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Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures

Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation – Partie 2: Procédures d'essai

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4.3.5 Test requirements

绝缘性能

a) No dielectric breakdown or surface tracking.

b) For modules with an area of less than 0,1 m^2 the insulation resistance shall not be less than 400 MΩ.

c) For modules with an area larger than 0,1 m^2 the measured insulation resistance times the area of the module shall not be less than 40 MΩ·m^2.

4.4 Measurement of temperature coefficients (MQT 04)

Determine the temperature coefficients of current (α), voltage (β) and peak power (δ) from module measurements as specified in IEC 60891. The coefficients so determined are valid at the irradiance at which the measurements were made. See IEC 60904-10 for evaluation of module temperature coefficients at different irradiance levels. For bifacial modules determine the temperature coefficients utilizing the same procedure, but insuring no backside irradiation. The backside shall be covered such that the contribution from the non-exposed side of the module is limited to or below the levels specified for "non-irradiated background" in IEC TS 60904-1-2. If open-circuit voltage or short-circuit current cannot be measured due to module-integrated electronics, the associated temperature coefficient shall be reported as "not measurable due to module-integrated electronics." Open-circuit voltage or short-circuit current shall not be determined by any method other than direct measurement, such as extrapolation.

NOTE For linear modules in accordance to IEC 60904-10, temperature coefficients are valid over an irradiance range of ±30 % of this level.

4.5 Placeholder section, formerly NMOT

The nominal module operating temperature (NMOT) test, formerly MQT 05, is no longer a part of this document. This subclause is preserved so that, in the following subclauses of the document, the MQT numbers match the subclause numbers.

4.6 Performance at STC (MQT 06.1)

4.6.1 Purpose

To determine how the electrical performance of the module varies with load at STC (1 000 W/m^2, 25 °C cell temperature, with the IEC 60904-3 reference solar spectral irradiance distribution). MQT 06.1 is a case of maximum power determination (MQT 02) performed at STC. MQT 06.1 is used to verify the name plate information of the module, and for determining power loss from the stress tests. Uncertainty, m_1, shall include a component from spectral mismatch, based either on measured spectral response or the worst-case possibility for a given technology type, and the method used to set the simulator intensity. For nameplate verification, the uncertainty m_1 is subject to the limits specified in the technology-specific parts. For determining the power loss from the stress tests, reproducibility of the test, r, is subject to the limits specified in the technology-specific parts.

4.6.2 Apparatus

a) The apparatus shall be as described in 4.2.2 (MQT 02).

b) It shall also be equipped with a means for monitoring the temperature of the test specimen and the reference device to an accuracy of ±1 °C and repeatability of ±0,5 °C.

c) For measurement of bifacial modules the following capability is also necessary: The radiant source utilized as specified in 4.6.2a shall be operable with adjustable irradiance levels and/or rear-side irradiance such that BNPI (as defined in IEC 61215-1:2021) can be applied by at least one method allowed by IEC TS 60904-1-2.

d) For measurement of multi-junction modules, the simulator and reference device shall meet the additional requirements imposed by IEC 60904-1-1.

c) Short-circuit the module and shadow at random a block in the module. Shadow at least 10 % of the cells within the block, and shadow an increasing area of the block until the maximum temperature is determined using thermal imaging equipment or other appropriate means.

d) Re-measure the un-shadowed module I-V characteristic and determine maximum power P_{max2}.

e) Apply the shadow found in step c) and maintain these conditions for a total exposure time of 1 h.

At the end of the endurance test, determine the hottest area on the shadowed cells using an IR camera or appropriate temperature detector.

4.9.6 Final measurements

Repeat tests MQT 01, MQT 02, MQT 03, and MQT 15.

4.9.7 Requirements

a) No evidence of major visual defects permitted, as defined in IEC 61215-1:2021, particularly looking for signs of melted solder, openings in the enclosure, delaminations and burn spots. If there is evidence of serious damage that does not qualify as a major visual defect, repeat the test on two additional cells within the same module. If there is no visual damage around either of these two cells the module type passes the hot-spot test.

b) Verify that the module shows the electrical characteristics of a functional photovoltaic device. MQT 02 is not a pass/fail requirement (Gate No 2) for power loss.

c) Insulation resistance shall meet the same requirements as for the initial measurements.

d) Wet leakage current shall meet the same requirements as for the initial measurements.

e) Any damage resulting from determining the worst case shadowing shall be noted in the test report.

4.10 UV preconditioning test (MQT 10)

紫外可靠性

4.10.1 Purpose

To precondition the module with ultra-violet (UV) radiation before the thermal cycle/humidity freeze tests to identify those materials and adhesive bonds that are susceptible to UV degradation.

NOTE MQT 10 is meant to detect gross susceptibility to UV degradation, as the dose is small compared to typical lifetime expectations for modern modules, and wavelength distribution of the UV source is not tightly specified. Documents applying MQT 10 toward other goals (such as comparative degradation studies) should consider what further requirements are necessary to achieve those goals.

4.10.2 Apparatus

a) A temperature-controlled test chamber with a window or fixtures for a UV light source and the module(s) under test. The chamber shall be capable of maintaining the module temperature at (60 ± 5) °C.

b) A means for monitoring the temperature of the module to an accuracy of ±2,0 °C and repeatability of ±0,5 °C. The temperature sensors shall be attached to the front or back surface of the module near the middle without obstructing any of the UV light incident on the active cells within the module. If more than one module is tested simultaneously, it will suffice to monitor the temperature of one of the test modules.

c) Instrumentation capable of measuring the irradiance of the UV light produced by the UV light source at the test plane of the module(s), within the wavelength ranges of 280 nm to 320 nm and 320 nm to 400 nm with an uncertainly of ±15 % or better.

d) A UV light source capable of producing UV radiation with an irradiance uniformity of ±15 % over the test plane of the module(s) with no appreciable irradiance at wavelengths below 280 nm and capable of providing the necessary total irradiance in the different spectral regions of interest as defined in 4.10.3.

e) The module shall either be short-circuited or open-circuited during exposure, as per manufacturer recommendations. The circuitry condition used during this test shall be noted in the test report.

4.10.3 Procedure

a) Measure the irradiance at the proposed module test plane and ensure that at wavelengths between 280 nm and 400 nm it does not exceed 250 W/m^2 (i.e. about five times the natural sunlight level) and that it has a uniformity of ±15 % over the test plane.

b) According to the recommendations of 4.10.2e), short-circuit or open-circuit the module. Mount it in the test plane at the location selected in a), normal to the UV irradiance beam. Make sure that the module temperature sensors read (60 ± 5) °C. For flexible modules, the modules shall be mounted per the manufacturer's documentation with prescribed substrate and adhesive or attachment/mounting means during the test.

c) Subject the module(s) front side to a total UV irradiation of at least 15 kWh/m^2 in the wavelength range between 280 nm and 400 nm with at least 3 %, but not more than 10 % in the wavelength band between 280 nm and 320 nm, while maintaining the module temperature within the prescribed range.

For bifacial modules repeat the procedure of UV irradiation on the rear-side of the modules.

4.10.4 Final measurements

Repeat the tests of MQT 01 and MQT 15.

4.10.5 Requirements

a) No evidence of major visual defects, as defined in IEC 61215-1:2021.

b) Wet leakage current shall meet the same requirements as for the initial measurements.

4.11 Thermal cycling test (MQT 11)

热循环可靠性

4.11.1 Purpose

To determine the ability of the module to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature.

4.11.2 Apparatus

a) A climatic chamber with automatic temperature control with means for circulating the air inside and means to minimize condensation on the module during the test, capable of subjecting one or more modules to the thermal cycle in Figure 7.

b) Means for mounting or supporting the module(s) in the chamber, so as to allow free circulation of the surrounding air. The thermal conduction of the mount or support shall be low, so that, for practical purposes, the module(s) are thermally isolated.

c) Measurement instrumentation having an accuracy of ±2,0 °C and repeatability of ±0,5 °C for measuring and recording the temperature of the module(s).

d) Means for applying a continuous current. The value of the current is defined in the technology specific parts in this standard.

e) Means for monitoring the flow of current through each module during the test.

f) A 5 N weight capable of being attached to the electrical termination leads of the module.

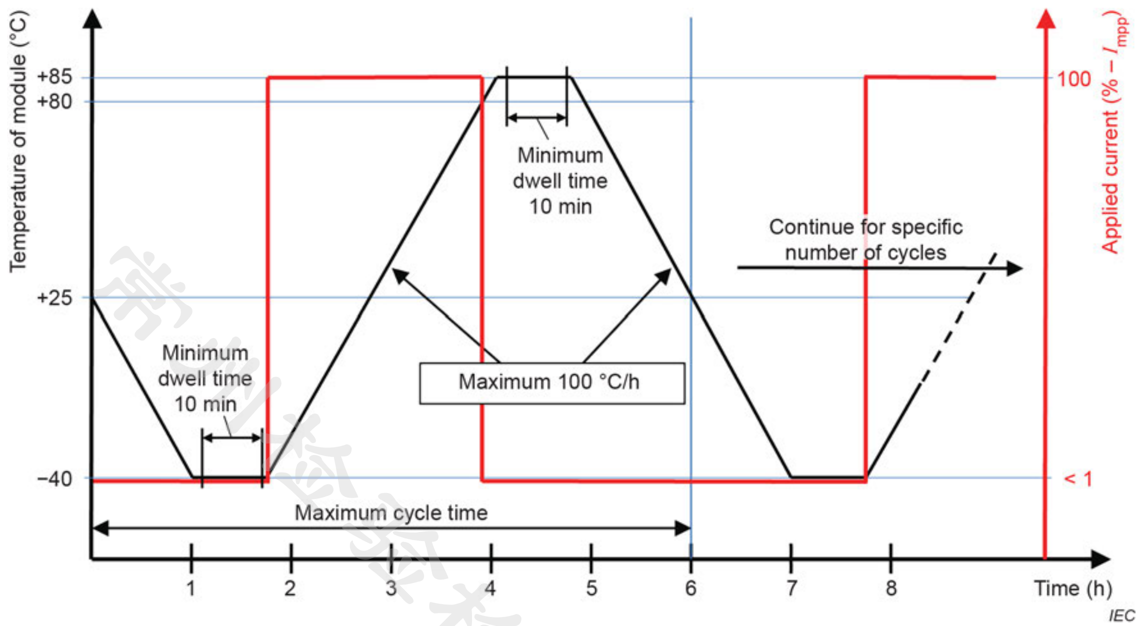


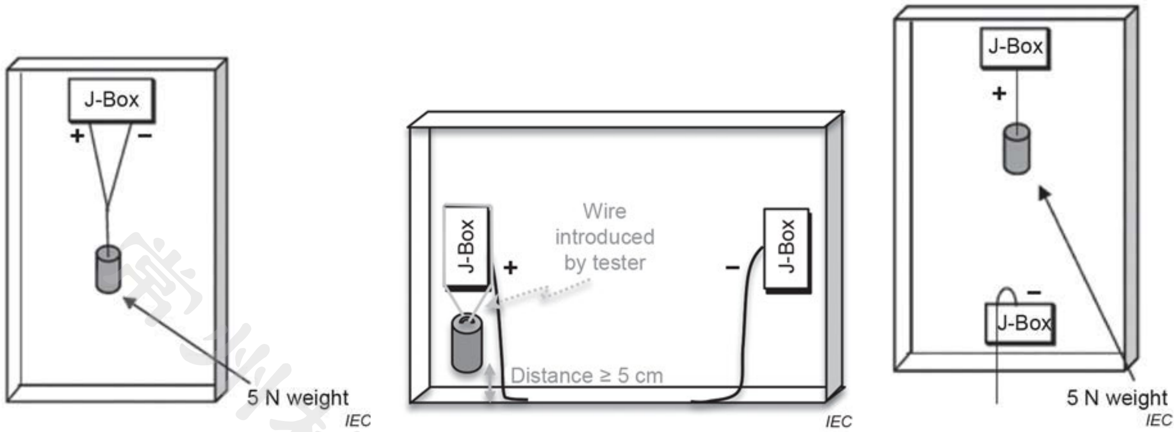
Figure 7 – Thermal cycling test – Temperature and applied current profile

4.11.3 Procedure

a) Attach a suitable temperature sensor to the front or back surface of the module(s) near the middle. If more than one module of the same type are tested simultaneously, it will suffice to monitor the temperature of one of the test modules.

b) Install the module(s) at room temperature in the chamber. Attach a single 5 N weight to the junction box using one of two options. The weight may be attached utilizing the electrical termination leads of each module so that it hangs down vertically from the junction box, as shown in Figure 8a). The weight may also be attached to the junction box using a wire introduced by the tester, as shown in Figure 8b). A wire introduced by the tester shall not be attached to the junction box lid. In either case, the weight shall not impact or damage the module back surface, and shall be at least 5 cm above the floor or module frame at the start of the test, as indicated in Figure 8b). If there are more than one similar junction boxes per module, only one junction box need be weighted, as shown in Figure 8b) or Figure 8c). However, if the junction boxes differ in design, each should carry weights independently.

For flexible modules, the modules shall be mounted per the manufacturer's documentation with prescribed substrate and adhesive or attachment/mounting means during the test.



a) b) c)

Figure 8 – Proper attachment of 5 N weight to junction box for module utilizing a) electrical termination leads, b) or wire for attachment, and c) only one junction box

c) Connect the temperature-monitoring equipment to the temperature sensor(s). Connect each module to the appropriate current supply by connecting the positive terminal of the module to the positive terminal of the power supply and the second terminal accordingly. During the thermal cycling test set the continuous current flow during the heat up cycle to the technology specific current specified in 4.11.2d), at temperature from -40 °C to +80 °C. During cool down, the -40 °C dwell phase and temperatures above 80 °C the continuous current shall be reduced to no more than 1,0 % of the measured STC peak power current to measure continuity. If the temperature rises too fast (greater than 100 °C/h) at the lowest temperature, the start of the current flow can be delayed until the temperature has reached -20 °C.

d) Close the chamber and subject the module(s) to cycling between measured module temperatures of (-40 ± 2) °C and (+85 ± 2) °C, in accordance with the profile in Figure 7. The rate of change of temperature between the low and high extremes shall not exceed 100 °C/h and the module temperature shall remain stable at each extreme for a period of at least 10 min. The cycle time shall not exceed 6 h unless the module has such a high heat capacity that a longer cycle is required. The number of cycles shall be as shown in the relevant sequences in Figure 2 of IEC 61215-1:2021. Air circulation around the module(s) has to ensure compliance with each module under test meeting the temperature cycling profile.

e) Throughout the test, record the module temperature and monitor the current flow through the module(s). Document in test report the actual dwell duration at high and low temperatures.

NOTE In a module with parallel circuits, an open circuit in one branch will cause a discontinuity in the voltage, but not cause the current to go to zero.

4.11.4 Final measurements

After a minimum recovery time of 1 h at (23 ± 5) °C and a relative humidity less than 75 % under open-circuit conditions, repeat the tests of MQT 01 and MQT 15.

4.11.5 Requirements

a) No interruption of current flow during the test; in the case of a module with parallel circuits, a discontinuity in current flow indicates an interruption of flow in one of the parallel circuit.

b) No evidence of major visual defects, as defined in IEC 61215-1:2021.

c) Wet leakage current shall meet the same requirements as for the initial measurements.

4.15 Wet leakage current test (MQT 15)

4.15.1 Purpose

To evaluate the insulation of the module under wet operating conditions and verify that moisture from rain, fog, dew or melted snow does not enter the active parts of the module circuitry, where it might cause corrosion, an earth fault or a safety hazard.

4.15.2 Apparatus

a) A shallow trough or tank of sufficient size to enable the module with frame to be placed in the solution in a flat, horizontal position. It shall contain a water/wetting agent solution sufficient to wet the surfaces of the module under test and meeting the following requirements:

   Resistivity: 3 500 Ω-cm or less

   Solution temperature: (22 ± 2) °C

   The depth of the solution shall be sufficient to cover all surfaces except junction box entries.

b) Spray equipment containing the same solution.

c) DC voltage source, with current limitation, capable of applying 500 V or the maximum rated system voltage of the module, whichever is more.

d) Instrument to measure insulation resistance.

4.15.3 Procedure

All connections shall be representative of the recommended field wiring installation, and precautions shall be taken to ensure that leakage currents do not originate from the instrumentation wiring attached to the module.

a) Immerse the module in the tank of the required solution to a depth sufficient to cover all surfaces except junction box entries. The cable entries shall be thoroughly sprayed with solution. If the module is provided with a mating connector, the connector should be sprayed during the test.

b) Connect the shorted output terminals of the module to the positive terminal of the test equipment. Connect the liquid test solution to the negative terminal of the test equipment using a suitable metallic conductor.

   Some module technologies may be sensitive to static polarization if the module is maintained at positive voltage to the frame. In this case, the connection of the tester shall be done in the opposite way. If applicable, information with respect to sensitivity to static polarization shall be provided by the manufacturer and documented in the test report.

c) Increase the voltage applied by the test equipment at a rate not exceeding 500 V/s to 500 V or the maximum system voltage for the module, whichever is greater. Maintain the voltage at this level for 2 min. Then determine the insulation resistance.

d) Reduce the applied voltage to zero and short-circuit the terminals of the test equipment to discharge the voltage build-up on the module.

e) Ensure that the used solution is well rinsed off the module before continuing the testing.

4.15.4 Requirements 湿漏电流

– For modules with an area of less than 0,1 m^2 the insulation resistance shall not be less than 400 MΩ.

– For modules with an area larger than 0,1 m^2 the measured insulation resistance times the area of the module shall not be less than 40 MΩ·m^2.

f) The environmental conditions for performing the tests are (25 ± 5) °C in a relative humidity not exceeding 75 %.

NOTE 2 As most adhesives will perform worse under elevated temperatures, room temperature is considered to be a best case condition for testing.

4.16.3 Procedure

a) Equip the module so that the electrical continuity of the internal circuit can be monitored continuously during the test.

b) Mount the module on a rigid structure using the method prescribed by the manufacturer including the mounting means (clips/clamps and any kind of fastener) and underlying support rails. If there are different possibilities each mounting method needs to be evaluated separately. For all mounting methods, mount the module in a manner where the loading is worst case. If there are different possibilities, each mounting configuration needs to be evaluated separately. Worst case loading is typically associated with largest cantilever (overhang span) or largest deflection. For all mounting configurations, mount the module in a manner where the distance between the fixing points is worst case, which typically results in the worst deflection of the module, while following manufacturer recommendations for the specified mounting means. Allow the modules to equilibrate for a minimum of 2 h after MQT 13 before applying the load. For flexible modules, the modules shall be mounted per the manufacturer's documentation with prescribed substrate and adhesive or attachment means during the test.

c) On the front surface, gradually and uniformly apply the test load. Load uniformity needs to be better than ±5 % across the module with respect to the test load. Maintain this load for 1 h.

d) Apply the same procedure as in step c) to the back surface of the module or as uplift load to the front surface.

e) Repeat steps c) and d) for a total of three cycles.

4.16.4 Final measurements

Repeat the tests of MQT 01 and MQT 15.

4.16.5 Requirements

a) No intermittent open-circuit fault detected during the test.

b) No evidence of major visual defects, as defined in IEC 61215-1:2021.

c) Wet leakage current shall meet the same requirements as for the initial measurements.

4.17 Hail test (MQT 17)

4.17.1 Purpose

To verify that the module is capable of withstanding the impact of hail.

4.17.2 Apparatus

a) Moulds of suitable material for casting spherical ice balls of the required diameter. Minimum requirement is a diameter of 25 mm. For hail prone locations larger ice balls may be required for testing as listed in Table 2. The test report should indicate what ice ball diameter and test velocity was used for the hail test.

b) A freezer controlled at (-10 ± 5) °C.

c) A storage container for storing the ice balls at a temperature of (-4 ± 2) °C.

d) A launcher capable of propelling an ice ball at the specified velocity, within ±5 %, so as to hit the module within the specified impact location. The path of the ice ball from the launcher to the module may be horizontal, vertical or at any intermediate angle, so long as the test requirements are met.

e) A rigid mount for supporting the test module by the method prescribed by the manufacturer, with the impact surface normal to the path of the projected ice ball.

4.19.7 Stress-specific stabilization – BO LID (MQT 19.3)

4.19.7.1 General

Some stress conditions may change the state of semiconductor defects in a way that is not representative of field behavior and is not related to the degradation mechanisms that are targeted by the stress tests. In this case, a stress-specific stabilization may be required to set the defects into a reproducible state either before or after stress. When to apply a stress-specific stabilization is prescribed in the technology-specific parts.

MQT 19.3 describes a stabilization procedure that puts the defects causing boron-oxygen light induced degradation into the regenerated state. It shall only be used at points in the test flow specifically allowed in IEC 61215-1-1:2021.

4.19.7.2 Apparatus for BO-LID stress-specific stabilization

a) A climatic chamber with automatic temperature control.

b) Means for mounting or supporting the module(s) in the chamber, so as to allow free circulation of the surrounding air. The thermal conduction of the mount or support shall be low, so that, for practical purposes, the module(s) is (are) thermally isolated.

c) Measurement instrumentation having an accuracy of ±2,0 °C and repeatability of ±0,5 °C for measuring and recording the temperature of the module(s).

d) Means for applying, throughout the test, a current equal to the module short-circuit current I_{sc}.

4.19.7.3 Procedure

a) Install the module(s) at room temperature in the climatic chamber.

b) Connect the temperature-monitoring equipment to the temperature sensor(s). Connect each module to the appropriate current supply by connecting the positive terminal of the module to the positive terminal of the power supply and the second terminal accordingly.

c) Close the chamber, and apply a current of I_{sc} ± 5 % to each module. As long as the current applied to each module is within 5 % of its I_{sc}, the currents applied through multiple modules in one chamber need not be the same.

d) Increase the climactic chamber setpoint such that the temperature of each module reaches (80 ± 5) °C, and never exceeds 85 °C.

e) Maintain the current and temperature within the limits prescribed in steps c) and d) for (48 ± 2) h.

4.20 Cyclic (dynamic) mechanical load test (MQT 20)

动态机械载荷可靠性

4.20.1 Purpose

The purpose of this test is to evaluate if components within the module are extremely susceptible to low levels of mechanical stress. The most likely reason for extreme susceptibility to low levels of mechanical stress is a module assembly process that compromises the integrity of module components (for example tabbing that puts too much pressure on the cell and creates microcracks). Components that may be evaluated by the cyclic dynamic mechanical load test (DML) include solar cells, interconnect ribbons, electrical bonds, and edge seals.

4.20.2 Procedure

The test shall be carried out in accordance with IEC TS 62782.

4.20.3 Final measurements

Repeat the tests of MQT 01 and MQT 15.

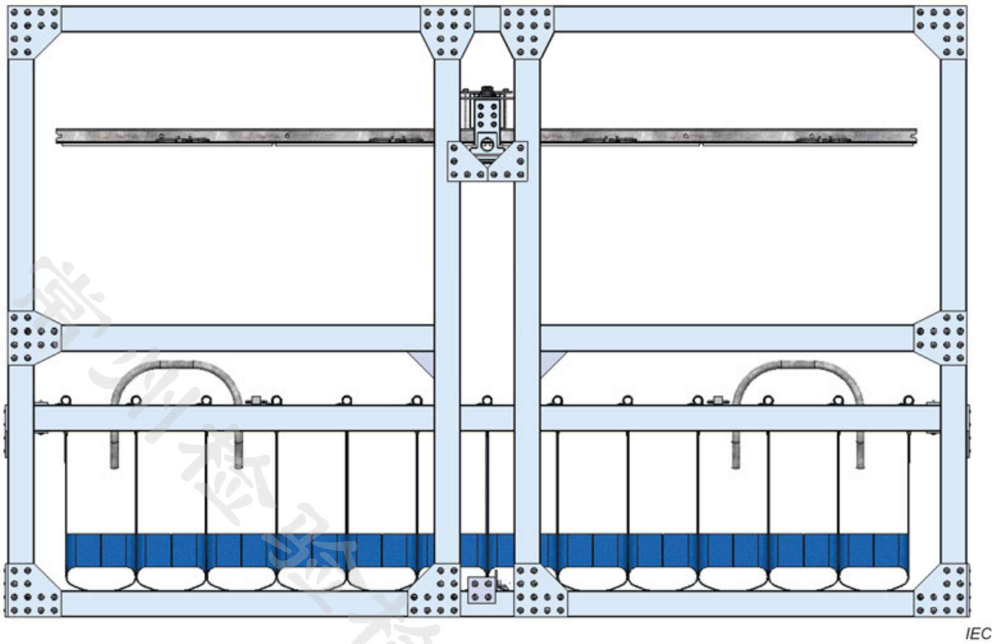


Figure A.3 – 2D view of mounting jig and loading jig

Figure A.4 and Figure A.5 show further detail of the loading jig with configurable channels where weights can be placed. The configurable channels can be fabricated from thick tarpaulin and adhesive tape, and are supported by rods. The rods can be moved on the T-slot rails of the mounting jig and clamped down by U clamps as illustrated to make room for any cross support rails in the module frame, thus avoiding loading such members. It is a critical to ensure load is not placed on frame members. The legs of the mounting jig are shorter than the depth of the channels so the weight can bottom out on the load surface before the legs make contact.

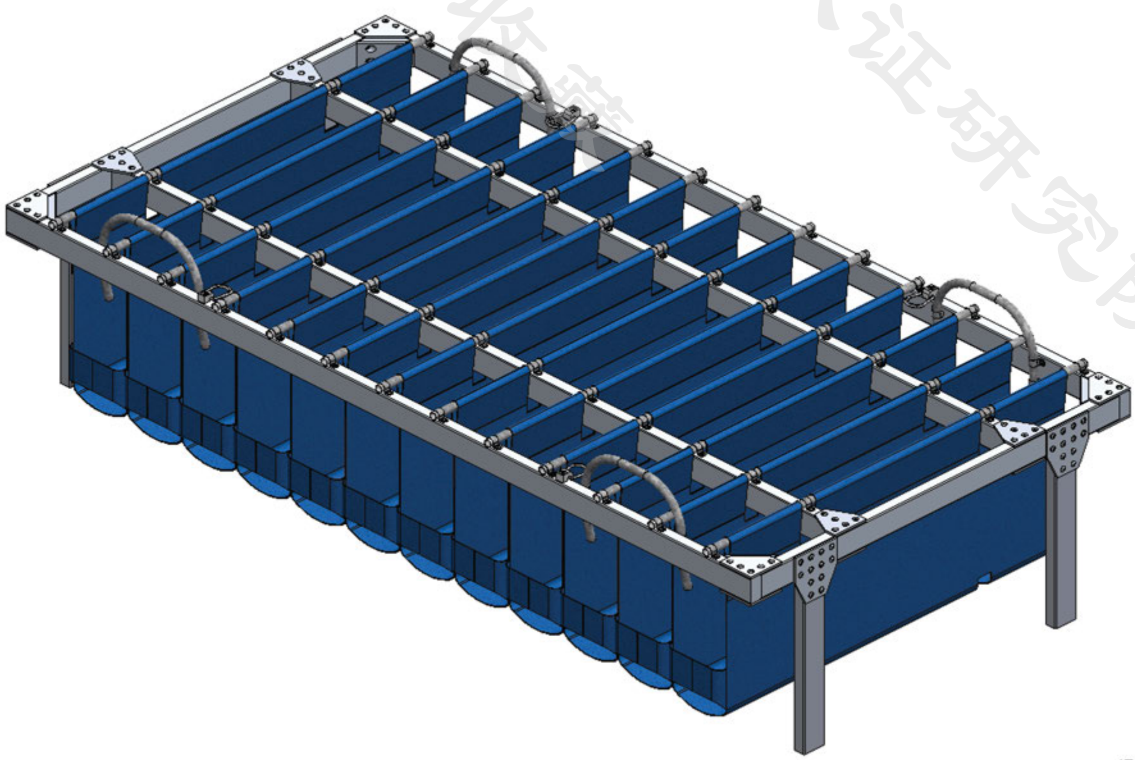


Figure A.4 – 3D view of loading jig

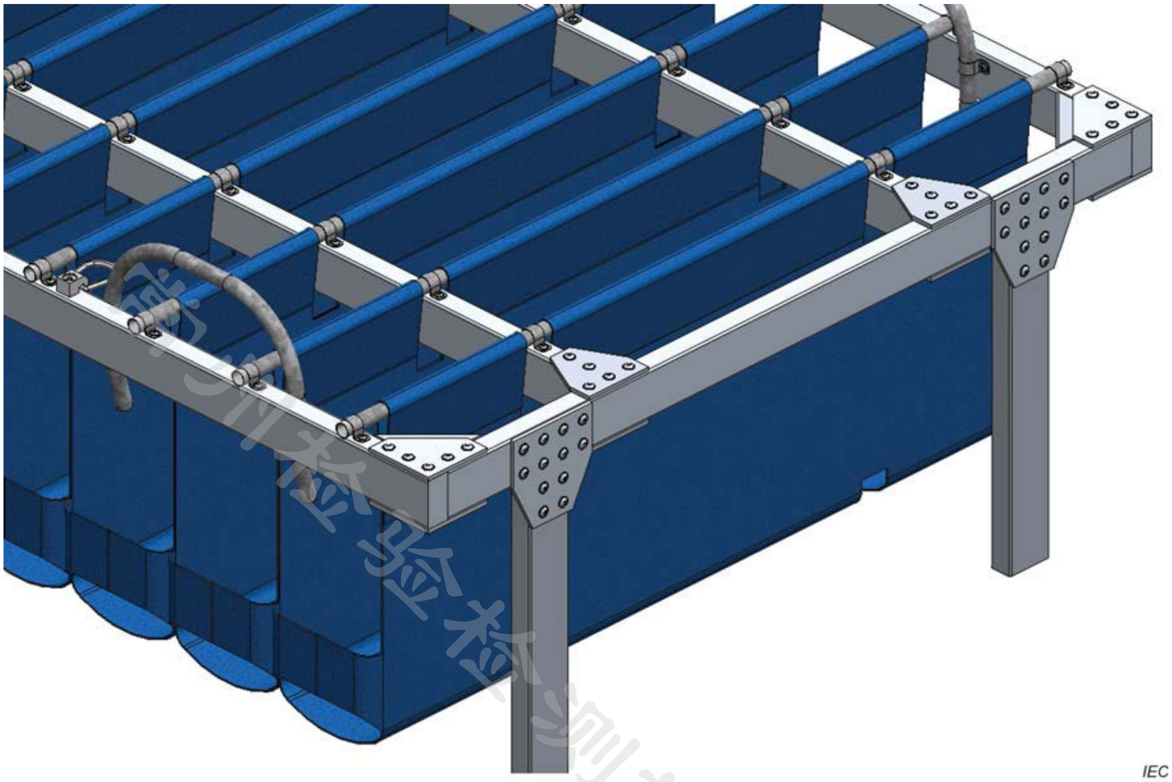


Figure A.5 – Close-up view of loading jig

While the media used for the load can vary (lead shot, sand, metal pellets, bricks etc.), some form of metal pellet is recommended as the load medium. The columnar bags should be constructed of heavy duty material, so that they can retain their shape and surface area. The size and shape of the bag chosen should be ergonomic and hold no more than 10 kg of weight. Each bag should be filled of same medium and measured by a calibrated scale prior to placing in the appropriate channel to assure a uniform load distribution on the module. Each channel should carry equal amount of weight to assure a loading uniformity of <5 % as specified in the test.