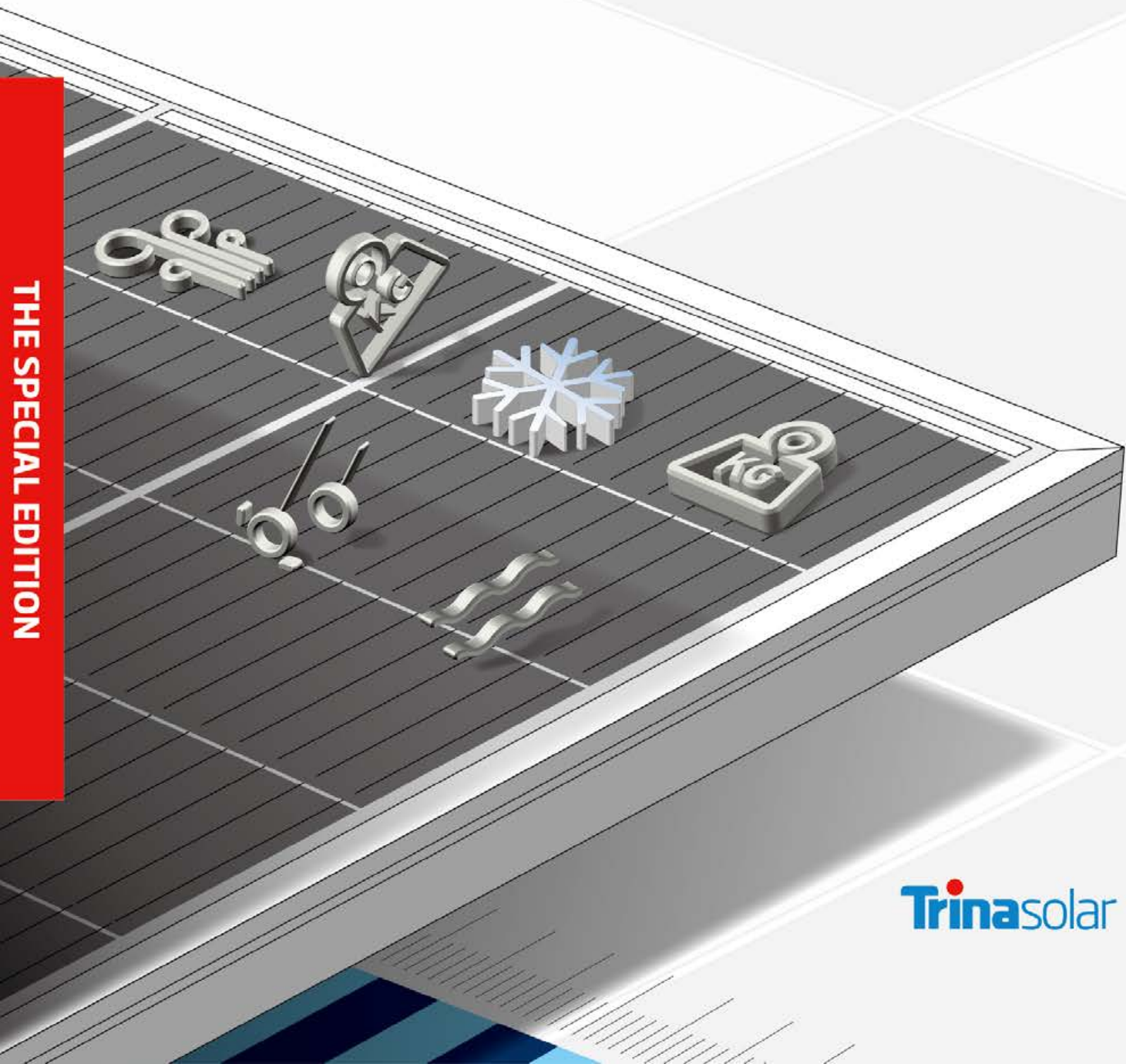




Mechanical Load Performance of Modules

Trina Solar publishes the white paper on mechanical reliability of the
670W **Vertex** module

THE SPECIAL EDITION



SERIAL MECHANICAL LOAD REPORTS

Authoritative Certification on Reliability

- Static load
- Dynamic load
- Non-uniform snow-load
- Stronger winds limit
- Extreme low temperature
- Hail test
- Win-win Ecology



Rigorous dynamic mechanical load test

Passing extreme DML testing with tightened 20-fold loading

Modules' stunning performance in 35mm hailstones test

Trina Solar proves its high mechanical reliability of Vertex 670W module, after passing 6 rigorous tests

In middle of this year, Trina Solar released a series of testing results on the mechanical reliability of the 670W Vertex module. Covering six tests, including static mechanical load test and five rigorous tests including non-uniform snow-load test, extreme low-temperature mechanical Load test, hail test, extreme DML test and extreme wind tunnel test, the serial testing results achieved an across-the-board verification of the excellent mechanical load reliability of the 670W Vertex modules.

Photovoltaic modules can be affected by multiple environmental factors in actual outdoor use, while extreme weather such as snowstorms and gale-force or higher winds necessitates a higher load performance. As a result, to protect the interests of the customers, module design needs to consider the ability to withstand extreme weather over the whole life cycle.



In May of this year, PV Evolution Labs (PVEL), one of the leading independent PV test laboratories, released its seventh annual global PV module test results, the 2021 PV Module Reliability Scorecard Report. Trina Solar again placed as a Top Performer for outstanding product reliability and performance among global PV module manufacturers. Dr. Zhang Yingbin, Head of Product Strategy and Marketing at Trina Solar said that completing the general reliability verification covered all the basics, while the advanced testing in this go-around was to verify that ultra-high-power modules can maintain their outstanding performance even when subject to extreme weather, creating one of the industry's most reliable modules.

— Among the lineup of rigid tests, the non-uniform snow-load test simulated uneven pressures caused by a large accumulation of heavy snow on the Trina Solar's 670W module surface, with the highest pressure applied to the bottom end of the module of up to 7000Pa (equivalent to a depth of 2.8 meters of snow), with the results showing that the power attenuation of the module is only 0.56%.

— The extreme low-temperature mechanical Load test, a static load

testing of positive 5400Pa/ negative 2400Pa under an extremely low -40°C, showed no variation in electroluminescence (EL) and power attenuation of only 0.11%.

— In the hail test that simulates the impact of hail of different sizes on modules, the 670W module eventually passed the test measuring the impact of hailstones 35 mm in diameter without causing any damage.

— In multiple extreme dynamic mechanical load test, 210 Vertex 670W module delivered better performance than competitors' modules with load capacity several times higher than the IEC standard. When installed by clamps, the 210 mm Vertex 670W double-glass module has passed the 20,000 cycles, 20-fold extreme testing, still remaining intact.

— In extreme wind tunnel test, the 670W Vertex module remains intact when the wind speed reached 62m/s (216km/h or 134 mph), passing the extreme wind speed test equivalent to the low end of a Category 4 hurricane on the Saffir-Simpson scale.

— Maintaining the consistent ultra-high reliability of Trina Solar modules, the 210 Vertex series modules integrated a series of design optimizations, including added frame wall thickness, larger cavities, optimized material selection and matching designs, to ensure ultra-high structural robustness. Through the series of rigid tests, the series' excellent ability to withstand external mechanical stress that can calmly handle extreme wind, snowstorms, extreme cold, hail and other extreme weather was confirmed.

"As the component with the highest power output in mass production in the industry, the reason we chose 670W Vertex module as a testing object is not only to empower customers to intuitively understand the high reliability of 670W+ modules, but also to share research results across the whole of the industry for continuous innovation, comprehensive application of 600W+ modules and supporting carbon neutral," said Dr. Zhang Yingbin.

Media report:

https://finance.yahoo.com/news/trina-solar-proves-high-mechanical-074900362.html?guccounter=1&guce_referrer=aHR0cHM6Ly9jaW50aW50LmNvbSB&guce_referrer_sig=AQAAAMZQwj23NqwisplDTCsMRs32VUSDrC4MdWAMAJR2oYMOFrPBefoV5qopGCohbMqmeJle-TVJRqYf1ELNpoFCejSzup_H1jYBBTjMRq9_wqCKTsBq3MmUmYG2jnbMGqn4lo2-gz1jDKYsxQCza4kdHhw7AQj1tBW3y00mqPmCHD

Non-uniform snow-load test:

Supreme performance shown under pressure by **2.8 meters** of snow



Recently, Trina Solar completed non-uniform snow-load testing at the CGC East China PV Testing Center with its new-generation Vertex 670W modules.

The data demonstrate the critical snow-load of Trina Solar's five modules exceeded 6,600 Pa, getting up to 7,000 Pa, equivalent to the pressure generated by 2.8 meters of snow, much higher than conventional non-uniform snow-load norms. This is sufficient proof of the excellent snow-load resistance of Trina Solar's Vertex 670W modules. Moreover, the strength convergence of the non-uniform snow-load testing of the five modules reflects the product's excellent quality consistency.

The current path taken by PV modules is increasingly high power and expanding module size, which poses more severe challenges to module materials, design and process and forces the upstream and downstream industry chain to set stricter requests for the mechanical performance of modules.

After passing the standard 5400Pa static mechanical load test and dynamic mechanical load test, the Vertex 670W module continues to challenge non-uniform snow-load testing in order to more rigorously evaluate the mechanical performance of the PV modules in heavy-snow conditions.

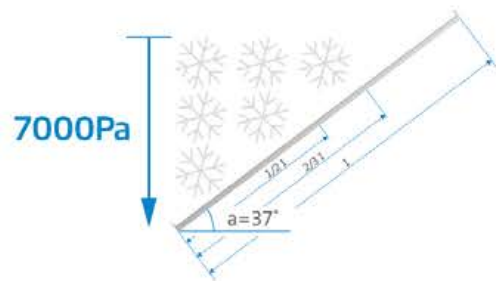


Snow exerts uneven pressure when it accumulates heavily on the module surface, especially at the bottom of the module. The non-uniform snow-load testing specifically evaluates the ability of PV modules to withstand such uneven pressure when encountering heavy snowfall,

thus more effectively circumventing snow pressure in areas with heavy snowfall causing module failure. This includes bent or broken frames, uneven backglass breakage and partial or complete disintegration of the installed system. In this way we can provide the optimal solution for our customers and owners.

The non-uniform snow-load testing of Trina Solar's Vertex 670W series was conducted at the CGC East China PV Testing Center. In contrast to the dynamic and static load tests based on IEC 61215 and IEC 62782,

the IEC 62938:2020-based non-uniform snow-load testing is a standard test that simulates the snow-load resistance of PV modules and can be considered as a risk control for differentiated application scenarios. It does so by simulating the module's snow-load resistance in real-world environmental testing. PV modules that pass this standard test exhibit two characteristic values: the value of snow load that accumulates on the surface when the module fails; and the power attenuation value and electrical safety performance of the module under critical snow-load conditions.



The test data demonstrating the critical snow load for all five of Trina Solar's modules to be as high as 6,600 Pa or more, with a maximum of 7,000 Pa, was much higher than the usual required norms for non-uniform snow loads. Based on the average snow density of 0.25g/cm³, this is equivalent to the pressure generated by 2.8 meters of snow unevenly pressing on the modules.

Combined with the ultimate load capacity of Trina Solar's Vertex 670 modules and a standard introduction of a safety factor of 1.5 for the final snow-load test, the 670 module power attenuation was just 0.56%. This test result thus manifestly demonstrates Trina Solar's Vertex 670W modules, not only integrate advantages of high-power, high-efficiency, and large-size cells, but also possess the excellent snow-load resistance.

Media report:

<https://www.pv-tech.org/industry-updates/trina-solars-vertex-670w-modules-pass-cgcs-n-on-uniform-snow-load-testing-with-extreme-loading-of-7000pa/>

Rigorous dynamic mechanical load test:

Passing extreme DML testing with tightened **20-fold** loading



Trina Solar recently conducted stringent dynamic mechanical load testing (DML) of its 210 Vertex 670W module, comparing with competitor's single-glass 540W and dual-glass 535W modules in extreme environments based on the International Electrotechnical Commission (IEC) standards. The testing demonstrated that the 210 Vertex 670W module delivered better performance than the 540W/535W modules in terms of DML reliability.

In addition, the 210 mm Vertex 670W double-glass module has passed the 20,000 cycles, 20-fold extreme testing, the DML reliability of the module has been fully validated.

Based on the IEC TS G2782 standard for DML testing, the testing was carried out at the State Key Laboratory of PV Science and Technology. Generally, the standard DML testing consists of 1,000 cycles with each circle applying a positive loading (front side) and negative loading (rear side) of 1,000Pa on the module tested, 3-7 cycles per minute. However, in extreme weather such as heavy snow, gale and hail, the PV module may rupture due to high pressure from mechanical loading, which would lead to moisture entry, battery cracks, fatigue of welded joints and battery corrosion, eventually resulting in module and system failure, which calls for a stricter testing.

This time, the extreme DML testing for Trina Solar's 210 Vertex 670W module is operated based on multi-fold standard DML. The 210 Vertex module delivered outstanding performance in the testing.

The testing included two rounds as follows:

Round 1

The multi-fold dynamic mechanical load testing was conducted based on the standard load of $\pm 1,000\text{Pa}$ while the appearance of the samples was observed every 500 cycles.

Secure the Single glass module in the crossbeam which is perpendicular to the long side by bolts: the 540W module showed cracks near the mounting holes after going through 3,000 DML cycles while the 210 mm Vertex 670W module continued functioning as normally at the end of 7,000 cycles.

Secure the Dual-glass framed module in the crossbeam which is parallel to the long side by bolts: the 540W module showed cracks after 2,000 DML cycles while the 210 Vertex 670W module continued operating normally after 3,500 cycles.

Secure the Dual-glass framed module in the crossbeam which is parallel to the long side by clamps: the appearance of the Vertex 670W module remained intact after 20,000 cycles!



535W: torn mounting holes

Round 2

The multi-fold dynamic mechanical load testing was conducted based on the standard load of $\pm 1,500\text{Pa}$ and the appearance of the samples was observed every 200 cycles.

Secure the Dual-glass framed module in the crossbeam which is parallel to the long side by bolts: the 535W module failed at the end of 200 DML cycles, with cracks occurring near two mounting holes, and another two mounting holes tearing completely, resulting in the screws dropping out; in contrast, the 210 Vertex module only has minor cracks around one mounting hole after 2,000 DML cycles.

Secure the Dual-glass framed module in the crossbeam which is parallel to the long side by clamps: the appearance of the Vertex 670W module remained intact even after 20,000 cycles!

The two rounds of comparative testing once again demonstrate the outstanding capability of the 210 Vertex module in resisting external mechanical stress.

Trina Solar, the world leading PV and smart energy total solution provider, has been committed to developing new and innovative products. With more than 20 years of process and technology expertise, the company has created the world's top modules with high efficiency and reliability, with worldwide shipments of the 210 Vertex module exceeding 16GW.

Media report:

<https://www.pv-tech.org/industry-updates/trina-solar-210-vertex-670w-module-passes-extreme-dml-testing/>

Wind tunnel test:

Withstanding a Category 4 hurricane



After passing advanced serial load tests including for non-uniform snow-load and 20,000 cycles of dynamic mechanical load, Trina Solar's 210mm Vertex 670W module has passed the extreme wind tunnel test. The result further confirms that ultra-high-power modules can maintain their outstanding performance even when subject to extreme weather.

Trina Solar, with the third-party authoritative organization CGC (China General Certification), conducted the wind tunnel test on the 210mm Vertex 670W dual-glass module (2.384 × 1.303m).

The 210 Vertex 670W module remains intact when wind speed reached 62.6m/s (225.4km/h or 140mph), which is equivalent to the low end of a Category 4 hurricane on the Saffir-Simpson scale.

The wind tunnel test results prove that the 210mm Vertex module not only generates super high power but also possesses extremely reliability.

The globalization of PV applications and diversification of scenarios have put higher demands on module performance, and extreme weather such as strong winds, snowstorms and hailstorms pose great challenges.

Bearing out Trina Solar's consistent ultra-high reliability, the 210 module has undergone an array of design optimizations, such as increased frame thickness, larger cavities and optimized material to ensure ultra-high structural strength. At the same time the non-destructive cutting gives the smallest cell a bending strength comparable to that of the whole cell, as well as significantly enhancing

resistance to hidden cracks.

In addition to the modules themselves, the mounting method is also critical to reliability. Cost-effective screw installation is suitable for large-scale power stations; clamp installation is widely used in distributed rooftop applications, which supports rapid installation. For particularly harsh snow or windy climates, Trina Solar enables customized installation methods to meet customers' higher demands.

In the spirit of innovation and always focusing on customer value, Trina Solar delivers products with the lowest BOS and higher power generation efficiency to promote the sustainable development of the PV industry and lead the transformation of the global energy industry.

Media report:

<https://solarquarter.com/2021/08/25/withstanding-a-category-4-hurricane-trina-solars-670w-modules-shows-its-mettle/>

Wind speed(m/s)	Reference modules(530W)	Trina Vertex modules(670W)
30.53	Slight vibration.	Slight vibration.
45.80	The surface of the module bulges in the middle, shake strongly.	The surface of the module bulges in the middle, shake strongly.
59.54	The bolt-mounted location was torn. Module under test(MUT) was blown away.	
62.60	/	Highest wind speed module under test can suffer, shake strongly.

Extreme low-temperature test:

Showing remarkable mechanical performance at **-40°C**



Verified by a serial rigorous tests including non-uniform snow-load test, extreme DML test and extreme wind tunnel test, Trina Solar's Vertex modules continue show outstanding performance and excellent mechanical load reliability by passing another -40°C extreme low-temperature mechanical load test, demonstrating excellent ability to withstand extreme cold conditions.

Trina Solar's modules are applied worldwide in various scenarios including those under extreme cold weather condition, from Heilongjiang in China to the countries within the Arctic Circle such as Sweden and Norway, where the average winter temperature is as low as -40°C.



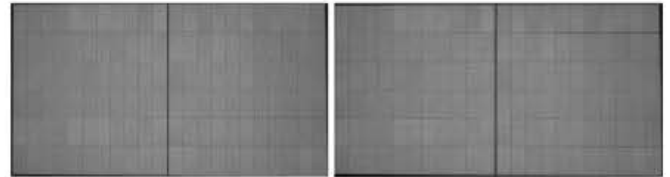
test site (Image: Trina Solar)



The temperature of testing environment (Image: Trina Solar)

Thus, it is fundamental for Vertex modules to keep high reliability and high power generation efficiency under low-temperature condition. The extreme low temperature is a major challenge to materials. The coefficient of thermal expansion varies among different materials and poses challenges to connecting parts of modules. For those organic materials such as EVA, backsheets and junction boxes, the low temperature will cause degrading shock resistant ability of materials and affect the ability to withstand mechanical load of module cells.

Trina Solar, together with the third-party organization CGC (China General Certification), according to the testing requirement of IEC TS 62782, conducted the mechanical reliability test to Vertex 670W module under extreme low-temperature condition. The static mechanical load test of 5400Pa at front side and 2400Pa at back side is completed under extreme low-temperature at -40°C and crossbeam screw installation conditions. The mechanical strength, resistant ability of materials and connection of trackers under extreme low temperature are simulated to test the reliability and performance of PV modules.



No variation in electroluminescence (EL)
(Image: Trina Solar)

The results show that the modules maintain in good appearance without cracks, and the testing of insulation and wet leakage are both passed, with power attenuation of only 0.11%. This well proves that even under extreme low-temperature condition, Trina Solar's 670W Vertex modules are safe and reliable, and guarantee excellent quality.

The 670W Vertex was launched in March, based on large 210mm silicon wafers, releases low-voltage and high-power and inherits the non-destructive cutting, high-density interconnection, achieving maximum power of 670W with an efficiency of 21.6%, single string power rising by 40%, creating more room for reduction of the LCOE and BOS cost.



Vertex modules in extreme cold weather (Image: Trina Solar)

Based on the R&D and manufacturing experience for the past 24 years, Trina Solar has been able to laid solid foundation in technology and forged products with high efficiency and high reliability that possesses world's best performance. No matter it is stronger winds, snowstorms or extreme cold, Trina Solar's Vertex modules exhibit perfect performance and offer customized services including product design and installation design for different application scenarios to provide various total solutions for customers.

Media report:

<https://www.pv-tech.org/industry-updates/trina-solar-670w-vertex-modules-show-outstanding-mechanical-performance-at-40c/>

Hail test:

Modules' stunning performance in 35mm hailstone test



Extreme weather events everywhere are doing what cool logic had failed to do: convince even the most abudurate sceptics that climate change is indeed real. What has also become clear is that photovoltaic modules, one tool in the planet's armory as it seeks to reduce carbon emissions by using alternative energy sources, need to be extremely sturdy as they are exposed to such weather over very long lengths of time.



In an analysis published on 30th July 2021, Trina solar proves its high mechanical reliability of Vertex 670W module, after passing 6 rigorous tests, including the 35mm hail test, non-uniform snow-load tests, extreme DML tests, extreme wind tunnel tests and extreme low-temperature mechanical load tests, among others. They have thus proven their ultra-high reliability in withstanding wind, pressure and freezing temperatures.

In the 35mm hailstone test, power attenuation of single-glass 670W modules was just 0.17%, and no attenuation was detected in dual-glass modules.

Under the stringent requirements of the IEC 61215 series, the hail test of Trina Solar's Vertex 670W modules simulated the shock of hail on the modules' surface. Using a pneumatic emissions device, natural hail was imitated, with artificial ice balls hitting the modules at a constant speed. After the

modules had been subjected to these shocks the outward appearance, electrical safety and any change of output performance were thoroughly checked.

In the test ice balls with a diameter of 35mm (similar to a regular egg's central diameter) were used, and these hit the surface of the module at a speed of 27.2 meters a second. Meteorologists class hail as heavy when the diameter of the hailstones exceeds 20mm. After the test the surface of the 670W Vertex modules was intact, and there were no micro-cracks.

The modules also passed insulation and wet leakage tests. Power attenuation of single-glass modules was only 0.17%, and no attenuation was detected for dual-glass modules. All this means that under extreme hail weather conditions, Trina Solar's 670W Vertex modules will withstand high-speed shock and are still safe and reliable. In short, excellent quality is guaranteed.

PV modules' ability to withstand hail is mostly related to the material of the frontsheet, made of glass. The thickness of the glass and its tolerance to shock have direct bearing on its capacity.

Single glass (hail test)

IEC standard		Trina test results	
Hail size	Power attenuation	Hail size	Power attenuation
25mm	<3%	35mm	0.17%

Dual glass (hail test)

IEC standard		Trina test results	
Hail size	Power attenuation	Hail size	Power attenuation
25mm	<3%	35mm	0.53%

Chen Lin, technology head of Xinyi Glass Holdings Limited, said: "We have enlarged the size of the steel furnace and adjusted fan configuration and strictly controlled our manufacturing and management process, so that the steel strength of the glass, which is matched with 210 modules, is guaranteed, with full technological reliability."

In the 210 modules the ability of the glass to resist shock fully guarantees their safety and reliability.

In addition, based on the structural features of various modules, Trina Solar has special requirements for the performance of glass. The inspection and test specifications of both suppliers and Trina Solar ensure that the reliability of the glass is fully integrated into the design and structure of the products.

This in turn creates a corporate standard that is promoted to become the industrial standard, and indeed a national standard.

In 2007 Trina Solar adopted a management policy of continuing reliability tests that established the material ORT concept in the industry and included it in the reliability corporate standard, including full series testing programs such as the IEC 61215, IEC 61730, and IEC 63216. In most cases the company's internal standards are set at a level two to three times that of the IEC standard.

Media report:

<https://www.pv-tech.org/industry-updates/trina-solar-670w-vertex-module-displays-excellent-performance-in-35mm-hailstone-testing/>



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