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PQS Independent type-testing protocol

TITLE: Solar Direct Drive Basic Energy Harvest Control devices

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Contents

1. Scope

At health facilities with limited or no electrical service there is increasing demand for solar generated electricity for solar direct drive (SDD) vaccine refrigeration and water-pack freezing as well as power for remote temperature monitoring devices. SDD power systems are oversized to assure that safe vaccine storage conditions are sustained and therefore are a potential source of harvestable solar electricity for other unmet immunization and facility needs. Next generation SDD appliances coupled with an optional accessory energy harvest control (EHC) can safely supply some of these power needs while assuring the priority need to keep vaccine within the acceptable temperature range.

A Basic EHC is an accessory control device and/or system to enable the use of harvestable solar electricity for powering remote temperature monitoring devices (RTMD) in addition to an immunization appliance. Three categories of energy harvesting strategies have been identified: Basic, Kit and Custom.

A Basic EHC is the simplest energy harvest strategy, is integrated into the SDD appliance and output to load is limited to 5 V dc and a minimum of 0.5 amp to a maximum of 1 amp (i.e., 2.5 to 5 watts). The single output is through a USB-A port with protections against electrical overload, short circuit, reverse polarity, high voltage input and damage from high temperatures. More complex EHC strategies include less limited USB ports, "kit" and adjustable output types of EHC that may also include USB ports, may be standalone from the appliance, are not limited in voltage output(s) and can provide any amount of watt hour per day. These more complex EHC strategies must comply with **WHO/PQS/E007/EHC01** specifications and testing per **WHO/PQS/E007/EHC01-VP.1**. The requirements of a Basic EHC as defined in **WHO/PQS/E007/EHC02** do not apply or modify the testing of any EHC that requires prequalification per **WHO/PQS/E007/EHC01-VP.1** including those that include only a USB-A output with power output that is not limited per this specification.

The scope of this verification protocol is to verify compliance of a Basic EHC that assures the SDD appliance will operate correctly and provide limited solar generated electricity for secondary 5 V dc electric consuming devices (loads) such as remote temperature monitoring devices (RTMD) that comply with **WHO/PQS/E006/TR03.** This is generally done with a power management circuit that must simultaneously satisfy: a high voltage input, high efficiency, and high reliability.

A Basic EHC is an optional accessory for SDD appliances prequalified per **WHO/PQS/E003/FZ03** or **E003/RF05**. Specific Basic EHC testing is described in this verification protocol for llaboratory testing to be conducted on the Basic EHC when coupled with a specific SDD appliance(s) to assure:

- the Basic EHC does not have an adverse impact on appliance operation;
- if the Basic EHC fails the appliance cooling circuit will remain fully functional;
- if the load is improperly connected to the Basic EHC the appliance is undamaged; and
- harvestable solar electricity to a 5 V dc load is a minimum of 0.5 amp to a maximum of 1 amp (i.e., 2.5 to 5 watts).

To become prequalified the Basic EHC requires laboratory testing with two full verification protocols:

1. Regular SDD appliance testing modified to include a fixed dc load set to 5 V dc and limited between 2.5 watts to 5 watts continuously connected throughout all SDD appliance tests and then assuming the SDD passes all tests
2. Basic EHC testing to assure it operates correctly and has required fail safe features per this verification protocol.

The Basic EHC will be required to be tested with at least one compatible SDD appliance where the Basic EHC option will be offered. A specific SDD appliance with a Basic EHC will be tested per the applicable WHO/PQS/E003 appliance verification protocol modified to include a 5 V dc load defined by the legal manufacturer and limited between 2.5 watts to 5 watts that will remain continually connected to the appliance through all testing. The Basic EHC will also be required to be tested for fail safe operation and to assure it operates correctly per **WHO/PQS/E007/EHC 02**. If multiple different model SDD appliances use the identical Basic EHC, identical cooling system, identical control system and identical solar power system then a single set of tests can be accepted to prequalify multiple SDD appliance models with the identical Basic EHC. Loads are not specified herein, not tested and not prequalified.

Any SDD that has also been prequalified with a Basic EHC with only USB-A port outputs prior to the publication date of this specification will not be required to undergo further PQS prequalification testing.

Basic EHC design must account for performance degradation over the 10-year target life of the appliance in order to sustain operation and features including USB-A port connection/disconnection durability rated to 10,000 cycles per **EIA-364-09**.

The build quality of the Basic EHC must be consistent with the conditions under which these SDD appliances are used, including, but not limited to, the following:

- Transport by air, sea and over rough, dusty road surfaces.
- High and low temperatures in transport, storage and operation.
- High humidity in transport, storage and operation.
- Operating locations with high wind and high density of dust particles.
- Operating locations near corrosive marine environments.
- Users with inconsistent training.
- Users with no specific maintenance tools.

2. Normative references

Use most recent version.

EIA-364-09, Revision D, January 17, 2018 - TP-09D Durability Test Procedure for Electrical Connectors and Contacts
EMAS: *European Union Eco-Management and Audit Scheme*.
GHS Rev 5. United Nations: *Globally Harmonized System of Classification and Labelling of Chemicals.*
IEC 60335-1: Amendment 1: *Household and similar electrical appliances - Safety - Part 1: General requirements.*
IEC 60335-2-24: 2020 *Household and similar electrical appliances - Safety - Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances and ice-makers.*
IEC 60364-1: 2005: *Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions*.

IEC 61000-6-1 edition 3.0: 2016: *Electromagnetic compatibility (EMC) Generic standards - Immunity for residential, commercial and light-industrial environments.*
IEC 61000-6-3 edition 3.0: 2020: *Electromagnetic compatibility (EMC) Generic standards - Emission standard for residential, commercial and light-industrial environments.*
IEC 62552: Parts 1, 2 & 3: *Household refrigerating appliances – Characteristics and test methods.*
ISO 9001: *Quality Management Systems – Requirements.*
ISO 14001: 2015: *Environmental management systems - Requirements with guidance for use.*
ISO 20282-1: 2006: *Ease of operation of everyday products - Part 1: Context of use and user characteristics.*
ISO/IEC 17025: 2017 *General requirements for the competence of testing and calibration laboratories.*
WHO/PQS/E003/FZ03: *Performance specification: Water-pack freezer: Solar direct drive without battery storage.*
WHO/PQS/E003/FZ03 VP.1: *Independent type testing protocol: Water-pack freezer: Solar direct drive without battery storage.*
WHO/PQS/E003/RF05.4: *Performance specification: Refrigerator or combined refrigerator and water-pack freezer: Solar direct drive without battery storage.*
WHO/PQS/E003/RF05 VP.4: *Independent type testing protocol: Refrigerator or combined refrigerator and water-pack freezer: Solar direct drive without battery storage.*
WHO/PQS/E003/PV01: *Performance specification: Solar power system for compression-cycle vaccine refrigerator or combined refrigerator and water-pack freezer.*
WHO/PQS/E006/TR03.2*: Programmable remote temperature and event monitoring systems*
WHO/PQS/E007/EHC02.1: *Performance specification: Solar direct drive Basic Energy Harvest Control devices.*

3. Terms and definitions

Adverse impact: Any cause preventing the appliance from continually sustaining acceptable vaccine storage temperatures and/or water pack freezing performance as defined by applicable PQS appliance performance specification(s).
Appliance: Any solar direct drive (SDD) vaccine refrigerator, water-pack freezer or combined vaccine refrigerator and water-pack freezer.
Basic EHC: an energy harvest control strategy where electrical energy is delivered via one USB-A port integrated in a solar direct drive appliance output at nominal 5 V dc of at least 2.5 watts and not more 5 watts.
Energy harvest: The collection, distribution and use of surplus solar electricity for loads in addition to an immunization appliance.
Energy harvest control (EHC): Accessory control device and/or system to enable the use of surplus solar photovoltaic electricity for powering other electricity consuming devices (loads) in addition to an immunization appliance. An EHC may harvest surplus electricity when the active cooling circuit is off and/or when the active cooling circuit is on and sufficient surplus electricity is available.

Fixed dc load: A laboratory test device to simulate the connection of a continuous direct current load (i.e., 5 V dc, minimum of 2.5 watts up to a maximum of 5 watts).
Harvestable solar electricity: Direct current electricity generated by the solar direct drive appliance solar power system.
In writing: Communication by letter, fax or email.
Legal manufacturer: The natural or legal person with responsibility for the design, manufacture, packaging and labelling of a product or device before it is placed on the market under her/his own name, regardless of whether these operations are carried out by that person or on her/his behalf by a third party.
Load: Any end-use device in an electrical circuit (other than the primary appliance and EHC) that can consume power when the electrical circuit is energized.
Operate(s) correctly: The component or components being referred to function as normally expected.
Preventive maintenance: Activities associated with the upkeep of an appliance or solar power system to protect against normal wear and tear. This type of maintenance requires minimal skills and training, and is usually scheduled for regular intervals (daily, weekly, or monthly). On-site workers who have received appropriate training are responsible for preventive maintenance.
Remote temperature monitoring device (RTMD): electrically powered cold chain temperature measuring equipment that uses some means of communication (mobile network, GPRS, UHS, satellite, etc.) to periodically transmit data to the cloud.
Reseller: A commercial entity, licensed to act on behalf of a legal manufacturer, and which carries product liability and warranty responsibilities no less onerous than those carried by the legal manufacturer.
SDD: solar direct drive as defined in **WHO/PQS/E003/RF05** or **WHO/PQS/E003/FZ03**.
Solar power simulator (SPS): A supply of power intended to simulate solar array output at specific instantaneous solar radiation values.
Solar power system: An assembly of solar module(s), electrical cabling and support structure complying with **WHO PQS E003/PV 01**.
Standard electrical connector: Common electrical connectors including all USB receptacles, 12 V dc receptacles as used in vehicles and 120/230 V ac receptacles as used in buildings and electrical generators.
USB-A port: a 5 V dc connection complying with USB.org power specifications specific to USB-A.

4. Applicability

Type-testing will be carried out by an independent **ISO/IEC 17025** testing laboratory, accredited by WHO.

5. Type-testing procedure

5.1 Evidence of conformity assessment:

Products must carry the CE mark, UL mark and/or equivalent internationally accepted evidence of conformity assessment.

5.2 Number of samples

The legal manufacturer or reseller must supply the testing laboratory with a full duplicate set of the Product Dossier already supplied to WHO in accordance with the requirements of specification clause 7. One sample of the complete product is required including appliance with a compatible Basic EHC integrated in the appliance. A compatible solar power system is not required. Manufacturer to supply Basic EHC ready to be tested and testing laboratory to provide a fixed DC load device with capacity to test the Basic EHC power output to the load equal to a.) 2.5 up to 5 Watts, 5 Vdc continuous and b.) 10 Watts, 5 Vdc continuous.

If more than one version of the Basic EHC and appliance assembly is available provide one sample of each version.

If the Basic EHC is to be used with multiple different appliance models, then all appliances must be provided and tested with the Basic EHC. If a legal manufacturer or reseller certifies in writing that multiple appliances use the identical cooling system, identical appliance control system and identical solar power system and with preapproval in writing from the PQS Secretariat then a single sample and single set of tests can be accepted to prequalify multiple SDD appliance models with a specified Basic EHC.

5.3 Test procedure

5.3.1 Solar power simulator (SPS) and fixed DC load

All performance tests use direct current (DC) sources to simulate 1. a solar power array and 2. a fixed DC load to simulate a 2.5 to 5 watt, 5 Vdc load and 10 watt, 5 V dc load. The fixed DC load must both consume and dissipate the specified test watts. Tests 2-5 in this document use part or all of the solar radiation variation defined in Table 1.

To simulate a solar power array, use an electronic power supply or multiple power supplies connected to timers. The combined power supply and timer accuracy must be of ±0.1% or better. The power supply must simulate solar radiation variations by staging the power output with output stages equal to 0.0 kWh/m^2, 0.05 kWh/m^2, 0.25 kWh/m^2, 0.35 kWh/m^2 and 0.45 kWh/m^2 for appliance testing per **WHO/PQS/E003/FZ03** and **WHO/PQS/E003/RF05**. Additional output stages of 1.00 kWh/m^2 are required to simulate solar radiation variations equal to solar module/solar array maximum power point at standard test condition (STC) of 1.00 kW/m^2 and a second additional stage of 1.35 kWh/m^2 to simulate possible peak power conditions.

The manufacturer must also specify the required solar power system profile including:

- Volts (in operation).
- Amperes (Imp from solar module specification).

Amperage will be verified from solar module data sheets and will be based on solar module specifications as reported under standard test conditions (STC =1000 W/m² at 25˚C). The amperes will vary directly with the power supply output variations (e.g., use 45% of reported STC value for output stage 0.45 kWh/m2). The voltage may remain constant or may vary only if cooling system voltage varies with corresponding amperage.

TABLE 1: Solar Radiation Variation

Daytime solar phase variations
1 hour at 50 W/m²
2.5 hours of 5 cycles of 15 minutes at 250 W/m² followed by 15 minutes at 0 W/m²
0.5 hours of 1 cycle of 15 minutes at 350 W/m² followed by 15 minutes at 0 W/m²
4 hours at 1350 W/m²
0.5 hours of 3 cycles of 5 minutes at 350 W/m² followed by 5 minutes at 0 W/m²
2.5 hours of 15 cycles of 5 minutes at 250 W/m² followed by 5 minutes at 0 W/m²
1 hour at 50 W/m²

Note: All appliance tests utilize only the 3.5 kWh/m^2/day solar radiation reference period per **WHO/PQS/E003/RF05 VP** and **WHO/PQS/E003/FZ03 VP.** All appliance tests must be conducted with the Basic EHC energized and a fixed DC load of 2.5 to 5 Watt, 5 Vdc continuous as specified by the legal manufacturer.

5.3.2 Test temperatures and other measurements

All appliance and Basic EHC assemblies are to be tested to hot zone temperatures and per **Annex 1- General Test Conditions**. Other temperatures may be optionally tested in addition to the hot zone temperature requirement. Record test room ambient and internal cabinet temperatures for at least 48 hours prior to all tests. The specific tests listed below apply equally to a moderate zone, temperate zone and hot zone appliance. Relevant test chamber temperatures are given in the following format M:<XX>°C for moderate zone; T:<XX>°C for temperate zone and H:<XX>°C for hot zone.

Measurements will be required to determine power flow to Basic EHC from solar power system, between Basic EHC and appliance as well as between Basic EHC and the fixed DC load. Both voltage and current measurements are required. Measurement accuracy required is:

- Solar power simulator combined power supply (voltage and amperage) and timer accuracy: ± 0.1% or better
- Power to Basic EHC (voltage and amperage): ± 0.1% or better
- Power to cooling system (voltage and amperage): ± 1%.
- Power to fixed DC load (voltage and amperage): ± 1%.
- Fixed DC load: (Watts) ± 1%.
- Thermostat voltage or signal for cooling: ± 1% or better

5.3.3 Test 1: Type examination

- **Step 1:** Unpack the product. Using the manufacturer's installation instructions only, set up the system components. Record the process and any problems encountered.

- **Step 2:** Check all samples for similarities between different models[1], dissimilarities between samples of one model, any defects or damage or any problem which make it difficult or impossible to test the complete assembly of appliance and Basic EHC.

- **Step 3:** Record any differences between the samples ordered and those received.

- **Step 4:** Tabulate the following information for each model submitted for examination. Obtain any additional supporting information required in writing from the legal manufacturer or reseller and attach this information to the report:

Identification:

- Code (a unique identifier to be assigned by the testing laboratory).
- Model (SDD appliance and include any further identifiers for the Basic EHC).
- Legal manufacturer or reseller.
- Country of origin.
- Conformity assessment markings (e.g. CE mark).

Performance characteristics:

- Load is defined by manufacturers conforms/does not conform to specification clause 4.1.
- Basic EHC disconnect means or bypass conforms/does not conform to specification clause 4.2.
- Legal manufacturer statement of the minimum daily quantity of energy harvest (Wh/average day) conforms/does not conform with specification clause 4.3.
- Compliance with related references conforms/does not conform to specification clause 4.4 (written certification required).
- SDD Appliance/Basic EHC power on/off switch conforms/does not conform to specification clause 4.5
- Appliance operation conforms/does not conform to specification clause 4.5 (written certification required).
- Appliance compatibility conforms/does not conform to specification clause 4.6.
- Solar power system compatibility conforms/does not conform to specification clause 4.7 (written certification required).

[1] The purpose of this inspection is to establish whether products offered by competing companies are re-badged versions of an otherwise identical product.

- Load compatibility conforms/does not conform to specification clause 4.8 (written certification required).
- Evidence that the USB-A port is rated to 10,000 cycles as certified by **EIA-364-09** conforms/does not conform with specification clause 4.8.
- Legal manufacturers statement of the minimum daily quantity of energy harvest (Wh/average day) conforms/does not conform with specification clause 4.9.
- Electrical safety rating conforms/does not conform to specification clause 4.10 (written certification required).
- Electromagnetic compatibility conforms/does not conform to specification clause 4.11 (written certification required).
- Restricted materials conforms/does not conform to specification clause 4.12 (written certification required).
- Maintenance and servicing provision conforms/does not conform to specification clause 4.13 (written certification required).
- Essential spare parts conforms/does not conform to specification clause 4.14.
- Disposal and recycling conforms/does not conform to specification clause 4.15.
- Instructions and labelling conforms/does not conform to specification clause 4.16.
- Training conforms/does not conform to specification clause 4.17 (written certification required).
- Human factors conforms/does not conform to specification clause 4.18 (written certification required).
- Repair or replacement requirement conforms/does not conform to specification clause 4.18.
- Warranty conforms/does not conform to specification clause 4.19.
- Ambient temperature range during transport and storage conforms/does not conform to specification clause 4.20.
- Ambient humidity range during transport, storage and use conforms/does not conform to specification clause 4.21.
- Protection against dust and water ingress conforms/does not conform to specification clause 4.22.

Physical data:
Wiring diagram for the appliance, Basic EHC and load provided.
- Record major Basic EHC dimensions in centimetres (± 1.0 cm).

- **Step 5:** Take high resolution digital photographs of the Basic EHC (if accessible.) Take additional photographs showing all external surfaces of the Basic EHC and the USB-A port connection(s). High resolution digital images should be provided for attachment to the PQS report.

Acceptance criteria: Inspection indicates full conformity with all major specification requirements. System setup must be straightforward and trouble-free.

5.3.4 Test 2: Excess load and solar radiation variation

This test is to 1. assure that the Basic EHC is limiting output to the level specified by the legal manufacturer between 2.5 to 5 Watts at 5 V dc by imposing an excessive 10-Watt load on the system; 2. overload protection automatically returns to correct operation when the overload condition is removed and c.) stress the energy harvest components by imposing a peak value of simulated solar power.

Test conditions: Test chamber, appliance and Basic EHC to be +43ºC. Simulated solar power (SPS) input to be varied per Table 1.

- **Step 1:** Following completion of all applicable appliance tests **(WHO/PQS/E003/RF05 VP** or **WHO/PQS/E003/FZ03 VP)** continue testing per Test 3 Stable Running test conditions. Adjust the SPS per Table 1.
- **Step 2:** Connect the entire equipment assembly per manufacturer's instruction including the Basic EHC and appliance per manufacturer's instructions and then connect an excessive fixed DC load adjusted to 10 watts at 5 Vdc.
- **Step 3:** Connect the SPS and start the appliance and Basic EHC with fixed DC load connected and switched on. See Table 1 for power staging detail.
- **Step 4:** Allow the assembly to operate for one hour at SPS output equivalent to 50 W/m².
- **Step 5:** Beginning in the second hour and continuing for 2.5 hours, cycle the SPS supply at equivalent of 250 W/m² for 15 minutes and then 0 W/m² for 15 minutes.
- **Step 6:** Continue for 0.5 hours and cycle the SPS supply at equivalent of 350 W/m² for 15 minutes and then 0 W/m² for 15 minutes.
- **Step 7:** Beginning in the fourth hour and continuing for 4 hours, increase the SPS supply to equivalent of 1350 W/m² (peak power = solar array maximum rated power per STC x 1.35 safety factor).
- **Step 8:** Continue for 0.5 hours and cycle at the equivalent of 350 W/m² for 5 minutes and then 0 W/m² for 5 minutes.
- **Step 9:** Beginning in hour 8.5 and continuing for 2.5 hours, cycle the SPS supply at equivalent of 250 W/m² for 5 minutes and then 0 W/m² for 5 minutes.
- **Step 10:** Beginning in hour 11 allow the assembly to operate for one hour at SPS output equivalent to 50 W/m².
- **Step 11:** Report SPS output, appliance power (Watts) required to start cooling, appliance energy consumption in kWh/day, energy harvest input in Wh/day, energy harvest output in Wh/day, thermostat voltage (or other thermostat signaling) and the percentage of time the cooling system was running during the 12-hour solar phase. Graphically display all of the above and time, thermostat voltage (or cooling system signal for when cooling is required) and cooling system on/off cycles. Calculate the efficiency of the EHC.

Acceptance criterion: The appliance remains in correct operation and sustains acceptable vaccine storage temperature range and/or water pack freezer temperature range per applicable E003 specifications. Energy harvest continues and load is limited to the legal manufacturers specification of a single output value at 5 V dc (2.5 watts up to a maximum of 5 watts). EHC efficiency is calculated equal to or greater than 80%.

Rejection criterion: The cooling system control does not operate correctly at any time during the daytime solar phase. The appliance does not operate correctly and cannot 1. sustain acceptable vaccine storage temperature range for vaccine refrigerators; or 2. sustain acceptable water pack freezer temperature range; or 3. sustain both conditions a.) and b.) for combined vaccine refrigerator-water pack freezer. Load exceeds legal manufacturer specification, exceeds 5 watts or exceeds 5 Vdc. EHC efficiency less than 80%.

Acceptance criterion (excess load): No obvious or quantifiable damage to Basic EHC and appliance and the Basic EHC and appliance continue to operate correctly. The Basic EHC automatically returns to correct operation when the excessive load is removed.

Rejection criterion (peak power input): The Basic EHC fails one or more acceptance criteria.

5.3.5 Test 3: Connection sequence

This test will determine if connection in any other possible sequence will result in damage or abnormal operation to either the appliance or the Basic EHC. If a hot swap repair feature is provided it will require this testing.

Test conditions: Continue Test 2 temperature conditions. Set the SPS to a power level equal to the solar array maximum power at STC (1000 W/m²).

- **Step 1:** Adjust the appliance to start the test with cooling system requiring cooling.

- **Step 2:**
  1. Connect SPS to appliance and switch appliance on. Confirm if appliance will operate correctly, confirm voltage and current measurements at USB-A port.
  2. Connect fixed DC load to USB-A port and switch USB-A port on (if switch supplied). Confirm voltage and current measurements at USB-A port.
  3. Switch off SPS, confirm voltage measurement at USB-A port.
  4. Switch off appliance, confirm voltage and current measurements at USB-A port.
  5. Disconnect fixed DC load, confirm voltage measurement at USB-A port.
  6. Switch on SPS, confirm voltage and current measurements at USB-A port.

7. Connect fixed DC load, confirm voltage and current measurements at USB-A port.
8. Switch on appliance, confirm if appliance will operate correctly, confirm voltage and current measurements at USB-A port.
9. Switch off solar power, confirm voltage and current measurements at USB-A port.
10. Disconnect fixed DC load.

- **Step 3:** Confirm if appliance will operate correctly, confirm voltage and current measurements at USB-A port.

- **Step 4:** Repeat step 2-3 until all possible connection sequences have been tested. For each separate connection sequence this test is to be conducted when appliance requires cooling to observe the impact on cooling system. If hot swap repair feature is included the laboratory will conduct one complete series of this Test 3 sequence with the repair USB-A part(s) provided by legal manufacturer.

Acceptance criterion: After all possible connection sequences have been tested the Basic EHC and the appliance does operate correctly.

Rejection criteria: Failure of the Basic EHC and/or appliance to operate correctly following any sequence of connections.

5.3.6 Test 4: Reverse polarity connections

This test will determine if a reversed polarity fixed DC load will result in damage or abnormal operation to either the appliance or the Basic EHC.

Test conditions: Continue Test 2 temperature conditions. Set the SPS to a power level equal to the solar array maximum power at STC (1000 W/m²).

- **Step 1:** Adjust the cooling system control to continually require cooling. Switch on the SPS, appliance, and fixed DC load and confirm all operate correctly. Disconnect SPS.
- **Step 2:** Reverse the SPS input polarity (+ and -) and reconnect to the appliance.
- **Step 3:** Turn on SPS output.
- **Step 4:** Record and report appliance cooling system and Basic EHC operation.
- **Step 5:** Switch off all components, disconnect fixed DC load and reconnect all components per manufacturer's instruction (i.e., correct polarity).
- **Step 6:** Confirm the Basic EHC and cooling system operate correctly in all modes of operation.
- **Step 7:** Reverse the fixed DC load polarity (+ and -) and reconnect to the appliance.
- **Step 8:** Turn on SPS output.

- **Step 9:** Record and report appliance cooling system and Basic EHC operation.
- **Step 10:** Switch off all components, disconnect fixed DC load and reconnect all components per manufacturer's instruction (i.e., correct polarity).
- **Step 11:** Confirm the Basic EHC and cooling system operate correctly in all modes of operation.

Acceptance criterion: At the end of the reverse polarity testing and after polarity connections are all correctly reconnected the appliance cooling system and Basic EHC now operate correctly.

Rejection criteria: Failure of an overcurrent protection device to reconnect automatically. At the end of the reverse polarity testing and after polarity connections are all correctly reconnected any failure of Basic EHC and/or appliance cooling system to operate correctly.

5.3.7 Test 5: Short circuit

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This test will determine if a short circuit at the fixed DC load will result in damage or abnormal operation to either the appliance or the Basic EHC.

Caution: Lab to provide an adequately rated overcurrent protection device such a DC circuit breaker or fuse in the Basic EHC output circuit located between the EHC and fixed DC load.

Caution: Lab technicians should wear personal protective equipment as required depending on hazards possible in this test.

Test conditions: Continue Test 2 temperature conditions. Set the SPS to a power level equal to the solar array maximum power at STC (1000 W/m²).

- **Step 1:** Adjust cooling system to continually not require cooling to test the performance of the Basic EHC when all electricity is available for energy harvest.
- **Step 2:** Connect the fixed DC load and confirm voltage and current measurements at USB-A port. When energy harvest is confirmed with measurement equal to legal manufacturers specification (between 2.5 to 5 watts) remove the fixed DC load and establish a short circuit at the USB-A port.
- **Step 3:** Adjust the cooling system to require cooling.
- **Step 4:** After at least 5 minutes record and report cooling system operation. Proceed to Step 5 if the cooling system will operate correctly. Halt the tests if the cooling system will not operate correctly.
- **Step 5:** Correct short circuit. Reset any breakers or replace any blown fuses.
- **Step 6:** Connect the fixed DC load. Confirm the Basic EHC will operate correctly.

- **Step 7:** Adjust system to not require cooling and initiate energy harvest diversion to fixed DC load. Confirm cooling system will operate correctly and Basic EHC will operate correctly. Additionally record and report any notable abnormal Basic EHC operation.

Acceptance criterion: After short circuit is established the Basic EHC must not create an adverse impact for the appliance cooling system operation. After short circuit is corrected the Basic EHC must demonstrate that the cooling system will operate correctly, the Basic EHC is undamaged, will operate correctly and restores energy harvest diversion to the fixed DC load.

Rejection criteria: Basic EHC creates any adverse impact on appliance cooling system operation during short circuit. Failure of the Basic EHC to sustain appliance cooling system operation and restore energy harvest diversion to load after short circuit correction. Identification of any notable damage or change to Basic EHC operation that does not return to operate correctly after short circuit is corrected.

5.4 Test criteria for qualification

A final report must be issued after all testing is complete. The report of the tests must contain the following data and analyses:

- **Statement of acceptance of all tests:** The SDD appliance, when coupled to the Basic EHC with a USB-A port connected continuously to a fixed DC load at a single output value specified by the legal manufacturer at 5 Vdc and between 2.5 and 5 Watts at 5 Vdc, has passed all applicable SDD appliance tests per **WHO/PQS/E003/RF05 VP** or **WHO/PQS/E003/FZ03 VP** with no reports of Basic EHC failure or appliance failure at any time during or after the tests. The Basic EHC has passed all tests per **WHO/PQS/E007/EHC 02 VP** with no reports of Basic EHC failure or appliance failure at any time during or after the tests. The measured solar electricity harvested in Wh/day averaged over the five-day test period of the Day/Night appliance test is equal to or greater than the manufacturer's stated minimum daily quantity of harvested energy (Wh/average day).

- **Summary:** Conclusions and recommendations, including confirmation of the temperature zone(s) for which the product is suitable.

- **Test 1:** Comments on samples received, tabulated data on the type-examination test, certifications and relevant photographs.
- **Test 2:** Excess load and solar radiation variation
- **Test 3:** Connection sequence.
- **Test 4:** Reverse polarity connections
- **Test 5:** Short circuit.
- **Annexes:** Description of the test apparatus including solar power simulator (SPS) and fixed DC load. Test chamber temperature records. Copy of reference thermometer calibration certificate(s). Diagrams showing the location and identification codes for sensors, clearly distinguishing between sensors measuring voltage, current, and temperatures. Additional

supporting documentation requested and received from the Legal manufacturer or Reseller during the course of the type-testing.

6. Quality control checklist

6.1 Quality control standards

All testing and reporting must be carried out in accordance with the requirements of **ISO 17025:2005** or later edition.

6.2 Quality control checklist

An on-site inspection of the manufacturing plant is not required.

6.3 Quality control evaluation

Not required.

7. Prequalification evaluation

A product will qualify for inclusion on the register of PQS prequalified equipment in accordance with WHO procedures provided the final report indicates full conformity with the requirements of specification **E007/EHC02** and the appliance complies with the applicable **E003/FZ03** or **E003/RF05** specification when tested with the Basic EHC and a fixed DC load specified by the legal manufacturer between 2.5 and 5 watts continuously coupled to it**.**

8. Modified products

The legal manufacturer or reseller must notify WHO in writing of any changes which affect the performance of the product. WHO will carry out a desk evaluation of the reported change(s). If any change is deemed adversely to affect the performance of the product, WHO may request full or partial re-verification based on the test procedures described in this document.

Annex 1 – General test conditions

The following conditions are applicable to all EHC.

Test conditions:

- Carry out tests in a test chamber in which temperatures can be controlled to ±1ºC and humidity within the range of 45% to 75% unless otherwise stated below. Measure test chamber temperatures in accordance with **IEC 62552**, clause 8.2.
- Maximum test chamber temperatures of +43ºC are required for the tests.
- Position the test SDD appliance and Basic EHC in the test chamber with its back face 50 mm clear of one of the chamber walls. Ensure that it is positioned per manufacturers requirements (e.g. for ventilation).

Annex 2 – Temperature sensor specification

Complying with **IEC 62552**, clause 8.7.1. Probe, accurate to ±0.5°C, inserted into brass or tin-covered copper mass of 25 g ± 5 % and of minimum external area (diameter = height = about 15.2 mm).

Revision history:			
Date	Change summary	Reason for change	Approved