



Address: PO BOX 4321, PALMERSTON, NT 0831
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WIND PRESSURE TESTING OF LONGi SOLAR PANEL MODELS: LR5-54HPH-XXXM, SOLAR PHOTOVOLTAIC MODULES

ACE REFERENCE: 22-0373.01, REV: 03

Date of Issue: 20th September 2022

LONGi Solar Australia Pty Ltd

Attention: Richard Qian
Mob: 0432 330 008
Email: richardqian@longi.com
Address: L17, 570 George Street, Sydney NSW 2000, Australia

RE: LONGi Solar Panel Modules, 1722 mm x 1134 mm x 30 mm, 20.8 kg, LONGi: LR5-54HPH-405M; LR5-54HPH-410M; LR5-54HPH-415M; LR5-54HPH-420M & LR5-54HPH-425M, With 2 Supports at 800 mm & 2 Supports at 1200 mm Centres

This Test Report certifies the Recommended Design Wind Pressure(s) for the above mentioned LONGi LR5 Solar Panel Modules. This Test Report is for the testing of the PV Module Frames only, and does not cover the supporting elements/ rails and or associated fixings of the tested panels to the supporting elements/ rails.

This Report also verifies that the PV Modules are capable of withstanding the Design Wind Loads when installed to an approved railing system with the corresponding support points as listed in Table 1.

Albright Consulting Engineers (ACE) Pty Ltd were engaged by LONGi Solar Australia Pty Ltd to carry out and witness 6 individual mechanical load tests (simulated static, wind load strength test). The testing was performed on new panels supplied by LONGi Solar Australia Pty Ltd.

A total of 6 individual panels were tested. The following tests were carried out:

- Test Scope 1: 3 individual test samples with 2 supports/ clamps at 800 mm centres;
- Test Scope 2: 3 individual test samples with 2 supports/ clamps at 1200 mm centres.

The solar panel module(s) were mounted front side up using fixing clamps and brackets, which are then bolted to the test bed chassis. This is was to imitate a real-world situation; (this process was repeated for each test sample).

A constant pressure/ load was applied by an airbag located the back of the panel. A calibrated digital manometer was used to measure and track the design test pressures, while a calibrated digital deflection meter was used to measure and record the centre (vertical) deflection of the solar panel at 1kPa intervals. The electrical continuity or the cells themselves were not monitored during each of the tests.



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Note that a mechanical load testing and or simulated static, wind load strength testing was carried out for the above-mentioned solar panel module samples and the support fixing configuration(s). The testing procedure that was adopted is generally accordance to the methods outlined in AS4040 (series), Static Strength Test Regime.

The 6 individual simulated static, wind load strength tests were conducted and observed by Nicholas Kastellorizios of Albright Consulting Engineers in Darwin Northern Territory, on the 7th September 2022. The behaviour of the modules was observed and recorded.

Material Variability Factor AS/NZS 1170.0, Table B1 – kt:

The applied factor for variability for 1 individual test sample (1 individual units tested per support centre) and adopting a coefficient of variation of structural characteristics of 10% in accordance with AS/NZS 1170.0, Table B1 (when determining the allowable design capacity) is 1.46.

The applied factor for variability for 2 individual test samples (2 individual units tested per support centre) and adopting a coefficient of variation of structural characteristics of 10% in accordance with AS/NZS 1170.0, Table B1 (when determining the allowable design capacity) is 1.38.

The applied factor for variability for 3 individual test samples (3 individual units tested per support centre) and adopting a coefficient of variation of structural characteristics of 10% in accordance with AS/NZS 1170.0, Table B1 (when determining the allowable design capacity) is 1.33.

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Results & Observations:

Test No.1, x3 Samples: LONGi Solar Panel Modules, 1722 mm x 1134 mm x 30 mm, 20.8 kg, LONGi: LR5-54HPH-415M, with 2 Supports at 800 mm Centres. Serial Numbers: LRP910109220305607870; LRP910109220305607886 & LRP910109220305607238

The solar panels (**1722 mm x 1134 mm x 30 mm**) were mounted to the test rig with 2 supports at **800 mm** centres apart on each side with a cantilever/ overhang of approximately **461 mm** at each end.

During all individual tests, the solar panel modules were observed to be able to support an equivalent test pressure of **5.5 kPa**, with a centre vertical deflection **78 mm** (approximately).

It was observed during each test, that while in an attempt to increase the design test pressure(s), the solar panels shattered at approximately **6.0 kPa**. These results were recorded just as the solar panel module frames failed/buckled, causing the glass front face to shatter.

In all three cases there were visually obvious signs of moderate to major and permanent buckling to the shorter rails that make up the overall aluminium frame of the solar panel module. This indicated that the frames had yielded (plastic phase of the material).

The corners of the rails framing elements also deflected apart as they were not fixed or restrained to each other. The glass face of the panel failed/ shattered due to the excessive deflections.

In our opinion the changes to the physical geometry of the solar panel module were a major contributing factor to the overall failure of the panel, i.e., grade of aluminium; the depth of the frame being 30 mm, as well as the length of the shorter rails being slightly longer at 1134 mm, than other previous tested solar panels (997 mm to 1000 mm).

Other likely factors that may have contributed to the failure of these panels include:

1. Thickness & Grade of Glass Face;
2. Thickness of Backing Material;
3. Grade of Aluminium used in the manufacturer of the Frame;
4. Inner Frame Connections/ Junctions;
5. Glass Supports within Frame &
6. Lack of and or quality of Adhesive of between the rails & Sheeting Layers.

Note there were very consistent results and observations during all three tests.

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Test No.2, x3 Samples: LONGi Solar Panel Modules, 1722 mm x 1134 mm x 30 mm, 20.8 kg, LONGi: LR5-54HPH-415M, with 2 Supports at 1200 mm Centres. Serial Numbers: LRP910109220305607895; LRP910109220305607389 & LRP910109220305607868

The solar panels (**1722 mm x 1134 mm x 30 mm**) were mounted to the test rig with 2 supports at **1200 mm** centres apart on each side with a cantilever/ overhang of approximately **261 mm** at each end.

During all individual tests, the solar panel modules were observed to be able to support an equivalent design test pressure of **6.0 kPa**, with a centre vertical deflection **95 mm** (approximately).

It was observed during each test, that while in an attempt to increase the design test pressure(s), the solar panels shattered at approximately **6.5 kPa**. These results were recorded just as the solar panel module frames failed/buckled, causing the glass front face to shatter.

In all three cases there were visually obvious signs of moderate to major and permanent buckling to the shorter rails that make up the overall aluminium frame of the solar panel module. This indicated that the frames had yielded (plastic phase of the material).

The corners of the rails framing elements also deflected apart as they were not fixed or restrained to each other. The glass face of the panel failed/ shattered due to the excessive deflections.

In our opinion the changes to the physical geometry of the solar panel module were a major contributing factor to the overall failure of the panel, i.e., grade of aluminium; the depth of the frame being 30 mm, as well as the length of the shorter rails being slightly longer at 1134 mm, than other previous tested solar panels (997 mm to 1000 mm).

Other likely factors that may have contributed to the failure of these panels include:

1. Thickness & Grade of Glass Face;
2. Thickness of Backing Material;
3. Grade of Aluminium used in the manufacturer of the Frame;
4. Inner Frame Connections/ Junctions;
5. Glass Supports within Frame &
6. Lack of and or quality of Adhesive of between the rails & Sheeting Layers.

Note there were very consistent results and observations during all three tests.

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Table 1: Test Summary: Recommended Ultimate Design Strength, Limit Design Capacity

| Test | Panel Manufacturer, Model & Size (mm) | Support Centres (mm) | Maximum Applied Load (kPa) | Material Variability Factor AS/NZS 1170.0 Table B1 – kt | Recommended Ultimate Design Strength Limit State Design Capacity (kPa) |
|------|--|----------------------|----------------------------|---|---|
| No.1 | X3 Samples: LONGi Solar Panel Modules, 1722 mm x 1134 mm x 30 mm, 20.8 kg, LONGi: LR5-54HPH-405M; LR5-54HPH-410M; LR5-54HPH-415M; LR5-54HPH-420M & LR5-54HPH-425M | 2 Supports at 800mm | 5.5 | 1.33 | 4.13 |
| No.2 | X3 Samples: LONGi Solar Panel Modules, 1722 mm x 1134 mm x 30 mm, 20.8 kg, LONGi: LR5-54HPH-405M; LR5-54HPH-410M; LR5-54HPH-415M; LR5-54HPH-420M & LR5-54HPH-425M | 2 Supports at 1200mm | 6.0 | 1.33 | 4.51 |

Note that the above mentioned Recommended Ultimate Design Strength, Limit Design Capacities are only applicable to the models & power series stated within this certificate, as well as listed on the attached data sheet.

Note that the Project Engineer/ Design Engineer should consider the panel deflection as a design criteria. These deflections could cause the panels to pop/ slip out of the fixing clamps.

LONGi, LR5-54HPH-XXXXM, Mechanical Properties:

| | |
|------------------------------|--------------------------------|
| Cell Type: | No Data Given |
| Cells: | 108 (6x18) |
| Dimensions: | 1722 mm x 1134 mm x 30 mm |
| Weight: | 20.8 kg |
| Junction Box: | IP68 |
| Backing Material/ Substrate: | No Data Given |
| Front Material/ Superstrate: | 3.2 mm Coated Tempered Glass |
| Frame: | Anodized Aluminium Alloy Frame |

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Summary:

We recommended and certify that the **LONGi Solar Panel Modules, 1722 mm x 1134 mm x 30 mm, 20.8 kg, LONGi: LR5-54HPH-405M; LR5-54HPH-410M; LR5-54HPH-415M; LR5-54HPH-420M & LR5-54HPH-425M**, Solar Panel Modules can resist the following vertical design loads, with a Recommended Ultimate Design Strength (Limit State Design Capacity), as listed for the following support conditions:

When supported on purlins and or battens with 2 supports/ rails at 800 mm centres: 4.13 kPa

When supported on purlins and or battens with 2 supports/ rails at 1200 mm centres: 4.51 kPa

This Report has been prepared on behalf of and for the exclusive use of LONGi Solar Australia Pty Ltd and is for the testing of the PV Module Frame only; and **not** the supporting elements, clamps, rails and or associated fixings of the PV Modules to the rails.

The Recommended Ultimate Design Strength, Limit State Design Capacities, (kPa) are only applicable for the panel model; size, weight and support/ rail spacing's as the above-mentioned tested model(s). Any additional power output models referenced may also be covered under this certificate provided that they are referenced in the same technical datasheet (attached); are mechanically & physically identical to the (tested): **LR5-54HPH-415M (1722 mm x 1134 mm x 30 mm, 20.8 kg)** Solar Panel Modules; and that they are manufactured in the exact same way with the exact same materials as the (tested): **LR5-54HPH-415M (1722 mm x 1134 mm x 30 mm, 20.8 kg)** Solar Panel Modules. Refer to Appendix A for datasheets: Silver & Black Panels/ Models.

This certificate and certification is no longer valid if:


1. If any of the Engineering & Mechanical Properties used in the manufacture of the solar panel modules/ models is altered or changed in any way to the above mentioned tested solar panel modules/ models.
2. If any of the manufacturing processes or techniques used in the manufacture of the solar panel modules/ models is altered or changed in any way to the above mentioned tested solar panel modules/ models.
3. It is the responsibility of the manufacturer to confirm if there has been any alterations, changes or revisions to the physical makeup of the frame, i.e. aluminium grade, front glass face or backing sheet, etc.; or if the manufacturing process has altered or changed in any way, re-testing may be required.
4. This certificate is rendered invalid if any changes have occurred to the tested modules/ models as noted above.

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Important Notes:

1. Note that the deflection criteria of the panels themselves may govern or limit the structural design and should be considered in high design wind pressure zones; as excessive deflections may cause the panel's to slip and or pop out from the fixing clamps.
2. The panel fixing clamps; the support rails; their associated fixings or the fixings of the L Feet to the immediate supporting structure, were not tested as part of the test procedure/ scope, and therefore no comment can be made as to their role as a potential failure mode. Note that these elements must be individually evaluated and confirmed by the Project Engineer and or the Design Engineer, as they may limit the structural design or capacity of the total structural system.
3. The railing system is excluded from this certification and is designed & certified by others.
4. The immediate supporting elements for the PV Roof Mounted Solar Panel System is also excluded from this certification and is designed & certified by others.
5. This Report Certifies the Design Wind Pressures for the above referenced Solar Panel Modules/ Modes. However, they are subject to the analysis and approval by the Project Engineer; Design Engineer and or Approved Competent Person on a project by project basis. Note that the Design Engineer must confirm that the Design Wind Pressures are less than the Recommend Capacities referenced within this report, for each specific project.

| | | | |
|--|--|--|---------------------------|
| Company Name if certification issued on behalf of a corporation Albright Services Group Pty Ltd, Trading as Albright Consulting Engineers | | Company NT Registration Number 215037ES | |
| I certify that reasonable care has been taken to ensure that the structural engineering aspects of the works as described above have been designed in accordance with the requirements of the Building Code of Australia and the Northern Territory Building Regulations | | | |
| Name Nicholas Kastellorizios Nominee for Albright Services Group Pty Ltd, Trading as Albright Consulting Engineers | Nominee/Individual NT Registration Number 215037ES | Signature  | Date 20/09/2022 |

Please contact our office if you require any further information in relation to this report.

Nicholas Kastellorizios
 Director/ Structural Engineer
Albright Consulting Engineers



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Appendix:

Data Sheet – LONGi Solar Panel Modules, 1722 mm x 1134 mm x 30 mm, 20.8 kg, LONGi: LR5-54HPH-405M; LR5-54HPH-410M; LR5-54HPH-415M; LR5-54HPH-420M & LR5-54HPH-425M

Hi-MO 5m

LR5-54HPH 405~425M

- Suitable for distributed projects
- Advanced module technology delivers superior module efficiency
 - M10 Gallium-doped Wafer
 - Integrated Segmented Ribbons
 - 9-busbar Half-cut Cell
- Excellent outdoor power generation performance
- High module quality ensures long-term reliability

15

15-year Warranty for
Materials and Processing

25

25-year Warranty for Extra
Linear Power Output

Complete System and Product Certifications

IEC 61215, IEC 61730, UL 61730

ISO9001:2015: ISO Quality Management System

ISO14001: 2015: ISO Environment Management System

ISO45001: 2018: Occupational Health and Safety

TS62941: Guideline for module design qualification and type approval

LONGi



21.8%
MAX MODULE
EFFICIENCY

0~3%
POWER
TOLERANCE

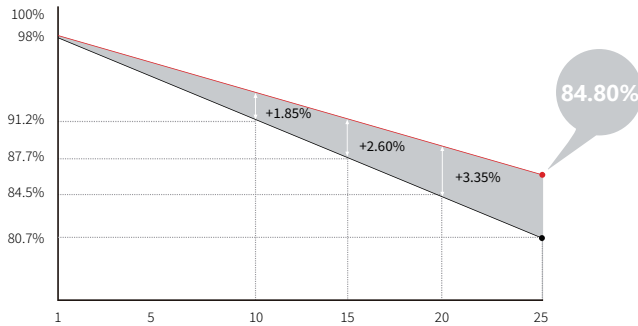
<2%
FIRST YEAR
POWER DEGRADATION

0.55%
YEAR 2-25
POWER DEGRADATION

HALF-CELL
Lower operating temperature

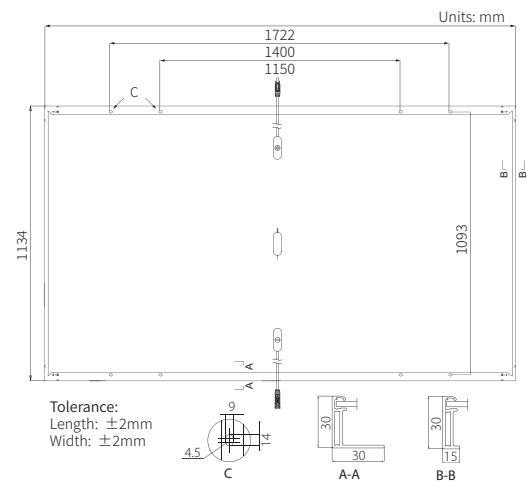
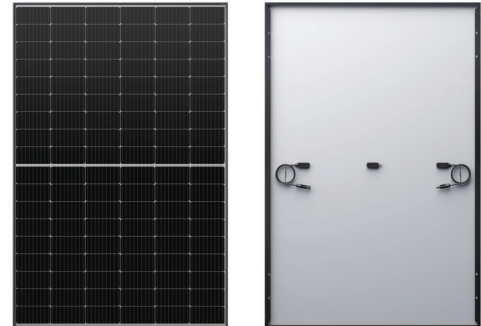
Additional Value

25-Year Power Warranty



Mechanical Parameters

| | |
|------------------|--|
| Cell Orientation | 108 (6×18) |
| Junction Box | IP68, three diodes |
| Output Cable | 4mm ² , 1200mm |
| Connector | Staubli MC4 EVO2 |
| Glass | Single glass, 3.2mm coated tempered glass |
| Frame | Anodized aluminum alloy frame |
| Weight | 20.8kg |
| Dimension | 1722×1134×30mm |
| Packaging | 36pcs per pallet / 216pcs per 20' GP / 936pcs per 40' HC |



Electrical Characteristics

STC : AM1.5 1000W/m² 25°C NOCT : AM1.5 800W/m² 20°C 1m/s Test uncertainty for Pmax: ±3%

| Module Type | LR5-54HPH-405M | | LR5-54HPH-410M | | LR5-54HPH-415M | | LR5-54HPH-420M | | LR5-54HPH-425M | |
|----------------------------------|----------------|-------|----------------|-------|----------------|-------|----------------|-------|----------------|-------|
| Testing Condition | STC | NOCT | STC | NOCT | STC | NOCT | STC | NOCT | STC | NOCT |
| Maximum Power (Pmax/W) | 405 | 302.7 | 410 | 306.5 | 415 | 310.2 | 420 | 313.9 | 425 | 317.7 |
| Open Circuit Voltage (Voc/V) | 37.00 | 34.79 | 37.25 | 35.02 | 37.50 | 35.26 | 37.75 | 35.49 | 37.96 | 35.69 |
| Short Circuit Current (Isc/A) | 13.83 | 11.18 | 13.88 | 11.22 | 13.94 | 11.27 | 14.01 | 11.32 | 14.08 | 11.38 |
| Voltage at Maximum Power (Vmp/V) | 31.00 | 28.80 | 31.25 | 29.03 | 31.49 | 29.25 | 31.73 | 29.47 | 31.94 | 29.67 |
| Current at Maximum Power (Imp/A) | 13.07 | 10.52 | 13.12 | 10.56 | 13.18 | 10.60 | 13.24 | 10.65 | 13.31 | 10.71 |
| Module Efficiency(%) | 20.7 | | 21.0 | | 21.3 | | 21.5 | | 21.8 | |

Operating Parameters

| | |
|------------------------------------|-------------------------------|
| Operational Temperature | -40°C ~ +85°C |
| Power Output Tolerance | 0 ~ 3% |
| Voc and Isc Tolerance | ±3% |
| Maximum System Voltage | DC1500V (IEC/UL) |
| Maximum Series Fuse Rating | 25A |
| Nominal Operating Cell Temperature | 45±2°C |
| Protection Class | Class II |
| Fire Rating | UL type 1 or 2 IEC Class C |

Mechanical Loading

| | |
|-----------------------------------|--------------------------------------|
| Front Side Maximum Static Loading | 5400Pa |
| Rear Side Maximum Static Loading | 2400Pa |
| Hailstone Test | 25mm Hailstone at the speed of 23m/s |

Temperature Ratings (STC)

| | |
|---------------------------------|------------|
| Temperature Coefficient of Isc | +0.050%/°C |
| Temperature Coefficient of Voc | -0.265%/°C |
| Temperature Coefficient of Pmax | -0.340%/°C |