

Bonding and  
Installation Manual  
for *UNI-SOLAR*<sup>®</sup>  
*PowerBond*<sup>™</sup> ePVL

*UNI-SOLAR*<sup>®</sup>



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This document must be read and understood before attempting to handle, install, wire, operate, and/or perform maintenance to the laminates and ePVL system. The laminates produce DC electricity when exposed to sunlight or other light sources. Contact with electrically active parts of the laminates can cause injury or death, whether they are connected to other laminates or individually. The installer assumes any risk of personal injury or property damage that might occur during the installation and handling of laminates or the ePVL system.



To avoid product damage, personal injury, or even possible death, anyone installing or handling the laminates and/or ePVL system must carefully read, understand, and follow all the installation and safety instructions in this document before attempting to install, wire, operate the array, and/or perform maintenance on the laminates.



Observe all electrical safety precautions to prevent electrical shock while installing laminates, and while wiring, testing, and/or performing maintenance of the PV array. Use insulated tools and proper personal protective equipment to reduce the risk of electric shock.

The following references can help you determine the appropriate bonding and installation approach for your system:

#### References

IEC 61140	Protection against electric shock, common aspects for installation and equipment
IEC 62548	Installation and safety requirements for photovoltaic (PV) generators
NFPA70 Article 690	Solar photovoltaic systems National Electric Code in the U.S.
CSA 22.1	Safety standard for electrical standards, Part 1 of the Canadian Electrical Code

# Introduction

## Overview

Installation of a roof photovoltaic (PV) system will vary from site to site, depending on environment and complexity. This manual will:

- Explain the precautions that should be taken when working with this product
- Provide proper installation procedures
- Recommend safety procedures and special equipment that will help ensure the safety of installation personnel

Please ensure that you have the most recent version of this manual by visiting:

[www.uni-solar.com/resource-center/installation-guides/](http://www.uni-solar.com/resource-center/installation-guides/)

## Tested and Certified

These *UNI-SOLAR*<sup>®</sup> *PowerBond*<sup>™</sup> ePVL laminates are certified to comply with IEC 61646:2008 and IEC 61730:2007 for Class A installations up to 1000 Vdc, fulfilling the requirements of Safety Class II.



- Qualified, IEC 61646
- Safety Tested, IEC 61730
- Periodic Inspection

These laminates are also certified to meet the requirements of UL 1703 for a maximum system voltage of 600 Vdc and Class C fire classification.

### Disclaimer of Liability

The information contained in this document is based on United Solar Ovonic's knowledge and experience, but such information and suggestions do not constitute a warranty expressed or implied. The methods of installation, use, and maintenance of roofing surfaces are beyond the control of USO.

USO assumes no responsibility and expressly disclaims liability for any loss, damage, or expense associated with the use, installation, and/or operation of its solar systems. Any liability of USO is strictly limited to the Limited Warranty.

USO reserves the right to make changes to product specifications and this document without notice. The content of this document was current to the time of publication.

### Limited Warranty

Product limited warranties are described in full in the USO Limited Warranty, obtainable at [www.uni-solar.com](http://www.uni-solar.com). In summary, the Limited Warranty does not apply to any of the following: damage, malfunctions, or failures of PV product that, in the judgment of USO, has been subject to misuse, abuse, neglect, alteration, accident, vandalism, excessive wear and tear, improper or inadequate installation, and/or application. The Limited Warranty also does NOT apply to installations not in conformance with USO specifications, installation manuals/documents, operation manuals, and maintenance instruction.

## Contact

For further information about United Solar Ovonic, LLC (USO) products, email USO at [info@uni-solar.com](mailto:info@uni-solar.com).

If you have questions or need support for specific roof PV system applications, contact your local *UNI-SOLAR* office, referring to the contact information on page 2 of this document.

# Safety Warnings and Cautions

## General

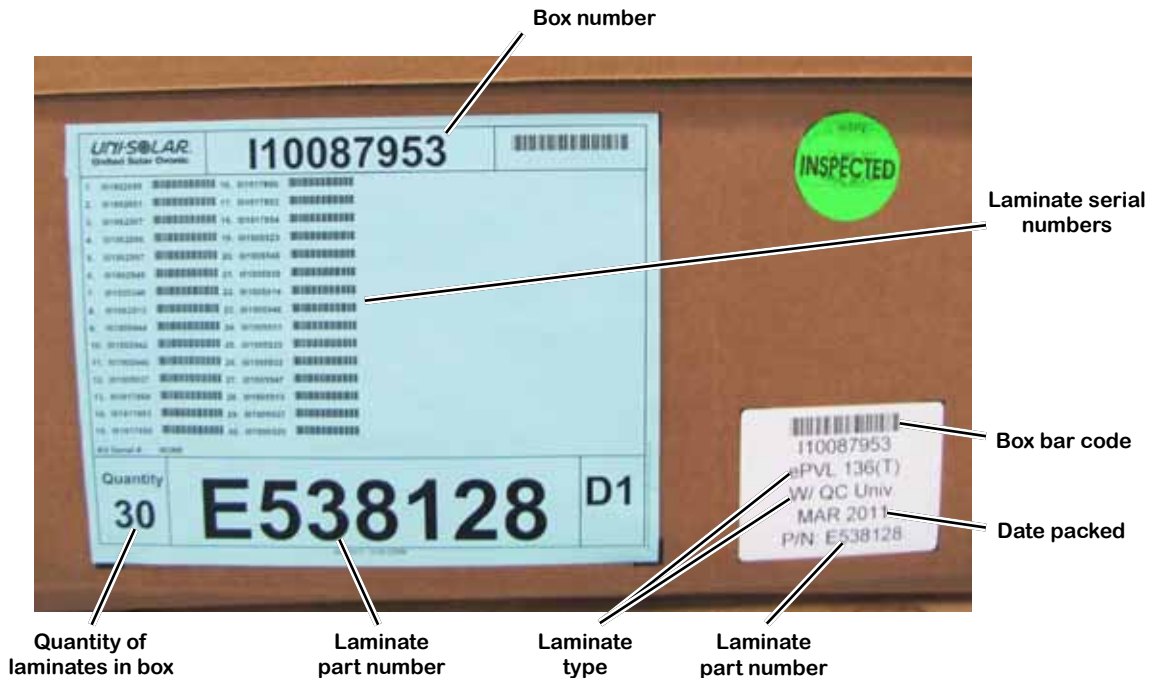
- Installation of *UNI-SOLAR* products must be in accordance with NFPA 70, Article 650, Solar Photovoltaic Systems, of the National Electric Code of the United States, or CSA 22.1 Safety Standard for Electrical Installations, Part 1 of the Canadian Electrical Code, or other local codes as applicable
- Contact appropriate local authorities to determine if permits and inspections are required in the jurisdiction of the installation
- Potentially lethal DC voltages can be generated whenever laminates are exposed to a light source, therefore, avoid contact with electrically active parts and be sure to isolate live circuits before attempting to make or break any connections
- Do NOT proceed if any doubt arises about the correct or safe method of performing any of the procedures found in this document
- Always wear appropriate safety and protective equipment, such as:
  - Rubber soled shoes
  - Cut resistant and chemical resistant gloves
  - Safety glasses
  - Hard hat
- When working on electrical connections, remove all metallic jewelry, and use insulated tools
- Wear cut resistant gloves whenever handling laminates
- *UNI-SOLAR* laminates contain electrical components enclosed and protected within. Do NOT cut or trim or alter them in any way. Do NOT drive screws into any part of the photovoltaic laminate. Altering the laminate or improper installation could cause electric shock, may result in fire, and will void the product Limited Warranty. In extreme cases where additional fixation of the laminate to the substrate is required, consult your USO representative to learn about approved options
- Do NOT install this product when laminates are wet or in the presence of standing water on roofs. Installing product without drying all surfaces or in the presence of water could cause you to slip and personal injury can result. Before installation, ensure that the roof surface is dry



- Ensure that the work area is clear of trip hazards, such as power cords, tools, electrical conduit, natural gas lines, and/or installation materials
- Personal injury can result from improper handling or use of products such as isopropyl alcohol. Alcohol vapors are both flammable and hazardous to breathe and may cause irritation to eyes, nose, throat, and skin
- Work on this ePVL system should only be carried out by qualified and authorized personnel
- Do NOT use water to extinguish fires of electrical origin

## Storage

- At time of receipt, verify that the product delivered is in fact the product ordered. The product name, part number, and serial number of each laminate are clearly marked on the outside of each packing box. Label colors can vary
- Leave the product in its original packing box until you are ready to use it
- Store packing boxes in a clean, dry area with relative humidity below 80% and ambient temperatures between 10°C to 30°C (50°F to 85°F)
- Do NOT stack packing boxes more than four (4) high



## Packed Dimensions and Shipping Information

Product type	Pallet length cm (in)	Pallet width cm (in)	Pallet height cm (in)	Pallet weight kg (lb)	Pieces per pallet stack (4 high)	Pallets per 6 m/20 ft standard container	kW per 6 m/20 ft standard container	Pallets per 12 m/40 ft standard container	kW per 12 m/40 ft standard container
ePVL-144	113 cm 44.5"	113 cm 44.5"	53.3 cm 21"	243 kg 536 lb	120	40	172.8	80	345.6
ePVL-136	113 cm 44.5"	113 cm 44.5"	53.3 cm 21"	243 kg 536 lb	120	40	163.2	80	326.4
ePVL-128	113 cm 44.5"	113 cm 44.5"	53.3 cm 21"	243 kg 536 lb	120	40	153.6	80	307.2
ePVL-72	113 cm 44.5"	113 cm 44.5"	53.3 cm 21"	216 kg 475 lb	200	40	144.0	80	288.0
ePVL-68	113 cm 44.5"	113 cm 44.5"	53.3 cm 21"	216 kg 475 lb	200	40	136.0	80	272.0
ePVL-64	113 cm 44.5"	113 cm 44.5"	53.3 cm 21"	216 kg 475 lb	200	40	128.0	80	256.0



## Work Site

- Follow all appropriate safety practices for the site
- Do NOT handle PV laminate assemblies in high wind conditions
- Do NOT install or perform maintenance on this product when laminates are wet or are in standing water
- Ensure that the work area is clear of trip hazards
- Provide clear warning signage at each access point to the installation. This signage should clearly state the dangers associated with a high voltage solar system, the personal protection equipment that should be worn, and emergency telephone numbers for fire and emergency medical service
- PV laminates contain electrical components, and cannot be trimmed or altered in any way
- Do NOT connect or disconnect quick connect cables under load
- To reduce the risk of electric shock or arc flash, cover laminates with an opaque material before making wiring connections
- All test equipment, leads, and probes must be rated for maximum system voltage
- Observe proper polarity when connecting laminates into an electrical circuit, as reverse connections may damage the laminates and will void the product Limited Warranty

## Additional

- Scratches to the front surface of PV laminates that may occur during transportation and installation are NOT covered by the USO Limited Warranty
- Try NOT to walk or kneel on the laminates. Wear clean (free from small stones) soft soled shoes to avoid possible scratching of the front surface of the laminates
- Avoid dropping sharp objects or placing objects on the laminates, and do NOT wheel carts or drag items across them
- Do NOT attempt to concentrate sunlight (via lenses, mirrors, etc.) on the laminates to increase output, as damage may occur, which will void the product Limited Warranty
- Follow all roof manufacturer and material safety data sheet (MSDS) instructions for the safe use of any chemicals
- Do NOT use any chemical agents on or around laminates that are NOT approved by USO
- Do NOT use the laminate cables to lift or maneuver the laminate



## UNI-SOLAR PowerBond ePVL Specifications

Product	ePVL-64	ePVL-68	ePVL-72	ePVL-128	ePVL-136	ePVL-144
Maximum Power ( $P_{max}$ ) ( $\pm 5\%$ )	64 W	68 W	72 W	128 W	136 W	144 W
Voltage at $P_{max}$ ( $V_{mpp}$ )	16.5 V	16.5 V	16.5 V	33.0 V	33.0 V	33.0 V
Current at $P_{max}$ ( $I_{mpp}$ )	3.9 A	4.1 A	4.4 A	3.9 A	4.1 A	4.4 A
Open-Circuit Current ( $V_{oc}$ )	23.1 V	23.1 V	23.1 V	46.2 V	46.2 V	46.2 V
Short-Circuit Current ( $I_{sc}$ )	4.8 A	5.1 A	5.3 A	4.8 A	5.1 A	5.3 A
Max. Series Fuse Rating	10 A	10 A	10 A	10 A	10 A	10 A
Length mm (in) ( $\pm 5$ mm)	2771 (109.1)	2771 (109.1)	2771 (109.1)	5412 (213.1)	5412 (213.1)	5412 (213.1)
Width mm (in) ( $\pm 5$ mm)	373 (14.7)	373 (14.7)	373 (14.7)	373 (14.7)	373 (14.7)	373 (14.7)
Laminate Thickness cm (in)	3.0 (.12)	3.0 (.12)	3.0 (.12)	3.0 (.12)	3.0 (.12)	3.0 (.12)
Laminate Thickness cm (in) including adhesive and strain relief assembly	21.0 (.83)	21.0 (.83)	21.0 (.83)	21.0 (.83)	21.0 (.83)	21.0 (.83)
Weight kg (lb)	3.9 (8.5)	3.9 (8.5)	3.9 (8.5)	7.4 (16.2)	7.4 (16.2)	7.4 (16.2)

The above electrical specifications are based on measurements performed at Standard Test Conditions (STC) of 1000 W/m<sup>2</sup> irradiance, air mass 1.5, and a cell temperature of 25°C (77°F) per ASTM E892, after stabilization.

Production tolerance for  $P_{max}$  at STC is  $\pm 5\%$ , while for other electrical parameters it is  $\pm 10\%$ .

During the first 8-10 weeks of operation, modules have higher electrical output than rated output. The output power may be higher by 15%, the operating voltage ( $V_{mpp}$ ) may be higher by 8%, operating current ( $I_{mpp}$ ) may be higher by 7%, open-circuit voltage ( $V_{oc}$ ) may be higher by 4% and the  $I_{sc}$  may be higher by 2%.

Module performance will vary depending on irradiance and temperature. Use the appropriate Temperature Coefficient to determine performance at different temperatures:

Temperature Coefficient (TC) of  $I_{sc}$ : 0.0010°/K (0.10%/°C)  
 Temperature Coefficient (TC) of  $V_{oc}$ : -0.0038°/K (-0.38%/°C)  
 Temperature Coefficient (TC) of  $P_{max}$ : -0.0021°/K (-0.21%/°C)  
 Temperature Coefficient (TC) of  $I_{mpp}$ : 0.0010°/K (0.10%/°C)  
 Temperature Coefficient (TC) of  $V_{mpp}$ : -0.0031°/K (-0.31%/°C)

$$y = y_{reference} \cdot [1 + TC \cdot (T - T_{reference})]$$

## Bonding and Installation

PowerBond ePVL laminates come with a peel and stick protective release liner on the back surface of the product.

This adhesive is suitable for many different types of substrates, however, bonding to a non-approved substrate or using a non-approved installation method will void the product Limited Warranty.

UNI-SOLAR product installation should only be carried out by companies/installers who have been trained and certified by USO. Contact your USO representative to locate USO certified installers in your area.

### Approved Substrates:

To be eligible for USO's product Limited Warranty, the product must be applied to an approved substrate. New substrates are continuously being tested and an extensive list is available from your USO representative. Typical examples of approved substrates are:

Aluminum-Zinc coated steel, AZ50 minimum per ASTM A792\792M (Galvalume®, Zinalume®, or equivalent) with or without PVDF (Kynar® 500, Hylar® 5000, Valspar® Fluoropon, or equivalent). United Solar approved single-ply membranes, TPO, EPDM, and single-ply Modified Bitumen.

Only ePVL applications to membranes from USO's approved substrate list are available for extension of USO's product Limited Warranty.

An approved substrate list is available from your USO representative. Contact your substrate manufacturer for more information on approved primer/sealer materials and procedures.

### Fire Classification:

Class A per UL 790 — Metal roofing applications at slopes up to 2:12; single-ply roofing membranes EPDM and TPO roofing applications at 1-1/2:12 and 1:12, respectively.

Class C per UL 790 and IEC 61730-2 — Metal roofing applications at unlimited slope (5:12).

For more details concerning fire classifications, refer to: [http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/showpage.html?name=TGFU.E182242&ccnshorttitle=Roofing+Systems&objid=1075924584&cfgid=1073741824&version=versionless&parent\\_id=1073993597&sequence=1](http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/showpage.html?name=TGFU.E182242&ccnshorttitle=Roofing+Systems&objid=1075924584&cfgid=1073741824&version=versionless&parent_id=1073993597&sequence=1)

## Precautions for Bonding to a Substrate

- The substrate must be approved by United Solar
- The substrate must be clean and dry
- Ambient temperature must be greater than 10°C (50°F)
- Avoid bonding at times of high humidity (>80%) or condensation, and allow morning dew to dry off before bonding
- Metallic substrates can be cleaned using a mixture of 70/30 isopropyl alcohol and distilled water, or for visibly dirty substrates, you can use an all-purpose cleaner, followed by the isopropyl alcohol/water cleaning
- Membranes must be installed and primed in accordance with substrate manufacturer recommendations
- Coated Modified Bitumen must be prepared in accordance with substrate manufacturer recommendations
- The use of any sealants or chemicals on or around laminates requires prior approval from USO

## Precautions for High Snow Areas

If the product is to be installed in areas classed as high snow risk, and the roof slope is greater than 60°, then additional edge protection should be fitted to the upper edge of all laminates. This added protection serves to protect the bond between the substrate and laminate from sliding snow and ice, helping to ensure long-term reliability.

Edge protection kits are available from your USO representative.

## Precautions for High Temperature Areas

In areas where high temperatures are common and/or can exceed 85°C (185°F), and the roof slope is greater than 20°, additional bonding solutions may be required.

## Precautions When Bonding in a Factory

- Bonding of the product should NOT be attempted when the surface is wet, or if the surface temperature is less than 10°C (50°F)
- Keep laminates in a shaded area away from direct sunlight and avoid bonding when laminate temperatures exceed 30°C (80°F). These high temperatures make it difficult to remove the white protective release liner on the back of the PowerBond ePVL, which will significantly increase installation time
- When manipulating flexible substrates, support the substrate center and the ends immediately after bonding to prevent stress on the bond BEFORE the bond is fully cured
- Leave the bonded laminate and substrate in a horizontal position for at least 12 hours from the time of bonding to ensure recommended bonding strength
- Ensure that packaging and handling of the final product does not stress the laminate or bond in any way during transportation and unloading on-site
- From the time the ePVL is bonded, the substrate must never be creased, folded, or rolled tighter than the ePVL minimum bend diameter of 500 mm (20 in)
- Product staged before installation could be subjected to wind or other forces that cause the ePVL minimum bend radius, 500 mm (19.7 in) diameter, to be violated. Care should be taken to ensure staged product is well secured and that wind will not subject the product to damage
- There needs to be a minimum separation of 2 mm (0.1 in) between laminates, but 20 mm (0.8 in) is recommended to accommodate variations in laminate positioning



Chemical Solvent Hazard: Follow all manufacture instructions or MSDS sheets for the safe use of chemicals.

## Precautions When Bonding On-Site

- Bonding of the product should NOT be attempted in high winds, when the surface is wet, or if the ambient temperature is less than 10°C (50°F)
- Keep laminates in a shaded area away from direct sunlight and avoid bonding when laminate temperatures exceed 38°C (100°F). These high temperatures make it difficult to remove the white protective release liner on the back of the PowerBond ePVL, which will significantly increase installation time
- Where possible, avoid bonding over roof seams, as this can result in an un-bonded area under the laminate. These un-bonded areas can fill with ice, dirt, or water over time, and reduce adhesion of the entire laminate to the roofing substrate
- Any laminates which are bonded over roof seams need to be inspected for voids in sealing, both at the time of installation and during subsequent maintenance
- Identify any areas which are prone to pooling water, which is defined as standing water one hour after a rain. Standing water is defined as water which will NOT drain from the roof and requires evaporation for removal
- Every effort should be made to avoid placing laminates over seams in membrane roofs. In a metal roofing system, avoid all overlaps

## Planning Your Installation

When planning an installation with *UNI-SOLAR* PowerBond ePVL laminates, keep in mind the following:

### Laminate Orientation

- Laminates should be installed so that the length of the laminate is parallel to the roof slope
- There needs to be a minimum separation of 2 mm (0.1 in) between laminates, but 20 mm (0.8 in) is recommended to accommodate variations in laminate positioning

## Pooling Water

- Identify any areas which are prone to pooling water, which is defined as standing water one hour after a rain, and avoid installing laminates in these areas
- Drainage areas are prone to water pooling if drains become blocked

## Roofs with a Slope of >60°

- Additional procedures may be required, contact your USO representative for specific advice for your application

## High Snow Areas

- Additional edge protection or sealing may be needed to prevent snow and ice from collecting on the laminates
- Contact your USO representative for specific advice for your application
- Refer to the *UNI-SOLAR* Operation and Maintenance manual for snow removal guidance

## Hurricane Areas

- *UNI-SOLAR* products have been certified by Miami-Dade county to be suitable for installation in hurricane areas
- Special installation instructions may be required for your particular substrate
- Contact your USO representative for specific advice for your application

## High Temperature Areas

- If the surface temperature of the substrate is likely to exceed 85°C (185°F), contact your USO representative for specific advice for your application

## Shaded Areas

- System performance will be impaired if laminates are shaded
- Shading can normally be minimized by ensuring that the distance between the obstruction and laminate is greater than three times the obstruction's height

## Site Preparation

- When lifting pallet stacks up to a roof, first ensure that the staging area is capable of supporting the weight of the pallet stack
- Ensure that the area where the laminates are unpacked, handled, and bonded is safe, clean, and free from excessive dust and sharp objects which could cause damage to laminate surfaces
- Laminates are manufactured with bypass diodes on each cell. This makes them particularly resistant to power loss due to shading. To maximize system performance, it is advised to avoid shaded areas while maintaining sufficient distance between objects and laminates
- Plan your installation so that traffic does not have to pass over installed laminates. If this cannot be avoided, place a thick protective sheet over installed laminates to prevent damage
- Wherever possible, provide sufficient space between laminates to ensure minimal walking on the installed PV system
- Ensure that access to the installation is safe, that operators are aware of PV system electrical hazards, and appropriate personal protection equipment is used



## Recommended Tools

Use the following tools to ensure correct bonding. These can be purchased through your USO representative using the USO part numbers shown below:

USO Part No.	Description	Purpose
A100050	500 mm smooth tube	Prevents the laminate from being coiled tighter than the minimum diameter of 500 mm (19.7 in)
A100051	Large J Roller (with long handle)	Bonding the main body of the laminate
A100052	Small J Roller	Bonding of the edges
A100053	Kit of the above three items	



MC4 connector tool

## Bonding Procedure

The following process should be performed in a clean, dry, and well-illuminated area:

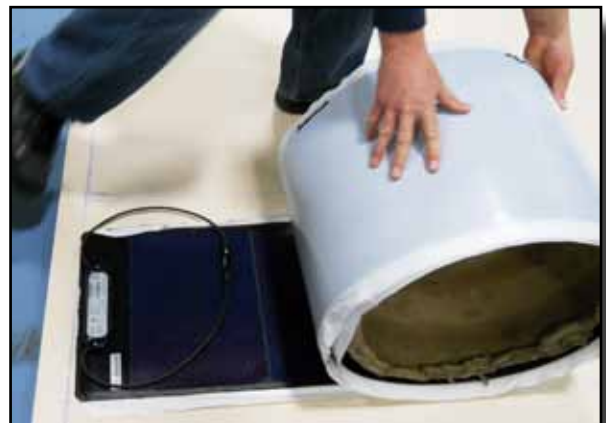
- Remove the lid of the packing box and wrap the innermost laminate around a 500 mm smooth tube to remove it from the box
- NEVER remove more than one laminate at a time



- Do NOT use the PV laminate electrical wires/cables to lift the laminate, as this can result in damage that would invalidate the product Limited Warranty
- Unroll the laminate on a clean surface where it can not come into contact with other objects that may damage the laminate



- Inspect the laminate for any damage or defects, referring to USO visual inspection criteria. Any defective or damaged laminates must NOT be bonded
- Connect a multimeter across the positive and negative terminals to perform a simple voltage check, ensuring that no electrical connections were damaged during shipping and handling
  - Depending on the light source, typically a voltage greater than 50% of  $V_{oc}$  is sufficient
  - Results may vary depending on your conditions, but results from one laminate to another should be similar
- Prepare the substrate as noted previously
- Position and orient the laminate precisely in the location it will be bonded, using chalk guidelines to ensure accuracy
  - Roll each laminate out starting at the strain relief assembly/connectors end, rolling the laminate out completely to ensure correct positioning
  - Ensure that there is sufficient room to position the laminates without undue stress to the product



**CAUTION**

Wear proper personal protection cut-resistant or leather gloves when handling this product.



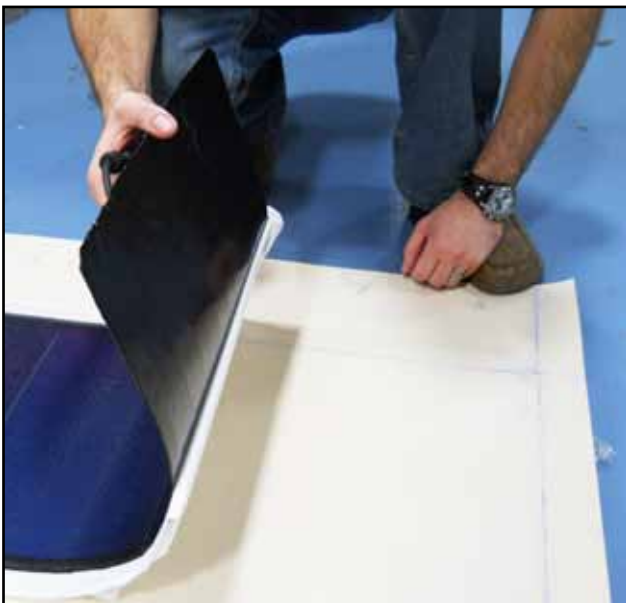
- With the laminate still rolled out, and while holding it in place, lift the laminate up about 300 mm (12 in) off the substrate or factory surface



- Ensure that the laminate is aligned, and that it does NOT move
  - This is critical, as the laminate's position will be fixed after the first 150 mm (6 in) is bonded
- Roll the laminate's exposed adhesive back down to the bonding surface
- Press down firmly on the laminate, using both hands and/or a J roller to ensure the adhesive is bonded
  - Pay special attention to the end of the laminate around the terminal enclosure to ensure secure bonding



- Peel the protective release liner off the double stick material, approx. 150 mm (6 in) from the substrate surface, and fold it under the laminate



- While staying lined up on your chalk guidelines, coil the laminate back on the 500 mm smooth tube. Do so until it is recoiled to the strain relief assembly end that is bonded to the substrate, with the white release liner tucked under

- Start unrolling the laminate again, this time pulling the white release liner away from the coiled laminate



- Apply pressure to the laminate surface to bond the laminate to the substrate as the liner is removed, preventing air pockets from being formed between the adhesive and the substrate surface (see above)
- Using a clean J roller, firmly apply pressure to the entire laminate surface, paying particular attention to the edges and corners (see above right)
- Verify that the entire laminate is firmly adhered and that there are no gaps in the bonded area or bubbles (air pockets) beneath the laminate
- Ensure that the MC4 cable connectors are connected together, then attach the ring of the cable to the laminate with tape to help prevent it from being snagged and damaged



# Electrical Installation

## Electrical Installation Guidelines

- All laminate wiring should be performed in accordance with applicable electrical codes by qualified, licensed professionals
- Depending on conditions, a photovoltaic module can produce more current and/or voltage than its listed output. Therefore, always apply a minimum 25% safety factor to the  $I_{sc}$  and  $V_{oc}$  when determining component voltage ratings, conductor current ratings, fuse sizes, and size of controls connected to the PV output

Refer to Section 690-8 of the National Electrical Code for an additional multiplying factor of 125% (80% derating) which may be applicable.

- Maximum system open-circuit voltage is determined by relevant regulations, with PowerBond ePVL certified to a maximum voltage of 600 Vdc per UL and 1000 Vdc per IEC regulations

## System Wiring

- PowerBond ePVL laminates come factory-equipped with polarized MC4 plugs and sockets
  - This provides for fast and reliable connection of groups or strings of modules
  - These components are NOT designed for use as a disconnect switch
  - MC4 connectors are not load-break rated, and should not be disconnected while exposed to sunlight and under load



Socket

Plug



Electrical Shock: Observe all electrical safety precautions to prevent electrical shock while installing laminates, and while wiring, testing, or performing maintenance on the PV array.

- If the wiring system cannot be completed at the time of laminate installation, leave the laminate connectors short circuited together (as factory shipped) to avoid connector corrosion
- Cover the laminate with an opaque material before disconnecting when exposed to sunlight
- Cables should be covered and/or housed in a protective sheath or tray to protect them from long term exposure to the elements
- Sub-array cables should be rated for use with maximum system voltage, should have a temperature rating of 90°C/194°F, and should be suitable for long-term outdoor use
- For improved system performance, determine the voltage drop in the array cables to ensure that power loss is minimized. Average power loss in the string to inverter connecting cables should be less than 2%
- Because laminates in a string can generate up to 1000V, ensure safety when making repairs or making connections to a laminate by disconnecting the laminate from others in the string beforehand
- An over-current protection device must be installed in each series string of ePVL modules. For proper installation location, refer to IEC 62548, section 5.2.5, or other applicable local codes
- The system requires an inverter with an internal transformer
- There is no need to ground any pole, though it is possible to ground the negative pole
- Check system polarity before connecting the string
- If module interconnect wires are exposed to direct weathering, use conductor type USE-2 or PV Wire listed to UL 4703, or other applicable local codes. If module interconnect wires/cables going from the modules to the combiner box are to be run inside of a wire chase, use RHW-2, THWN-2, or XHHW-2 conductors, or alternatively PV Cable/PV Wire listed to UL 4703, or other applicable local codes
- The conductor should be sized according to Table 250-122 in the NEC, or other applicable local codes
- PV source circuits must be terminated in a terminal box and then run in metal conduit prior to entering dwellings. See NEC, or other applicable local codes, for further guidance
- Refer to local codes (NEC, CSA, IEC, etc.) for further guidance related to all wiring associated with the photovoltaic system
- Temperature de-rated calculations for the current carrying capacity (ampacity) of the DC side of your PV system should be based on 156% of the short-circuit current (Isc)
- The de-rated ampacity must be greater than the rating of the over-current device
- Prior to entering a dwelling, the source circuits must be contained in metal conduit

## Grounding

- Section 690.5 of the NEC requires that systems with PV modules on the roof of a dwelling have ground fault protection equipment
- Grounding of the standing seam metal pans to which the ePVL modules have been adhered can be accomplished with the use of grounding clamps (IlSCO GBL-1/0, or equivalent)
- Grounding clamps can be fastened to the metal roofing pan seams by ¼" stainless steel machine screws with star lock washers and nuts
- Grounding of metal parts where the photovoltaic laminate or PV source wire are passing under or over (in close proximity or otherwise come in contact with), can be accomplished with the use of grounding clamps as described above, or by other listed methods meeting KDER and NEC requirements
- The equipment-grounding conductor will need to be bonded to earth via a ground rod. The conductor can be bare copper or have green colored insulation

## Pre-Commissioning Tests

Prior to a full test by local electrical authorities, the installer should conduct a pre-test to verify that the system is correctly installed and suitable for connection.

This pre-test should include the following three tasks:

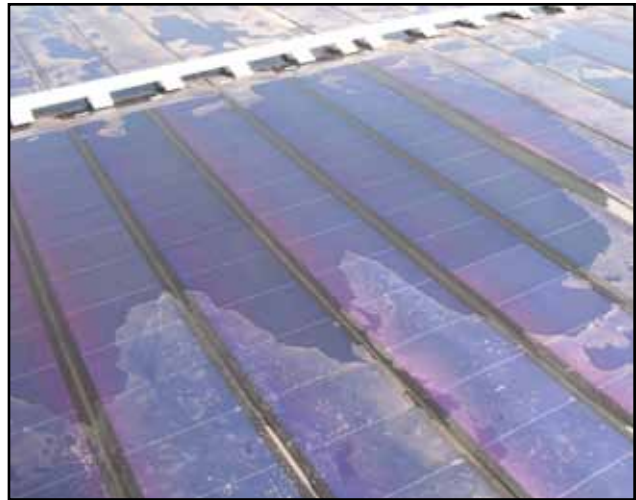
- A visual audit of the installation
- Verification of electrical connections
- Verification of system performance once the system has been connected

### Visual Audit

Performing a visual audit of the solar array at the completion of installation is important, as this will provide a good baseline for future operation and maintenance visits.

- Ensure that appropriate safety signs are in place at each access point to the installation
- Record the serial number of each laminate, its location on the roof, and to which combiner box and inverter each laminate is connected
- Check that each laminate is bonded perfectly to the substrate. If any areas of the laminate are NOT perfectly bonded, mark the product with a permanent marker or crayon to flag an area to be repaired or monitored during subsequent maintenance
- Check the front surface of the laminate for any scratches or surface damage that may have occurred during installation. Contact your USO representative immediately for repair guidelines
- Clean any laminates which are particularly dirty before performing electrical checks. Excessive dirt, debris, or film on the laminates will limit performance and create false test results
- Verify that all laminates are located in areas that will not be shaded
- Verify that all laminates are located in areas which are not subject to water pooling

Commissioning procedures outlined by this document are provided as reference only and reflect United Solar experience in the PV industry. Any additional tests or procedures required by local permitting jurisdiction, utilities, or other authorities may also be required.



**Water pooling:**  
laminates should not be subjected to water pooling

- Verify that the cables are appropriate for outdoor use, fit properly in a cable duct, and are NOT in standing water. Inspect cables to verify that the connections are tight
- If the DC system is floating (not earthed or grounded), then fuses should be connected in both the positive and negative poles
- Verify that appropriate string fuses (max. 10A) are in place and that these are located in each non-earthed pole
- When the laminates are mounted on conducting substrates which require grounding, verify that there is continuity between all substrates and that the ground connection is appropriate
- Fill in the warranty registration form and attach a list of laminate serial numbers

## Electrical Connections Verification

The following tests should only be performed by qualified personnel who are familiar with working on high voltage solar power systems and understand local electrical code requirements.

The best weather conditions that will provide the most accurate system verification tests are cloudless days with strong sun conditions.

Before performing any of the following tests, ensure that:

- All DC isolation switches are open (OFF)
- All string fuses have been removed
- All test equipment, leads, and probes are rated for maximum system voltage
- The inverter is switched OFF

Tag each box with a warning sign to signify that work on the PV system is in progress, locking OFF switches, if possible.

Record the total number of *PowerBond* ePVL laminates connected to each array combiner box, and note how the system is configured.

- Verify that the number of laminates in series does NOT exceed the maximum system voltage as dictated by local codes (NEC/IEC) or the maximum input voltage of the inverter
- Measure and record the open circuit voltage of each series string, verifying that all strings that are feeding the inverter's mpp tracker have the same polarity and a similar open circuit voltage. It is easier to perform this test in the array combiner box or fuse box
- If the variation in string voltages is significant, or if the string delivers 0V, there is either a short or an open circuit within the string, requiring a check of each individual module
- Differences in string voltage can be due to a misconnection of the laminates. Check that the correct number of laminates is connected in series and that each laminate is providing correct voltage. To test for the latter, laminates need to be disconnected and the voltage checked directly across the module

- Verify that the polarity of each string is the same. A reversed string or module can result in damage to the product or protection circuits
  - Reversed polarity on an inverter can cause damage that is NOT covered by the USO product Limited Warranty

In addition to checking voltage across the series string, it is important to verify insulation resistance ( $R_{iso}$ ) from both positive and negative poles of the string to ground. This can be accomplished with a megger meter.

- Close fuse switches in the DC disconnect switch combiner box
- Check open circuit voltage at the DC disconnect switch to ensure it is within proper limits, per the manufacturer's installation manual
- Close each switch after each test, except for the final switch before the inverter
- Follow the proper inverter startup procedure from the inverter manufacturer's installation manual

## System Performance Verification

Once you have validated that the solar array has been correctly wired and configured, the final step is to verify that the system is performing properly.

The following tests can only be performed once the inverter has been connected into the circuit and commissioned in accordance with manufacturer instructions.

These tests, together with the majority of the checks included in the visual audit, should be performed every time there is an operation and maintenance visit.

- Measure and record the operating voltage of each series string and verify that all strings feeding the same inverter have a similar operating voltage. Any significant difference between strings needs to be investigated
- Measure and record the operating current of each series string and verify that all strings with the same number of laminates, have a similar operating current within 10% of each other. A variation in operating current can indicate areas of the array which are shaded or need cleaning
- Check the alarm status of each inverter
- Record DC and AC power at the input and output of the inverter, and determine inverter operating efficiency
- Perform and record insulation resistance ( $R_{iso}$ ) on the input to each inverter

