



WHITE PAPER

SOLAR MOUNTING ON METAL ROOFS



Metal Roof Solar Project Survives Category 5 Hurricane Winds

S-5! Clamps Protect Mexico Superstore Roof During Hurricane Otis

Photo courtesy of Energia Real

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Solar Mounting Off Purlin on Metal Roof Sheeting

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Executive Summary & Introduction

Executive Summary

The data, testing and code analysis presented in this white paper conclusively demonstrate that metal roof panels possess inherent structural capacity that can be reliably utilized for solar mounting between purlins, provided the system is properly engineered and installed. The assumption that solar attachment points must be located directly over purlins to ensure structural adequacy is unsupported by testing, codified standards or real-world performance.

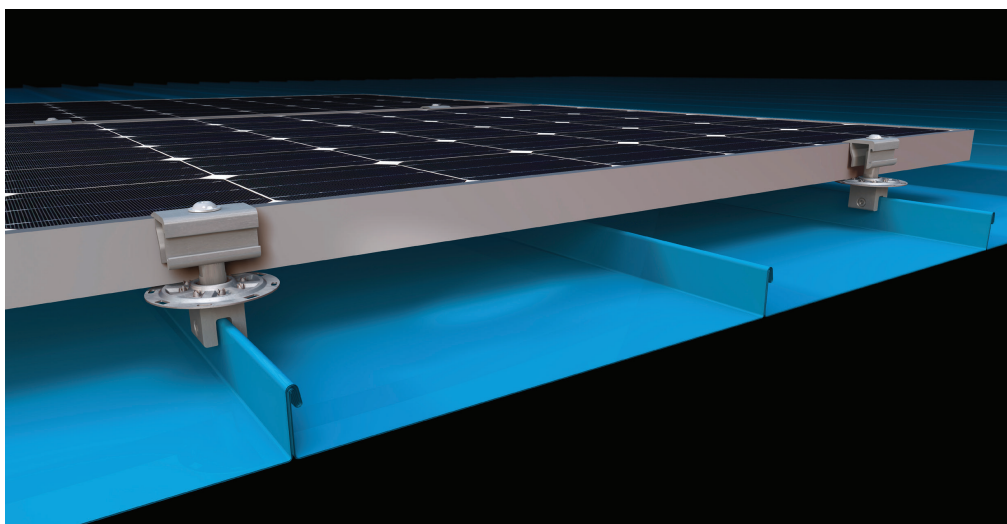
Introduction

Rail-less, DirectAttach™ solar mounting on metal roofs was pioneered by S-5!® at least 20 years ago. Closing in on 10 GW of installations worldwide, S-5! has never experienced a mounting system failure in systems that were properly engineered and installed.

Metal roofs come in two distinct styles, each with a different method of attachment: standing seam (or concealed-fix), and exposed-fastened (exposed-fix). In both roof types, the seams or ribs that run from the eave to the ridge act as structural elements. Clamps or brackets are attached to the seams or ribs with an interface called the PVKIT® to secure the PV module frames, eliminating the need for rails.

The clamps and brackets can be attached anywhere along the seams or ribs, as well as directly over the purlins. As the industry leader in metal roof attachments, S-5! fully endorses and stands behind the PVKIT rail-less method, mounting both off purlin and over/near the purlin when proper engineering and installation are practiced.

Contrary industry commentary has pressed forward with technical assertions regarding excessive mid-span deflection, cyclic movement, clamp loosening, progressive failure and the allegedly “non-structural” role of roof sheeting without publishing the supporting test data, calculations, cited standards or documented failure evidence needed to substantiate those assertions. This paper evaluates those assertions against published standards, assembly and connection testing and observed field performance.



PVKIT rail-less solar mounting system shown on standing seam metal roof. Image: S-5!

Roof Sheeting and Structural Capacity

Although cross-sectional geometries vary, metal roof panels have structural capacity (spanning capability) carrying live and dead loads to spaced supporting structural members (purlins). All commercially available metal roof sheeting must undergo testing via applicable codes and standards to verify its specific structural capacity, which varies depending upon the profile's gauge thickness and profile details. S-5! has performed thousands of tests that isolate failure to the clamp or bracket's connection to the seam or rib, given these variables.

In addition, S-5! has also performed numerous roof system assembly tests on different roof panel types to determine an ultimate failure point (concentrated) load and quantify the roof sheet and assembly's capacity in the upward load direction at various locations, both on or near purlin and mid-span.

Any metal roof sheet used on open framing for commercial roofing must be rated for live loads, including foot traffic for maintenance and varying wind uplift pressures. Metal roofing is manufactured and tested to withstand these forces without compromising the integrity of the roof. AS 1562 [1] ensures the proper design and installation of cladding while AS 4040.0 [2], AS 4040.1 [3] and AS 4040.2 [4] prescribe the test methods and required performance metrics. AS 1562 [1] Section 3.2 requires that the cladding, its fastenings and the supporting members be designed to withstand loads calculated in accordance with AS/NZS 1170, including live loads, wind loads and snow loads.

A roof sheet, as part of a roof system to which solar is mounted, would not be considered a stand-alone element. As part of the system, it is a structural member that transfers these loads through its attachment into supporting purlins. It's clear that manufacturers do indeed design their roof sheets with structural characteristics to meet the codes and standards mentioned here, validating the position of this writing. Roof clips and their fastenings are also designed to withstand uplift forces as required by codes and standards.

The roof sheet carries all its tributary environmental loads through the roof's points of attachment into the purlins, which are spaced according to site-specific wind pressures. Cladding manufacturers publish span tables indicating the wind pressures that the cladding has been designed and tested to withstand at various purlin spacings.

Testing

In addition to the required testing that metal roofing Original Equipment Manufacturer (OEM)s perform on their products, S-5! has performed extensive testing to prove the viability of off-purlin solar mounting and the upward structural capacity of metal roof cladding, focusing on upward point loads, both isolated and as part of a solar assembly. This section will briefly describe the different tests performed and the implications of their results. The full testing descriptions, setups and results are included in the appendix.

Load Testing on Klip Lok HS With S-5-KL7™

Clamps were mounted mid span between purlins (purlin spacing shown in Fig 1), 100 mm from clips and at purlin over roof clips. Tests were run on 0.48 mm and 0.42 mm steel thicknesses attached with the OEM's roof clips to purlins spaced as shown in **Fig 2** below. Loading was performed in intervals of 445 N (100 lbs.) and held for 5 minutes at each interval until failure. Deflection was noted at the clamp location, on the rib at the clip location and at the pan (flat) of the panel adjacent to the clamp. Observations were recorded at each load interval.

0.42 mm BMT Steel	0.48 mm BMT Steel
1650 mm	2050 mm

Fig 1: LYSAGHT® recommended maximum single span support spacings

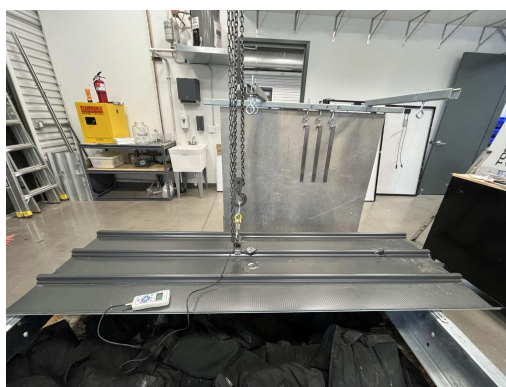


Fig 2: S-5-KL7 mounted mid-span with load cell attached

Loads at failure for the 0.48 mm steel KLIP-LOK® HI-STRENGTH® tests:

Mid Span: 2.18 kN (492 lbf)

100 mm from Purlin: 2.45 kN (550 lbf)

On Purlin: 2.60 kN (586 lbf)

Loads at failure for the 0.42 mm steel KLIP-LOK HI-STRENGTH tests:

Mid Span: 2.11 kN (474 lbf)

100 mm from Purlin: 3.25 kN (728 lbf)

On Purlin: 2.98 kN (668 lbf)

Tests with clamps mounted mid span between purlins demonstrated the roof's ability to withstand loads more than the downward concentrated test load limits (strength limit state) of (0.5 kN x 1.5 = 0.75 kN) steep slope and (1.1 kN x 1.5 = 1.65 kN) low slope, tested according to AS 4040:1[3] and set forth by AS1170.1 [8]. Differences in deflection, depending on mounting location, can be observed in the results provided in the appendix.

Mid-span failure was nearly the same load for both 0.48 mm and 0.42 mm. With the 0.48 mm thickness material, disengagement from the clip occurs at similar loads regardless of clamp location. Disengagement of the panel from the roof clip was the failure mode in all cases for either thickness. The goals of the testing were successfully met.

1. Upward mid-span failure loads are greater than the downward loads prescribed by AS/NZS 1170.1 [8]
2. Design loads are established for proper system engineering
3. No damage to the roof panels was observed during testing

Static Testing and Low-High-Low Cyclonic Testing

This is an assembly test with clamps mounted 300 mm from the purlins (**Fig 3**) on three separate roof types. Pressure is applied from below via an airbag. It is a pass/fail cyclic load test. The metal roof cladding, its connections and immediate supporting members must be capable of remaining in position, without any permanent distortion, fracture or damage that might occur in the sheet or fastenings under the pressure sequences A to G.

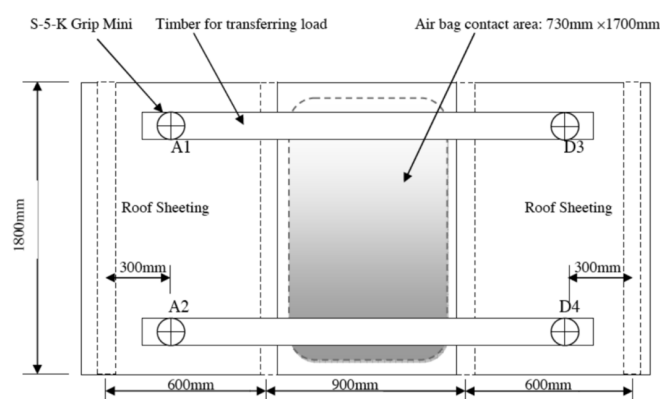


Fig 3: Test setup conforms to the requirements of AS 4040.0 - 1992

The test was run on three concealed-fix roof types; LYSAGHT KLIP-LOK CLASSIC® 700, LYSAGHT KLIP-LOK 406, and Stramit Speed Deck Ultra® with steel thicknesses of either 0.42 mm or 0.48 mm. A maximum pressure is established via static loading for each specimen. The following sequence of cyclic loading is then run (**Fig 4**).

Sequence	Number of Cycles	Applied Airbag Pressure ($P_{test} = P_a =$ Max. kPa)
A	4500	0 to $0.45 \times P_a$
B	600	0 to $0.6 \times P_a$
C	80	0 to $0.8 \times P_a$
D	1	0 to P_a , held for at least 10 sec.
E	80	0 to $0.8 \times P_a$
F	600	0 to $0.6 \times P_a$
G	4500	0 to $0.45 \times P_a$

Pressure Multipliers and Loading Sequence

Fig 4 Loading sequence and pressure multipliers

Cyclonic testing passed for all specimens, and a load per clamp was established. This testing demonstrates the roof panel's structural capacity and provides a load value for use in system design. It also shows the clamp's ability to withstand fluctuating wind pressures without loosening or disengaging from the panel ribs. The full test report and references can be found in the appendix.

The National Construction Code for Australia (NCC) [5] requires all roof claddings, fixing connections and immediate supporting members to withstand a low-high-low (LHL) cyclonic testing regime for installation in wind regions C and D (AS/NZS 1170.2 [9]).

LYSAGHT's cyclonic design manual references the NCC's requirement and has Ultimate Limit State Wind Pressure (kPa) published for spans from 600 mm to as high as 2700 mm (depending on profile) for all claddings e.g. KLIP-LOK 406, KLIP-LOK 700 and TRIMDEK®, to name a few.

S-5-HR™ Clamp Mid-Span Mounted Load Testing

Steel & Tube Hi Rib in 0.55 BMT steel was mounted to roof purlins spaced at 2.3 m with roof clips supplied by the OEM. The S-5-HR clamp was mounted mid span (1.15 m) from the roof purlins. Negative load (upward) was applied to the clamp in intervals of 222 N (50 lbf) and held for five minutes at each interval (**Fig 5**). Testing was performed on both the lapped rib and intermediate rib, repeated three times each, with the following average loads at failure:

Intermediate Rib:

Maximum load held for five minutes: 2.89 kN (650 lbf)

Ultimate load at failure: 3.09 kN (695 lbf)

Lapped Rib:

Maximum load held for five minutes: 3.18 kN (716 lbf)

Ultimate load at failure: 3.27 kN (736 lbf)



Fig 5: S-5-HR clamp mounted mid-span holding load

In all cases, the failure mode was the disengagement of the roof panel from the roof clip. In one case, the clamp also disengaged from the seam on the lapped rib. The roof panel itself remained undamaged during all tests. These results affirm all the same points as the mid-span testing performed on the LYSAGHT KLIP-LOK HI-STRENGTH outlined above and confirms the viability of mid-span mounting.

Exposed-Fastened Trapezoidal Roofing Mid Span Test

Trapezoidal R-panel (AKA TRIMDEK) in both 24 ga (0.6 mm) and 26 ga (0.45 mm) was tested for uplift point loads mid span between purlins. The test setup was a multi-span (three-span) condition with four purlins spaced 1.2 m apart. RibBracket™ III was mounted mid span on the center span to an intermediate (non-lapped) rib. Negative load (upward) was applied to the bracket in intervals of 222 N (50 lbf) and held for five minutes at each interval.

0.45 mm (26 ga) Ultimate Load at Failure: 5.23 kN (1175 lbf)

0.6 mm (24 ga) Ultimate Load at Failure: 4.77 kN (1072 lbf)

Failure Mode: Yielding of the bracket to sheeting connection; fastener(s) attaching bracket to rib pulls out one or more threads (**Fig 6**).

No permanent deformation or buckling of the roof panels occurred.

This testing provides design values and proves the roof panel's ability to withstand point loads imposed by a mid-span sheet rib-only attachment.



Fig 6: RibBracket III under load just prior to failure

FM 4478 Testing

This is a test standard from FM Global designed to test a rooftop solar assembly under extreme wind events. It is performed on a full roof assembly, including the structure, the clips and metal roof, the solar mounting system (in this case the DirectAttach S-5-PVKIT® HUR 2.0) and mounted PV panels. The assembly is sealed inside a pressure chamber that applies uplift pressure. Pressure is increased in increments of 720 Pa (15 psf) and held for one minute until system failure or the required pressure level is exceeded.

The S-5-PVKIT HUR 2.0 was tested on Butler MR-24 with OEM-supplied FM-listed clips and fasteners. The pressure rating achieved was 7.2 kPa (150 psf). The testing demonstrated failure of the roof clips in the system at locations where the clamps were mounted at or near the purlin. This occurred due to most of the load from one attachment point concentrated into a single clip rather than being spread between two clips when mounted mid span. Clamps mounted mid span did not disengage or damage the roof to the point of failure.

Testing Takeaways: Proof of Metal Roof's Structural Capacity

Load testing performed on KLIPLOK and Hi Rib in both 0.42 mm and 0.48 mm, and trapezoidal rib (TRIMDEK) style roofing in both 0.6 mm (24 ga) and 0.45 mm (26 ga) with clamps or brackets mounted mid span shows that the roof can support uplift loads greater than the concentrated load limits for strength prescribed by AS/NZS 1170.1.

The failure mode on concealed-fix profiles, regardless of clamp location, was roof clip disengagement from the cladding. The roof panel itself undergoes some deflection, being put into tension but does not buckle or become damaged before it disengages from the roof clip.

For the trapezoidal exposed-fastened roofing, the failure mode was the yielding of the bracket-to-rib connection and/or fasteners attaching the bracket to the rib pulling out; the same failure mode was consistently exhibited during standard testing by S-5!, which isolates the failure point to the bracket-to-rib connection. FM 4478 assembly testing on standing seam panels showed that the failure point in the system occurred at the clamp locations directly over the purlins, rather than at mid span.

Metal roof panels are designed to resist positive and negative loads. Their stiffness can be measured via testing and used as a design limit when incorporating solar systems. Solar array attachment points may lie on or near purlins or mid-span, and the system designed around the weakest component in the load chain.

Mounting off purlin is a safe and structurally sound practice when done correctly. The system should be designed to reduce point loads below the point load capacity of the roof at the given span between purlins. The very nature of a DirectAttach, rail-less system allows for maximum uniformity in load distribution. The DirectAttach method maximizes favorable load distribution into the roof, spreading the load with frequent attachment points and thus reducing tributary point loads per attachment.

Deflection and Fluctuating Wind Forces

Common wind events used when designing to AS/NZS 1170 have a 1/200 probability of exceedance, and a safety factor is applied to S-5! clamp or bracket test data, making it very unlikely that the system would be stressed enough to cause significant (elastic) deflection at any point in the system. When engineering to code and standard, design loads are assigned for extreme wind events that rarely occur.

Experience shows that fluctuating wind forces are not an issue with properly engineered systems by S-5!, as the clamps, bolts or setscrews do not loosen over time. In fact, the A2 stainless steel setscrews or bolts provided with the clamps form a thin oxide layer between the fastener and the aluminum threads, preventing accidental back-out.

Additionally, cyclic load testing performed to AS 4040.3 with both the S-5-K Grip™ and K700 clamps indicates that loosening of the clamps does not occur due to fluctuating wind conditions.

Failure Point of the System

It cannot be assumed that mounting on or near purlins always results in a stronger load chain. In fact, the inverse is often true. Testing frequently shows that the weak point in the system is the roof disengaging from the clips at purlin locations.

FM 4478 testing performed on S-5-PVKIT HUR 2.0 mounted with the S-5-E™ clamp on a Butler MR-24 roof system shows the clips that failed had a clamp mounted at or near the purlin, which forced all the load from the tributary area of a MidGrab into a single clip. Clamps mounted mid span between purlins did not cause any damage or failures. This may seem counterintuitive to speculation about a system's failure point; however, prudent testing supersedes those speculations.

Engineered Systems

The key to avoiding system failure and excessive deflection at mid-span mounts comes down to load distribution. The site-specific design pressures should be calculated using AS/NSZ 1170, and the system should be designed with enough attachment points to lower the point loads to below what the roof sheeting and all components of the load chain can withstand.

When establishing attachment counts per module for direct attachment or spacing of rail-mounted systems, S-5! uses a proprietary design tool that has been reviewed and certified by an Australian-registered professional engineer to follow all aspects of the standards listed below:

- AS 1170:0 – 2002 *Structural Design Actions, Part 0: General Principles* [7]
- AS 1170.1 – 2002 (R2016) *Structural Design Actions, Part 1: Permanent, imposed and other actions* [8]
- AS 1170.2 – 2021 *Structural Design Actions, Part 2: Wind actions* [9]
- AS/NZS 1170.3:2003 Amdt 2:2017 *Part 3: Snow and Ice actions* [10]

An ultimate load capacity for the clamp-to-seam or bracket-to-rib holding strength, in both the upward and downslope directions, is established through S-5!'s industry standard testing method officially recognized by the International Code Council (ICC-ESR 3869) and High Wind Hurricane Zones in the most demanding area in the United States, which is the Florida Product Approval (FL46688 and FL47050).

All testing is performed in a third-party 17025-certified laboratory. S-5! publishes all load test results on its website for easy access to a library of thousands of roof and clamp/bracket specific combinations.

To maintain structural integrity and longevity of the solar system, the designer should understand the capacity of all components in the load chain and factor them into the design.

Experience & Global Recognition

S-5! was founded by Rob Haddock, a long-time metal roofing contractor, consultant and educator who has more than 50 years of experience in the metal roofing industry. He invented the standing seam metal roof clamp in 1991, being the first to recognize the need for a simple, engineered solution for attachment of rooftop ancillaries, such as snow guards, service walkways, antennae, HVAC and more. As the solar industry began to take hold, many installers and producers have looked to S-5! for their solar metal rooftop mounting needs.

The direct attachment method was pioneered in 2007 when S-5! invented the PVKIT, a unique solar mounting solution eliminating the need for rails. The success and track record of the S-5! product line is in large part due to the founder's and staff's experience and deep understanding of all aspects of metal roofing.

S-5! designs products that protect the roof integrity first and foremost, and has been successfully using the DirectAttach method, which employs mid-span mounting for at least 30 years.

Metal roofs are produced in many shapes and sizes from standing seam and concealed-fix to exposed-fastened. Within these categories, metal roof manufacturers have innovated a great variety of seam and rib geometries and dimensions that serve to attach the cladding to the structure, providing structural characteristics.

S-5! takes a hand-in-glove approach to designing and engineering clamps specific to each seam or rib type, ensuring the best fit and holding strength possible. With 272 patents and more than 50 individual roof manufacturer endorsements worldwide, S-5! provides confidence that solar systems are mounted to roofs using a proven product approved by many of the roof OEMs themselves.

Conclusion

All commercially available metal roof cladding systems are designed, tested and code-mandated to resist positive and negative loads while spanning over purlins. Standards such as AS 1562 [1] and AS 4040 [2], together with load derivation from AS/NZS 1170, explicitly require roof sheeting, clips and fasteners to function as part of an integrated structural system.

As such, roof panels are not passive elements; they actively distribute applied loads through clips and fasteners into the spaced supporting structure.

Independent and in-house laboratory testing, including static uplift, cyclic LHL loading and full assembly FM 4478 [6] testing, consistently and harmoniously confirm that mid-span attachment locations can resist uplift loads exceeding code-prescribed design.

Across multiple profiles, steel thicknesses and fastening methods, failure occurred at the roof clip or fastening interface — not within the roof sheet itself. Importantly, the FM 4478 [6] test demonstrated that attachments placed directly over purlins can introduce higher localized demands on individual clips, while mid-span mounting distributes loads across adjacent clips, resulting in equal or improved system performance.

These findings directly disprove claims that off-purlin mounting is inherently unsafe or structurally unsound. Such claims fail to recognize the structural role of metal roof sheeting, ignore published span capacities and overlook the governing principle of load distribution within the roof system.

When solar arrays are designed using site-specific wind pressures, appropriate attachment quantities and distribution, conservative safety factors, and verified test data, mid-span mounting is not only permissible — it is demonstrably effective.

Over three decades of field performance, supported by extensive third-party testing and compliance with internationally recognized standards, further validate this conclusion. Engineered, rail-less DirectAttach systems that rely on mid-span mounting have been deployed globally at scale without system failure.

In summary, mounting solar attachments between purlins on metal roofs is a viable, code-compliant, and structurally reliable practice. The governing factor is not attachment proximity to purlins, but rather an engineered system that respects the capacity of every component in the load path. Assertions to the contrary are not supported by testing, standards, or observed performance and should not be relied upon as a basis for design or specification.

Load Testing on Klip Lok HS With S-5-KL7™:

<https://3482954.fs1.hubspotusercontent-na1.net/hubfs/3482954/Research%20and%20Development/White%20Paper%20-%20Solar%20Mounting%20Off%20Purlin%20on%20Metal%20Roof%20Sheeting/S-5-KL7%20-%20Mid%20Span%20Normal%20to%20Seam%20Pull%20Test%20PDF.pdf>



Static and LHL Cyclonic Assembly Testing AS4040

<https://3482954.fs1.hubspotusercontent-na1.net/hubfs/3482954/Research%20and%20Development/White%20Paper%20-%20Solar%20Mounting%20Off%20Purlin%20on%20Metal%20Roof%20Sheeting/AU%20Testing%20Cyclonic%20HLH%20-%20Cyclonic%20Load%20Tests%20PDF.pdf>



S-5-HR™ Clamp Mid-Span Mounted Load Testing

<https://3482954.fs1.hubspotusercontent-na1.net/hubfs/3482954/Research%20and%20Development/White%20Paper%20-%20Solar%20Mounting%20Off%20Purlin%20on%20Metal%20Roof%20Sheeting/S-5-HR%20-%20Multi-Span%20Test%20Report%20with%20Images%20PDF.pdf>



Exposed-Fastened Trapezoidal Roofing Mid-Span Test

<https://3482954.fs1.hubspotusercontent-na1.net/hubfs/3482954/Research%20and%20Development/White%20Paper%20-%20Solar%20Mounting%20Off%20Purlin%20on%20Metal%20Roof%20Sheeting/RBIII%20Multi-Span%20Test%20-%20Specimen%20Information%20PDF.pdf>



FM 4478 Test Certificate:

[https://3482954.fs1.hubspotusercontent-na1.net/hubfs/3482954/Resources/Resource%20Center%20Cards%20\(Multi-Lingual\)/Certifications/240829%20FM%20Certificate%20PR468837coc240828.pdf](https://3482954.fs1.hubspotusercontent-na1.net/hubfs/3482954/Resources/Resource%20Center%20Cards%20(Multi-Lingual)/Certifications/240829%20FM%20Certificate%20PR468837coc240828.pdf)



Real world installations that have survived hurricanes:

Project Name	Dairy Industries Jamaica Ltd.
Location	Kingston, Jamaica
EPC Contractor	Grid Electrical Solutions (GES)
Solar Modules	Jinko 580 W
System Size	709 kW
Roof Profile	26 ga, exposed-fastened trapezoidal metal roof
S-5! Product	RibBracket™ II with PVKIT®



Dairy Industries Jamaica Ltd., Kingston, Jamaica.

The solar mounting system for this project needed to meet strict engineering and structural standards, including resilience to extreme wind uplift forces typical of Category 4 hurricanes. GES selected S-5! for its strong engineering reputation, its extensive testing and certifications, including Florida Product Approval (FPA) for High Velocity Hurricane Zones (HVHZ)—a key indicator of performance in extreme wind conditions, and robust technical support.

Early in the project, S-5! conducted a thorough review of site-specific conditions, including roof geometry, exposure levels, building height and panel thickness.

Appendix | Hurricane Melissa (continued)

Based on this analysis, S-5! developed a comprehensive engineering report detailing the specific zones of the roof where additional attachment points were required to resist Category 4 hurricane conditions. It also included wind uplift resistance calculations, wind load zones and attachment spacing tailored to the roof profile, all backed by rigorous laboratory testing.

The S-5! system proved to be an ideal solution. Its rail-less design significantly reduced the number of roof penetrations, helping to preserve watertightness and eliminate the risk of leaks—a critical factor. The streamlined installation process allowed the system to be deployed more quickly and safely than traditional racking systems.

To ensure a smooth installation, S-5! deployed two application engineers onsite to provide support and guidance for the installation crew.

S-5!'s components offered high reliability, third-party certifications and laboratory-tested performance—including 5,000+ individual load tests across a wide range of material types, gauge thicknesses and manufactured brands. With proven mechanical strength, ASTM E-2140 certified watertightness and fast, secure installation, the system enabled GES to meet the project's strict structural and environmental demands while significantly reducing installation time.

On October 28, 2025, Hurricane Melissa reached the shores of Jamaica. The Category 5 hurricane storm subjected the PV array to 253 kph+ wind speeds, putting the solar attachments to the ultimate test. The PV system survived the storm with the roof and solar array remaining completely intact.

The RibBracket™(s) were mounted to 26 ga steel, which is the thinnest commercially available steel for this roof profile. A system of this size requires many off-purlin attachment points all throughout the array. The spacing of the engineered PVKIT solution allowed the system to distribute the severe loads experienced during the storm safely through the roof and into the building structure.

Appendix | Hurricane Otis



Hurricane Otis, Acapulco, Mexico. Photo courtesy of Energia Real

Project Name	Grupo Comercial Chedraui
Location	Acapulco, Mexico
EPC Contractor	Energia Real
Solar Modules	Trina Solar 545 W
System Size	293 kW
Roof Profile	KR-18
S-5! Product	S-5-MX™ Mini and PVKIT®

This array was installed on one of the leading grocery store chain locations in Mexico. The rooftop is a KR-18 style standing seam metal roof. The S-5-MX mini was designed for this roof type, and the PVKIT is used to mount the solar array. The majority of these attachments were off purlin.

On October 25, 2023, Hurricane Otis made landfall near the port of Acapulco, devastating the coast with maximum sustained winds of 270 kph, one of the strongest recorded hurricanes to have hit the Mexican Pacific. While most of the surrounding shops, restaurants, hotels and businesses were completely destroyed by the Category 5 hurricane, remarkably, this store's roof and solar array remained mostly intact.

In the aftermath of the hurricane, the roofing contractor visited the site to inspect the roof damage. Sections of the roof that were without solar experienced severe roof blow-off. However, the store's rooftop solar array, secured in place by S-5! PVKIT solar mounts and MX Mini clamps withstood the devastation.

Case Study Relevance to Off-Purlin Mounting

The 293 kW Hurricane Otis installation provides field-scale evidence consistent with the tested load-path behavior described in this paper. At the Acapulco store, wind-induced loads on the modules were transferred through the PVKIT solar mounts and S-5-MX Mini clamps into the KR-18 roof panels, then through the concealed clips and fasteners into the purlins.

The project account states that the DirectAttach configuration used a greater number of connection points distributed along the seams; the case history for this project identifies off-purlin attachments throughout the array. Post-storm inspection found the array, clamps, roof panels beneath the array, clips and supporting connections intact, while nearby roof areas without solar experienced substantial roof panel loss [11].

The observed performance is also consistent with two mechanisms relevant to off-purlin design. First, the greater number and distribution of DirectAttach connection points reduces the tributary point load assigned to an individual attachment. Second, the seam clamps provide restraint along the roof seams and can supplement the roof assembly's resistance to seam separation and clip disengagement.

Together, these mechanisms help distribute module reactions through multiple roof components rather than concentrating the full reaction at a single roof clip or purlin location [11].

The observed performance demonstrates that an engineered load path containing numerous off-purlin attachment locations remained intact during an extreme wind event. That performance is inconsistent with treating off-purlin mounting as inherently unsafe or structurally ineffective.

Metal Roofing in High Wind Conditions

Metal roofing, in particular standing seam metal roofing, is known for its exceptional performance in high-wind conditions, due in part to the attachment methods and interlocking installation where roof panels are overlapped and attached to the structure of the building, reducing the ability of wind to disrupt the panels. Metal roofing lends itself to high-wind areas because it can be easily engineered to withstand nearly any uplift force within the design stage.

Appendix | Hurricane Otis Observations

Observations

Photos of the site taken post-hurricane clearly indicate the vast majority of roof damage was to areas of the roof without solar installed. This is evident, even in the higher-pressure edge roof zones, where the roofing panels under the solar modules were not damaged while the nearby bare roofing was blown off.

The conclusion is that the solar modules, the S-5! PVKIT solar mounts and MX Mini clamps installed over portions of the roof prevented those portions from failing, preserving both the solar modules and the roof.

In addition to securing the solar modules to the roof, the MX Mini clamps served a secondary function as wind clamps, often referred to as **External Seam Clamps**. These clamps measurably increase a roof's wind uplift resistance, helping prevent multiple modes of failure, including seam separation and clip disengagement.

Third-party testing conducted in 2013 demonstrated a 300% increase in uplift resistance of a metal roof when S-5! **WindClamp**™ external seam clamps were installed on the roof seams. During the Category 5 hurricane in Acapulco, the MX Mini clamps on the grocery store roof served this same secondary function.

Considering how the wind causes uplift forces when approaching and blowing across the solar array installed on the roof, the dynamics of the wind forces shifted from direct pressure on the roof to split pressure on both the roof and the solar modules. The metal roof seams were strengthened from the installation of the MX Mini clamps to resist uplift pressures on the roof and met the challenge to secure the solar modules to the building, preventing wind uplift forces from tearing them off the building while also preserving the roof.

In this scenario, those uplift forces were transferred into the KR-18 roof through the PVKIT solar mounts and MX Mini clamps, then from the roof panels to the roof clips and into the building structure. Together, these components and connections were sufficiently durable to prevent the modules from disengaging from the roof panels and prevent the roof from pulling off the building's structure.

Often, there is a concern that a metal roof panel is not strong enough to transmit the forces as part of the load path described above, or that the roof clips may be overloaded and fail from these discrete point loads. From observations in this case study, such concerns are not valid. All the components in the load path and all the connections between the components remained intact and connected, keeping the system together and undamaged, including the roof panels and roof clips.

Appendix | Hurricane Milton

Project Name	Florida Residence
Location	Sarasota, Florida
Solar Modules	ZNShine Solar – ZXM6-NH120-360/M
System Size	17 kW
Roof Profile	New Tech SS450 SL 0.6 mm (24) ga steel
S-5! Product	S-5-N™ 1.5 Mini and PVKIT®

The S-5! PVKIT was used to mount this residential array 5 miles inland from the ocean. Hurricane Milton was ranked as a Category 3 when it reached the array. The array and its attachments withstood 172 kph+ wind speeds. There was no failure or loosening of the mounting system components. The only damage to the array was one slightly bent module frame. The PVKIT and the off-purlin mounting method proved to be an ideal solution to survive hurricane force winds.

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