TITLE: Single-phase voltage protection for AC and DC powered refrigerators and freezers

Product verification protocol:	E007/VS01-VP.6
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Contents

1. Scope

This document describes the procedure for verifying the performance of single-phase voltage stabilizers suitable for protecting alternating current (ac) powered refrigerators and freezers. AC-to-DC switching mode power supplies (SMPS) are also covered under this verification protocol.

This protocol applies to protection devices that are either integrated or standalone from the appliance for which it is intended to protect. Different testing considerations for standalone, integrated, and dedicated devices are indicated where relevant. Inquiries about stabilizer types can be addressed to PQS.

If seeking prequalification of a voltage stabilizer that will always be an integrated component of an appliance, i.e., not sold as a standalone product, only the stabilizer or associated components shall be submitted for testing. If the protection device alters in any way the performance of the appliance within which it is being integrated, or if the stabilizer is not distinct and separable from the appliance, the entire appliance shall be submitted for power protection testing (this verification protocol) and appliance performance testing (see relevant **WHO/PQS/E003** verification protocols).

Voltage protection integrated into an appliance, both AC voltage stabilizers and SMPS, shall provide a way for test laboratories to measure the device's output voltage. If the legal manufacturer feels that its design should be exempt from output protection testing requirements due to the nature of the design, it may provide design information and data to justify that claim.

For integrated voltage stabilizers, the legal manufacturer or reseller of a voltage stabilizer or SMPS may obtain prequalification for that protection device. Legal manufacturers of appliances wishing to integrate prequalified protection devices may rely on this prequalification and are not required to conduct the testing described herein.

2. Normative References

Use the most recent version.

CISPR 14-1: 2020 Electromagnetic compatibility - Requirements for household appliances, electric tools, and similar apparatus - Part 1: Emission
CISPR 14-2: 2020 Electromagnetic compatibility - Requirements for household appliances, electric tools, and similar apparatus - Part 2: Immunity - Product family standard
EMAS: European Union Eco-Management and Audit Scheme.

IEC 60068-2-6: 2007 Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)
IEC 60085: 2007 Electrical insulation – Thermal evaluation and designation.
IEC 60335-1: 2015 Household and similar electrical appliances - Safety - Part 1: General requirements.
IEC 60417-5017: 2006 Graphical symbols for use on equipment – Ground label
IEC 60898-1: 2015 Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations – Part 1: Circuit-breakers for A.C. operation
IEC 60947-4-1: 2018 Low-voltage switchgear and control gear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters
IEC 61000-3-2,3: 2018 Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase); Part 3-3: Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection
IEC 61000-4-5: 2014 Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test
IEC 61000-6-1: 2019 Electromagnetic compatibility (EMC) – Part 6-1: Generic standards - Immunity for residential, commercial, and light- industrial environments.
IEC 61000-6-3: 2020 Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial, and light-industrial environments.
IEC 61204-3: 2018 Low-voltage switch mode power supplies - Part 3: Electromagnetic compatibility
IEC 61204-7: 2016 Low-voltage switch mode power supplies - Part 7: Safety requirements
IEC 62321-8: 2017 Determination of certain substances in electrotechnical products - Part 8: Phthalates in polymers by gas chromatography-mass spectrometry (GC-MS), gas chromatography-mass spectrometry using a pyrolyzer/thermal desorption accessory (Py-TD-GC-MS)
ISO 2859: 2020 Sampling procedures for inspection by attributes
ISO 3951: 2013 Sampling procedures for inspection by variables
ISO 9001: 2015 Quality Management Systems – Requirements.
ISO 14001: 2015 Environmental management systems - Requirements with guidance for use.
ISO/IEC 17025: 2017 General requirements for the competence of testing and calibration laboratories.
ISO 20282-1: 2006 Ease of operation of everyday products - Part 1: Context of use and user characteristics.
RoHS 3: Restrictions on Hazardous Materials Directive 2015/863

3. Terms and definitions

Appliance: Cold-chain equipment (CCE), e.g. refrigerators or freezers, intended to be protected by voltage stabilizers.
Dedicated voltage stabilizer: A stabilizer model integrated into the appliance for use with a specific product. The stabilizer cannot be removed from the appliance and therefore

must be tested with the complete appliance. See Integrated and Standalone voltage stabilizers.

Dynamometer: A measuring device used to determine the torque, force, speed, and power required to operate the drive on a machine or motor, which can be measured by evaluating the torque and rotational speed of a motor simultaneously.

Electrical withstand: The root mean square (RMS) value of the maximum input voltage that the device can continuously tolerate without any form of electrical or mechanical damage.

Impedance: The effective resistance of an electric circuit or component to alternating current, arising from the combined effects of ohmic resistance and reactance.

Impulsive transient: A sudden, non-power frequency change in the steady-state condition of voltage, current, or both that is unidirectional in polarity – either primarily positive or negative. Often characterized by extremely high voltages that can drive high levels of current into an electrical circuit for periods ranging from a few milliseconds to a few microseconds.

Integrated voltage stabilizer: A stabilizer model integrated into the appliance for general use or for use with specific products. The stabilizer can be removed from the appliance and be operated separately from the appliance for testing. See Dedicated and Standalone voltage stabilizers.

In writing: Means 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 their own name, regardless of whether these operations are carried out by that person themselves or on their behalf by a third party.

Over-voltage: Root mean square voltage greater than or equal to 110% of the nominal value for a period longer than a half cycle of the nominal input waveform.

Overload: A situation where an electrical device is subjected to a greater electrical load than what it was designed for. Results in larger than design electric current passing through conductors, leading to excessive generation of heat, and the risk of fire or damage to equipment.

Programmable electronic load: Laboratory test equipment capable of simulating AC and/or DC loads. Inductive, resistive, and capacitive loads can be simulated by adjusting a power factor setting, and loading modes can typically be constant power, constant current, or resistive.

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.

Rated current: Maximum continuous current at which the device is intended to safely operate.

Rated frequency: The nominal design frequency for safe operation of the device.

Rated voltage: The nominal design voltage for safe operation of the device.

Short circuit: An accidental electrical circuit in a device with no or low resistance when compared to that of the normal circuit, especially one resulting from the unintended contact of components and consequent accidental diversion of current.

SMPS: Switched mode power supply.

Standalone voltage stabilizer: A stabilizer model external from the appliance for general use or for use with specific products. See Dedicated and Integrated voltage stabilizers.

Under-voltage: Root mean square voltage less than or equal to 90% of the nominal value for a period longer than a half cycle of the nominal input waveform.

4. Applicability

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

5. Type-testing procedure

5.1 Evidence of conformity assessment

Devices shall carry the CE mark, UL mark and/or equivalent internationally accepted evidence of conformity assessment. The legal manufacturer or reseller shall confirm to which clauses the device conforms. Certifications from accredited tests labs are preferable. If conformity is self-declared, then a technical construction file shall be provided as part of the dossier to validate conformity.

5.2 Number of samples

The legal manufacturer or reseller shall supply the testing laboratory with a full duplicate set of the Product Dossier already supplied to WHO PQS in accordance with the requirements of specification Clause 7. One sample of the device is required. If the device is available in more than one of the versions and voltage combinations described in specification Clause 4.2.2, one sample of each version shall be provided for complete testing.

5.3 Condition of samples

The legal manufacturer or reseller shall supply all samples to the testing laboratory in the final form to be supplied to the end-customer. In the case of stabilizers or SMPS meant to be integrated into/unto the body of another product but tested outside it (integrated stabilizers), the stabilizer or SMPS samples shall be supplied to the testing laboratory mounted on a sturdy testing chassis (if necessary) that will mimic as closely as possible the final mounting method and orientation of all stabilizer components in the final device to be supplied to the end customer.

5.4 Test procedure

5.4.1 Voltage and frequency

The specific tests listed below apply equally to each combination of stabilizer or SMPS type and rated input voltage/frequency. Tests 2 to Test 10 shall be conducted in numerical order. Relevant input voltage/frequencies are given in the format: 120/50-60 or 230/50-60. The input to the stabilizer should be variable from 0 V to the upper limit of the legal manufacturer specified continuous operating input voltage range, and shall be regulated to ±1.0% of the nominal voltage used in all tests below.

If the device is designed to operate at both 120 and 230 V AC nominal inputs, Tests 2 to Test 10 shall be conducted in numerical order with conditions relevant to both nominal voltages tested at each step. All results shall be reported for each test at each nominal voltage.

5.4.2 Loading

Many of the tests listed below require voltage stabilizers to operate under load. The load or loads used should be adjustable to draw current at 20%, 50%, 100%, 150%, 720% and 1000% of full rated current at rated output voltage. The following load types are acceptable:

- **Motor / dynamometer:** Based on the type of device being tested, connect an AC (120 volt / 50-60 Hz or 230 volt / 50-60 Hz single phase) capacitor start induction motor or DC motor (12, 24, 48 volt) to the output of the voltage stabilizer or SMPS. The motor shall be the nearest size equivalent to the rated capacity of the voltage stabilizer or SMPS. Connect the output from the motor to a dynamometer so that calibrated loads of 20%, 50%, and 100% capacity can be obtained. Use this same motor for the 150% load point if possible, and a different motor or different load for the 720% and 1000% load requirement, if necessary. Set the dynamometer to control for constant torque equivalent to these load levels at expected rated speed. Motors should have starting current at least five times greater than the full-load current to approximate compressor start currents. For example, if a motor has a full-load current of 4.5 A, its start current rating should be ≥ 22.5 A.
- **Programmable electronic load:** A programmable AC or DC electronic load (as applicable) may be used to simulate a compressor or other load. Set the load to use constant current mode and for AC stabilizers, set the load power factor (PF) to 0.8 lagging (inductive). If used in the high-load starting test, note that 500% load current is needed and that transient or "inrush" capability would be helpful.
- **Resistor load:** Acceptable for the impulsive transient test where it may be preferred not to connect sensitive equipment to the device under test.
- **Internal load for dedicated stabilizers:** When testing an appliance that contains a dedicated stabilizer, the appliance's internal load may be used to simulate the 100% loading and starting conditions. Use conditions that create the maximum appliance load. For example, compressors shall be run with the appliance equilibrated at +43°C. Potential scenarios for integrated and dedicated stabilizers are discussed in Annex 1.

Note the special loading requirements described in Test 7, the high-load starting test.

5.4.3 Test 1: Type examination

- **Step 1:** Check sample against product dossier to verify consistency; check for any defects or damage to the device.
- **Step 2:** Record any differences between the sample ordered and the one received.

- **Step 3:** 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.
- Legal manufacturer or reseller.
- Country of origin.
- Conformity assessment markings (e.g., CE, UL mark).

Performance characteristics

- Mode of operation conforms/does not conform to specification Clause 4.2.1.
- Nominal input and output voltage and frequency options conform/do not conform to specification Clause 4.2.2.
- Input voltage regulation range conforms/does not conform to specification Clause 4.2.3 (tested as specified in Test 5).
- Voltage protection complies with specification Clause 4.2.4 (tested as specified in Tests 3 and 4).
- Capacity rating conforms/does not conform to specification Clause 4.2.5 (legal manufacturer declaration).
- Tolerance of input frequency fluctuations conforms/does not conform to specification Clause 4.2.6 (tested as specified in Test 6).
- Output voltage accuracy conforms/does not conform to specification Clause 4.2.7 (tested as specified in Test 5).
- No fuses in conformity with specification Clause 4.2.8 (legal manufacturer declaration).
- Load Power Factor conforms with specification Clause 4.2.9 (legal manufacturer declaration).
- Ac stabilizer output wave form complies with specification Clause 4.2.10 (legal manufacturer or reseller shall supply documentary evidence of testing).

Materials and construction

- Tabulate all materials in major visible components.
- Manufacturer provides evidence of corrosion resistance complies with specification Clause 4.3.1.
- Manufacturer provides evidence that insulation materials comply with specification Clause 4.3.2.
- All materials used in the device conform/do not conform to specification Clause 4.3.3.
- Manufacturer provides evidence of electrical safety compliance as stated in specification Clause 4.3.4.
- Manufacturer provides evidence of electromagnetic compliance as stated in specification Clause 4.3.5.
- Robustness conforms/does not conform to specification Clause 4.3.6.

- Protection against dust and water ingress, including coating of printed circuit board assemblies, conforms/does not conform to specification Clause 4.3.7.
- Markings conform/do not conform to specification Clause 4.3.8.
- Manufacturer provides evidence that efficiency conforms to specification Clause 4.3.9.

Environmental requirements

- Device environmental capabilities conform/do not conform to specification Clauses 4.4.1 and 4.4.2.

Physical characteristics

- Measure and report the overall dimensions of device (±1.0 mm).
- Measure and report the weight of device (±0.1 kg).

Interface requirements

- Compatibility with electronic circuits conforms/does not conform to specification Clause 4.6.1.
- Power lead conforms/does not conform to specification Clause 4.6.2.
- Power output outlet conforms/does not conform to specification Clause 4.6.3.

Human factors

- General design of device conforms/does not conform to specification Clause 4.7.1.
- Control panel conforms/does not conform to specification Clauses 4.7.1 and 4.7.2.

Warranty

- Warranty conforms/does not conform to specification Clause 4.8.

Servicing provision

- Servicing provision conforms/does not conform to specification Clause 4.9 (to be self-certified by legal manufacturer or reseller and verified through field performance of the device during deployment in-country).

Spare parts

- Spare parts provision conforms/does not conform to specification Clause 4.10.

Disposal and recycling

- Information materials provided with device conform/do not conform to specification Clause 4.11.

Instructions

- Instructions conform/do not conform to specification Clause 4.12.

Packaging

- Packaging conforms/does not conform to specifications Clause 5.

- **Step 4:** Take a digital photograph of all sides of the sample. A digital image should be provided for attachment to the PQS report. Take any other photographs needed to illustrate features of the device for the report.

Acceptance criteria: Inspection indicates full conformity with all major specification requirements.

Rejection criterion: Failure to meet one or more of the acceptance criteria.

5.4.4 Test 2: Vibration test

- **Note:** Not applicable for voltage stabilizers or SMPS meant to be integrated within the body of another device (integrated or dedicated stabilizers).
- **Condition of sample:** in legal manufacturer or reseller's standard packaging.
- **Test conditions:** Ambient temperature and humidity.
- **Step 1:** Securely strap the sample to a vibrating table. Conduct vibration tests following the procedure in IEC 60068-2-6: Test Fc as follows:
  - Frequency: 10-150-10 Hz
  - Amplitude: (mean to peak) 0.35 mm
  - Rate of change: approximately 1 octave per minute
  - Acceleration: limited to 2 g (cross-over at 37 Hz)
  - Direction: vertical
  - Endurance: 20 sweep cycles.

- **Step 2:** Unpack the samples and inspect for damage. Check operation of the stabilizer. Report any damage to the package or to the inside or the outside of the stabilizer. If appropriate, take photographs to illustrate and explain the damage.

Acceptance criteria: There shall be no damage to circuit boards, or their mountings and the unit shall function normally. Light damage to the packaging is acceptable but extensive damage to the packaging is not acceptable – for example if the stabilizer is able to fall out.

Rejection criterion: Failure to meet one or more of the acceptance criteria.

5.4.5 Test 3: Impulsive transient protection test

- **Test conditions:** Ambient temperature and humidity, loaded at 100% capacity.
- **Step 1:** Connect an **IEC 61000-4-5** surge generator to the input of the voltage stabilizer or SMPS. Set the supply input voltage to the minimum voltage within the input voltage regulation range, as specified by the legal manufacturer, plus 5 V. Set and note the input frequency within the 50-60 Hz range. Set the surge generator's source impedance to 2 Ω. Check whether the stabilizer output voltage is within plus (+) 10% maximum and minus (-) 15% of the nominal output voltage.

- **Step 2:** Superimpose one (1) 4 kV impulsive transient voltage with an 1,2/50 µs waveform applied line-to-neutral on the input of the voltage stabilizer. The impulse shall be positive in polarity and be applied at the positive peak (90 degrees) of the AC waveform. Measure the maximum residual (let through) voltage resulting from this impulsive transient on the line-to-neutral output for AC voltage stabilizers and positive-to-negative for SMPS. (Note: An appropriate sampling rate to accurately characterize this short duration impulsive transient event should be utilized for measurement equipment, where appropriate). Record the maximum residual voltage and measurement sampling rate used.
- **Step 3:** Based on **IEC 61000-4-5**, superimpose five positive and five negative 2 kV voltage impulses at each of the following waveform phases: 0°, 90°, 180°, 270° with surge impedance set to 2 Ω. The impulses shall have 1,2/50 µs waveform applied line-to-neutral on the input. Wait one minute between pulses. Measure the maximum residual (let through) voltage resulting from this impulsive transient on the line-to-neutral output for AC voltage stabilizers or the positive-to-negative output for SMPS. (Note: An appropriate sampling rate to accurately characterize this short duration impulsive transient event should be utilized for measurement equipment, where appropriate). Record the maximum residual voltage and measurement sampling rate used.
- **Step 4:** Change the source generator's source impedance to 12 Ω. Superimpose five positive and five negative 4 kV voltage impulses at each of the following waveform peaks: 0°, 90°, 180°, 270°. The impulses shall have 1,2/50 µs waveform applied line-to-ground on the input. Wait one minute between pulses. Measure the maximum residual (let through) voltage resulting from this impulsive transient on the line-to-neutral output of the AC voltage stabilizer or positive-to-negative for SMPS. (Note: An appropriate sampling rate to accurately characterize this short duration impulsive transient event should be utilized for measurement equipment, where appropriate). Record the maximum residual voltage and measurement sampling rate used.
- **Step 5:** Continue with the source generator's source impedance set to 12 Ω. Superimpose five positive and five negative 4 kV voltage impulses at each of the following waveform phases: 0°, 90°, 180°, 270°. The impulses shall have 1,2/50 µs waveform applied neutral-to-ground on the input. Wait one minute between pulses. Measure the maximum residual (let through) voltage resulting from this impulsive transient on the line-to-neutral output of the AC voltage stabilizers or positive-to-negative for SMPS. (Note: An appropriate sampling rate to accurately characterize this short duration impulsive transient event should be utilized for measurement equipment, where appropriate). Record the maximum residual voltage and measurement sampling rate used.
- **Step 6:** Inspect the unit externally and internally for any form of mechanical or electrical component failure, damage, or flashover.

Acceptance criteria:

- No component failures (mechanical or electrical).
- No component damage or evidence of arc flash between conductors and/or components.

- Sample continues to operate and stabilize voltage after the test.
- The maximum residual (let-through) voltage on the voltage stabilizer output in Step 3 to comply with specification Clause 4.2.4. That is, for AC voltage stabilizers residual voltage must be less than 400 V for 120 V / 50-60 Hz devices and 750 V for 230 V / 50-60 Hz devices. For SMPS, the residual voltage shall be no greater than three times the desired output and shall return to the set output voltage within two milliseconds.
- For dedicated voltage stabilizers tested within an appliance, the appliance and compressor operate normally following tests.

Rejection criterion: Failure to meet one or more of the acceptance criteria.

5.4.6 Test 4: Electrical withstand test

- **Test conditions:** +43°C ±1°C at Relative Humidity 95%, loaded at 100% capacity.
- **Step 1:** Prepare to measure surface temperatures as described below with an uncertainty of ±0.5°C.
- **Step 2:** Set and note the input frequency within the 50-60 Hz range.
- **Step 3:** Carry out the tests below, with the specified supply input voltage being maintained for 120 minutes for each test. For each test below, note the surface temperature of the hottest surface of the device at the start and end of the test. For dedicated stabilizers, measure the temperature of the appliance's exterior surfaces closest to the stabilizer components and the surfaces of any internal enclosure around the dedicated stabilizer.

For all devices:

Test	Type	Supply Input Voltage
4.1	*AC voltage stabilizers*	
	120/50-60	40 V
	230/50-60	100 V
	230/50-60: Extended	60 V
	SMPS	60 V
4.2	*AC voltage stabilizers*	
	120/50-60	220 V
	230/50-60	500 V
	230/50-60: Extended	500 V
	SMPS	500 V

Additional dielectric test for SMPS:
I/P-O/P (Input to Output): 1.5 kV AC / 1 min
I/P-F/G (Input to Protective Earth or "Ground"): 1.5 kV AC / 1 min
O/P-F/G (Output to Protective Earth or "Ground"): 0.5 kV DC / 1 min

Acceptance criteria:
- No component failure or damage (mechanical or electrical).
- Surface temperature of standalone stabilizers limited to the lesser of 68°C and the operating temperature limit of the enclosure. For integrated and dedicated

stabilizers, internal enclosures must remain cooler than the operating temperature limit of the enclosure. For dedicated stabilizers, external surface temperatures of the protected appliance must not exceed 68°C.

– No insulation breakdown during the SMPS dielectric test.

Rejection criterion: Failure to meet one or more of the acceptance criteria.

5.4.7 Test 5: Voltage regulation range test

- **Test conditions:** Ambient temperature and humidity, variable load as described in Step 2.
- **Step 1:** Set the input frequency to 60 Hz. Prepare to measure input and output power for SMPS efficiency tests.
- **Step 2:** Carry out the following tests, with supply voltage being varied from 0 V to the legal manufacturer specified upper limit of the continuous operating voltage range in increments of 5 V, with each voltage step being maintained for 5 minutes. Also sweep the voltage in the downward direction near the low voltage cut-in/cut-out and the high-voltage cut-out/cut-in points to determine if they are different due to hysteresis.

Test	Variable	Constants	Measurements required
5.1	Voltage: 0 – Specified upper limit	Frequency: 50 or 60 Hz as applicable Load: none	Voltage output
5.2	Voltage: 0 – Specified upper limit	Frequency: 50 or 60 Hz as applicable Load: 20% of rated capacity	Voltage output
5.3	Voltage: 0 – Specified upper limit	Frequency: 50 or 60 Hz as applicable Load: 50% of rated capacity	Voltage output
5.4	Voltage: 0 – Specified upper limit	Frequency: 50 or 60 Hz as applicable Load: 100% of rated capacity	Voltage output For SMPS also measure input and output power

- **Step 3:** Collate results in graphical or tabular form.
- **Step 4:** Repeat Steps 2 and 3 with the power supply adjusted to a frequency of 50 Hz.

Acceptance criteria:

– Input range: Input voltage regulation range as specified by the legal manufacturer, which shall be equal to the range outlined in specification Clause 4.2.3 or extend beyond it in either or both directions. An input range beyond the legal manufacturer's specifications is acceptable. Record the voltage and

frequency at which the device cuts out and no longer corrects voltage at the lower and upper bounds of voltage correction range. These cut-out points may vary depending on load. For clarity, the following relationships shall be satisfied at the lower and upper bounds of the input range for each loading level:
    - **Lower:** (lower measured cut-out voltage) ≤ (lower measured cut-in voltage) ≤ (Legal manufacturer's specified lower voltage bound) ≤ (lower voltage bound as outlined in specification Clause 4.2.3)
    - **Upper:** (upper voltage bound as outlined in specification Clause 4.2.3) ≤ (Legal manufacturer's specified upper voltage bound) ≤ (upper measured cut-in voltage) ≤ (upper measured cut-out voltage)
- Output range: For AC voltage stabilizers, 120 V or 230 V plus (+) 10% or minus (-) 15% over the full input voltage range between measured cut-out voltages. For SMPS, the nominal output plus (+) or minus (-) 5% of the nominal output voltage over the full input voltage range between measured cut-out voltages.
- For SMPS, the operating efficiency shall be 90% or greater when loaded at 100% of rated capacity.

Rejection criteria:

- Failure to control output voltage within the required tolerance over the input voltage range between cut-out voltages.
- Cut-in voltages inside the legal manufacturer's specified range; or
- Legal manufacturer's specified range inside the range outlined in specification Clause 4.2.3.
- For SMPS, efficiency less than 90% when loaded at 100% capacity.

5.4.8 Test 6: Frequency cut-off range test

- **Test conditions:** Ambient temperature and humidity, loaded at 100% capacity.
- **Step 1:** Set the supply voltage to the rated voltage of the device.
- **Step 2:** Vary the frequency in increments of 0.5 Hz, with each frequency step being maintained for a minute or until the output is disconnected.

Test	Variable	Constants	Measurements required
6.1	Frequency of 50 Hz adjusted down to 46 Hz for ac-output stabilizers and 44 Hz for SMPS	Voltage: rated voltage for ac-output stabilizers and 230 V for SMPS Load: 100% of rated kVA capacity	Voltage and Frequency output
6.2	Frequency of 60 Hz adjusted up to 64 Hz for ac-output stabilizers and 65 Hz for SMPS	Voltage: rated voltage for ac-output stabilizers and 230 V for SMPS Load: 100% of rated kVA capacity	Voltage and Frequency output

- **Step 3:** Collate results in graphical or tabular form.

Acceptance criteria:

- Input: Note the frequency at which the device cuts off and no longer provides output power. Note the time taken from frequency change to any cut-off of output voltage. Verify compliance based on type of device and associated requirements as outlined in Clause 4.2.6 of the specification.
- Output: For AC voltage stabilizers, no frequency less than 47 Hz and greater than 63 Hz is detected.
- Output is automatically restored when frequency is adjusted back in range after an optional delay of three to six minutes.

Rejection criterion: Failure to cut off output power within five seconds when input frequency is outside 47-63 Hz for voltage stabilizers or the legal manufacturer's stated frequency range for SMPS.

5.4.9 Test 7: High load starting test

- **Loading:** by load and stabilizer types:
  - Motor/dynamometer with standalone or integrated stabilizers: Set the load to 100% capacity.
  - Programmable electronic load with standalone or integrated stabilizers: Set the load to draw five times the current of 100% capacity to simulate the start current of a refrigeration compressor. If the load has an "inrush" function, it is advisable to use that to avoid interaction with overcurrent protection. Prepare to measure the stabilizer's output voltage during the start transient.
  - Dedicated stabilizers: Use the appliance's internal load. Set up test conditions to create the worst-case load over the appliance's operating range. For instance, hot-zone refrigerators and freezers must be equilibrated to +43°C to create maximum load.
- **Test conditions:** Ambient temperature and humidity for standalone and integrated stabilizers. For dedicated stabilizers, use temperature conditions as necessary to create maximum load as discussed above.
- **Step 1:** Set the input frequency to 60 Hz.
- **Step 2:** Set the supply voltage to the minimum voltage within the measured input voltage regulation range (see Test 5), plus 5 V.
- **Step 3:** For motor loads and dedicated stabilizers using motor or compressor loads, cold start the motor ten times. For other stabilizers and loads, apply voltage ten times and measure the stabilizer output voltage during the high-current transient.
- **Step 4:** Repeat Steps 2 and 3 with the power supply set to a frequency of 50 Hz.

Acceptance criterion: For motor loads and dedicated stabilizers using motor or compressor loads, ten out of ten successful starts for each frequency setting tested. For stabilizers tested with programmable loads, voltage during the transient does not dip more than 25% from the nominal output voltage.

Rejection criterion: One or more start failures or voltage below the limits in the acceptance criterion.

5.4.10 Test 8 Endurance test

- **Test conditions:** +43°C ±1°C at Relative Humidity 95%, loaded at 100% capacity.
- **Step 1:** Prepare to measure surface temperature as described below with an uncertainty of ±0.5°C.
- **Step 2:** Set and maintain constant supply voltage at the rated voltage (230 V for SMPS) and vary frequency in four steps (as specified below). For each step below, note the surface temperature of the hottest surface of the device at the start and at the instant when frequency is returned to 50-60 Hz. For dedicated stabilizers, measure the temperature of the appliance's exterior surfaces closest to the stabilizer components and the surfaces of any internal enclosure around the dedicated stabilizer.

  For AC voltage stabilizers:
  - Provide frequency of 47 Hz for 10 minutes, then return to 50-60 Hz for 10 minutes.
  - Provide frequency of 48 Hz for 60 minutes, then return to 50-60 Hz for 10 minutes.
  - Provide frequency of 62 Hz for 60 minutes, then return to 50-60 Hz for 10 minutes.
  - Provide frequency of 63 Hz for 10 minutes, then return to 50-60 Hz.

  For SMPS
  - Provide frequency of 45 Hz for 10 minutes, then return to 50-60 Hz for 10 minutes.
  - Provide frequency of 46 Hz for 60 minutes, then return to 50-60 Hz for 10 minutes.
  - Provide frequency of 64 Hz for 60 minutes, then return to 50-60 Hz for 10 minutes.
  - Provide frequency of 65 Hz for 10 minutes, then return to 50-60 Hz.

- **Step 3:** Fix the input frequency to 50 or 60 Hz based on whichever end of the spectrum is shown to have the hottest surface temperatures from Step 2. Vary the supply voltage between the minimum in the measured input voltage regulation range (see Test 5), plus 10 volts, and the maximum (see Test 5) minus 10 volts, at a frequency of l0 cycles per minute. Continue the test including measuring temperatures for a minimum of 96 hours. Report any breakdowns.
- **Step 4:** Hold the supply voltage constant at the minimum value within the measured input voltage regulation range (see Test 5). On tap-changing stabilizers, this will be at an input voltage below the first tap change. Conduct this test for a further 12 hours and report any breakdowns.
- **Step 5:** Hold the supply voltage constant at the maximum value within the measured input voltage regulation range (see Test 5) for a further 12 hours. Report any breakdowns.

Acceptance criteria:

- No component failures (mechanical or electrical).
- Surface temperature of standalone stabilizers limited to the lesser of 68°C and the operating temperature limit of the enclosure. For integrated and dedicated stabilizers, internal enclosures must remain cooler than the operating temperature limit of the enclosure. For dedicated stabilizers, external surface temperatures of the protected appliance must not exceed 68°C.
- The change in the output voltage should be within plus (+) 10% and minus (-) 15% of the nominal output voltage for AC voltage stabilizers when the input frequency is varied between 47 Hz and 63 Hz, and within plus (+) and minus (-) 5% for SMPS when the input frequency is varied between 45 Hz and 65 Hz.

Rejection criterion: Failure to meet one or more of the acceptance criteria.

5.4.11 Test 9: High/low voltage cut-off test

- **Test conditions:** Ambient temperature and humidity, loaded at 100% capacity.
- **Step 1:** Set and note the input frequency within the 50-60 Hz range.
- **Step 2:** Refer to the upper and lower limits of voltage regulation range and input voltage cut out that were established in Test 5 for the fully loaded case.
- **Step 3:** Set the maximum voltage at which the under-voltage cut-out operates and maintain it for one minute. Then follow it with a period at nominal supply voltage (120/230 V) until the output voltage is restored. Record the time period between when nominal supply voltage is restored and when output voltage is restored.
- **Step 4:** Maintain the minimum voltage at which the over-voltage cut-out operates for a period of one minute followed by a period at nominal supply voltage (120/230 V) until the output voltage is restored. Record the time period between when nominal supply voltage is restored and when output voltage is restored.

Acceptance criteria: The over/under-voltage protection cut-out shall operate whenever acceptable output voltage cannot be maintained by cutting the output voltage to zero. When the supply voltage is restored to a value within the input voltage regulation range, the nominal output supply shall be restored automatically after a delay of three to six minutes unless this requirement is waived by the legal manufacturer and approved for waiver by PQS. Report the cut-out voltage thresholds and the cut-in thresholds and timings.

Rejection criterion: Failure to meet one or more of the acceptance criteria.

5.4.12 Test 10: Overload and short-circuit protection test

- **Applicable devices:** All stabilizers except appliances with dedicated stabilizers that contain safeguards to prevent overloading the stabilizer.
- **Test conditions:** Ambient temperature and humidity. Load as described in Clause 5.4.2 and detailed in each step below.
- **Step 1:** Set the supply voltage at the nominal value (120 V or 230 V, using 230 V for SMPS). Set and note the input frequency within the 50-60 Hz range.

- **Step 2:** Load the device to 150% the rated capacity of the device and record the time before the output voltage cuts out.
- **Step 3:** Reset the device (manually or automatically) and record the time period elapsed between output voltage cut-out and when it is possible to reset the overload disconnect mechanism.
- **Step 4:** Load the device to 720% of the rated capacity of the device and record the time before output voltage cuts out.
- **Step 5:** Reset the device (manually or automatically) and record the time period elapsed between output voltage cut-out and when it is possible to reset the overload disconnect mechanism.
- **Step 6:** Load the device to 1,000% the rated capacity (in output current) of the device for AC stabilizers and SMPS to simulate a short-circuited load and record the time before output voltage cuts out

Acceptance criteria:

- The device disconnects its output within 120 seconds when connected to a load equal to 150% the rated capacity and remains undamaged.
- The device disconnects its output within 10 seconds when connected to a load equal to 720% the rated capacity and remains undamaged.
- The device disconnects its output within 100 milliseconds when subjected to a simulated short circuit and remains undamaged.
- A period of three to six minutes shall elapse before an automatic reconnect device resets the overload disconnect mechanism or before the output voltage is automatically restored.

Rejection criterion: Failure to meet one or more of the acceptance criteria.

5.4.13 Test 11: IP rating test to IEC 60529

- **Test conditions:** Ambient temperature and humidity. Loading not applicable.
- **Step 1:** For integrated and dedicated voltage stabilizers or SMPS, the voltage protection device shall meet the requirements of the appliance within which it is integrated. For standalone voltage stabilizers and SMPS, obtain an independent test report from the legal manufacturer or reseller showing full conformity with **IEC 60529: IP31** or better.
- **Step 2:** If an independent test report is not available, carry out **IP31** tests on the single sample.

Acceptance criteria: IP31 test passed.
Rejection criterion: IP31 test failed.

5.5 Test criteria for qualification

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

- **Summary:** Conclusions and recommendations.
- **Test 1:** Result of type examination plus comments on samples received, tabulated data, compliance with required specifications (plus supporting documentation) and photographs of samples.
- **Test 2:** Results of vibration test.
- **Test 3:** Results of impulsive transient protection test.
- **Test 4:** Results of electrical withstand test.
- **Test 5:** Results of voltage regulation range test.
- **Test 6:** Results of frequency cut-out range test
- **Test 7:** Results of high load starting test.
- **Test 8:** Results of endurance test.
- **Test 9:** Results of high-low voltage cut-off test.
- **Test 10:** Results of overload and short-circuit protection test.
- **Test 11:** Results of IP rating test.
- **Annexes:** A pre-approved test protocol verifying that the procedures set out in this document have been followed. Description of the test apparatus. Test chamber temperature and humidity records. Copies of reference thermometer and humidity measurement calibration certificate(s). 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 shall be carried out in accordance with the requirements of **ISO 17025**.

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 device will qualify for inclusion on the register of PQS prequalified voltage stabilizers in accordance with WHO procedures provided the final report indicates full conformity with the requirements of specification **WHO/PQS/E007/VS01.6**.

8. Modified products

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

Annex 1: Integrated and dedicated voltage stabilizers

Integrated voltage stabilization enables equipment to operate in a wide range of voltage conditions without needing a separate protection and stabilization device. As mentioned in Clause 1: Scope, this verification protocol applies to a variety of types of integrated and dedicated stabilization. It is difficult to anticipate all the forms stabilization may take, so this annex attempts to explain the goals of **WHO/PQS/E006/VS01** and this associated verification protocol and provide examples illustrating how the protocol should be applied.

- Voltage stabilization should enable appliances to operate reliably from wide-ranging and time-varying mains voltages.
- Voltage stabilization should protect the appliance from mains voltage conditions that could be damaging. This means protecting against sustained overvoltage and undervoltage, impulsive transients, out-of-specification frequency, and also not producing conditions that could be harmful to personnel or equipment (e.g. high temperatures).
- Voltage stabilization meant for general use should perform well with all anticipated load types. General use includes standalone stabilizers and integrated stabilizers. Common loads for refrigerators and other cold-chain equipment are compressors or other electric motors with their challenging start transients.

Here are some potential integrated and dedicated voltage stabilizers and testing considerations for them:

Configuration	Configuration details	Requirements and test considerations
Integrated enclosed stabilizer developed by a non-appliance manufacturer	Single piece, in an enclosure, connectors for input/output power	Must be tested like a standalone stabilizer at rated capacity because it is a general-purpose device.
Integrated components developed by a non-appliance manufacturer	Controller in a plastic enclosure, connected to a transformer without an enclosure	Must be tested like a standalone stabilizer at rated capacity because it is a general-purpose device.
Appliance-manufacturer-developed integrated stabilizer module for its product line	Single piece, not separately enclosed	This is a general-purpose integrated stabilizer. If tested at maximum load of product line, could be integrated into other equal- or lower-load products without retest.
Compressor-based appliance with dedicated stabilization capabilities	The refrigerator control module also contains relays to switch a stabilization transformer. Thermal control and stabilization control are not easily separable into distinct modules to test.	Must be tested as a complete appliance with a dedicated stabilizer. Preferable to use the appliance's load for the tests requiring full capacity loading.

Variable-speed drive	Mains-input variable-speed drive for compressors. It has an input voltage range and protections compliant with **WHO/PQS/E007/VS01**. Output is three-phase drive for a compressor.	Should be tested with a compressor in a complete appliance with the refrigeration system load as a dedicated stabilizer. Output requirements (i.e., voltage regulation, frequency, overload, short circuit) do not apply because the output is neither single-phase ac, nor a fixed DC voltage.
Battery charger integrated in a transportable powered vaccine storage appliance	Mains-input battery charger integrated into a **WHO/PQS/E003/TS01** appliance. It has an input voltage range and protections compliant with **WHO/PQS/E007/VS01**. Output is a varying DC voltage suitable for charging a specific battery.	Must be tested with the battery load under high loading conditions as a dedicated stabilizer. Should be tested with the complete appliance for thermal considerations. Output requirements (i.e., voltage regulation, frequency, overload, short circuit) do not apply because the output is neither single-phase ac, nor a fixed DC voltage.

Notes:
Consistent with specification **WHO/PQS/E007/VS01.6** Clause 4.2.5, integrated and dedicated stabilizers may have rated capacity < 1 kVA, because pairing with the known load can be properly engineered by the integrating appliance manufacturer.

Annex 2: Test set-up for different types of voltage stabilizers

The different types of voltage stabilizer (VS) have to meet the same PQS requirements but it is recognized that there can be different set-ups or configurations as follows:

8.1 Standalone voltage stabilizer

A stand-alone stabilizer model for general use. These are designed for an unknown load up to a designed maximum.

Temperature measurements will be taken over all the external casing to ensure that no temperature exceeds a safe maximum. See Test 4: Electrical withstand test and Test 8: Endurance test.

8.2 Integrated voltage stabilizer

Stabilizers intended to be integrated into multiple appliance models and submitted for prequalification as a separate voltage stabilizer device. These may be designed and produced by the appliance manufacturer or another manufacturer. These are designed for an unknown load but the enclosure, markings and connections might differ from appliance to appliance. They should be tested in the same set-up as any standalone voltage stabilizer.

Measurements will be taken over any external casing or surface that may be visible to ensure that no temperature exceeds safe maximums. See Test 4: Electrical withstand test and Test 8: Endurance test.

8.3 Dedicated voltage stabilizer

Stabilizers already integrated into appliances and submitted for prequalification as part of a complete appliance. It will receive PQS qualification for use with that appliance only, unless it can be shown to be compatible with similar models that have a smaller load or power demand with compressors that have similar start characteristics, e.g. peak current.

Appliances with voltage stabilization capability that are being prequalified as a complete unit have the opportunity for tighter coupling in the design between the stabilizer and the load, and there may not even be a discrete “voltage stabilizer” device in the fridge that could be separated and tested *ex-situ*.

Annex 3: Uncertainties

Uncertainty should be calculated for each measured parameter and includes all contributors from the tip of the measuring instrument to the read-out or logged data.

Uncertainties should be no worse than the following for the following measurands:

Temperature	± 0.5°C
Humidity	± 5% RH
Power	± 0.1%
Frequency	± 0.1%
Voltage	± 0.5%
Current	± 0.5%

Actual calculated uncertainties depend on measurement range and type of instrument. The PQS laboratory should quote uncertainties in their test report. An uncertainty "budget" should include all the influences on the measured value.

Revision History

Date	Change summary	Reason for change	Approved
May 2022	Overload/short circuit reverted to VS01.5 and fuses removed	Industry feedback on proposed overload requirements; expert feedback on fuses.	
	Tests 5 and 9: clarifications to make them output-voltage focused	Industry feedback	
April 2022	3. Terms and definitions: Add appliance and dedicated, integrated, and standalone.	Simplify references to different types	
	5.4.6 Test 4: Electrical withstand test: Clarify surface temperature testing requirements	Industry and expert feedback	
	5.4.10 Test 8: Endurance test: Clarify surface temperature testing requirements	Industry and expert feedback	
	5.4.12 Test 10: Overload: Add applicable appliances.	Industry feedback	
	5.4.13 Test 11: IP test: Clarify test descriptions.	Clarification	
September 2021	Reduce number of samples per test from 2 to 1	A single voltage stabilizer shall pass all tests to demonstrate compliance.	IG
	Eliminated reference to IEC 60950-1 in favor of IEC 60335-1	Applicability of IEC 60335-1 to voltage protection equipment	IG
	5.4.4 Test 3: Impulsive transient protection test: Revised testing regimen to be more in line with IEC 61000-4-5; Acceptance criteria: allowable limits for residual voltage updated. Acceptance criteria: allowable limits for residual voltage updated.	The tests done in IEC 61000-4-5 typically superimpose the transient at different points in the AC waveform: 0, 90, 180, and 270 degrees, and both positive and negative impulsive polarities. Adding a positive impulse at the positive peak (90 degrees) or negative impulse at the negative peak (270 degrees) are probably the worst-case conditions. Since there is only one pulse, the positive condition is selected. Also, the voltage waveform is defined as 1.2usec rise time and 50usec width (1.2/50, or 1,2/50 depending on decimal separator). The corresponding current waveform that flows if the surge generator is short circuited will be 8/20us, hence the change.	IG
	5.4.5 Test 4: Electrical withstand test: Clarified requirements for SMPS and dielectric test.	Industry and expert feedback.	IG

	5.4.5 Test 4: Electrical withstand test: updated overvoltage test level from 415 V to 500 V	Field data on frequency of overvoltage instances and magnitude	IG
	5.4.7 Test 6: Frequency cut-out range test: added to verify ability for devices to cut out dangerous frequencies	Improve robustness of devices against high and low supply voltage frequencies	IG
	5.4.9 Test 8: Endurance test: Clarified requirements for VS and SMPS with respect to frequency fluctuations	Industry and expert feedback.	IG
	5.4.11 Test 10: Overload and short-circuit protection test: Revised testing to reflect updates to specification on short-circuit conditions, time delay before automatic restart.	Industry and expert feedback.	IG
	5.4.12 Test 11: IP rating test to IEC 60529: Clarified requirement for integrated and standalone appliances	Industry and expert feedback.	IG
Mar. 2020	Included provisions for testing ac-to-DC switching devices.	Allow ac-to-DC switching solutions for power protection.	IG
	5.4.4 revised test procedure per IEC 61000-4-5	Refined protocol for impulsive transients testing.	IG
	5.4.8 revised supply frequencies in line with revisions in specification for AC voltage stabilizers	Reflect updated specifications	IG
	5.4.10 revised overload ratings	Revised to be in line with IEC standard	IG
Mar. 2018	5.4.10 Inclusion of verbiage to allow device to pass overload test with automatic reconnect switch	Specification updated to allow manual or automatic reconnect based on feedback from manufacturers	IG
Sept. 2017	1. Inclusion of electric-gas absorption cycle and thermoelectric equipment	To cover new technology type recently allowed by PQS	IG
	5.4.2 Inclusion of check for continuous operating input voltage range	Specification check missing in previous revision	IG
	5.4.4 Inclusion of impulsive transient protection test	To test protection against impulsive transients such as lightning	IG
	5.4.5 Inclusion of electric withstand test	To test equipment for continuous performance under sustained under/overvoltage	IG
	5.4.8 Removal of 230/450V spike test	These test conditions are now better covered by Clause 5.4.2	IG
	5.4.8 Modified ambient temperature from 45°C to 43°C	To be in line with maximum ambient operating temperatures required for refrigerators/freezers	IG
	5.4.8 Modified output voltage accuracy to +10% and -15%	To be in line with accuracy requirements in rest of document	IG
	5.4.10 Inclusion of overload protection test	To test protection of device against overload conditions	IG
	5.4.2–5.4.11 Reordered and tests are now required to	In order to present a more logical flow of performance tests	IG

	follow in numerical order		
	Throughout document – Various minor changes to verbiage	To more concisely reflect requirements of test protocol	IG
Oct. 2016	4. Removed requirement for testing laboratory to be accredited by WHO	ISO certified laboratory sufficient	IG
	5.3 Additional paragraph to specify condition of test sample provided to test laboratory.	Included to cover integrated stabilizer tests	IG
	5.4.3 Upper voltage limit of test updated to reflect manufacturer specified operating limit	Included to better reflect the minimum protection standard tested by this document	IG
	5.4.3 Output tolerance updated to reflect performance over full specified operating range	Included to better reflect the minimum protection standard tested by this document	IG
	5.4.5 Step 2 updated to reflect the lower limit of manufacturer specified voltage range	Included to better reflect the minimum protection standard tested by this document	IG
	5.4.5 Nomenclature of Step 3 updated to test endurance at upper limit of operating range	Included to better reflect the minimum protection standard tested by this document	IG
	5.4.5 Specification of spike test in Step 4 updated. Updated requirement during spike test	Included to better reflect the minimum protection standard tested by this document	IG
	5.4.5 Updated frequency band specification in Acceptance Criteria		IG
	5.4.6 Included Step 3 to test voltage recovery after over-voltage protection cut-off	Included to better reflect the minimum protection standard tested by this document	IG
	5.4.6 Updated Acceptance Criteria nomenclature to refer to manufacturer operating range	Included to better reflect the minimum protection standard tested by this document	IG
Dec. 2015	Modification of the working in test 2 step 2 to include the incremental change in voltage	Feedback from manufacturers	IG
	Inclusion of the effect on voltage of changes in frequency	Feedback from manufacturers	IG