WHO/PQS/E007/EHC01-VP.1
Original: English
Distribution: General

PQS Independent type-testing protocol

TITLE: Solar direct drive surplus energy harvest control devices.

Product verification protocol:	E007/EHC01-VP.1
Applies to specification ref(s):	E007/EHC01
Issue date:	1 November 2016
Date of last revision:	New

Contents:

1. Scope:

This document describes the procedure for verifying the performance of an energy harvest control (EHC) as an optional accessory for solar direct drive (SDD) appliances per **WHO PQS E003/RF05** and **E003/FZ03**. Defined loads will not be tested or prequalified.

In order to prequalify, the EHC must be also be tested with all SDD appliances that it will be connected with. Two sets of verification protocols must be successfully passed in order to achieve WHO PQS prequalification. First test the EHC with appliance per this document. If successful then test the same assembly of EHC with appliance per the most recent version of **E003/RF05 VP** or **E003/FZ03 VP** and include the test report per instructions in Test 10 of this document.

If an appliance is already PQS prequalified it must be tested as a complete assembly of appliance and EHC through all tests as described in this document including Test 10 of this document and the most recent version of **E003/FZ03 VP** or **E003/RF05 VP**.

If multiple different appliance models use the identical EHC, identical cooling system, identical control system and identical solar power system then a single set of tests can be accepted to prequalify multiple models if pre-approved by the PQS Secretariat.

Field testing is required of all prequalified EHC and prequalified appliance(s). The PQS Secretariat is to pre-approve all field study plans in advance.

2. Normative references:

EMAS: European Union Eco-Management and Audit Scheme.
EN ISO 6270-1 / ASTM D2247 / EN 13523-26: Determination of resistance to humidity – Part 1: Continuous condensation.
EN ISO 6270-2 / EN 13523-25: Determination of resistance to humidity - Part 2: Procedure for exposing test specimens in condensation-water atmospheres.
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: 2007: 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 2.0: 2005: Electromagnetic compatibility (EMC) Generic standards - Immunity for residential, commercial and light-industrial environments.
IEC 61000-6-3 edition 2.1: 2011: Electromagnetic compatibility (EMC) Generic standards - Emission standard for residential, commercial and light-industrial environments.
IEC 62552: 2007: Household refrigerating appliances – Characteristics and test methods.
ISO 2409: 2013: Paints and varnishes – cross cut test (external cabinet).
ISO 6272 / EN 13523-5: Impact resistance - external cabinet.
ISO 9001: Quality Management Systems – Requirements.
ISO 14001: 2004: 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: 2005: 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/E007/EHC01 VP.1: Independent type testing protocol: Solar direct drive excess energy harvest control and strategy.

3. Terms and definitions:

Appliance: Any solar direct drive (SDD) vaccine refrigerator, water-pack freezer or combined vaccine refrigerator and water-pack freezer.
Defined load: Specific load(s) matched to the EHC and supplied by the Legal Manufacturer/Reseller. The defined load(s) would be permanently connected to the EHC or would connect to the EHC with a unique, non-standard electrical connector to restrict the addition of undefined loads with standard electrical connectors.
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.
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. Two categories of electrical loads are considered: defined loads and undefined loads.
Operate(s) correctly: The component or components being referred to function as normally expected. More explicitly with respect to the appliance, the cooling circuit functions as required by the thermostat (i.e. when the thermostat requires cooling the cooling circuit provides cooling within a delay

time expected from an undamaged example of the appliance and when the thermostat does not require cooling the cooling circuit shuts off or remains off depending on the initial condition of the cooling circuit).
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.
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.
Simulated solar power (SSP): 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 Vdc receptacles as used in vehicles and 120/230 Vac receptacles as used in buildings and electrical generators.
Surplus solar electricity: Any electricity the SDD appliance cannot use because the:
- appliance does not require electricity at that instant; or
- electricity being generated is insufficient to power the appliance at that instant; or
- electricity is powering the appliance and there is surplus electricity that the appliance cannot use at that instant.
Undefined load: User selected load devices that are not supplied by the Legal Manufacturer/Reseller as a defined load with the appliance and EHC system.
Uninterrupted: With respect to an electronic component or device, to operate continually, without pause.
Variable DC load: A laboratory test device to simulate the range of secondary loads.

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, compatible EHC and defined load if supplied (defined load will be inspected, photographed and noted in Test 1 but will not be used for any laboratory performance testing). A

compatible solar power system is not required. Manufacturer to supply EHC ready to be tested with a variable DC load device with capacity to test the EHC power output to the load equal to the solar array maximum power x 1.35.

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

If the EHC is to be used with multiple different appliance models then all appliances must be provided and tested with the 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 has received preapproval from the PQS Secretariat then a single sample and single set of tests can be accepted in order to prequalify multiple appliances models with a specified EHC.

5.3 Test procedure:

5.3.1 Solar power simulator (SSP) and variable DC load:

Refer to specification **E003/PV01** for solar power system specifications. All performance tests use a direct current (DC) source to simulate a solar power array and a variable DC load to simulate load. Tests 2-9 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 **E003/FZ03** and **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/m² 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 of Test 10 per **E003/RF05 VP** and **E003/FZ03 VP** will use the 3.5 kWh/m^2/day solar radiation reference period defined in **E003/RF05 VP** or **E003/FZ03 VP.**

To simulate a DC load a variable DC load will be used in all laboratory tests. If an EHC is to power a defined load the manufacturer is to prepare the EHC load output to connect only to the laboratory supplied variable DC load. Adjust the variable DC load to be equal to the solar array output ratings at 1.00 kWh/m² (e.g. for a 360 Watt solar rated at 18 Vmp and 20 Imp set the variable DC load with the identical voltage and current settings).

5.3.2 Test temperatures and other measurements:

All appliance and 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 EHC from solar power system, between EHC and appliance as well as between EHC and the variable 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 EHC (voltage and amperage): ± 0.1% or better
Power to cooling circuit (voltage and amperage): ± 1%.
Power to variable DC load (voltage and amperage): ± 1%.
Variable DC load: ± 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 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.
- For use with undefined load or defined load (specify which).
- Legal Manufacturer or Reseller.
- Country of origin.
- Conformity assessment markings (e.g. CE mark).

Performance characteristics

- Compliance with related references conforms/does not conform to specification clause 4.4 (written certification required).
- 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).
- Load compatibility conforms/does not conform to specification clause 4.8.
- 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).

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

- 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 (written certification required).

Physical data:
- Wiring diagram for the appliance, EHC and load(s) provided.
- Record major EHC dimensions in centimetres (± 1.0 cm).
- Record EHC weight in kilograms (± 0.25 kg).
- Record major defined load dimensions in centimetres (± 1.0 cm).
- Record defined load weight in kilograms (± 0.25 kg).

Step 5: Take a three quarter view digital photograph of the EHC and all defined loads. Take additional photographs showing all external surfaces of the EHC, the connectors and defined loads, if supplied. 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: Solar radiation variation

Test 2 is to be completed before proceeding to Test 3. Test 2 is conducted for two days. The first day will test when the appliance continually requires cooling to observe the impact on cooling circuit operation. The second day will test the cooling circuit with power input but continually not requiring cooling to test the performance of the EHC when all electricity is available for loads other than the appliance.

Using the manufacturers wiring diagram and instructions connect the assembly of appliance, EHC and variable DC load.

If the EHC provides standard electrical connectors connect one variable DC load to each different type of standard electrical connector. Adjust the variable DC load to match the connector voltage(s) and test with all variable DC loads on.

If a combination of defined load and undefined load connections are provided then connect one variable DC load to each load type and test with all variable DC loads on.

To accomplish this begin the test with the appliance preconditioned sufficiently or adjusted so that the cooling circuit control continually requires cooling through Step 12 of Test 2.

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

Step 1: Precondition the test chamber, appliance and EHC at test conditions (+43°C) for a minimum of 48 hours. Adjust the solar power simulator (SSP) per Table 1.
Step 2: Connect the entire equipment assembly per manufacturer's instruction including the EHC and appliance per manufacturer's instructions and then connect variable DC load(s).
Step 3: Adjust the appliance to continually require cooling and then start the appliance and EHC with all variable DC loads connected and switched on. See Table 1 for power staging detail.
Step 4: Allow the assembly to operate for one hour at SSP output equivalent to 50 W/m².
Step 5: Beginning in the second hour and continuing for 2.5 hours, cycle the SSP 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 SSP 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 SSP 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 SSP 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 SSP output equivalent to 50 W/m².
Step 11: Report Day One SSP output, appliance power (Watts) required to start cooling, appliance energy consumption in kWh/day, energy harvest in kWh/day, thermostat voltage (or other thermostat signaling) and the percentage of time the cooling circuit was running during the 12 hour solar phase. Graphically display all of the above and time, thermostat voltage (or cooling circuit signal for when cooling is required) and cooling circuit on/off cycles.
Step 12: With the appliance requiring cooling, disconnect the SSP (i.e.; 0 Watts supplied). Turn off appliance, EHC and all variable DC loads.
Step 13: Adjust the appliance to continually not require cooling. Adjust the solar power simulator (SSP) per Table 1. Start the appliance and EHC with all variable DC loads connected and switched on. Assure that the cooling circuit control is powered as normal.
Step 14: Repeat Steps 4 through 10.
Step 15: Report Day Two SSP output, appliance energy consumption in kWh/day, energy harvest in kWh/day, thermostat voltage (or other thermostat signaling) and the percentage of time the EHC was diverting electricity to the secondary load during the 12 hour solar phase. Graphically display all of the above and time.
Acceptance criterion (Day One cooling required): At all times during the daytime solar phase, solar power is provided to cooling circuit control (e.g. thermostat). Anytime the appliance requires cooling the EHC provides cooling circuit with adequate power (Watts) to operate correctly the cooling circuit (if SSP is equal or greater than cooling circuit power requirement).

Rejection criterion (Day One cooling required): The cooling circuit control does not operate correctly and uninterrupted at any time during the daytime solar phase. The appliance does not operate correctly when appliance requires cooling and there is adequate power (Watts) required to start cooling (SSP is equal or greater than cooling circuit power requirement).

Acceptance criterion (Day Two, no cooling required): At all times during the daytime solar phase, solar power is provided to cooling circuit control (e.g. thermostat). The EHC provides the variable DC load with some amount of electricity.
Rejection criterion (Day Two, no cooling required): The cooling circuit control does not operate correctly and uninterrupted at any time during the daytime solar phase. The EHC does not provide variable DC load with electricity.
Acceptance criterion (peak power input): No obvious or quantifiable damage to EHC and appliance and the EHC and appliance continue to operate correctly.
Rejection criterion (peak power input): The EHC fails one or more acceptance criteria.

5.3.5 Test 3: Connection sequence

Note: Manufacturers instruction may require adherence to a specific connection sequence. For example:
1.) First connect appliance to EHC and switch on.
2.) Next connect load to EHC and switch on.
3.) Lastly connect solar power to EHC and switch on.
This test will determine if connection in any other possible sequence will result in damage or abnormal operation.

For each separate connection sequence this test is to be conducted when appliance requires cooling to observe the impact on cooling circuit operation and when appliance does not require cooling. To accomplish this the cooling circuit control could be adjusted to first require and then to not require cooling (or other arrangement to assure both on and off operation of the cooling circuit).

Test conditions: Continue Test 2 temperature conditions. Set the SSP to a power level equal to the solar array maximum power at STC (1000 W/m²).
Step 1: Start the test with cooling circuit requiring cooling.
Step 2: Switch off the SSP, appliance and variable DC load and disconnect all from EHC.
Step 3: Switch on all components and then reconnect components in an incorrect sequence (i.e.; not as specified by the manufacturer).
Step 4: Confirm if the cooling circuit operates correctly when requiring cooling and when not requiring cooling.
Step 5: Switch off the SSP, appliance and variable DC load and disconnect all from EHC then correctly reconnect following all manufacturer's instructions.

Step 6: Confirm if the cooling circuit operates correctly when requiring cooling. Adjust the cooling circuit to not require cooling and confirm cooling circuit operates correctly when not requiring cooling.
Step 7: Repeat steps 2-6 until all possible connection sequences have been tested.
Acceptance criterion: After all possible connection sequences have been tested the cooling circuit operates correctly after being correctly reconnected per manufacturer's instructions.
Rejection criteria: Failure of cooling circuit to operate correctly following any sequence of connections after being correctly reconnected per manufacturer's instructions.

5.3.6 Test 4: Alternate connections

This test is to be conducted when appliance requires cooling to observe the impact on cooling circuit operation
Test conditions: Continue Test 2 temperature conditions. Set the SSP to a power level equal to the solar array maximum power at STC (1000 W/m²).
Step 1: Adjust the cooling circuit control to continually require cooling. Switch off the SSP, appliance and variable DC load and if physically possible, disconnect all inputs and outputs from EHC. If not physically possible to make any disconnections then omit this test and proceed to Test 5 Reverse Polarity.
Step 2: If physically possible, reconnect the inputs and outputs at the EHC to and from the SSP, appliance and variable DC load in an incorrect position (i.e.; not as specified by the manufacturer).
Step 3: Turn on SSP output.
Step 4: Turn on the EHC, appliance and variable DC load.
Step 5: Leave the system powered for at least 5 minutes to ensure that the cooling circuit is running if possible in the configuration. Subsequently force the cooling circuit to not require cooling power.
Step 6: Record and report whether the cooling circuit operates correctly and whether the EHC harvests power as expected when it operates correctly. A similar format to Table 3 below can be used. Note that the connection designations correspond to the notation used in **Annex 3 – Connection notations and schematic**.

TABLE 3: **Example reporting table for alternate connections test**.

Connections (assuming a male and a female connector from each of the appliance and SSP supply and two of each from the EHC)				Possible (yes/no)	Operates correctly as connected (yes/no)		Operates correctly after re-connecting in mfr. specified locations (yes/no/NA)	
					Appliance	EHC	Appliance	EHC
1	2	3	4					
F1-M6	F2-M5	F3-M8	F4-M7					
F1-M6	F2-M8	F3-M5	F4-M7					
F1-M6	F2-M8	F4-M5	None					
F1-M6	F3-M8	F4-M5	None					
F1-M7	F2-M5	F3-M8	F4-M6					
F1-M7	F2-M8	F3-M5	F4-M6					

F1-M7	F2-M8	F4-M5	None					
F1-M7	F3-M8	F4-M5	None					
F1-M8	F2-M5	F4-M6	None					
F1-M8	F2-M5	F4-M7	None					
F1-M8	F3-M5	F4-M6	None					
F1-M8	F3-M5	F4-M7	None					

Step 7: If either the appliance or EHC fails to operate correctly, turn off and disconnect SSP, appliance, and load from EHC and reconnect in the manufacturer specified locations. Repeat Steps 3 through 6 and report.
Step 8: Repeat Steps 1 through 7 until all physically possible alternate connections have been tested. This must include at least all of the connection configurations noted in Table 3 that are physically possible. Each row represents one set of connections to test a single configuration. Note that the connection designations correspond to the notation used in **Annex 3 – Connection notations and schematic**.
Step 9: At the end of the alternate connections testing turn off all components and reconnect to the EHC per manufacturer's instruction and repeat Steps 3 through 6.
Acceptance criterion: After all possible alternate connection configurations have been tested the cooling circuit and EHC must operate correctly after being reconnected per manufacturer's instruction.
Rejection criteria: Failure of EHC and/or cooling circuit to operate correctly after all sequence testing.

5.3.7 Test 5: Reverse polarity connections

Test conditions: Continue Test 2 temperature conditions. Set the SSP to a power level equal to the solar array maximum power at STC (1000 W/m²).
Step 1: Adjust the cooling circuit control to continually require cooling. Switch on the SSP, appliance, and load and disconnect the SSP supply from the EHC.
Step 2: Reverse the SSP input polarity (+ and -) to the EHC.
Step 3: Turn on SSP output and switch on the other components.
Step 4: Record and report cooling circuit and EHC operation.
Step 5: At the end of the reverse polarity testing turn off all components and reconnect to the EHC per manufacturer's instruction.
Step 6: Confirm the EHC and cooling circuit operates correctly in all modes of operation.
Acceptance criterion: After reverse polarity testing the cooling circuit and EHC must operate correctly after polarity is connected as specified.
Rejection criteria: Failure of EHC and/or cooling circuit operate correctly after reverse polarity testing.

5.3.8 Test 6: Short circuit

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Caution: Lab to provide an adequately rated overcurrent protection device such a DC circuit breaker or fuse in the energy harvest output circuit located between the EHC and variable 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 SSP to a power level equal to the solar array maximum power at STC (1000 W/m²).
Step 1: Adjust system to continually not require cooling to test the performance of the EHC when all electricity is available for energy harvest.
Step 2: When energy harvest diversion to the variable DC load is confirmed establish a short circuit between the EHC overcurrent protection and the variable DC load.
Step 3: Adjust the cooling circuit to require cooling.
Step 4: After at least 5 minutes record and report cooling circuit operation. Proceed to Step 5 if the cooling system correctly operates. Halt the tests if the cooling circuit will not correctly operate.
Step 5: Correct short circuit. Reset any breakers or replace any blown fuses.
Step 6: Adjust the cooling circuit control to require cooling. Confirm the cooling circuit operates correctly.
Step 7: Adjust system to not require cooling and initiate energy harvest diversion to variable DC load. Confirm cooling system operates correctly and EHC operates correctly. Additionally record and report any notable variation in the EHC operation at this point.
Acceptance criterion: After short circuit is established the EHC must sustain the cooling circuit operation. After short circuit is corrected the EHC must demonstrate that the cooling circuit operates correctly, the EHC is undamaged, operates correctly and restores energy harvest diversion to load.
Rejection criteria: Failure of EHC to sustain cooling circuit operation during short circuit. Failure of the EHC to sustain cooling circuit operation and restore energy harvest diversion to load after short circuit correction. Identification of any notable damage or change to EHC operation that does not return to operate correctly after short circuit is corrected.

5.3.9 Test 7: Progressive load current draw

Test conditions: Continue Test 2 temperature conditions. Set the SSP to a current level equal to the solar array STC maximum power (i.e. 1000 W/m²).
Step 1: Test the cooling circuit with power input but continually not requiring cooling to test the performance of the EHC when all electricity is available for loads other than the appliance.
Step 2: Set SSP input voltage and current to rated solar array voltage and current at STC maximum power (i.e. 1000 W/m²).
Step 3: Set the variable DC load to draw constant current equal to 25% of the maximum rated solar array current output (i.e. current output at 250 W/m).
Step 4: Adjust the appliance to continually not require cooling then operate the variable DC load for five minutes. Record currents through and voltages across EHC input from SSP supply, EHC output to appliance and EHC output to variable DC load.
Step 5: Adjust the appliance to continually require cooling and after 5 minutes verify that the appliance operates correctly.
Step 6: Increase the DC load current setting by 25% of the maximum solar array current rating.

Step 7: Repeat steps 4 through 6 three additional times until the maximum solar array current output is reached.
Step 8: Increase the SSP output current to 135% of the rated solar array current at maximum power point, and increase the DC load current setting by another 25% to 125% of the full solar array current rating. Repeat steps 4 through 6 one final time. Report SSP output, appliance energy consumption in kWh/day, energy harvest in kWh/day, thermostat voltage (or other thermostat signaling) and the percentage of time the EHC was diverting electricity to the load during the test. Graphically display all of the above including time and cooling circuit on/off cycles.
Acceptance criterion: The cooling circuit must operate correctly at each level of loading.
Rejection criteria: Failure of cooling circuit to operate correctly at any setting.

5.3.10 Test 8: Inductive load

Note: this test intends to challenge the EHC operational logic by cycling the SSP on and off (simulated solar radiation from 1000 W/m² to 0 W/m²) while the appliance requires cooling and an inductive load is connected directly to the EHC load output. Lab to supply and test with a brushless DC motor rated at nominal 12 Vdc, 6 amps (± 20%) running current and 12 amps (± 20%) starting current.
This test is to be conducted when appliance requires cooling to observe the impact on cooling circuit operation.
Test conditions: Continue Test 2 temperature conditions. Set the SSP to a power level equal to the solar array maximum power at STC (1000 W/m²).
Step 1: Disconnect the SSP and then disconnect the variable DC load from the EHC and replace it with the DC motor with DC motor switched off.
Step 2: Switch on the SSP and confirm cooling circuit operation.
Step 3: With the cooling circuit actively operating switch on the DC motor load, allow load to reach steady state and leave the load running for at least 15 minutes. Record and report currents through and voltages across EHC input from SSP, EHC output to appliance, and EHC output to load.
Step 4: Switch off SSP for 15 minutes and then switch SSP on with both the appliance and load switched on. After 15 minutes determine if the cooling circuit is operating correctly and receiving full power as required. Confirm EHC is operating correctly (note: Certain EHC designs may harvest surplus solar electricity only when the active cooling is off or an alternate EHC design may harvest surplus solar electricity simultaneously when the active cooling circuit is on and sufficient surplus solar electricity is available).
Step 5: Switch off the appliance and confirm the EHC is operating correctly and the load is being powered. After 15 minutes switch the appliance on again. After an additional 15 minutes determine if the cooling circuit is operating correctly and receiving full power as required. Confirm EHC is operating correctly (note: Certain EHC designs may harvest surplus solar electricity only when the active cooling is off or an alternate EHC designs may harvest surplus solar electricity simultaneously when the active cooling circuit is on and sufficient surplus solar electricity is available).
Step 6: Repeat Steps 5 and 6 two additional times and then proceed to Step 7.

Step 7: Disconnect SSP and remove the DC motor load. Report SSP output, appliance energy consumption in kWh/day, energy harvest in kWh/day, thermostat voltage (or other thermostat signaling) and the percentage of time the EHC was diverting electricity to the load during the test. Graphically display all of the above including time and cooling circuit on/off cycles.

Acceptance criterion: The appliance and EHC both operate correctly throughout and after the test.
Rejection criteria: Failure of the appliance and/or EHC to operate correctly at any time during or after the test.

5.3.11 Test 9: Abrupt current change

Test conditions: Continue Test 2 temperature conditions. Adjust the SSP to a power level equal to 1.35 times the solar array maximum power at STC (1350 W/m^2).
Step 1: Connect EHC, SSP supply, appliance and a variable DC load. Test the cooling circuit with power input but continually not requiring cooling to test the performance of the EHC when all electricity is available for loads other than the appliance.
Step 2: Record currents through and voltages across EHC input from SSP supply, EHC output to appliance, and EHC output to variable DC load.
Step 3: Adjust the variable DC load to draw constant current of 1 Amp or less and then operate for no less than 5 minutes
Step 4: Adjust the current on the variable DC load to the maximum current available from the SSP supply (at solar variation of 1.35 kWh/m2).
Step 5: Run variable DC load at maximum current for 5 minutes.
Step 6: Adjust the variable DC load to 1 amp or less and then operate for no less than 5 minutes.
Step 7: Turn on appliance. If the cooling circuit is not requiring cooling adjust thermostat (or cooling system) to switch on cooling circuit.
Step 8: Repeat Steps 4-7 two more times and then proceed to Step 9.
Step 9: Confirm that the appliance and EHC operate correctly throughout the test. Report SSP output, appliance energy consumption in kWh/day, energy harvest in kWh/day, thermostat voltage (or other thermostat signaling) and the percentage of time the EHC was diverting electricity to the load during the test. Graphically display all of the above including time and cooling circuit on/off cycles.
Acceptance criterion: The appliance and EHC operate correctly throughout the test.
Rejection criteria: Failure of the appliance or EHC to operate correctly at any time throughout the test.

5.3.12 Test 10: SDD appliance testing with EHC

After successful completion of Tests 1-9 in this document then all tests in **E003/RF05 VP** or **E003/FZ03 VP** must also be carried out with the same sample appliance, same sample EHC and same variable DC load.

Legal Manufacturer or Reseller to state the estimated minimum daily energy harvest per average day (Wh/average day) that is available for use. The estimated Wh/average day will be verified based on the test results from the Day/Night test using a variable DC load. For an EHC with defined loads the test result (Wh/average day) cannot be greater than the defined load Wh/day requirement for average daily defined load operation. Manufacturer to provide clear examples of energy available to users (e.g., X quantity of Y device in operation for Z hours per average day). The total energy harvest (in Wh/average day) has no set criteria but will be measured, compared to manufacturer estimates and reported. Results will be published for the minimum available Wh/average day and overall energy efficiency estimated as the available Wh/average day divided by the possible average surplus solar electricity as measured in the Day/night appliance testing.

Include a copy of the test report for the appliance per **E003/RF05 VP** or **E003/FZ03 VP** when coupled to the EHC and variable DC load.

Note: All Test 10 appliance testing per **E003/RF05 VP** and **E003/FZ03 VP** will use the 3.5 kWh/m^2/day solar radiation reference period defined in **E003/RF05 VP** and **E003/FZ03 VP.**

Acceptance criterion: The appliance when coupled to the EHC and variable DC load has passed all tests **E003/RF05 VP** or **E003/FZ03 VP** with no reports of EHC failure at any time during or after the tests. The measured surplus solar electricity harvested in Wh/day averaged over the five day test period of the Day/Night test is equal to or greater than the manufacturer's stated minimum daily quantity of harvested energy (Wh/average day).

Rejection criteria: Failure of the appliance to pass any test in **E003/RF05 VP** or **E003/FZ03 VP** and/or failure of the EHC to operate correctly at any time during the tests. The measured surplus energy harvested in Wh/day averaged over the five day test period of the Day Night test is less than the manufacturer's stated minimum daily quantity of harvested energy (Wh/day).

Note that failure of the EHC during any of the appliance tests will not disqualify the appliance from prequalification as an SDD appliance (with no EHC) if the appliance can pass all appliance tests in **E003/RF05 VP** or **E003/FZ03 VP.**

If multiple appliances models are pre-approved by the PQS Secretary to prequalify with the identical appliance control, identical cooling circuit, identical EHC, identical solar power system and identical load type then an estimation of average daily surplus solar electricity harvest based on the

appliance Day/Night test report is to be calculated, justified and presented for each appliance as a condition of Test 10 completion.

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:

- **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:** Solar radiation variation.
- **Test 3:** Connection sequence.
- **Test 4:** Alternate connections.
- **Test 5:** Reverse polarity connections.
- **Test 6:** Short circuit.
- **Test 7:** Progressive load power draw.
- **Test 8:** Inductive load.
- **Test 9:** Abrupt current change.
- **Test 10:** SDD test appliance testing with EHC.
- **Annexes:** Description of the test apparatus including simulated solar power (SSP) supply, variable DC load and 12 Vdc brushed motor. 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. Pre-qualification evaluation:

A product will qualify for inclusion on the register of PQS pre-qualified equipment in accordance with WHO procedures provided the final report indicates full conformity with the requirements of specification **E007/EHC01** and the appliance complies with the applicable **E003/FZ03** or **E003/RF05** specification when tested with the EHC 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:

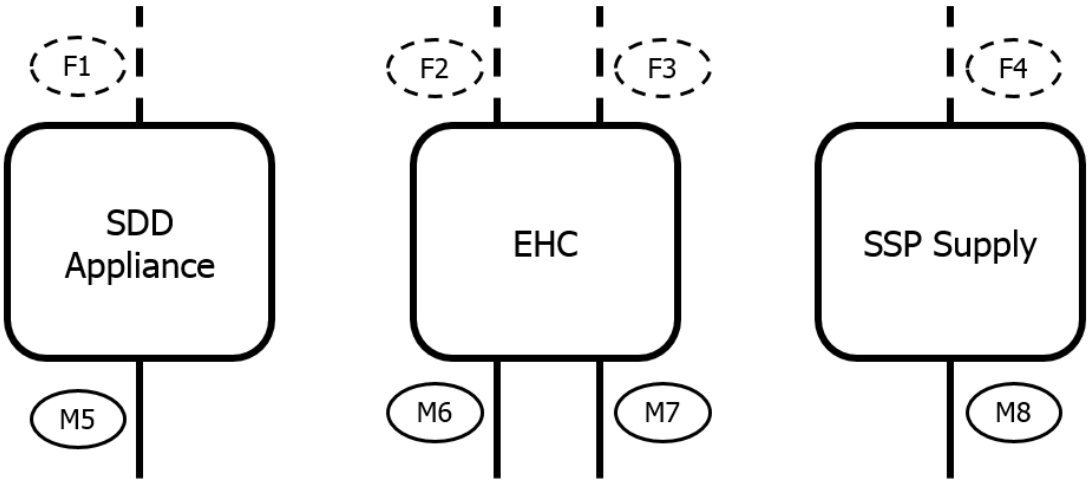
- Carry out tests in a test chamber in which temperatures can be controlled to ±1ºC and humidity within the range of 45% to 75% unless otherwise stated below. Measure test chamber temperatures in accordance with IEC 62552, clause 8.2.
- Maximum test chamber temperatures of +43ºC are required for the tests.
- Position the test 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).

Annex 3 – Connection notations and schematic
The following schematic diagram and numbering system is intended to assist in distinguishing possible combinations of connections to be tested in Test 4. Depending upon the configuration of the system components, leads, wires, and connectors some connections may not be physically possible. The diagram below assumes that there is a separate male and female connector on separable wires coming from both the appliance and the simulated solar power (SSP) power supply. It also assumes that two male and two female connectors all on separate wires are accessible and connected to the EHC (intended to connect to the appliance and the photovoltaic power supply).

As an example, using the figure below, one configuration (possibly the configuration intended for normal usage by the manufacturer) would be F1-M6, F2-M5, F3-M8, F4-M7. Another possible configuration most likely not intended by a manufacturer would be F1-M8, F2-M5, F4-M7, with two un-connected leads, namely F3 and M6.

Load connections are not included in this diagram or in Test 4 under the assumption that the inputs and output connectors for the load will not be compatible with those used for the three system components below.


F1
SDD
Appliance
M5
F2
F3
EHC
M6
M7
F4
SSP Supply
M8

Revision history:			
Date	Change summary	Reason for change	Approved