference for close agreement near the maximum power point, the SSR at each point should be weighted by the product of the duration of each solar radiation step (from Table S.2) and the power in the scaled NOCT curve:

$$\text{weighted SSR} = \sum_i \left(t_i \times \sum_j I_{\mathrm{pv},i}\left(V_j\right) \times V \times \left(I_{\mathrm{fit},i}\left(V_j\right) - I_{\mathrm{pv},i}\left(V_j\right)\right)^2 \right)$$

where

t_i	is the duration of time at each solar radiation level i, in hours (h);
V_j	is the voltage at each current and voltage point j, in volts (V);
$I_{\mathrm{pv},i}(V_j)$	is the scaled, interpolated current at each solar radiation level i and voltage point j, in amperes (A);

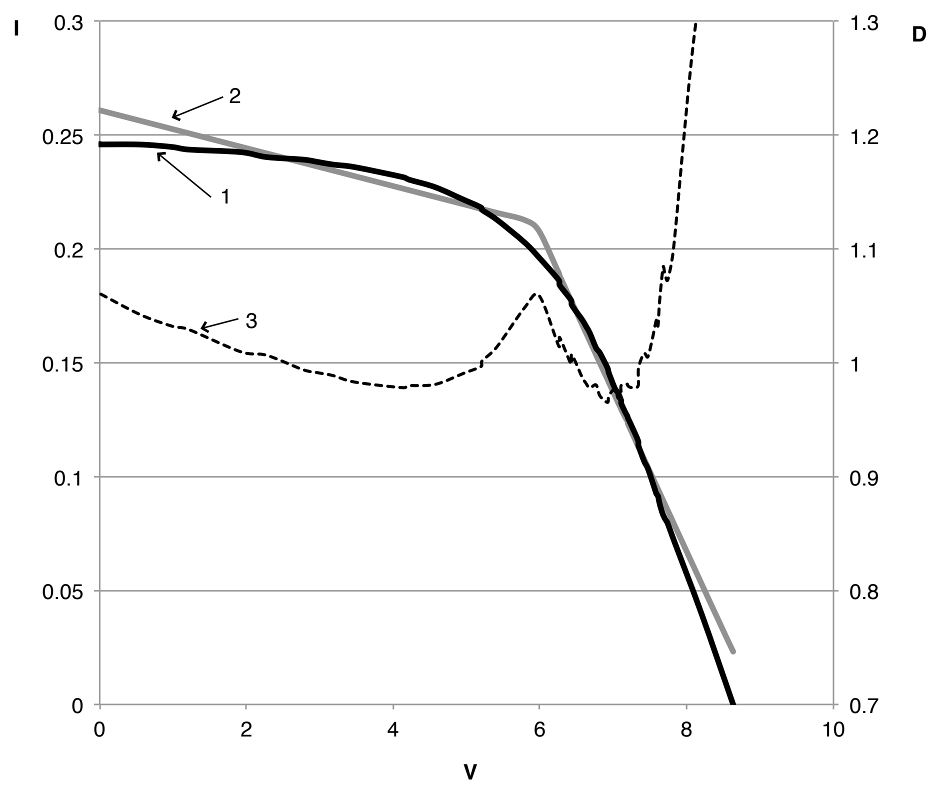
$I_{\text{fit},i}(V_j)$ is the fitted simulated current at solar radiation level i and voltage j, in amperes (A);

- The outcomes of the spreadsheet are the best fit input variables:
  - Series resistance (R_s)
  - Parallel resistance (R_p)
  - Voltage setpoint (V_{sim})
  - Current setpoints ($I_{sim,1000}$, $I_{sim,900}$, $I_{sim,700}$, $I_{sim,500}$, $I_{sim,300}$)

b) Build a PV simulator circuit like the one pictured in Figure S.1 using fixed or variable resistors with an appropriate power rating wired in parallel and series with the power supply.

c) Measure the actual values of the parallel and series resistance in the PV simulator circuit and input them in the spreadsheet from step (a). Re-solve the minimization problem with those resistances held constant to find new ideal values for the other input variables.

d) Check that the simulated I-V curve is a reasonable approximation of the true curve by calculating the deviation ratio between the simulated and scaled, interpolated NOCT I-V curves. The deviation ratio is defined as the simulated current divided by the scaled, interpolated NOCT current at each voltage point. For this calculation, use the true values of the input variables rounded to the precision of the test equipment. In the example below, the deviation ratio is close to unity (between 0,95 and 1,05, or less than 5 % error) in the key parts of the I-V curve (at and to the left of the maximum power point).



Key

I is current with units of amperes on the primary vertical axis

V is voltage with units of volts on the horizontal axis

D is the deviation ratio (unitless) on the secondary vertical axis

1 is the measured "true" I-V curve, plotted against the primary axis

2 is the I-V curve from the PV simulator, plotted against the primary axis

3 is the deviation ratio as a function of voltage, plotted on the secondary axis

Optionally, experimentally verify the calculated deviation for the 1 000 W/m² I-V curve:

e) Connect datalogging current and voltage sensors to the PV simulator output. Set the sensors to log data at very short intervals, 1 s or less.

f) Simulate a PV module at NOCT and 1 000 W/m². Set the power supply current and voltage setpoints to $I_{sim,1000}$ and V_{sim}.

g) Measure an I-V curve for the PV simulator. Connect a variable resistor between the positive and negative terminals of the PV simulator and slowly sweep from high to low resistance and back.

h) Disconnect the resistor and stop the data collection.

Check to ensure the quality of the I-V curve data; cross check with the original (target) I-V curve to ensure the PV simulator is reasonably close, particularly in the region with voltages slightly below the maximum power point. The figure below shows an example comparison. The true I-V curve (line 1) is compared to the simulated I-V curve (line 2). The deviation ratio between the two curves is defined as the simulated current divided by the true current at each voltage point.

Charging the DUT using the PV simulator:

i) Set up the prepared DUT (see notes in section S.4.1.2) and PV simulator circuit with current and voltage sensors. Set the data logging at 1 minute or more frequent intervals.

- Current entering the DUT's battery(s), in amperes (A).
- Voltage across the DUT's battery(s), in volts (V).
- Current provided by the PV simulator circuit, in amperes (A).
- Voltage across the PV simulator circuit output, in volts (V).

j) Programme the power supply to simulate a "standard solar day" of charging using the steps indicated below (Table S.2). It is acceptable to insert short pauses at 0 volts between steps to facilitate identification of solar radiation levels during data analysis.

Table S.2 – Simulated solar day power supply settings

Step duration	Simulated solar radiation	Current setpoint	Voltage setpoint
0,5 h	300 W/m^2	$I_{sim,300}$	V_{sim}
0,5 h	500 W/m^2	$I_{sim,500}$	V_{sim}
1 h	700 W/m^2	$I_{sim,700}$	V_{sim}
1 h	900 W/m^2	$I_{sim,900}$	V_{sim}
1 h	1000 W/m^2	$I_{sim,1000}$	V_{sim}
1 h	900 W/m^2	$I_{sim,900}$	V_{sim}
1 h	700 W/m^2	$I_{sim,700}$	V_{sim}
0,5 h	500 W/m^2	$I_{sim,500}$	V_{sim}
0,5 h	300 W/m^2	$I_{sim,300}$	V_{sim}

k) Check the connections and setpoints, then begin data logging and start the simulated charging cycle. After the 7 h charging cycle is complete, stop the power supply, stop the data logging, disconnect the product from the PV simulator, and ensure the current and voltage data are valid with a quick check.

S.4.1.5 Calculations

a) Determine the energy supplied by the PV simulator circuit ($E_{pvsim,o}$) using the following formula:

$$E_{\text{pvsim,o}} = \sum_{j} \left(I_{\text{pvsim},j} \times V_{\text{pvsim},j} \times t_j \right)$$

where

$E_{pvsim,o}$ is the energy supplied by the power supply, in watt-hours (Wh);
$I_{pvsim,j}$ is the current supplied by the power supply, in amperes (A);
$V_{pvsim,j}$ is the voltage supplied by the power supply, in volts (V);
t_j is the duration of time associated with each current and voltage point i, in hours (h).

b) Determine the energy entering each battery ($E_{b,i}$) using the following formula:

$$E_{b,i} = \sum_j \left(I_{b,i,j} \times V_{b,i,j} \times t_j \right)$$

where

$E_{b,i}$	is the energy entering battery i, in watt-hours (Wh);
$I_{b,i,j}$	is the current entering battery i at time j, in amperes (A);
$V_{b,i,j}$	is the voltage entering battery i at time j, in volts (V);
t_j	is the duration of time associated with each current and voltage point j, in hours (h).

c) Determine the energy allocation ratio for each battery using the following formula:

$$\alpha_i = \frac{E_{b,i}}{\sum_i E_{b,i}}$$

where

α_i	is the energy allocation ratio for battery i, a unitless ratio;
$E_{b,i}$	is the energy entering battery i, in watt-hours (Wh);

d) Determine the generator-to-battery charging circuit efficiency ($\eta_{g\text{-}b}$) using the following formula:

$$\eta_{g\text{-}b} = \frac{\sum E_{b,i}}{E_{pvsim}}$$

where

$\eta_{g\text{-}b}$	is the generator-to-battery charging circuit efficiency;
$E_{b,i}$	is the energy entering the battery, in watt-hours (Wh);
E_{pvsim}	is the energy supplied by the power supply, in watt-hours (Wh).

e) Determine the deviation ratio as a function of voltage for each simulated I-V curve. For this calculation, use the spreadsheet from step (a) with the actual values of the input variables that were used during the test.

$$D_i\left(V_j\right) = \frac{I_{\mathrm{fit},i}\left(V_j\right)}{I_{\mathrm{pv},i}\left(V_j\right)}$$

where

$D_i(V_j)$	is the deviation ratio at each simulated solar radiation level i and voltage point j (unitless);
$I_{\mathrm{fit},i}(V_j)$	is the simulated current for simulated solar radiation level i and voltage point j, in amperes (A);
$I_{\mathrm{pv},i}(V_j)$	is the true current at each point from the scaled, interpolated I-V curve for simulated solar radiation level i and voltage point j, in amperes (A).

f) Modify the current data by the deviation ratio to correct for deviation from optimal operation caused by the simulated PV circuit's lack of fit with the true I-V curve. Use interpolation to estimate the deviation ratio at each voltage operating point i using linear interpolation between adjacent deviation ratios from the series that was calculated in the previous step. The modified current values calculated below can be described as the "current that would have been produced if a PV module were operated at the same point relative to the true I-V curve as was observed relative to the simulated I-V curve."

$$I_{\mathrm{pvsim,mod},j} = \frac{I_{\mathrm{pvsim},j}}{D_i\left(V_j\right)}$$

where

$I_{\mathrm{pvsim,mod},j}$	is the modified current at each point in the simulated solar charging day, in amperes (A);
$I_{\mathrm{pvsim},j}$	is the measured current at each point in the simulated solar charging day, in amperes (A);
$D_i(V_j)$	is the deviation ratio at each point in the solar charging day, which depends on the operating voltage and the simulated solar radiation level (unitless).

g) Estimate the modified energy for the simulated solar charging day

$$E_{\text{pvsim,mod}} = \sum_{j} \left(I_{\text{pvsim,mod},j} \times V_{\text{pvsim},j} \times t_j \right)$$

where

$E_{\text{pvsim,mod}}$	is the modified energy supplied by the PV simulator, in watt-hours (Wh);
$I_{\text{pvsim,mod,i}}$	is the modified current supplied by the PV simulator, in amperes (A);
$V_{\text{pvsim,i}}$	is the voltage supplied by the PV simulator, in volts (V);
t_i	is the duration of time associated with each current and voltage point i, in hours (h).

h) Estimate the solar operation efficiency ($\eta_{\text{sol-op}}$).

$$\eta_{\text{sol-op}} = \frac{E_{\text{pvsim,mod}}}{G \times P_{\text{pv,NOCT}}}$$

where

$\eta_{\text{sol-op}}$	is the solar operation efficiency (unitless);
$E_{\text{pvsim,mod}}$	is the modified energy supplied by the PV simulator, in watt-hours (Wh);
G	is the solar resource (typically 5) in kilowatt-hours per square meter (kWh/m^2) or equivalent full-sun hours (h);
$P_{\text{pv,NOCT}}$	is the maximum power point of the PV module at NOCT and 1000 W/m^2 in watts (W).

i) Estimate the solar run time on each setting for each battery with the equation below:

$$t_{\text{SRT,s},i} = \min\left(\frac{G_{\text{solar}} \times P_{\text{mpp,NOCT}} \times \eta_{\text{sol-op}} \times \alpha_i \times \eta_{\text{g-b}} \times \eta_{\text{batt}}}{P_{\text{FBR,s},i}}, t_{\text{FBR,s},i} \right)$$

where

$t_{\text{SRT,s},i}$	is the solar run time on setting "s" for battery *i* in hours (h);
G_{solar}	is the total solar resource in kWh/m^2 (or "full sun hours") – typically use the standard solar day, 5 kWh/m^2;
$P_{\text{mpp,NOCT}}$	is the maximum power point of the PV module at NOCT in watts (W);
$\eta_{\text{sol-op}}$	is the solar operating efficiency as a fraction;
$\eta_{\text{g-b}}$	is the generator-to-battery circuit efficiency as a fraction;
η_{batt}	is the battery efficiency as a fraction;
$P_{\text{FBR,s},i}$	is the average power during the full-battery run time test on setting "s" for battery *i* in watts (W);
$t_{\text{FBR,s},i}$	is the full-battery run time on setting "s" for battery *i* in hours (h).

j) (optional step) Repeat previous step with an alternative solar resource

k) Based on the test data, identify if the following characteristics are present in the circuit between the solar module and the battery:

- DC-DC converter (check to see if the current is different)
- Constant current with voltage drop (use the relationship between current and voltage drop to approximate the resistance of the circuit)

S.5 Reporting

Report the following in the electronics efficiency test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Results for tested DUT aspects for samples 1 through n
  - Generator-to-battery charging efficiency (%)
  - Solar operation efficiency (%)
  - Solar run time from a standard solar day on each setting
  - Solar run time from an alternative solar day on each setting (optional)
- Average of n sample results for tested DUT aspects
- Coefficient of variation of n sample results for tested DUT aspects
- Solar charging circuit characteristics
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n
- Figures
  - Plot showing the solar charging cycle for each sample in time series over the 10-hour charging period including the maximum power available, modified power, and power to the battery. In a separate plot or on a secondary axis show the solar operation efficiency and generator-to-battery efficiency in time series.

Appendix T
(normative)
Charge controller behaviour test

T.1 Background

Deep discharge and overcharge protection is important for user safety and battery longevity. Charge controlling is most important for products with lead-acid, Li-ion, and LiFePO4 batteries.

The charge controller behaviour test contains five methods to examine a DUT's charge controller. Every DUT must be tested with the active deep discharge method, where the DUT is discharged until reaching its low voltage disconnect (LVD) voltage or appropriately exceeding its recommended deep discharge voltage threshold. Every DUT must also be tested with the active overcharge protection method, where the DUT is charged until reaching its over voltage protection (OVP) voltage or appropriately exceeding its recommended OVP voltage threshold. For DUTs with NiMH batteries that have no active deep discharge protection, the passive deep discharge protection method must be used, where the DUT's long-term discharging battery voltage is examined for safety. For DUTs with NiMH batteries that have no active overcharge protection, the passive overcharge protection method must be used, where the DUT's long-term charging current is examined for safety.

Every DUT must also be examined for self-consumption. It is possible that a DUT's electronics may draw substantial amounts of energy from the DUT's batteries while the DUT is not in use. This self-consumption may lead to shorter run times or problems when storing the DUT for long periods of time.

T.2 Test outcomes

The test outcomes of the charge controller behaviour test are listed in Table T.1.

Table T.1 – Charge controller behaviour test outcomes

Metric	Reporting Units	Related aspects	Notes
Active deep discharge protection	Yes/no	4.2.2.10 Battery protection strategy	--
Deep discharge protection voltage	Volts (V)	4.2.2.10 Battery protection strategy	Measured only if the DUT has active deep discharge protection
Active overcharge protection	Yes/no	4.2.2.10 Battery protection strategy	--
Overcharge protection voltage	Volts (V)	4.2.2.10 Battery protection strategy	Measured only if the DUT has active overcharge protection
Passive deep discharge protection	Yes/no	4.2.2.10 Battery protection strategy	Measured only for NiMH batteries with no active deep discharge protection
Passive deep discharge protection battery voltage at 24 h	Volts per cell (V/cell)	4.2.2.10 Battery protection strategy	Required only if tested for passive deep discharge protection
Passive overcharge protection	Yes/no	4.2.2.10 Battery protection strategy	Measured only for NiMH batteries with no active overcharge protection
Passive overcharge protection continuous charging current	Milliamperes (mA)	4.2.2.10 Battery protection strategy	Required only if tested for passive overcharge protection
30-day battery self-consumption fraction	Percentage (%)	4.2.2.10 Battery protection strategy	Fraction of the battery's measured capacity that is self-discharged over 30 days

T.3 Related tests

The results of the active deep discharge protection test (section T.4.1) may be substituted for results of the full-battery run time test combined with low voltage disconnect measurement (section N.4.2).

Appendix T must be performed after the outdoor PV module I-V characteristics test (Appendix R) because the active overcharge protection test (section T.4.2) requires the DUT's maximum power point current (I_{mpp}) and the passive overcharge protection test (section T.4.4) requires the DUT's entire I-V curve data set.

T.4 Procedure

T.4.1 Active deep discharge protection test

The DUT is discharged until its battery voltage reaches the DUT's LVD voltage or drops sufficiently below the specified deep discharge protection voltage threshold for the DUT's battery chemistry.[12)]

T.4.1.1 Equipment requirements

- DC power supply
- Volt meter and/or multimeter
- Data-logging voltage measurement device (optional)
- Data-logging light meter or data-logging current measurement device (e.g., voltage data logger with a current transducer) (optional)

[12)] Recommended deep discharge protection voltage thresholds according to battery chemistry are: 1,87 V/cell ± 0,05 V/cell for lead-acid, 1,00 V/cell ± 0,05 V/cell for NiMH and NiCd, 3,00 V/cell ± 0,05 V/cell for Li-ion, and 2,00 V/cell ± 0,05 V/cell for $LiFePO_4$.

T.4.1.2 Test prerequisites

The DUT must be either fully charged at the start of the test or charged enough to provide at least 30 min of light before reaching its deep discharge protection voltage or sufficiently below the specified deep discharge protection voltage threshold for the DUT's battery chemistry.

T.4.1.3 Apparatus

The DUT must be set in a secure location such that its parameters can be monitored and/or data-logged.

T.4.1.4 Procedure

a) Turn on the DUT to begin discharging the battery. Continuously monitor the battery terminal voltage and visual light output.[13)]

b) If the DUT automatically turns off, the voltage immediately before it turns off is the DUT's deep discharge protection voltage.

c) If the battery terminal voltage drops sufficiently below the specified deep discharge protection voltage threshold without the DUT turning off, no active deep discharge protection is incorporated into the DUT's charge controller.[14)]

T.4.1.5 Calculations

There are no calculations for the active deep discharge protection test.

T.4.2 Active overcharge protection test

The DUT is charged until its battery voltage reaches the DUT's OVP voltage or sufficiently exceeds the specified overcharge protection voltage threshold for the DUT's battery chemistry. [15)]

T.4.2.1 Equipment requirements

- DC power supply
- Volt meter and/or multimeter
- Ammeter and/or multimeter
- Data-logging voltage measurement device (optional)
- Data-logging light meter or data-logging current measurement device (e.g., voltage data logger with a current transducer) (optional)

T.4.2.2 Test prerequisites

The DUT must be either fully discharged at the start of the test or discharged enough to accept at least 30 min of charging before reaching its overcharge protection voltage or sufficiently exceeds the specified overcharge protection voltage threshold.

---

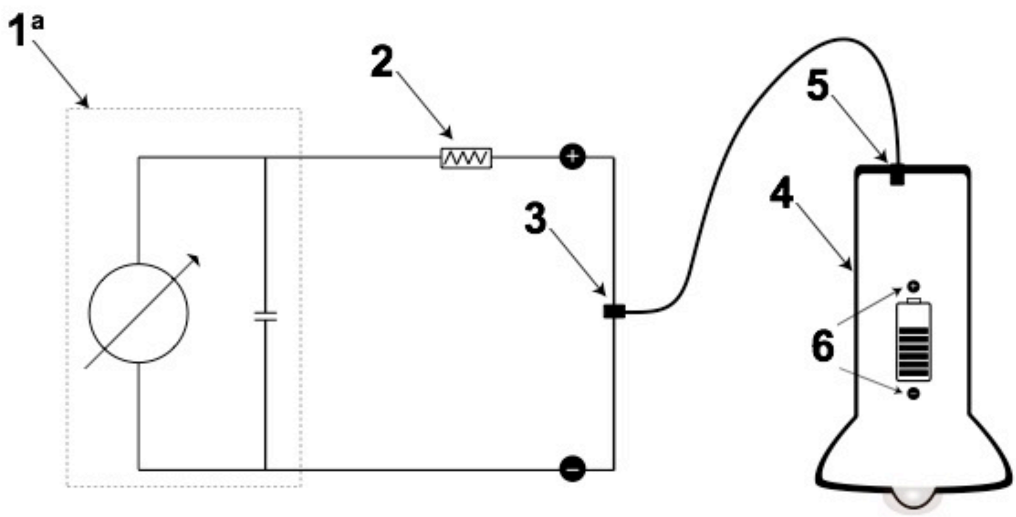
13) If using data-logging devices, the light does not need to be continuously visually monitored. The battery voltage and either the battery current or light output must be collected at intervals less than or equal to 1 min.

14) In some cases, the DUT's charge controller will have a LVD voltage that is less than the specified deep discharge protection voltage threshold; therefore, the person conducting the test has the discretion to allow the battery voltage to proceed slightly below the specified deep discharge protection voltage threshold if deemed safe and necessary.

15) Recommended overcharge protection voltage thresholds according to battery chemistry are: 2,42 V/cell ± 0,05 V/cell for lead-acid, 1,40 V/cell ± 0,05 V/cell for NiMH and NiCd, 4,10 V/cell ± 0,05 V/cell for Li-ion, and 3,60 V/cell ± 0,05 V/cell for $LiFePO_4$.

T.4.2.3 Apparatus

The DUT must be set in a secure location such that its parameters can be monitored and/or data-logged. The DUT is charged via the PV module socket from a DC power supply with a series resistor in place (Figure T.1).



Key

1 DC power supply

2 Series protection resistor

3 Plug

4 DUT

5 DUT's PV module input socket

6 Battery

a Set current limiting with the maximum power point current at STC, I_{mpp}, from the outdoor PV module I-V characteristics test (Appendix R)

Figure T.1 – Schematic of the DC power supply-DUT connection using a series protection resistor

T.4.2.4 Procedure

a) Adjust the current limiting value of the DC power supply to the PV module's maximum power point current at STC, I_{mpp} (refer to the results of the outdoor PV module I-V characteristics test (Appendix R)).

b) Due to voltage drops from the PV module's blocking diode, cable losses, and the series resistor, set the power supply output voltage, V_{ps}, using the following formula:

$$V_{ps} = 1{,}25 \times V_{b,max}$$

where

V_{ps} is the DC power supply output voltage, in volts (V);

$V_{b,max}$ is the DUT's battery's maximum charge voltage, in volts (V), which can be obtained from the battery cycling recommended practices appendix (Appendix M).

c) Connect the PV module socket of the DUT to the DC power supply in series with a protection resistor.[16] The voltage drop in the series resistor should be between 10 % and 15 % of the voltage setting of the DC power supply (V_{ps}); therefore, size the resistor based on the following formula:

$$\frac{0{,}1 \times V_{\mathrm{ps}}}{I_{\mathrm{mpp}}} \leq R_{\mathrm{s}} \leq \frac{0{,}15 \times V_{\mathrm{ps}}}{I_{\mathrm{mpp}}}$$

where

V_{ps}	is the DC power supply output voltage, in volts (V);
I_{mpp}	is the PV module's maximum power point current at STC, in amperes (A), obtained from the outdoor PV module I-V characteristics test (Appendix R);
R_s	is the resistance of the series resistor, in ohms (□).

d) Ensure the series resistor's power dissipation rating is greater than or equal to the value given by the following formula:

$$P_{\mathrm{rs}} = I_{\mathrm{mpp}}^{2} \times R_{\mathrm{s}}$$

where

P_{rs}	is the series resistor's minimum required power dissipation, in watts (W);
I_{mpp}	is the PV module's maximum power point current at STC, in amperes (A), obtained from the outdoor PV module I-V characteristics test (Appendix R);
R_s	is the resistance of the series resistor, in ohms (□).

e) Charge the DUT at V_{ps} and I_{mpp} while continuously monitoring the battery voltage and current.[17]

f) If the DUT automatically stops accepting charge, the voltage immediately before it turns off is the DUT's overcharge protection voltage.

NOTE For some DUT's, the current will not stop completely, but will begin tapering off when the DUT's battery voltage reaches its overcharge protection voltage.

g) If the battery terminal voltage sufficiently exceeds the specified OVP voltage threshold while the DUT continues charging, no active overcharge protection is incorporated into the DUT's charge controller.[18]

T.4.2.5 Calculations

There are no calculations for the active overcharge protection test.

T.4.3 Passive deep discharge protection test

The DUT is left to discharge for 24 h and the voltage after 24 h is recorded. This method is only performed on DUTs with NiMH batteries that show no active deep discharge protection.

---

[16] This protection resistor is only needed in cases where a "shunt regulator" is built in; however, as a schematic of the DUT's electronics is usually not provided, this resistor should be used in all cases for safety reasons.

[17] If using a data-logging device, the battery voltage and current input must be collected at intervals less than or equal to 1 min.

[18] In some cases, the DUT's charge controller will have an OVP voltage that is greater than the specified OVP voltage threshold; therefore, the person conducting the test has the discretion to allow the battery voltage to proceed slightly above the specified OVP voltage threshold if deemed safe and necessary. **Never let the battery voltage exceed 4,25 V/cell for Li-ion batteries, otherwise there is a risk of explosion.**

T.4.3.1 Equipment requirements

- DC power supply
- Volt meter and/or multimeter

T.4.3.2 Test prerequisites

The DUT must have undergone the active deep discharge protection test, such that its battery voltage has just passed 0,95 V/cell when discharging.

T.4.3.3 Apparatus

The DUT must be placed in a secure location where it can discharge for 24 h.

T.4.3.4 Procedure

a) Specify the accepted 24 h passive deep discharge battery protection voltage.[19)]

b) Turn on the DUT and let it discharge for 24 h.

c) The battery voltage after 24 h is the DUT's passive deep discharge battery protection voltage.

T.4.3.5 Calculations

There are no calculations for the passive deep discharge protection test.

T.4.4 Passive overcharge protection test

The DUT's PV module's short circuit current alone may prove the DUT has passive overcharge protection, otherwise the DUT is overcharged and the charging current is observed to determine if the DUT has passive overcharge protection. This method is only performed on DUTs with NiMH batteries that show no active overcharge protection.

T.4.4.1 Equipment requirements

- DC power supply
- Current meter and/or multimeter
- Data-logging voltage measurement device (optional)
- Data-logging current measurement device (e.g., voltage data logger with a current transducer) (optional)

T.4.4.2 Test prerequisites

The DUT must have undergone the active deep discharge protection test, such that its battery voltage has just passed 1,45 V/cell when charging.

T.4.4.3 Apparatus

The DUT must be set in a secure location such that its parameters can be monitored and/or data-logged. The DUT is charged via the PV module socket from a DC power supply.

T.4.4.4 Procedure

a) Determine the accepted passive overcharge protection continuous battery charging current.[20)]

---

19) A 24 h passive deep discharge battery protection voltage of greater than or equal to 0,08 V/cell is recommended for NiMH batteries.

20) A passive overcharge protection continuous battery charging current of less than or equal to twice 0,1 I_t A is recommended for NiMH batteries.

b) Compare the PV module's short-circuit current at STC (I_{sc}) to the passive overcharge protection continuous battery charging current (I_{sc} can be obtained from the outdoor PV module I-V characteristics test (Appendix R)). If I_{sc} is the smaller of the two, the DUT has passive overcharge protection and no further testing is necessary.

c) Convert the PV module's I-V pairs from the outdoor PV module I-V characteristics test (Appendix R) to a panel temperature that could be achieved under real operating conditions (e.g., temperatures greater than 50 °C are realistic in some locations). Refer to section R.4.3.4 of Appendix R for conversion equations.

d) Plot the new I-V curve using the I-V pairs corresponding to a realistic operating temperature.

e) Set the current limiting and voltage values of the DC power supply to the PV module's new (i.e., at a realistic operating temperature) short-circuit current and open-circuit voltage, respectively.

f) Connect the DC power supply to the DUT's PV module input socket and entire PV cable and calculate the voltage drop, V_{drop}, between the power supply's output and the DUT's battery terminals.[21)]

g) Add V_{drop} to the battery end of charge voltage, V_{charge}, which is determined by multiplying the number of battery cells by the specified OVP voltage threshold for NiMH batteries from the active overcharge protection test (section T.4.2). This is called the total charge voltage, V_{max}.

h) Plot a vertical line at V_{max} on the new I-V curve (see part (d)) that extends from the voltage axis to the I-V curve.

i) Plot a horizontal line that intersects the new I-V curve at the same point V_{max} does and extends to the current axis. The current where the horizontal line intersects the current axis is the charging current.

j) If the charging current is less than or equal to twice 0,1 I_t A, the DUT has passive overcharge protection.

T.4.4.5 Calculations

There are no calculations for the passive overcharge protection test.

T.4.5 Standby self-consumption measurement

This measurement quantifies the self-consumption of a DUT when not in use. If the self-consumption is substantial, it may affect the use of the DUT.

T.4.5.1 Equipment requirements

- Ammeter with a precision of 0,01 mA (data-logging functionality is optional)

T.4.5.2 Test prerequisites

The DUT's battery should be discharged to its LVD or, in the case of the DUT not having a LVD, the specified deep discharge protection voltage threshold (see section T.4.1).

T.4.5.3 Apparatus

The DUT must be set in a secure location such that its battery's current draw can be recorded for 15 min.

---

21) If the DUT is has an integrated PV module, connect the DC power supply to the ends of the internal leads where the PV module connects to the DUT's circuitry.

T.4.5.4 Procedure

a) Break the DUT's circuit at the battery's negative terminal, connect the current meter in series, and ensure the DUT is turned off.

b) Wait 5 min to allow the DUT to stabilize. Then, over a 10 min period, record (or data-log) the current draw at the battery's negative terminal at intervals less than or equal to 1 min.

T.4.5.5 Calculations

c) Determine the fraction of capacity the battery self-consumes over a 30-day period using the following formula:

$$F_{\mathrm{b,self}} = \frac{I_{\mathrm{avg,self}} \times (720\,\mathrm{h}/30\,\mathrm{days})}{C_{\mathrm{b}}}$$

where

$F_{\mathrm{b,self}}$	is the fraction of capacity the battery self-discharges over 30 days (%);
$I_{\mathrm{avg,self}}$	is the average battery current draw over the 10 min data-collection period, in milliamperes (mA);
C_{b}	is the measured battery capacity, in milliampere-hours (mAh), obtained from the battery test (Appendix L).

T.5 Reporting

Report the following in the charge controller behaviour test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Results for tested DUT aspects for samples 1 through n
  - Presence of active deep discharge protection (yes/no)
  - Active deep discharge protection voltage, if applicable (V)
  - Presence of active overcharge protection (yes/no)
  - Active overcharge protection voltage, if applicable (V)
  - Presence of passive deep discharge protection (yes/no)
  - Passive deep discharge voltage (V/cell)
  - Presence of passive overcharge protection (yes/no)

    - Passive overcharge protection continuous charging current (mA)
    - 30-day battery self-consumption fraction (mAh)
- Average of n sample results for each DUT aspect tested
- Coefficient of variation of n sample results for each DUT aspect tested (%)
- DUT's rating for aspects tested, if available
- Deviation of the average result from the DUT's rating for each aspect tested, if available (%)
- Comments
    - Individual comments, as necessary, for samples 1 through n
    - Overall comments, as necessary, for collective set of samples 1 through n
- Figures
    - Plot of the PV module's new, realistic-temperature I-V curve with lines indicating the presence of passive overcharge protection, if applicable

Appendix U
(normative)
Light distribution test

U.1 Background

Luminous flux and light distribution are two primary metrics used to assess the performance of a lighting product. Measurements of luminous flux (the total amount of light emitted by a source) are appropriate for any type of light and are discussed in Appendix J. Measurements of light distribution are also appropriate for any type of light, with particular relevance to the performance of task lights that have focused light outputs.

The light distribution of solar LED lights can vary greatly, ranging from very narrow-beam task lights to omni-directional ambient lights. While there is no distribution that is necessarily "ideal," some distributions are more appropriate for certain applications than others. This appendix is intended to characterize a product's light distribution so purchasers can select products that are appropriate for the applications in which they are used.

The most common applications for solar LED lights are:

- Ambient lighting
- Task lighting from a mounted or suspended fixture
- Task lighting from a fixture placed on the surface to be illuminated (e.g., a desk light)

Ambient lights - Products that have very wide or omni-directional light output are best characterized by measuring total luminous flux (Appendix J). A full width half maximum (FWHM) angle measurement can be used to help categorize a light distribution (ambient or task), and some lights can be considered for both ambient and task lighting applications. In circumstances where it is not clear how to classify a light, both luminous flux and light distribution testing is appropriate.

Task lights that have narrow, focused, or directed light distributions can be characterized by measuring the illuminance on a specified task plane. The task plane used in the light distribution appendix is 1 m^2 and is positioned relative to the DUT according to the type of task light (desk light or suspended light).

U.2 Test outcomes

The light distribution test outcomes are listed in Table U.1.

Table U.1 – Light distribution test outcomes

Metric	Reporting units	Related aspects	Notes
Vertical and horizontal full width half maximum (FWHM) angles	Degrees (°)	4.2.7.2 Full width half maximum (FWHM) angle 4.2.7.3 Average light distribution characteristics	--
Matrix of illuminance values over 1 m^2 surface through L_{70}	Lux (lx)	4.2.7.3 Average light distribution characteristics	
Plot of average area illuminated through L_{70}		4.2.7.3 Average light distribution characteristics	Maximum reported useable area is 1 m^2

U.3 Related tests

The light distribution test is related to the full-battery run time test (Appendix N) and the light output test (Appendix J). Specifically, the multi-plane method described in section J.4.2 of Appendix J can be used to gather all needed data to generate polar plots, surface plots, and FWHM calculations for ambient and suspended task lights.

U.4 Recognized test methods

As discussed above, this module utilizes three different test procedures to characterize DUTs based on their expected use application. For DUTs where the intended application is not clear or which may be designed to be used in multiple applications, it is necessary to conduct distribution tests using multiple procedures.

Furthermore, there are multiple approved methods for two of the three test procedures (ambient and suspended task). Each of the approved options and their associated apparatus are described in this section. Table U.2 summarizes the three different applications covered, the approved test methods for each application, and the test outcomes for each of the approved test methods.

Table U.2 – Summary of testing options for characterizing lamp distributions

Application	Test method	Test outcomes
Ambient light	Multi-plane or goniophotometer	• Total luminous flux (see Appendix J) • Polar plot of distribution in multiple planes • Vertical FWHM angle • Horizontal FWHM angle
Ambient light	Rotary disk	• Polar plot of distribution in one plane • Vertical FWHM angle (measured)
Suspended task light	Multi-plane	• Total luminous flux (see Appendix J) • Surface plot of light distribution • FWHM angle
Suspended task light	Illuminance on a 1 m^2 plane	• Surface plot of light distribution • FWHM angle
Desktop task light	Illuminance on a 1 m^2 desktop	• Surface plot of light distribution • FWHM angle

U.4.1 Ambient light characterization

Ambient lights are typically tested to determine the total luminous flux output.

U.4.1.1 Goniophotometer

A goniophotometer can be used to measure both the light distribution characteristics of a light source and also the total luminous flux. Operation of a goniophotometer is beyond the scope of this document, and testing with a goniophotometer device should refer to the following standard test methods, with the DUT operated using the average operating voltage as described in Appendix J:

- CIE084: The Measurement of Luminous Flux
- CIE127: Measurement of LEDs
- IESNA LM-79-08: Electrical and Photometric Measurement of Solid State Lighting Products

U.4.1.2 Multi-plane method

U.4.1.2.1 Equipment requirements

- Multi-plane test apparatus (described in Appendix J)
- DC power supply
- Illuminance meter

U.4.1.2.2 Test prerequisites

Preparation of test sample for lighting evaluation as described in Appendix H. Specify the distance and minimum lux value required to meet useable area requirements.

U.4.1.2.3 Apparatus

The multi-plane apparatus is described in Appendix J, section J.4.2.

U.4.1.2.4 Procedure

The test procedures for determining the ambient light characterization are the same procedures as those used to determine total luminous flux and are described in Appendix J, section J.4.2. This procedure needs only to be conducted once per test sample to gather all necessary information needed to calculate total luminous flux (as detailed in Appendix J) or ambient light distribution.

U.4.1.2.5 Calculations

In order to generate polar plots of the distribution and to calculate FWHM angles, the data collected by the multi-plane method will need to be adjusted. Measurements taken by the multi-plane method are at a variety of distances from the test source to the sensor (shorter near the centre of the test plane and further near the edge of the test plane) and are at a variety of angles (normal at the centre of the test plane and at increasing angles off-normal approaching the edge of the test plane). To accurately plot distribution and calculate FWHM angles, these values must be "corrected" so they represent a "virtual sphere" of readings around the DUT in which each reading is converted to the same distance and measurement angle. These calculations are only valid if the distance from the light source to the actual measurement is at least five times the longest dimension of the emissive surface of the DUT.

a) First, correct for differences in measurement distance by adjusting the illuminance values to a distance of 0,75 m from all directions. Do so by multiplying each measured lux value by the square of the ratio between the actual measurement distance and 0,75 m.

b) Next, correct for differences in measurement angle so that the illuminance values represent flux that is normal to the virtual sphere surface. Divide each measured illuminance value by the cosine of the angle between the beam and the original measurement surface.

c) The angle between the brightest point and the point that is half as bright on the horizontal axis is the horizontal FWHM angle. And the angle between the brightest point and the point that is half as bright on the vertical axis is the vertical FWHM angle. If the DUT's horizontal and vertical FWHM angles are within 20°, take an average of the two and report it as the DUT's FWHM angle. If they are not, report both angles separately.

d) Multiply the number of corrected illuminance values greater than or equal to a specified minimum illuminance by their associated areas (0,01 m^2 for interior points, 0,005 m^2 for edge points, and 0,0025 m^2 for corner points) and sum to obtain the total usable area for the specified minimum illuminance. Do this for a range of minimum illuminance values. See Table U.3 for an example of determining the usable area for numerous minimum illuminance values.

e) Plot the usable area as a function of minimum illuminance for each of the DUT's settings on the same plot. The domain of the plot must include the maximum illuminance value for the DUT's brightest setting.

U.4.1.3 Rotating disk method

This test will be performed with the help of a "rotary disk" (see figure U.1). The DUT is placed on the rotary disk platform and illuminance is measured at a distance of one meter (centre point LED/LEDs to sensor). Testing should be done in a completely dark space, except for illumination provided by the DUT.

U.4.1.3.1 Equipment requirements

- Rotating disk (see apparatus below)
- DC power supply
- Illuminance meter

U.4.1.3.2 Test prerequisites

Preparation of test sample for lighting evaluation as described in Appendix H.

U.4.1.3.3 Apparatus

This test will be performed with the help of a "rotary disk" (see figure U.1). The DUT is placed on the rotary disk platform and illuminance is measured at a distance of 1 m (centre point LED/LEDs to sensor). Testing should be done in a completely dark space, except for illumination provided by the DUT.

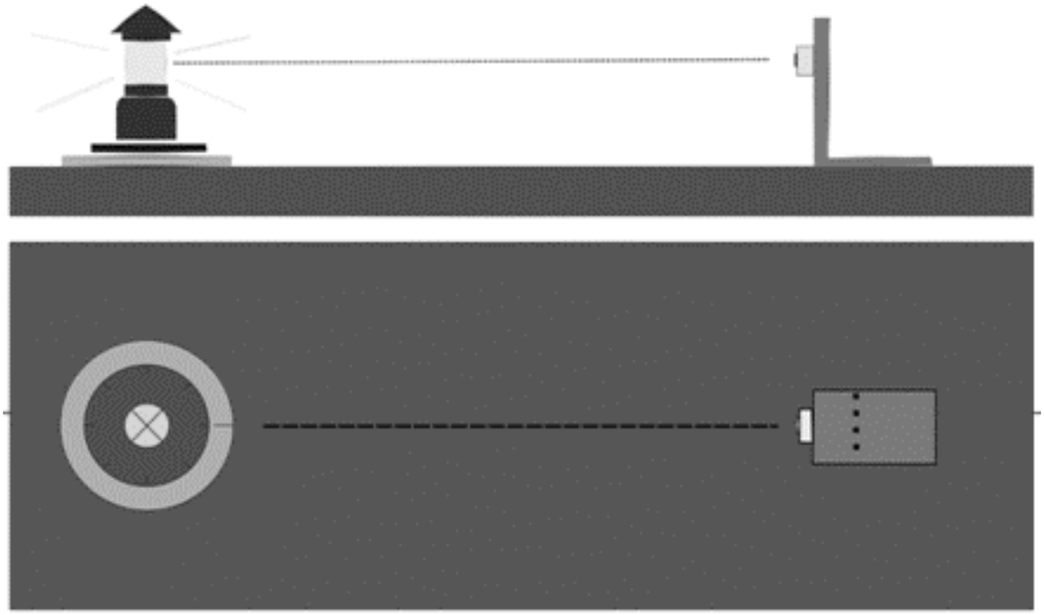


Figure U.1 – Schematic of "rotary disk" setup, with the DUT shown

U.4.1.3.4 Procedure

a) Set the voltage of the power supply to the average operating voltage of the battery (Appendix J).

b) If at desired voltage the DUT will not perform in its desired setting, increase the power supply voltage by increments of 0,05 V until the DUT can perform in its desired setting, then attempt to reduce the voltage to the desired level (Appendix J).

c) Operate the DUT for at least for 20 min before the first measurement is started.

d) Measure illuminance levels at every 10° sweep for the full 360° angle.

U.4.1.3.5 Calculations

The angle between the brightest point and the point that is half the illuminance of the brightest point on the horizontal axis is the horizontal FWHM angle.

U.4.2 Suspended task light characterization

U.4.2.1 Multi-plane method

U.4.2.1.1 Equipment requirements

- Multi-plane test apparatus (described below)
- DC power supply
- Illuminance meter

U.4.2.1.2 Test prerequisites

Preparation of test sample for lighting evaluation as described in Appendix H.

U.4.2.1.3 Apparatus

The multi-plane apparatus is described in Appendix J, section J.4.2.

U.4.2.1.4 Procedure

The test procedures for determining the suspended task light characterization using the multi-plane method are the same procedures at those used to determine total luminous flux and are described in Appendix J, section J.4.2. This procedure only needs to be conducted once per product sample to gather all necessary information needed to calculate total luminous flux (as detailed in Appendix J) or suspended task light distribution.

U.4.2.1.5 Calculations

In order to generate surface plots of the distribution and to calculate FWHM angles, the data collected by the multi-plane method will need to be adjusted. Measurements taken by the multi-plane method are at a variety of distances from the test source to the sensor (shorter near the centre of the test plane and further near the edge of the test plane) and are at a variety of angles (normal at the centre of the test plane and at increasing angles off-normal approaching the edge of the test plane). To accurately plot distribution and calculate FWHM angles, these values must be "corrected" such that they represent a "virtual sphere" of readings around the DUT in which each reading is at the same distance and measurement angle.

a) The process of making these corrections are identical to those described in section U.4.1.2.5. For suspended task lights that only significantly illuminate the multi-plane surface directly below the test device, corrections only need to be applied to this one surface (rather than all six multi-plane surfaces, as is required for ambient lights).

b) The angle between the brightest point and the point that is half the illuminance of the brightest point is the FWHM angle.

c) The constant-voltage useable area and average useable area to L_{70} are calculated as per section U.4.1.2.5.

U.4.2.2 Illuminance on a plane method

In this test, an examination is made and a report given of the illumination level on a surface of 1 m^2.

U.4.2.2.1 Equipment requirements

- DC power supply
- DC voltmeter
- DC ammeter
- Illuminance meter
- test grid

U.4.2.2.2 Test prerequisites

Preparation of test sample for lighting evaluation as described in Appendix H. Before measurement, the battery of the DUT must be replaced by a DC power supply.

U.4.2.2.3 Apparatus

The apparatus for this test consists of a 1 m^2 measurement target with 100 evenly-spaced measurement points, a photometer, and a mechanism capable of mounting DUTs 0,75 m from the measurement target (see Figure U.2). Testing should be done in a complete dark space, except for illumination provided by the DUT.

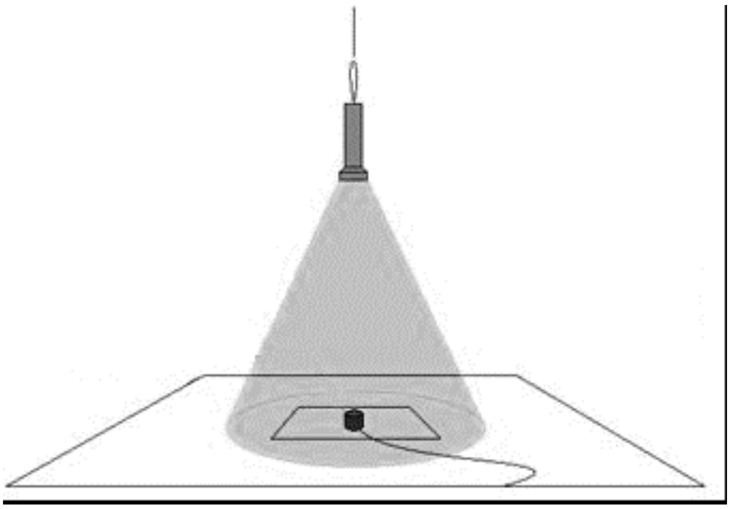


Figure U.2 – Schematic of a task light suspended 0,75 m above a photometer

U.4.2.2.4 Procedure

a) Set the voltage of the power supply to the average operating battery voltage (Appendix J).

b) If at desired voltage the DUT will not perform in its desired setting, increase the power supply voltage by increments of 0,05 V until the DUT can perform in its desired setting, then attempt to reduce the voltage to the desired level (Appendix J).

c) Suspend test lamp at a distance of 0,75 m from the top of the photometer head in a manner commensurate with the mounting device (preferably vertical) as shown in Figure U.2.

d) If the DUT features different brightness levels, the highest level is to be set. With DUTs which have a special task light function, this feature must be chosen.

e) The DUT must be operated for 20 min before the first measurement is started.

f) Illuminance is measured in the centre of each measurement square on the test plane.

U.4.2.2.5 Calculations

a) The angle between the brightest point and the point that is half the illuminance of the brightest point is the FWHM angle.

b) The average illuminance should be calculated for the square meter test surface.

c) The constant-voltage useable area and average useable area to L_{70} are calculated as per section U.4.1.2.5.

U.4.2.3 Desktop task light characterization

U.4.2.3.1 Equipment requirements

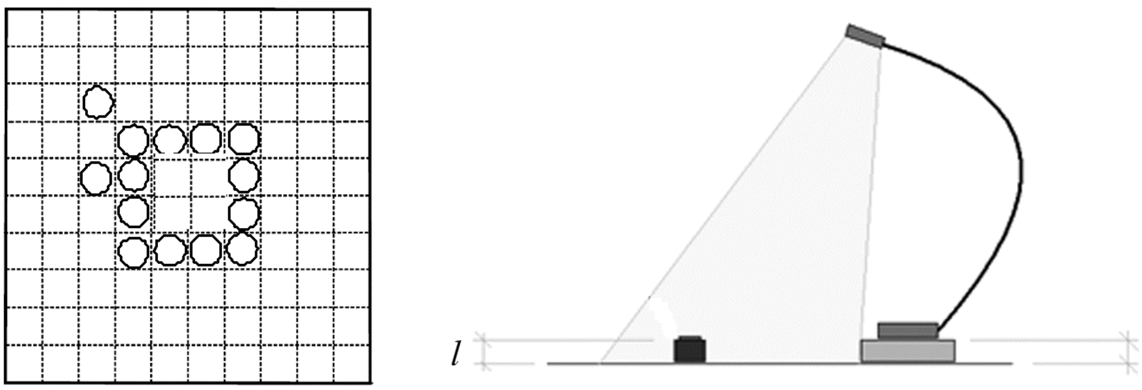
- DC power supply
- Photometer and test grid

U.4.2.3.2 Test prerequisites

Preparation of test sample for lighting evaluation as described in Appendix H. Before measurement, the battery of the DUT must be replaced by a DC power supply.

U.4.2.3.3 Apparatus

The sketch below shows the measurement scheme for measuring desktop lamps. The sketch on the left shows the top view of the desktop-specific grid setup, while the sketch on the right shows a side view of desktop light on setup.



Key

l Height of photometer head and desktop light spacer

Figure U.3 – Desktop measurement surface (grid), measurement points (circles), and side view of desktop light setup

Testing should be done in a complete dark space, except for illumination provided by the DUT.

U.4.2.3.4 Procedure

a) Set the voltage of the power supply to the average operating voltage of the battery and put the DUT onto its highest setting (Appendix J).

b) If at desired voltage the DUT will not perform in its desired setting, increase the power supply voltage by increments of 0,05 V until the DUT can perform in its desired setting, then attempt to reduce the voltage to the desired level (Appendix J).

c) Operate the DUT at least for 20 min before the first measurement is taken.

d) Illuminance is measured in the centre of each square of a desktop-specific grid surface. This grid surface has 100 measurement points.

e) Desktop lamps are placed on the surface using a spacer to compensate for errors owing to the height of the photometer head in such a way that the widest area of the surface with > 25 lux is illuminated.

U.4.2.3.5 Calculations

a) The angle between the brightest point and the point that is half the illuminance of the brightest point is the FWHM angle.

b) The constant-voltage useable area and average useable area to L_{70} are calculated as per section U.4.1.2.5.

U.5 Reporting

Report the following in the light distribution test report (a sample template is provided in Appendix Y):

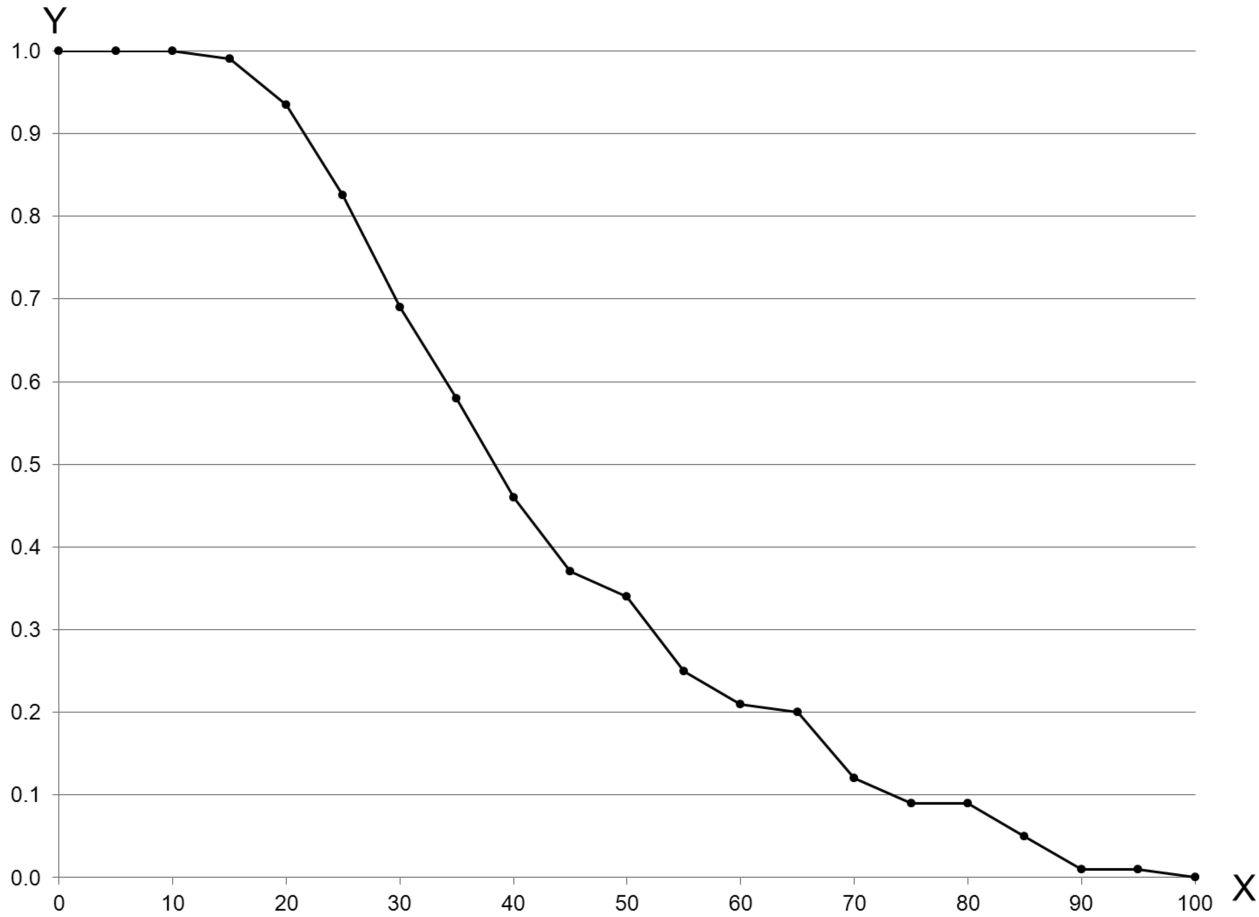
- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - DUT setting
  - Test room temperature (°C)
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Results for tested DUT aspects for samples 1 through n
  - Drive current (A)
  - Drive voltage (V)
  - Waiting time (min)
  - FWHM angle (°)
  - Constant-voltage useable area (m^2)
  - Average useable area through L_{70} (m^2)
- Average of n sample results for each DUT aspect tested
- Coefficient of variation of n sample results for each DUT aspect tested (%)
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n
- Tables

    - Table of corrected illuminance values on the brightest "face" of the 1 m^2 grid (see Table U.3 for an example).
- Figures
    - Plot of illuminated area as a function of minimum illuminance (see Figure U.4 for an example).
    - Surface plots and/or polar plots (see Figure U.5 and Figure U.6 for examples)

Table U.3 – Table of example illuminance measurements on the brightest "face" of the 1 m^2 grid and usable area as a function of minimum illuminance

Illuminance Measurements (lx)										
13,6	17,3	21,0	24,5	26,6	27,8	26,6	22,7	19,7	16,5	13,5
16,9	22,1	28,0	33,5	38,5	41,1	38,1	33,2	27,7	21,5	16,6
20,6	27,1	35,8	44,4	52,7	54,7	51,6	43,0	34,7	26,9	20,0
24,1	32,4	44,3	57,4	69,3	74,3	68,4	55,9	42,5	32,0	23,3
26,4	36,8	52,1	66,9	82,7	88,7	81,9	66,1	49,1	35,4	25,1
27,4	38,2	54,5	71,1	88,1	95,0	87,0	69,5	52,1	36,9	26,2
27,0	36,7	51,2	66,7	81,8	87,4	80,8	64,9	49,4	34,9	24,3
24,0	32,2	43,4	56,5	66,7	70,5	66,2	55,4	41,6	30,0	22,0
20,8	26,8	35,7	43,7	49,6	52,2	50,3	41,6	32,7	25,1	18,4
17,3	21,9	27,6	32,6	36,9	38,1	35,9	31,4	25,6	20,2	15,4
13,8	17,0	20,3	23,3	25,6	26,1	25,4	22,6	18,9	15,2	12,3

Minimum Illuminance (lx)	**Usable Area (m^2)**
0	1,00
10	1,00
20	0,94
30	0,69
40	0,46
50	0,34
60	0,21
70	0,12
80	0,09
90	0,01
100	0,00

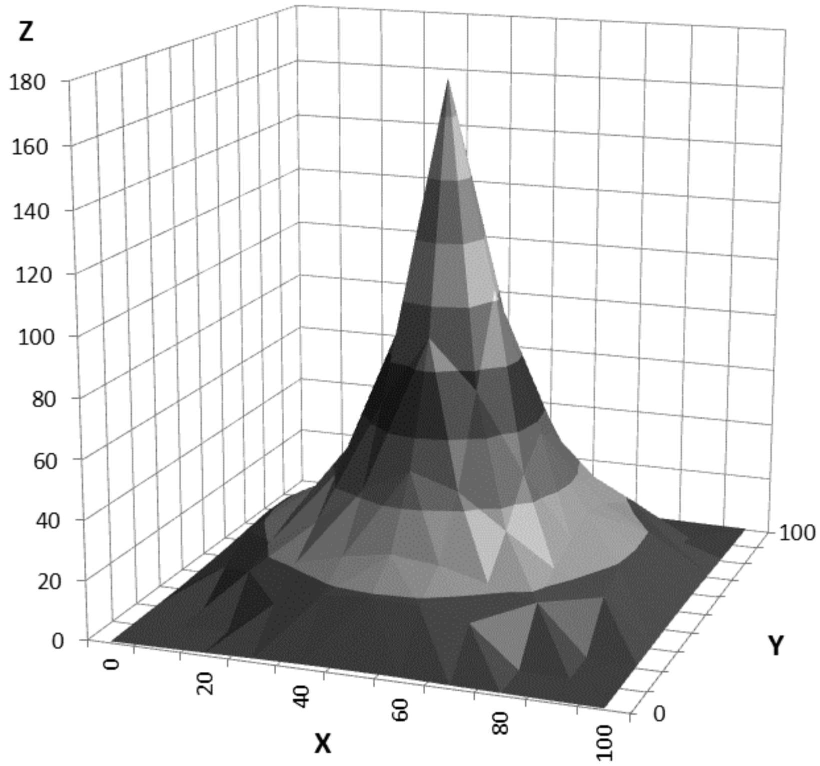


Key

X Minimum illuminance (lx)

Y Usable area (m²)

Figure U.4 – Example plot of usable area as a function of minimum illuminance



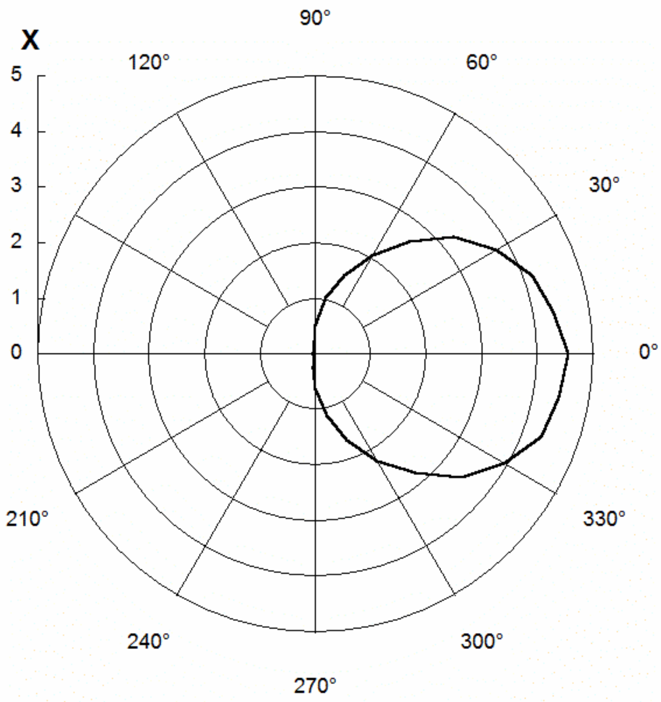
Key

X Length (cm)

Y Width (cm)

Z Illuminance (lx)

Figure U.5 – Plot of example results from the multi-plane method



Key

X Illuminance (lx)

Figure U.6 – Plot of example results from the rotating disk method

Appendix V
(normative)
Physical and water ingress protection test

V.1 Background

Ingress protection (IP) testing determines the degrees of protection provided by a DUT's enclosure. The IP rating uses two numerals to define the degrees of protection. The first numeral identifies the degree the DUT has protection against solid foreign objects. The second numeral identifies the degree the DUT has protection against ingress of water with harmful effects.

V.2 Test outcomes

The water exposure and physical ingress protection test outcomes are listed in Table V.1.

Table V.1 – Water exposure and physical ingress protection test outcomes

Metric	Reporting units	Related aspects	Notes
IP2x	Pass/fail	4.2.2.3 Physical ingress protection	12,5 mm diameter probe
IP4x	Pass/fail	4.2.2.3 Physical ingress protection	1 mm diameter probe
IP5x	Pass/fail	4.2.2.3 Physical ingress protection	No ingress of dust
IPx1	Pass/fail	4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage	Vertically dripping water
IPx3	Pass/fail	4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage	Direct sprays of water from within 60° of vertical
IPx7	Pass/fail	4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage	Temporary immersion in water

V.3 Related tests

Appendix V is not related to any of the other appendices.

V.4 Procedure

V.4.1 IP testing at an international laboratory

Samples are sent to an IP-certified test laboratory to determine the passing or failing for the desired IP requirements according to IEC 60529.

V.4.1.1 Guidance on working with external IP testing laboratory

Many international IP testing laboratories will require two samples for testing. These should be samples that have not been altered in anyway.

This test is destructive. Do not perform any additional tests on the samples after testing.

For water ingress testing, specify to the IP-certified test laboratory how the DUT must be oriented during testing. It must be oriented in the way that the DUT is most likely to be used.

V.4.2 IP preliminary inspection for ingress of solid foreign objects

The DUT is visually inspected for protection against ingress of solid foreign objects to determine the passing or failing for the desired IP requirement. This method applies for IP ratings IP2x and IP4x.

V.4.2.1 Equipment requirements

- 1 mm diameter rigid probe or 12,5 mm diameter rigid probe
- Camera

V.4.2.2 Test prerequisites

This test is destructive. Do not perform any additional tests on the sample after testing. The sample tested should have not been altered in anyway.

V.4.2.3 Apparatus

No apparatus is required for this test.

V.4.2.4 Procedure

a) Before the measurement, be sure that the DUT is properly functioning and that it is sufficiently charged to check for functionality during the test.

b) If the DUT requires passing IP2x, select the 12,5 mm probe. If the DUT requires passing IP4x, select the 1 mm probe.

c) Explore the DUT's entire surface to test for penetration with the selected probe.

d) If the probe can enter into the DUT's enclosure[22)] and touch the DUT's electronics, the DUT does not pass the required IP class for ingress of solid foreign objects. Document with photographs and text.

V.4.2.5 Calculations

No calculations are made for the ingress of solid foreign objects IP test performed through visual inspection.

V.4.3 IP preliminary inspection for ingress of water with harmful effects

The DUT is visually inspected for protection against ingress of water with harmful effects to determine if it is likely to pass or fail with respect to the desired IP requirement. This method can be performed for IP ratings IPx1 and IPx3.

V.4.3.1 Equipment requirements

- Controlled water source
- Camera

V.4.3.2 Test prerequisites

This test is destructive. Do not perform any additional tests on the sample after testing. The sample tested should have not been altered in anyway.

[22)]"Into the DUT's enclosure" does not include when the probe can enter into an external jack, unless it can enter into the DUT's enclosure through the external jack.

V.4.3.3 Apparatus

No apparatus is required for this test.

V.4.3.4 Procedure

a) Before the measurement, be sure that the DUT is properly functioning and that it is sufficiently charged to check for functionality during the test.

b) The DUT should be oriented in the way that it is most likely to be used.

c) If the DUT requires passing IPx1, sprinkle water from the controlled water source over the DUT so that the water drops are vertical to the DUT. The water flow rate should be close to 1 mm/min. Let the water drip over the DUT for 10 min while rotating the DUT at approximately 1 rpm about its vertical axis. The distance between the water source and DUT should be approximately 0,2 m.

d) If the DUT requires passing IPx4, spray water from the controlled water source over the DUT in all practical directions at an angle less than or equal to 60° from vertical. The water flow rate should be close to 10 l/min. Spray the water over the DUT for 1 min per square meter of enclosure surface area. The distance between the water source and the DUT should be between 0,3 m and 0,5 m.

e) After sprinkling or spraying water over the DUT, dry the enclosure's exterior with a towel.

f) Open the enclosure with the proper screw driver(s) or other devices.

g) If any water is found on electronic components inside the enclosure, the DUT does not pass the required IP class for ingress of water with harmful effects. Document with photographs and text.

V.4.3.5 Calculations

No calculations are made for the ingress of water with harmful effects IP test performed through visual inspection.

V.5 Reporting

Report the following in the water exposure and physical ingress protection test report (a sample template is provided in Appendix Y):

- Metadata
  - Report name
  - Procedure(s) used
  - DUT manufacturer
  - DUT name
  - DUT model number
  - Name of test laboratory
  - Approving person
  - Date of report approval
- Results for tested DUT aspects for samples 1 through n
  - IP rating for the ingress of solid foreign objects
  - IP rating for the ingress of water with harmful effects
  - Pass/fail for the IP rating for the ingress of solid foreign objects, if applicable

  - Pass/fail for the IP rating for the ingress of water with harmful effects, if applicable
- Comments
  - Individual comments, as necessary, for samples 1 through n
  - Overall comments, as necessary, for collective set of samples 1 through n
- Figures
  - Photographs to evidence the ingress of solid foreign objects or water, as necessary

Appendix W
(normative)
Level of water protection

W.1 Background

The enclosure of a solar lighting product can prevent water and solid foreign particles from coming in contact with internal electronic circuits, components, wires, and battery components (electronic components). The degree of protection provided by the enclosure is determined through Ingress Protection (IP) as outlined in Appendix V. IP testing does not, however, assess the actual or potential damage caused to electronic components by water exposure.

Alternate means of protection exist for electronic components exposed to water. These alternate means may allow manufactures to reduce the cost of their product(s) to the consumer, thereby increasing consumer access to modern lighting technology. This appendix outlines procedures for assessing overall water exposure protection based on IP test results combined with alternate protection means.

This Appendix does not attempt to characterize the damage caused by water exposure to sensitive electronic components. Rather, this Appendix provides a framework to assess the likelihood, during the service life of a product, that unprotected internal electronic components will be exposed to water that could negatively affect product operation.

W.2 Test outcomes

The procedures in this appendix can be used to establish a DUT's water exposure protection level. The four levels are:

a) **No protection** – The product has no water protection and may be damaged by any water exposure.

b) **Occasional rain** – The product can be exposed to occasional light rain without damage.

c) **Frequent rain** – The product can be exposed to frequent rain without damage.

d) **Permanent outdoor exposure** – The product can be exposed to frequent heavy rain without damage.

The water exposure and physical ingress protection test outcomes are listed in Table W.1.

Table W.1 – Water exposure and physical ingress protection test outcomes

Metric	Reporting units	Related aspects	Notes
Overall level of water protection	Qualitative (from list above)	4.2.10.1 Water protection integrated assessment 4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage 4.2.9.1 Product and manufacturer information 4.2.1.7 Packaging and user's manual information	This is the level of water protection that is achieved when considering user instructions and labels in addition to the technical elements of the product.
Technical level of water protection	Qualitative (from list above)	4.2.10.1 Water protection integrated assessment 4.2.2.1 Water protection – enclosure 4.2.2.2 Water protection – circuit protection and drainage 4.2.9.1 Product and manufacturer information	This is the level of water protection provided by only the technical elements of the product—the enclosure, circuits, and other physical aspects.
Enclosure-only level of water protection	Qualitative (from list above)	4.2.10.1 Water protection integrated assessment 4.2.2.1 Water protection – enclosure	This only refers to the IP rating of the enclosure.

W.3 Related tests

This appendix is related to Appendix V (Water exposure and physical ingress protection test) and Appendix G (Visual screening).

W.4 Laboratory requirements

The assessments in this Appendix are typically done by an organization with broad experience in the off-grid lighting sector, including technical and field experience.

Assessments regarding the technical level of water protection should be completed by an organization with expertise in product design, failure analysis, energy systems, and general engineering practices.

Assessments of the overall level of water protection (incorporating consumer labelling information) should be completed by a committee with expertise in communication and end-user behaviour in the off-grid lighting market.

W.5 Procedure

The following procedures establish a product's level of water protection. All of the procedures in this appendix require an IP test result as specified in Appendix V. Additional factors, such as product labelling or specific product design features, may also be considered when determining the level of water protection.

W.5.1 Level of water protection for enclosure only

This procedure uses a product's IP rating, and only its IP rating, to determine the level of water protection. No other tests are required. The level of water protection by IP rating is determined according to Table W.2.

Table W.2 – Enclosure-only level of water protection requirements

Enclosure level of water protection	IP rating requirement
No protection	IPx0
Occasional rain	IPx1
Frequent rain	IPx3
Permanent outdoor exposure	IPx5

W.5.2 Level of water protection from technical aspects

This procedure describes an assessment of the technical aspects of a product to establish the level of water protection that is achieved by a product from an engineering design standpoint. The aspects included in this holistic assessment are:

- The enclosure
- Circuit design and protection
- Internal draining
- Manufacturing processes
- Other innovative approaches

The overall product design must be assessed on a case-by-case basis to determine the technical level of water protection. The assessment includes information from lab tests, field experience, and statements supplied by the manufacturer.

Products may be considered to have a technical level of water protection according to Table W.3.

Table W.3 – Technical level of water protection requirements

Technical Level of water protection	Requirement
No protection	N/A
Occasional rain	Assessment indicates the enclosure and other technical aspects will protect from occasional rain, equivalent to IPx1 protection.
Frequent rain	Assessment indicates the enclosure and other technical aspects will protect from frequent rain, equivalent to IPx3 protection.
Permanent outdoor exposure	Assessment indicates the enclosure and other technical aspects will protect from permanent outdoor exposure, typically requiring an enclosure with at least IPx3 protection and additional circuit protection.

W.5.2.1 Gathering product design information from lab testing

Results and observations from the following tests are relevant for this assessment:

- Appendix V (physical and water ingress protection test)
- Appendix G (visual screening)

W.5.2.2 Gathering field and experiential information

Information from field trials and using samples of the product in a variety of environmental conditions can supplement other information and provide unique, targeted insights.

W.5.2.3 Gathering Product design information from the manufacturer

The manufacturer is responsible for providing information about product design and manufacturing that is part of a water protection strategy.

Ask the manufacturer to provide product design data and explanations justifying a technical level of water protection. This data should include the following:

a) Written descriptions of the product design elements and materials that will protect the circuit components from water exposure damage.
b) Photographs or video clips showing the relevant design features.
c) Specification sheets for materials used for protection.
d) Written descriptions of protection for each circuit component in W.5.2.3.1
e) Written descriptions of relevant manufacturing processes employed for circuit component protection.
f) Written descriptions of quality control processes relevant to circuit component protection.
g) Descriptions of tests performed by the manufacturer to demonstrate protection of circuit components from damage caused by water exposure.

W.5.2.3.1 Circuit design information

The relevant circuit components to provide information about include:

a) Printed circuit boards
b) Component solder joints
c) Wire to board solder joints
d) Wire to board connectors
e) Wire to battery terminal solder joints
f) Wire to battery terminal connectors
g) LED components
h) Switch components

W.5.2.3.2 Manufacturing quality control information

The manufacturer should describe quality control processes that are in place to ensure consistent application of coatings, use of gaskets, etc.

W.5.2.3.3 Water resistant coatings

Polymer coatings on printed circuit boards, wire solder joints, connectors, and electronic components have been shown to reduce or eliminate the negative effects of water exposure to live electronic circuit elements. In order to be effective, these coatings must be properly applied to clean substrates in a quality controlled manufacturing process.

W.5.2.3.4 Novel design approaches

Other means may be available to protect electronic components from water exposure damage. For example, the product may be designed to allow water to drain from the case and not collect on circuit components. These novel approaches must be outlined and explained by the manufacturer with supporting documentation justifying a level of water protection as outlined in Table W.3.

W.5.2.4 Assessment of technical level of water protection

The final assessment of the technical level of water protection should include information from each of the sources listed above.

The assessment details should include an evaluation of protection for critical components on a piece by piece basis. Reference should be provided where appropriate to the manufacturer supplied data. See table W.4 for an example product where the manufacturer is using conformal coatings and silicone sealants to protect internal circuit components:

Table W.4 – Example detailed assessment supporting technical level of water protection

Circuit component	**Method of protection**	**Manufacturer reference material**	**Notes**
Printed circuit boards	Conformal coating	Pcb_coating1.jpg	
Component solder joints	Conformal coating	Pcb_coating2.jpg	
Wire to board solder joints	None		Wire to board solder joints are not sealed or encapsulated
Wire to board connectors	N/A		None used
Wire to wire connectors	N/A		None used
Wire to battery terminal solder joints	Silicone encapsulant	Battery_coating1.jpg	
Wire to battery terminal connectors	N/A		None used
LED components	Case design	LED_lens1.jpg	Manufacturer statement
Switch components	None		Switch is not sealed

W.5.3 Overall level of water protection

The overall level of water protection assessment accounts for consumer labelling and instructions in combination with either the technical or enclosure-only level of water protection.

If appropriate consumer information is provided, the level of water protection is increased relative to the technical or enclosure-only findings.

This assessment cannot result in an increase to the permanent outdoor exposure level, since products that are permanently mounted outdoors are not protected from water by the end-user.

The table below lists the requirements for assessing the overall level of water protection.

Table W.5 – Overall level of water protection requirements

Technical level of water protection OR Enclosure-only level of water protection	Overall level of water protection WITHOUT consumer labelling	Overall level of water protection WITH consumer labelling
No protection	Same	Occasional rain
Occasional rain	Same	Frequent rain
Frequent rain	Same	Same
Permanent outdoor exposure	Same	Same

W.5.3.1 Assessing consumer labels and information

This section describes a framework for assessing consumer labels and instructions for appropriateness.

The overall requirement for consumer labels and instructions is that the communication strategy should be designed and implemented so that a typical user understands both the degree of protection from water for the product and what they should do to maintain the product in an instance of water exposure.

The factors to consider are:

- Language and literacy of expected end-users
- Prominence of information
- Clarity of presentation

W.5.3.1.1 Gathering information on water protection messages

Information from visual screening (Appendix G) and additional inspection of the packaging should be used to establish the messages to buyers and end-users concerning water protection.

Potential locations (not inclusive) of information:

- Labels and pictograms on packaging
- Instructions in the users manual
- Information on the warranty card
- Advertising and media

W.6 Reporting

Report the following in the Equivalent IP water exposure protection report:

- Metadata
  - Name of test
  - Procedures used to qualify for level of water protection (IP rating, labelling and/or product design)
  - DUT manufacturer
  - DUT name
  - DUT model number
  - Name of test laboratory

  - Approving person
  - Date of report approval
- Main findings:
  - Overall level of water protection
  - Technical level of water protection
  - Enclosure-only level of water protection
- Supporting information:
  - IP rating for enclosure
  - Description of other technical approaches (if applicable)
  - Suitability of consumer labelling for communicating level of technical water protection and steps to protect the product
- Manufacturer supplied data (Include all manufacturer supplied data in the test report)
- Assessment of manufacturer supplied data (include Table A.2)
- Comments
  - Individual comments, as necessary, on the specific material provided by the manufacturer demonstrating an equivalent IP level protection
  - Overall comments, as necessary, for the collective set of materials provided by the manufacturer demonstrating an equivalent level of IP protection

Appendix X
(normative)
Mechanical durability test

X.1 Background

The mechanical durability test captures a DUT's robustness in withstanding the rigors of expected daily usage. The mechanical durability test includes the drop test, the switch and connector test, the gooseneck test (if applicable), and the strain relief test (if applicable).

During the drop test, the DUT is dropped from a height of 1 m onto a concrete surface. Six drops occur per DUT sample, with each drop impacting a different side of the sample. During the switch and connector test, each switch and/or connector of the DUT sample is cycled 1000 times. The gooseneck test is only conducted on DUT samples with goosenecks, and it requires the gooseneck of the DUT sample to be bent 1000 times through its feasible range of usage. The strain relief test involves attaching a 2 kg weight onto any permanently-connected cable ends (i.e., cable ends without connectors) for 60 s. Throughout all four tests, the DUT sample is examined for functionality, damage, and the presence of user safety hazards.

X.2 Test outcomes

The test outcomes of the mechanical durability test are listed in Table X.1.

Table X.1 – Mechanical durability test outcomes

Metric	Reporting units	Related aspects	Notes
Drop test sample functionality	Yes/no	4.2.2.4 Drop resistance	--
Drop test user safety hazard(s) present	Yes/no, description	4.2.2.4 Drop resistance	--
Drop test sample damage	Yes/no, description	4.2.2.4 Drop resistance	--
Switch and connector test cycles achieved	Cycles	4.2.2.6 Connector durability 4.2.2.7 Switch durability	--
Switch and connector test sample functionality	Yes/no	4.2.2.6 Connector durability 4.2.2.7 Switch durability	--
Switch and connector test user safety hazard(s) present	Yes/no, description	4.2.2.6 Connector durability 4.2.2.7 Switch durability	--
Switch and connector test sample damage	Yes/no, description	4.2.2.6 Connector durability 4.2.2.7 Switch durability	--
Gooseneck test cycles achieved	Cycles	4.2.2.5 Gooseneck durability	
Gooseneck test sample functionality	Yes/no	4.2.2.5 Gooseneck durability	--
Gooseneck test user safety hazard(s) present	Yes/no, description	4.2.2.5 Gooseneck durability	--
Gooseneck test sample damage	Yes/no, description	4.2.2.5 Gooseneck durability	--
Strain relief time achieved for each weight and strain angle	Seconds (s)	4.2.2.8 Strain relief durability	--
Strain relief test sample functionality	Yes/no	4.2.2.8 Strain relief durability	--
Strain relief test user safety hazard(s) present	Yes/no, description	4.2.2.8 Strain relief durability	--
Strain relief test sample damage	Yes/no, description	4.2.2.8 Strain relief durability	--

X.3 Related tests

Appendix X is not related to any of the other appendices.

X.4 Procedures

X.4.1 Drop test

The DUT sample is dropped on six different sides from a height of 1 m onto a level concrete surface and examined for functionality, user safety hazards, and damage.

X.4.1.1 Equipment requirements

- Tape measure or ruler at least 1 m in length
- Camera

X.4.1.2 Test prerequisites

At the start of the drop test the DUT samples should be minimally altered (ideally unaltered), fully functional, and have sufficient charge to check for functionality throughout the test.

If the DUT samples have multiple units or components, determine an appropriate order to test the parts need to undergo the drop test. DUT samples or sample parts that are intended to be stationary (e.g., separate control boxes, lamp units intended to be mounted, etc.) and PV modules do not need to be drop-tested. Portable DUT samples or sample parts (e.g., torches, lanterns, desktop lamps, etc.) should be drop tested.

NOTE This test is destructive. Do not carry out additional tests with the tested samples.

X.4.1.3 Apparatus

Choose an appropriate location to perform the drop test. The location should have a smooth, level concrete surface with ample space to avoid personal injury from a DUT projectile (e.g., glass and/or plastic shards). A height of 1 m must be established from the ground to begin the drop.

X.4.1.4 Procedure

a) Drop the DUT sample six times from a height of 1 m—once on each of the six "faces" of the product, taking care to drop the DUT sample on parts deemed mechanically weak (e.g., handles, loose parts, etc.).

NOTE Each time the product should impact the concrete on a different face: the DUT sample is rotated by 90° along the x-axis following each of the first three drops, rotated by 90° along the y-axis from its initial drop orientation for the fifth drop, and rotated 180° along the y-axis from its fifth drop orientation for the sixth drop (see Figure X.1 below).

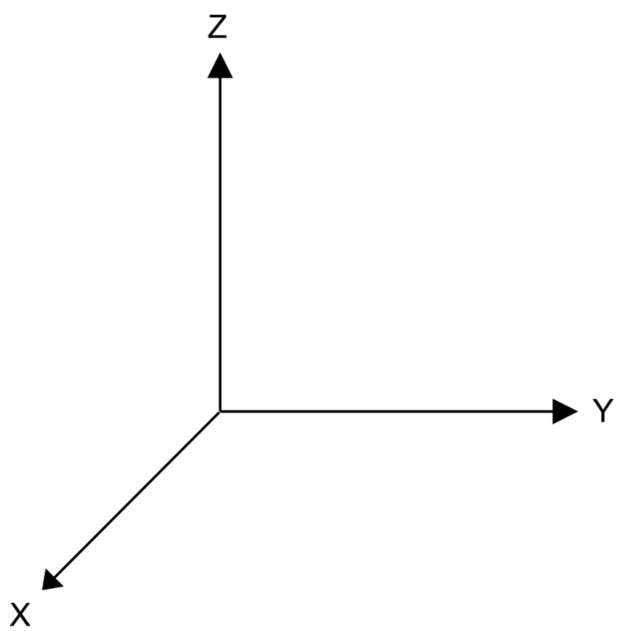


Figure X.1 – Three-dimensional Cartesian coordinate system for drop test reference

b) After each of the six drops, examine the DUT sample for functionality, the presence of user safety hazards (e.g., glass shards, short circuits, etc.), and damage and record the observations with descriptions and photographs. Superficial damage (minor scrapes or "popped off" components that can easily be put back in place) should not be noted; only note damage that is permanent and non-superficial.

X.4.1.5 Calculations

No calculations are made for the drop test.

X.4.2 Switch and connector test

Each DUT sample switch and/or connector is cycled 1 000 times and examined for functionality, user safety hazards, and damage.

X.4.2.1 Equipment requirements

- Camera

X.4.2.2 Test prerequisites

At the start of the switch and connector test the DUT samples should be fully functional and have sufficient charge to check for functionality throughout the test.

NOTE This test is destructive. Do not carry out additional tests with the tested samples, with the exception of the switch and connector test, the strain relief test, and the drop test (if the DUT samples are still functional after the switch and connector test).

X.4.2.3 Apparatus

No apparatus is required for the switch and connector test.

X.4.2.4 Procedure

a) Cycle each of the DUT sample's unique switch(es) and/or connector(s) 1 000 times.

b) If damaged is observed during the testing, record the observations with descriptions and photographs. Superficial damage (minor scrapes or "popped off" components that can easily be put back in place) should not be noted; only note damage that is permanent and non-superficial.

c) Continue testing until the product fails to function, a user safety hazard develops (e.g., short circuit), or 1 000 cycles are achieved.

NOTE If potential damage cannot instantly be observed during testing (e.g., damage to a PV module or mobile phone connector), check for DUT sample functionality after every 100 cycles.

X.4.2.5 Calculations

No calculations are made for the switch and connector test.

X.4.3 Gooseneck test

If applicable, each DUT sample's gooseneck is bent 1 000 times through its feasible range of usage.

X.4.3.1 Equipment requirements

- Camera

X.4.3.2 Test prerequisites

At the start of the gooseneck test the DUT samples should be fully functional and have sufficient charge to check for functionality throughout the test.

NOTE This test is destructive. Do not carry out additional tests with the tested samples, with the exception of other destructive tests (if the DUT samples are still functional after the gooseneck test).

X.4.3.3 Apparatus

No apparatus is required for the gooseneck test.

X.4.3.4 Procedure

a) Bend the DUT sample's gooseneck 1 000 times through its feasible range of usage.

b) If damaged is observed during the testing, record the observations with descriptions and photographs. Superficial damage (minor scrapes or "popped off" components that can easily be put back in place) should not be noted; only note damage that is permanent and non-superficial.

c) Continue testing until the product fails to function, a user safety hazard develops (e.g., short circuit), or 1 000 bends are achieved.

X.4.3.5 Calculations

No calculations are made for the gooseneck test.

X.4.4 Strain relief test

If applicable, each DUT samples' permanent cable ends (i.e., cable ends without connectors) are subjected to a 2 kg weight for 60 s at various strain angles.

X.4.4.1 Equipment requirements

- Camera
- Clamp or other means of holding DUT components in place
- Calibrated 2 kg weight
- Protractor or other means of determining the strain angle
- Stopwatch

X.4.4.2 Test prerequisites

At the start of the strain relief test the DUT samples and their PV modules should be fully functional and the DUTs should have sufficient charge to check for functionality throughout the test.

NOTE This test is destructive. Do not carry out additional tests with the tested samples, with the exception of the switch and connector test, the drop test, and the gooseneck test (if the DUT samples and PV modules are still functional after the strain relief test).

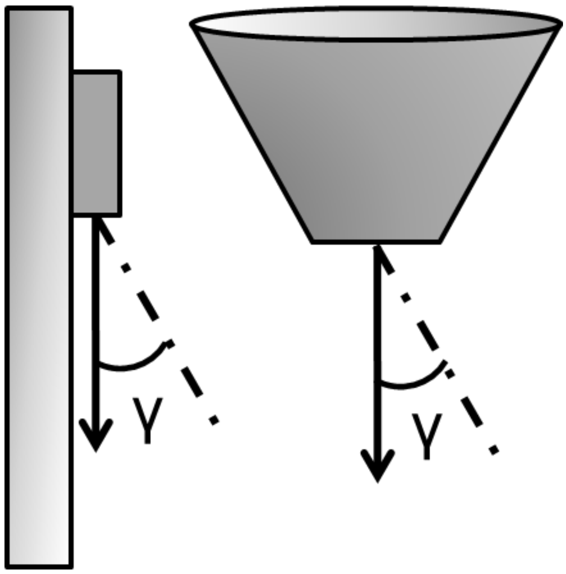
X.4.4.3 Apparatus

A clamp or other means of securely holding a 2 kg weight and the DUT and/or the DUT's PV module in place is required.

X.4.4.4 Procedure

a) Determine which DUT cable ends are permanently attached (i.e., do not have a connector end) to the DUT and/or PV module.

b) Clamp the DUT, DUT component, or PV module in place and attach the 2 kg weight to the cable so that the strain angle (γ) is 0° relative to the direction from which the cable protrudes from the DUT, DUT component, or PV module (see Figure X.2).



Key

γ Cable strain angle (º)

Figure X.2 – Cable strain angle (γ) schematics for a PV module junction box (left) and a separate light point (right)

c) Observe the DUT, DUT component, or PV module for 60 s. After 60 s, record the DUT's, DUT component's, or PV module's functionality, any physical damage, and the presence of safety hazards. Superficial damage (minor scrapes or "popped off" components that can easily be put back in place) should not be noted; only note damage that is permanent and non-superficial.

d) Repeat steps (b) and (c) for strain angles of 30°, 60°, and 90°.

e) Repeat step (b) through step (d) for each permanently-attached cable end found in step (a).

X.4.4.5 Calculations

No calculations are made for the strain relief test.

X.5 Reporting

Report the following in the mechanical durability test report (a sample template is provided in Appendix Y):

- Metadata
    - Report name
    - Procedure(s) used
    - DUT manufacturer
    - DUT name
    - DUT model number
    - Name of test laboratory
    - Approving person

  - Date of report approval
- Results for tested DUT aspects for samples 1 through n
  - Drop Tests:
    - Functions after each drop (pass/fail)
    - No damage present after each drop (pass/fail)
    - No user safety hazard present after each drop (pass/fail)
  - Switch / Connector Tests:
    - Cycles achieved for each switch and/or connector
    - Functions after test (pass/fail)
    - No damage present after test (pass/fail)
    - No user safety hazard present after test (pass/fail)
  - Gooseneck Test:
    - Cycles achieved for the gooseneck
    - Functions after test (pass/fail)
    - No damage present after test (pass/fail)
    - No user safety hazard present after test (pass/fail)
  - Strain relief test:
    - Time achieved for each strain angle (s)
    - Functions after test (pass/fail)
    - No damage present after test (pass/fail)
    - No user safety hazard present after test (pass/fail)
- Comments
  - Individual comments, as necessary, for samples 1 through n for each test
  - Overall comments, as necessary, for collective set of samples 1 through n for each test
- Figures
  - Photographs of observed user safety hazards and/or DUT sample damage

Appendix Y
(informative)
Example test report templates

Y.1 Background

All of the tests conducted on the lighting product samples have information, specifications, and/or results to report. Appendix Y provides example test report templates for organizing the outcomes of the tests in a consistent manner.

These templates contain fields for all pertinent outcomes of each test or procedure, and in some cases not every field will be completed. Furthermore, the size of the template fields will likely need to be increased to incorporate certain test outcomes and comments.

Y.2 Test report templates

Y.2.1 Manufacturer self-reported information

The following table can be used to report the manufacturer self-reported information (Appendix E).

Table Y.1 (1 of 2) – Manufacturer self-reported information test report template

Report name	**Manufacturer self-reported information**
Manufacturer	
Product name	
Model number	
Test lab	
Approving person	
Approval date	
	Confidential information
Manufacturer company physical address	
Contact person	
Contact person position at company	
Contact telephone number	
Contact fax number	
Contact e-mail	
Product markets	
Product FOB price ($)	
Typical shipping point of origin	
Product driver type (if known)	
Product battery charge control methods (if applicable)	
Description of battery charge control methods (if applicable)	

Table Y.1 (2 of 2) – Manufacturer self-reported information test report template

	Public information
Manufacturer company name	
Manufacturer company physical address	
Contact person name	
Contact person position at company	
Contact telephone number	
Contact fax number	
Contact e-mail	
Manufacturer company website	
Product name	
Product model number	
Product lighting technologies	
Product battery chemistry	
Product charging systems	
Included product features	
Optional product features	
Description of product warranty terms	
Manufacturer company certifications	
Product certifications	

Y.2.2 Product sampling information

The following table can be used to report the product sampling information (Appendix F).

Table Y.2 – Product sampling information test report template

Report name	Product sampling
Procedure(s)	
Manufacturer	
Product name	
Model number	
Test lab	
Approving person	
Approval date	
Sampling instructions	
Name of sampling agency	
Name(s) of sampling agent(s)	
Sampling location(s)	
Number of samples procured (at each location)	
Name of shipping agency	
Shipment tracking number	
Date samples are shipped to test lab	
Date samples are received at test lab	

Y.2.3 Visual Screening results

The following table can be used to report the visual screening results (Appendix G).

Table Y.3 (1 of 7) – Visual screening results test report template

Report name	Visual Screening
Procedure(s)	
Manufacturer	
Product name	
Model number	
Test lab	
Approving person	
Approval date	
Manufacturer contact information	
Retail box description	

Table Y.3 (2 of 7) – Visual screening results test report template

	Included (yes/no)	**Type**	**Language**	**Comments**
User's manual				

Warranty length (months)	
Warranty terms and conditions	

	Mass (g)	**List of components included in product mass measurement**
Complete product		

Cable	**Length (m)**	**Description of cable**
1		
2		
⋮		
n		

Component	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Number included**	**Description of component**
Lamp unit 1					
Lamp unit 2					
⋮					
Lamp unit n					
Battery					
Charge controller					

Lamp unit	**Type**	**Number of light points**	**Number of arrays**	**Description of lamp unit**
1				
2				
⋮				
n				

Product arrangement description	

Setting	**Name**	**Description of setting**
1		
2		
⋮		
n		

Component	**Material(s)**	**Description of material(s)**
Lamp unit 1		
Lamp unit 2		
⋮		
Lamp unit n		
Battery unit		
Charge controller		

Table Y.3 (3 of 7) – Visual screening results test report template

Component	Number of indicators	Description of indicator(s)
Lamp unit 1		
Lamp unit 2		
⋮		
Lamp unit n		
Battery unit		
Charge controller		

Component	Feature(s)	Description of feature(s)
Lamp unit 1		
Lamp unit 2		
⋮		
Lamp unit n		
Battery unit		
Charge controller		

Radio (yes/no)	
Mobile phone charging (yes/no)	
Describe other included product accessories and connectors	

Charging mechanism	Supported (yes/no)	Specific type	Description of robustness
Central			
Independent			

PV module	Length (cm)	Width (cm)	Active area (cm^2)	Form
1				
2				
⋮				
n				
PV module	**Cable length (m)**	**Active solar material**	**Encasing**	**Robustness**
1				
2				
⋮				
n				

PV module junction box workmanship description	
Additional PV module information	
Can the product be turned on while being charged with its PV module? (yes/no)	

Table Y.3 (4 of 7) – Visual screening results test report template

Primary form factor	
Secondary form factor(s)	
Expected uses	

Overall visual inspection comments	

Provided product specification	**Outside of product's packaging box**	**Product documentation inside packaging box**	**Component**	**Other**	**Source of "other"**
Battery chemistry					
Rated battery capacity (mAh)					
Nominal battery voltage (V)					
Lamp type(s)					
Lamp driver					
Charge controller present (yes/no)					
Charge controller deep discharge protection voltage (V)					
Charge controller overcharge protection voltage (V)					
PV module P_{mpp} (W_p)					
PV module V_{oc} (V)					
PV module I_{sc} (A)					
PV module V_{mpp} (V)					
PV module I_{mpp} (A)					

Describe any product specification discrepancies	

Table Y.3 (5 of 7) – Visual screening results test report template

Provided run time specification	**Lamp setting**	**Outside of product's packaging box**	**Product documentation inside packaging box**	**Other**	**Source of "other"**
Full-battery run time (h)	1				
	2				
	⋮				
	n				
Daily solar run time (h)	1				
	2				
	⋮				
	n				
Mechanical run time (h)	1				
	2				
	⋮				
	n				
Grid run time (h)	1				
	2				
	⋮				
	n				
Other run time (h)	1				
	2				
	⋮				
	n				
Describe any run time specification discrepancies					
Light output (lm)	1				
	2				
	⋮				
	n				
Describe any light output discrepancies					
Does the product function out of the box (yes/no)					

Sample ID	**Switch(es) function (yes/no)**	**Connector(s) function (yes/no)**	**Comments**
1			
2			
⋮			
n			
Indicate and describe strain reliefs, if applicable			

Table Y.3 (6 of 7) – Visual screening results test report template

Sample ID	**Number of poor solder joints**	**Number of workmanship deficiencies**	**Comments**
1			
2			
⋮			
n			

Fixture of parts	**Lamp unit(s)**	**Charge controller**	**PV module(s)**	**Remote**	**Other**
Screws (yes/no)					
Glue (yes/no)					
Tape (yes/no)					
Clamps/straps (yes/no)					
Other (describe)					
General fixture of parts comments					

Description of methods used to secure wires and cables	

Easily replaceable battery (yes/no)	
Easily replaceable PCB (yes/no)	
Comments on ease of battery and/or PCB replacement	

Overall description of internal workmanship	

Properties, features, and information photographs

Table Y.3 (7 of 7) – Visual screening results test report template

Specifications photographs
Functionality and internal inspection photographs

Y.2.4 Light output test results

The following table can be used to report the light output test results (Appendix J).

Table Y.4 – Light output test report template

Report name	**Light output test**
Procedure(s)	
Manufacturer	
Product name	
Model number	
Setting	
Test lab	
Approving person	
Approval date	

Sample ID	**Total luminous flux (lm)**	**Correlated colour temperature**	**Colour rendering index**	**Drive current (A)**	**Drive voltage (V)**	**Waiting time (min)**
1						
2						
⋮						
n						
Average						
Coefficient of Variation (%)						
Rating						
Average deviation from rating (%)						

Sample ID	**Comments**	**General comments**
1		
2		
⋮		
n		

Y.2.5 Battery test results

The following table can be used to report the battery test results (Appendix L).

Table Y.5 – Battery test report template

<table>
<tr><th>Report name</th><th colspan="2">Battery test</th></tr>
<tr><td>Procedure(s)</td><td colspan="2"></td></tr>
<tr><td>Manufacturer</td><td colspan="2"></td></tr>
<tr><td>Product name</td><td colspan="2"></td></tr>
<tr><td>Model number</td><td colspan="2"></td></tr>
<tr><td>Test lab</td><td colspan="2"></td></tr>
<tr><td>Approving person</td><td colspan="2"></td></tr>
<tr><td>Approval date</td><td colspan="2"></td></tr>
<tr><td>Battery chemistry</td><td colspan="2"></td></tr>
<tr><td>Nominal battery voltage (V)</td><td colspan="2"></td></tr>
<tr><td>Battery discharge rate during test</td><td colspan="2"></td></tr>
<tr><td>Sample ID</td><td>Battery capacity
(mAh)</td><td>Battery storage efficiency
(%)</td></tr>
<tr><td>1</td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td></tr>
<tr><td>⋮</td><td></td><td></td></tr>
<tr><td>n</td><td></td><td></td></tr>
<tr><td>Average (%)</td><td></td><td></td></tr>
<tr><td>Coefficient of Variation (%)</td><td></td><td></td></tr>
<tr><td>Rating</td><td></td><td rowspan="2"></td></tr>
<tr><td>Average deviation from rating (%)</td><td></td></tr>
<tr><td>Sample ID</td><td>Comments</td><td>Overall comments</td></tr>
<tr><td>1</td><td></td><td rowspan="4"></td></tr>
<tr><td>2</td><td></td></tr>
<tr><td>⋮</td><td></td></tr>
<tr><td>n</td><td></td></tr>
</table>

Y.2.6 Full-battery run time test results

The following table can be used to report the full-battery run time test results (Appendix N).

Table Y.6 (1 of 2) – Full-battery run time test report template

Report name	**Full-battery run time test**
Procedure(s)	
Manufacturer	
Product name	
Model number	
Setting	
Test lab	
Approving person	
Approval date	

Sample ID	**Run time to L_{70} (h)**	**Average relative light output to L_{70}**	**Average voltage operating point (V)**	**Average current operating point (mA)**	**Deep discharge protection present (yes/no)**	**Deep discharge protection voltage, if present (V)**
1						
2						
⋮						
n						
Average						
Coefficient of Variation (%)						
Rating						
Average Deviation from Rating (%)						

Sample ID	**Comments**	**General comments**
1		
2		
⋮		
n		

Plot of results

Y.2.7 Grid charge test results

The following table can be used to report the grid charge test results (Appendix P).

Table Y.7 (1 of 2) – Grid charge test report template

Report name	**Grid charge test**	
Procedure(s)		
Manufacturer		
Product name		
Model number		
Test lab		
Approving person		
Approval date		
Sample ID	**Grid-charge run time to L_{70} (h)**	
1		
2		
⋮		
n		
Average (%)		
Coefficient of variation (%)		
Rating		
Average deviation from rating (%)		
Sample ID	**Comments**	**Overall comments**
1		
2		
⋮		
n		

Y.2.8 Electromechanical charge test results

The following table can be used to report the electromechanical charge test results (Appendix Q).

Table Y.8 – Electromechanical charge test report template

Report name	**Electromechanical charge test**
Procedure(s)	
Manufacturer	
Product name	
Model number	
Test lab	
Approving person	
Approval date	

Sample ID	**Mechanical charger power (W)**	**Mechanical charge ratio**
1		
2		
⋮		
n		
Average (%)		
Coefficient of variation (%)		
Rating		
Average deviation from rating (%)		

Sample ID	**Comments**	**Overall comments**
1		
2		
⋮		
n		

Y.2.9 Outdoor PV module I-V characteristics test results

The following table can be used to report the outdoor PV module I-V characteristics test results (Appendix R).

Table Y.9 (1 of 2) – Outdoor PV module I-V characteristics test report template

Report name	**PV module I-V characteristics test**
Procedure(s)	
Manufacturer	
Product name	
Model number	
Test lab	
Test location	
Approving person	
Approval date	

Sample ID	**Measurements at STC**				
	Short-circuit current (A)	**Open-circuit voltage (V)**	**Maximum power point**		
			Power (W_p)	**Current (A)**	**Voltage (V)**
1					
2					
⋮					
n					
Average					
Coefficient of Variation (%)					
Rating					
Average deviation from rating (%)					

Sample ID	**Measurements at NOCT**					**Temperature coefficient for voltage (1/°C)**
	Short-circuit current (A)	**Open-circuit voltage (V)**	**Maximum power point**			
			Power (W_p)	**Current (A)**	**Voltage (V)**	
1						
2						
⋮						
n						
Average						
Coefficient of Variation (%)						

Table Y.9 (2 of 2) – Outdoor PV module I-V characteristics test report template

<table>
<tr><th>Sample ID</th><th>Comments</th><th>Overall comments</th></tr>
<tr><td>1</td><td></td><td rowspan="4"></td></tr>
<tr><td>2</td><td></td></tr>
<tr><td>⋮</td><td></td></tr>
<tr><td>n</td><td></td></tr>
<tr><td colspan="3">I-V curve plot(s)</td></tr>
</table>

Y.2.10 Solar charge test results

The following table can be used to report the solar charge test results (Appendix S).

Table Y.10 – Solar charge test report template

Report name	**Solar charge test**		
Procedure(s)			
Manufacturer			
Product name			
Model number			
Test lab			
Approving person			
Approval date			
Sample ID	**Generator-to-battery charging efficiency (%)**	**Solar operation efficiency (%)**	**Solar Run Time (h)**
1			
2			
⋮			
n			
Average (%)			
Coefficient of Variation (%)			
Sample ID	**Comments**		**General comments**
1			
2			
⋮			
n			

Y.2.11 Charge controller behaviour test results

The following table can be used to report the charge controller behaviour test results (Appendix T).

Table Y.11 – Charge controller behaviour test report template

Report name	**Charge controller behaviour test**
Procedure(s)	
Manufacturer	
Product name	
Model number	
Test lab	
Approving person	
Approval date	
Active deep discharge protection (yes/no)	
Active overcharge protection (yes/no)	
Passive deep discharge protection (yes/no)	
Passive overcharge protection (yes/no)	

Sample ID	**Deep discharge protection voltage (V)**	**Overcharge protection voltage (V)**	**Passive deep discharge protection voltage at 24 h (V/cell)**	**Passive overcharge continuous charging current (mA)**	**30-day battery self-consumption fraction (%)**
1					
2					
⋮					
n					
Average					
Coefficient of Variation (%)					
Rating					
Average Deviation from Rating (%)					

Sample ID	**Comments**	**General comments**
1		
2		
⋮		
n		

Y.2.12 Light distribution test results

The following table can be used to report the light distribution test results (Appendix U).

Table Y.12 – Light distribution test report template

Report name	**Light distribution test**
Procedure(s)	
Manufacturer	
Product name	
Model number	
Setting	
Test lab	
Approving person	
Approval date	

Sample ID	**Vertical full width half maximum angle (°)**	**Horizontal full width half maximum angle (°)**	**Average useable area through L_{70} (m^2)**	**Drive current (A)**	**Drive voltage (V)**
1					
2					
⋮					
n					
Average					
Coefficient of Variation (%)					

Sample ID	**Comments**	**General comments**
1		
2		
⋮		
n		

Plots

Y.2.13 Physical and water ingress protection test results

The following table can be used to report the water exposure and physical ingress protection test results (Appendix V).

Table Y.13 – Physical and water ingress protection test report template

Report name	**Physical and water ingress protection test**			
Procedure(s)				
Manufacturer				
Product name				
Model number				
Test lab				
Approving person				
Approval date				
Minimum required water exposure rating				
Minimum required physical ingress protection rating				
Sample ID	**Water exposure rating**	**Method used**	**Physical ingress protection rating**	**Method used**
1				
2				
⋮				
n				

Sample ID	**Comments**	**General comments**
1		
2		
⋮		
n		

Photographs

Y.2.14 Mechanical durability test results

The following table can be used to report the mechanical durability test results (Appendix X).

Table Y.14 (1 of 3) – Mechanical durability test report template

Report name	**Mechanical durability test**
Procedure(s)	
Manufacturer	
Product name	
Model number	
Test lab	
Approving person	
Approval date	

Sample ID	1. Functional (pass/fail) 2. Damage (pass/fail) 3. Safety hazard(s) (pass/fail)						Comments
	Drop 1	**Drop 2**	**Drop 3**	**Drop 4**	**Drop 5**	**Drop 6**	
1							
2							
⋮							
n							
General drop test comments							

Sample ID	1. Cycles achieved 2. Damage (pass/fail) 3. Safety hazard(s) (pass/fail)				Comments
	Switch/connector 1	**Switch/connector 2**	**...**	**Switch/connector n**	
1					
2					
⋮					
n					
General switch and connector test comments					

Table Y.14 (2 of 3) – Mechanical durability test report template

Sample ID	Gooseneck cycles achieved	Damage (pass/fail)	Safety hazard(s) (pass/fail)	Comments
1				
2				
⋮				
n				
General gooseneck test comments				

Sample ID	1. Strain relief hanging time achieved (s) 2. Damage (pass/fail) 3. Safety hazard(s) (pass/fail)																Comments
	Cable end 1				Cable end 2				...				Cable end n				
	0	30	60	90	0	30	60	90	0	30	60	90	0	30	60	90	
1																	
2																	
⋮																	
n																	
General strain relief test comments																	

Drop test photographs

Table Y.14 (3 of 3) – Mechanical durability test report template

Switch and connector test photographs
Gooseneck test photographs
Strain relief test photographs

Y.2.15 Summary of test results

The following table can be used to report a summary of the test results.

Table Y.15 (1 of 3) – Summary test report template

Report name	**Summary**			
Manufacturer				
Product name				
Model number				
Test lab				
Approving person				
Approval date				
Metric	**Average measured value**	**Coefficient of variation (%)**	**Rating (if available)**	**Deviation, if applicable (%)**
Battery capacity (mAh)				
PV module power (W_p)				
Full-battery run time, setting 1 (h)				
Full-battery run time, setting 2 (h)				
⋮				
Full-battery run time, setting n (h)				
Average luminous flux during discharge, setting 1 (lm)				
Average luminous flux during discharge, setting 2 (lm)				
⋮				
Average luminous flux during discharge, setting n (lm)				
Solar run time, setting 1 (h)				
Solar run time, setting 2 (h)				
⋮				
Solar run time, setting n (h)				

Table Y.15 (2 of 3) – Summary test report template

Working area ≥ 25 lux, setting 1 (m^2)				
Working area ≥ 25 lux, setting 2 (m^2)				
⋮				
Working area ≥ 25 lux, setting n (m^2)				
Angle of radiation ≥ 4 lux, setting 1 (°)				
Angle of radiation ≥ 4 lux, setting 2 (°)				
⋮				
Angle of radiation ≥ 4 lux, setting n (°)				
Percentage of initial lumen output maintained (%)				
Colour rendering index, setting 1				
Colour rendering index, setting 2				
⋮				
Colour rendering index, setting n				
Correlated colour temperature, setting 1				
Correlated colour temperature, setting 2				
⋮				
Correlated colour temperature, setting n				
Number of non-functional samples after drop test				
Number of samples with safety hazards after drop test				
Number of non-functional samples after switch/connector test				

Table Y.15 (3 of 3) – Summary test report template

Number of samples with safety hazards after switch/connector test				
Number of non-functional samples after gooseneck test				
Number of samples with safety hazards after gooseneck test				
Number of non-functional samples after strain relief test				
Number of samples with safety hazards after strain relief test				
General comments				

Appendix Z
(informative)
Photometer box for relative luminous flux measurements

Z.1 Background

This appendix includes plans and instructions for building a photometer box – an optical cavity for relative luminous flux measurements that can be used to measure the run time or lumen maintenance of lighting products. Photometer boxes can be built for much lower cost than integrating spheres or similar equipment.

NOTE Photometer boxes should not be used to measure absolute luminous flux.

The box is a cube that is painted with high-reflectivity, matte white paint inside. The DUT is placed in the centre of the box either by hanging from the top or on a stand. An illuminance meter is placed in one of the corners with a baffle blocking direct light from the DUT. Because the light meter only "sees" reflected light, the measurements of relative illuminance in time are less sensitive to the arrangement of the lighting device and therefore more robust.

For a given product in a fixed orientation, the reading from the illuminance meter is directly proportional to the luminous flux of the DUT but does not represent the absolute luminous flux. The same photometer box and light meter should be used for any given test, since different boxes and light meters will result in different relative light outputs.

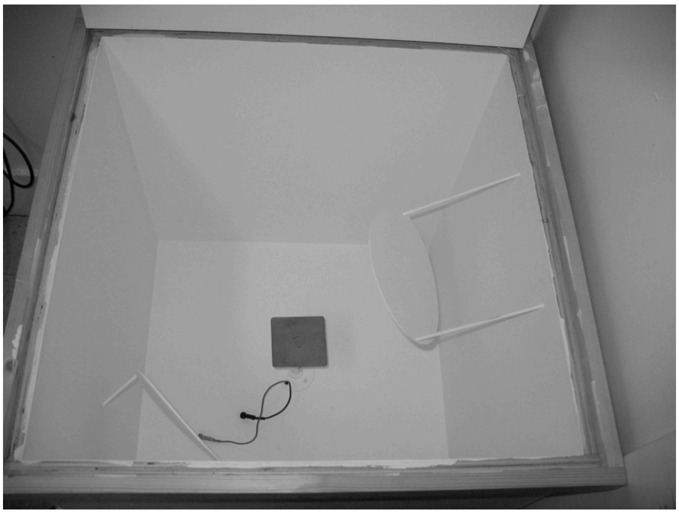
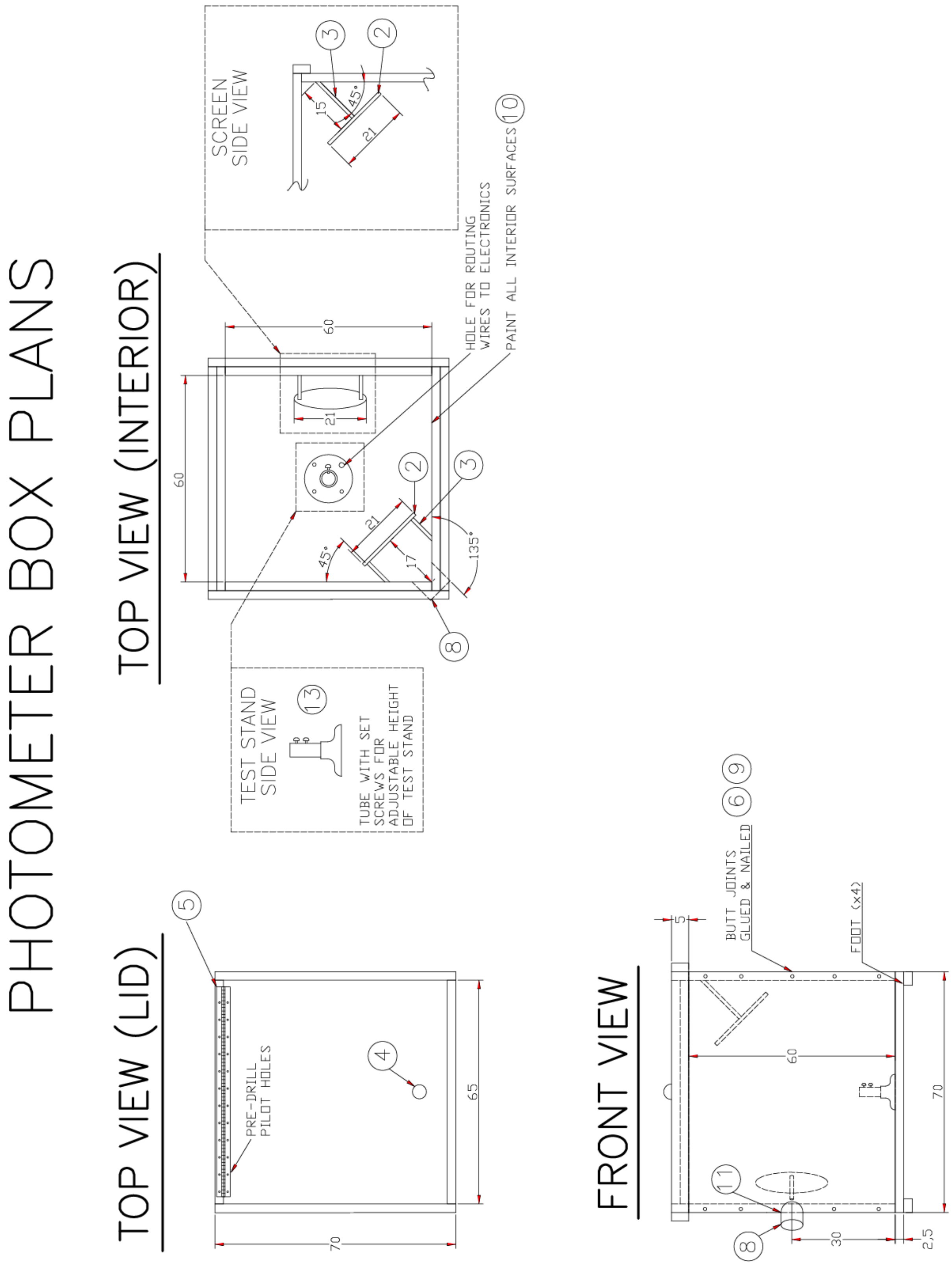


Figure Z.1 – Interior view of completed photometer box.

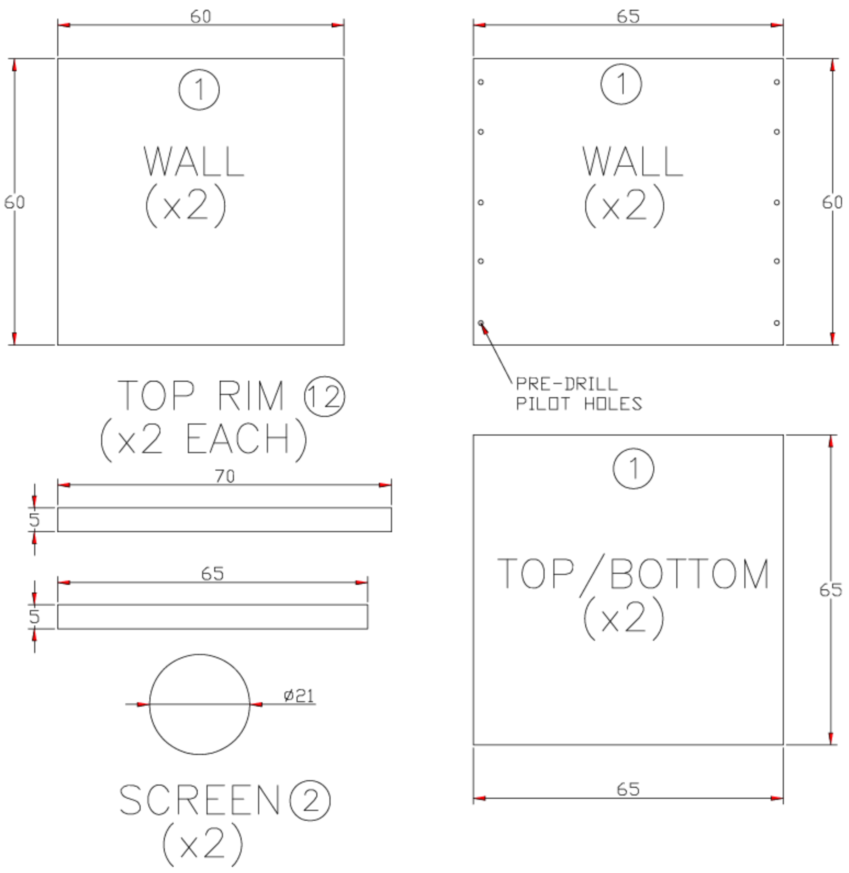
Figure Z.2 – Exterior view of completed photometer box.

Z.2 Plans

The measurements in the plans below are in cm.


PHOTOMETER BOX PLANS
TOP VIEW (INTERIOR)
SCREEN SIDE VIEW
HOLE FOR ROUTING WIRES TO ELECTRONICS
PAINT ALL INTERIOR SURFACES
TEST STAND SIDE VIEW
TUBE WITH SET SCREWS FOR ADJUSTABLE HEIGHT OF TEST STAND
TOP VIEW (LID)
PRE-DRILL PILOT HOLES
FRONT VIEW
BUTT JOINTS GLUED & NAILED
FOOT (x4)

MAIN PIECES FOR ASSEMBLY



LIST OF MATERIALS

1. PLYWOOD (2,5 CM THICK)
2. RIGID PLASTIC (0,5 CM THICK)
3. WOOD DOWEL (0,5 CM DIA.)
4. HANDLE (SCREW–IN)
5. HINGE (APPROX. 61 CM x 4 CM)
6. FINISHING NAILS
7. WOOD SCREWS
8. PVC PIPE
9. WOOD GLUE
10. WHITE EMULSION PAINT
11. CAULK SEALANT
12. NON–LAMINATED WOOD
13. TEST STAND COMPONENTS (BASE, PIPE, SET SCREWS)

Z.3 Instructions for construction

a) Cut the "MAIN PIECES FOR ASSEMBLY" to the dimensions shown on PHOTOMETER BOX PLANS – Use a table saw if available

b) Pre-drill pilot holes on 65cm x 60cm wall pieces

c) Apply glue along 2,5cm x 60cm area of wall pieces with pilot holes

d) Use four clamps (one at top, one at bottom for each side) to hold the four walls together as shown on in the top view of PHOTOMETER BOX PLANS

e) Drive finish nails into pre-drilled pilot holes

f) Allow 12 hours for glue to cure

g) Remove clamps

h) Check butt joints for structural integrity

i) Apply glue to bottom edges of walls

j) Align and clamp bottom piece to walls

k) Allow 12 hours for glue to cure

l) Remove clamps

m) Check for structural integrity

n) Cut 4cm x 4cm feet (as shown in front view of PHOTOMETER BOX PLANS) and glue to four exterior corners of bottom piece. The weight of the photometer box will hold the feet in place while the glue cures

o) Apply glue to 2,5cm width of "TOP RIM" pieces along top outside perimeter of walls

p) Place "TOP RIM" pieces on outside walls as shown in PHOTOMETER BOX PLANS and clamp in place

q) Allow 12 hours for glue to cure

r) Remove clamps

s) Check for structural integrity

t) Drill hole in corner of photometer box for placement of PVC section – Use a hole saw if available

u) Cut PVC pipe to appropriate length and mitre cut to tightly fit against hole in photometer box

v) Affix PVC section to photometer box with caulk sealant, making sure to seal against all possible light intrusion at joint

w) Assemble test stand and attach with wood screws to centre bottom of photometer box as shown in top view

x) Cut plastic screens and drill holes for insertion of dowels

y) Drill holes at appropriate angles and locations for screen dowels, refer to top view (interior)

z) Insert screen dowels into holes in photometer box walls. No glue should be required

aa) Place top lid piece onto photometer box

bb) Align hinge as shown in top view (lid)

cc) Pre-drill pilot holes and attach hinge with wood screws

dd) Pre-drill hole for handle (as shown in top view) and attach to lid

ee) Paint ALL interior surfaces of photometer box with white emulsion paint, matte finish. Several light coats are recommended (at least five coats).

Appendix AA
(informative)
Photometer tube for relative luminous flux measurements

AA.1 Background

This appendix includes plans and instructions for building a photometer tube – a very simple optical cavity for relative illuminance measurements that can be used to measure the run time or lumen maintenance of lighting products. Photometer tubes are very low cost option; the only option with lower equipment costs is placing a lighting product in a dark room or closet and arranging the light meter in a fixed position relative to the product.

NOTE Photometer boxes should not be used to measure absolute luminous flux.

The tube simply a cardboard (or similar) tube with a photometer sensor fixed on one end. The other end of the tube is placed so the sensor has a clear view of the peak light output from the DUT. The function of the cardboard tube is to block stray light.

For a given product in a fixed orientation, the reading from the illuminance meter is directly proportional to the luminous flux of the DUT but does not represent the absolute luminous flux. The same photometer tube and light meter should be used for any given test, since different boxes and light meters will result in different relative light outputs.

AA.2 Plans

The photo (below) and schematic (see section K.4.1.1.3) give a general indication of how to construct a photometer tube.

Figure AA.1 – Completed photometer tube.

AA.3 Instructions for construction

Photometer tubes can be constructed of a variety of materials. The specific materials should be selected based on availability. Below are some guidelines for selecting materials:

Tube: cardboard or paperboard is typically used. PVC pipe or similar materials may also be used. The inside diameter should be between 5-7 cm. The length should be approximately 50 cm. No coatings are required on the inside of the tube.

Photometer: the photometer should have appropriate sensitivity to measure.

Cap: The cap should fit snugly in one end of the tube and hold the photometer sensor in a fixed position so it is faced directly down the centre axis of the tube. Wood that has been turned on a lathe is often the best material, since it can be sanded to fit.