
SOLAR PHOTOVOLTAIC AND THERMAL SYSTEMS REVIEW AND APPROVAL REQUIREMENTS

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Division of the State Architect (DSA) documents referenced within this publication are available on the [DSA Forms](#) or [DSA Publications](#) webpages.

PURPOSE

This Interpretation of Regulations (IR) describes the Division of the State Architect (DSA) requirements for review and approval of solar systems (see Definitions) used in construction projects under the jurisdiction of DSA.

SCOPE

This IR clarifies the requirements for structural support of solar systems, anchorage of solar systems, solar support frame systems, balance-of-system (BOS) equipment, and building-integrated photovoltaic (BIPV) roofing systems. It also addresses the basic requirements of the California Building Code (CBC) for Fire and Life Safety, Access Compliance, and certain electrical requirements. Projects involving the installation of solar systems and/or battery storage to existing buildings or structures or projects involving the installation of ground-mounted solar systems are not exempt from DSA review and construction oversight regardless of cost.

BACKGROUND

Typical solar photovoltaic (PV) panel or thermal systems consist of the solar or thermal panels and their BOS equipment. Building-integrated photovoltaic (BIPV) roof covering systems consist of solar elements integrated into the roofing material. Throughout this document, generic reference to “solar systems” includes all three system types (see Definitions below). Where requirements are provided for a particular solar system, that system is specifically identified.

Structural design requirements for primary framing of buildings or structures supporting solar systems and for anchorage of those systems are discussed in Sections 1 through 4 below of this IR. Solar systems are anchored to buildings or structures or are ground mounted. Anchoring of solar PV panel and thermal systems relies on various attachment methods such as support frame and rack-mounted systems (Section 5 below), standing-seam metal roof systems (Section 5.1 below) and ballasted systems (Section 5.2 below). BIPV anchorage requirements are provided in Section 5.3 below.

BIPV wall cladding systems are not covered in this document and shall be submitted as an alternative material in accordance with California Administrative Code (CAC), Section 4-304 and CBC Section 104.11. See procedure *PR 18-01: Request for Alternate Design, Materials and Methods of Construction* for additional information. BIPV wall systems will require a preliminary meeting with DSA prior to submittal of project.

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DEFINITIONS

Balance-of-System (BOS) Equipment

Includes solar support frame systems, anchoring devices, DC-to-AC inverters, electrical wiring, electrical protection, monitoring, and safety equipment. In certain applications, the BOS equipment may also include the factory-assembled primary structural framing or structure.

Solar Systems

The term “solar systems” is used in this IR when referring generically to solar PV panel systems, solar thermal panel systems, and BIPV roof covering systems.

Support Frame Systems

The term “support frame systems” is used generically in this IR to refer to structural framing systems designed by the responsible project design professional (see Section 7 below) or prefabricated rack-mounted frame assemblies from a manufacturer to support solar PV panel and solar thermal systems that are anchored to primary structure or foundation. Support frame systems can be mounted parallel to roof slope or foundation or can be at inclined angles to the roof slope or foundation. Where requirements are provided for a particular solar frame system, that system is specifically identified.

Ballasted Solar PV Systems

Ballasted solar PV arrays are systems that rely on weight and friction to resist wind and seismic forces and typically have no (or very few) mechanical attachments to the roof structure.

Building-Integrated Photovoltaic (BIPV) Roof Covering Systems

As defined in International Code Council Evaluation Service (ICC-ES) AC365, a BIPV roof panel is an integrated, manufactured assembly consisting of the PV laminate and other factory-assembled components, including its integrated support structure, with interlocking or overlapping edges. BIPV roof covering systems include solar modules, shingles and panels that are attached to the roof by mechanical fasteners or affixed by adhesive.

1. REQUIREMENTS FOR SOLAR PROJECT COMPONENTS SUBJECT TO DSA REVIEW

1.1 General Requirements

1.1.1 See Sections 2, 3 and 4 below respectively for gravity, wind and seismic design considerations specific to solar systems, their anchorage, and support. The applicable load combinations in CBC Section 1605A shall be applied to all loading conditions, including evaluating the effects of dead load to counteract wind uplift for ballasted and anchored systems.

1.1.2 DSA reviews the anchorage of solar systems and their BOS equipment, as well as any battery storage racks, to the building structure, foundation, or enclosure. DSA also reviews the design of any enclosures housing battery racks or other solar system equipment. The anchorage design of components must meet the wind design requirements of CBC Section 1609A and American Society of Civil Engineers (ASCE) 7, Chapter 29, and the seismic design requirements of CBC Section 1613A and ASCE 7 Chapter 13. DSA will also review the design and detailing of enclosures for compliance with wind design provisions and ASCE 7 Chapter 15 (the enclosure is not treated as a “black box”). Alternatively, DSA will permit the enclosure to be prequalified in accordance with ASCE 7 Section 13.1.5 in lieu of satisfying Chapter 15 design requirements. Calculations, supporting data, plans and details as required in this IR shall be provided in accordance with Section 7 below.

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1.1.3 The building's or structure's vertical and lateral load resisting primary framing systems will be evaluated, including the additional loads from the solar system, BOS equipment, and any battery storage racks. The primary framing systems must meet the wind design requirements of CBC Section 1609A and ASCE 7 Chapter 29, and the seismic design requirements of CBC Section 1613A and ASCE 7 Chapter 12.

1.1.4 DSA reviews all elements of support frame systems that are designed by the design professional in charge or delegated engineer. DSA will review primary framing elements of the supporting buildings and structures, foundations, anchorage details of panels to support frames, and connection details of support frames to primary structures or foundations. DSA does not review the design and construction of the individual elements of solar systems (e.g., PV panels). DSA also does not review individual elements of prefabricated rack-mounted frame systems which are included in an approved evaluation report per *IR A-5: Acceptance of Products, Materials, and Evaluation Reports*, nor other components of the BOS equipment. However, all elements of solar systems and BOS equipment must be designed and constructed to meet the requirements of Title 24 and applicable standards, including, but not limited to Underwriter Laboratories (UL) and American Society for Testing and Materials (ASTM) International.

1.1.5 The design of support frame systems shall be based on calculations or on testing in compliance with ICC-ES AC428 "Acceptance Criteria for Modular Framing Systems Used to Support Photovoltaic (PV) Modules," or equal, per IR A-5.

1.1.6 For open-framed roof structures, design of solar systems shall meet the additional requirements in *IR PC-7: Pre-Check (PC) Design Criteria for Steel Cantilevered Column Structures (Ordinary and Special) – 2019 CBC*.

1.1.7 See Sections 6.1, 6.2 and 6.3 below for design and/or submittal requirements for Access Compliance, Fire and Life Safety and Electrical, respectively.

1.2 Solar Panel System Requirements

1.2.1 Solar panels shall be listed and labeled in accordance with UL 1703 per CBC for the panel orientations shown on plans, and this shall be indicated on the drawings.

1.2.2 Solar panel orientation (portrait and/or landscape layouts), anchorage point location, and installation tolerance range shall be specified on the drawings. Panel connection geometry shall be consistent with UL 1703 tests (and UL 2703 tests if utilized). If horizontal slip joints (e.g., thermal expansion joints) in framing members are present, panels must not span across nor be connected on opposing sides of the slip joints.

1.2.3 Drawings must specify overall solar panel dimensions and fully-dimensioned frame configuration of the specified panel including height, length, width, thickness of each web/flange, and material grade.

1.2.4 Drawings must specify the solar panel load rating in pounds per square foot (psf) based on an effective area equal to the area of one PV panel. The load rating shall be provided as both allowable and strength level capacities, for clarity.

2. GRAVITY DESIGN REQUIREMENTS

Primary framing and foundations of buildings or structures or ground-mounted structures that support solar systems shall be designed for gravity loads and load combinations as required by CBC and described in this section. For open-framed steel cantilevered column structures, provisions of IR PC-7 shall also apply. These design loads apply to solar system attachments to support frames or structure, support frame system anchorage to structure or foundation, and to ballast requirements for ballasted systems.

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Structural Engineers Association of California (SEAOC) PV3 “Gravity Design for Rooftop Solar Photovoltaic Arrays” provides further guidance for gravity design of solar PV panel systems; see References Section at the end of this document.

2.1 Requirements for Dead Load

In accordance with CBC Section 1607A.13.5, the dead load of solar panels shall be considered in the design of:

- Framing members of the building or structure upon which the solar support frames are placed.
- Anchorage of the solar support frames to the building or structure.
- Solar panel attachments to the support frames and/or directly to structural framing.

For installations on existing roofs, the additional dead load may be offset by the roof live load per Section 2.2 below, provided the roof design is adequate for the concentrated loads from solar panel support framing. The increase in effective seismic weight on the structure shall be evaluated in accordance with CAC Section 4-309.

2.2 Requirements for Live Load

Framing members of buildings and structures that support solar systems shall be designed for the following live load conditions and in accordance with CBC Section 1607A.13.5. Unbalanced live loads shall be included in design of the structure.

For buildings or structures supporting solar PV or thermal panel systems, it is not necessary to include roof live load (20 psf, 300 lb point load) in the area(s) covered by the panels when these area(s) are inaccessible, or signs are posted prohibiting storage under the panels. Areas where the clear space between the panels and the rooftop is 24 inches or less are considered inaccessible. Where the panels do not cover the entire area of the roof, the remaining area shall have the roof live load applied.

Roof framing shall also be designed for uniform and concentrated live load requirements in CBC Section 1607A.13.5.1 without the solar PV panel or thermal panel system present.

For structures of open grid framing and no roof sheathing or decking, such as carports and shade structures supporting solar panels, see IR PC-7 Section 2.2 above for live loading conditions in combination with other applicable loads.

2.3 Requirements for Snow Load

When applicable, include snow loads and loads from snow drift created by solar PV panel or thermal panel systems per CBC Sections 1607A.5.2 and 1607A.13.5.2.

3. WIND DESIGN REQUIREMENTS

The wind design requirements for solar systems are given in CBC Section 1609A and ASCE 7 Chapters 29 and 30 and as described below. See also IR PC-7 for wind loads on open-framed steel cantilevered column structures and solar panel attachment to those structures. It is not permitted to use a lower mean recurrence interval for a reduction in basic wind speed below that of ASCE 7 Figures 26.5-1 and 26.5-2.

As an alternate means, the “Wind Tunnel Procedure” in ASCE 7 Chapter 31 and Section 3.6 of this document may be used to establish design wind loads for any solar panel system.

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3.1 Rooftop Solar PV Panel Systems

3.1.1 Rooftop Solar Panels on Buildings of All Heights with Flat, Gable or Hip Roofs

Solar panel systems installed on buildings of all heights with flat, gable or hip roofs with slopes less than 7 degrees shall be designed and located in accordance with ASCE 7 Section 29.4.3.

3.1.2 Rooftop Solar Panels Parallel to Roof Surface

Solar panel systems installed parallel to roof surface on buildings of all heights and roof slopes shall be designed and located in accordance with ASCE 7 Section 29.4.4.

3.1.3 Shielding or Shadowing Effects on Rooftop Solar Panel Systems

No reduction of wind load shall be taken for shielding or shadowing effect of multiple rows of solar panel arrays for the design of solar panels, support frames and attachments to the roof framing or structure.

As an alternate means of approval, shielding or shadowing effects may be considered for approval by DSA:

- When derived utilizing the wind tunnel procedure in ASCE 7 Chapter 31.
- When justified utilizing SEAOC PV2 "Wind Design for Solar Arrays," Section 4.3 below regarding shielding or shadowing effects of edge panel arrays, parapets and roof projections.

3.2 Solar Thermal Systems

CBC and ASCE 7 do not contain specific wind design provisions for solar thermal systems. Thermal flat-panel systems that meet geometric, gap and spacing requirements for rooftop solar PV panels may use the wind design provisions of ASCE 7 Section 29.4.3 or 29.4.4 accordingly and as described in Section 3.1 above. Non-flat panel thermal systems shall meet the requirements of ASCE 7 Section 29.4.1 or design loads may be established by a recognized evaluation report or by the Wind Tunnel Procedure in ASCE 7.

3.3 BIPV Roof Covering Systems

BIPV roof covering systems shall meet the wind requirements for Components and Cladding in ASCE 7 Chapter 30.

3.4 Freestanding Ground Supported Systems

Freestanding ground supported systems (e.g., solar carports, ground-mounted arrays, etc.) shall be designed using the open building provisions in ASCE 7 and additional requirements in IR PC-7. Shielding or shadowing effects are not permitted unless validated and approved as an alternate means by DSA in accordance with Section 3.1.3 above.

3.5 Other Systems

Solar panel systems not meeting the requirements and limitations of Sections 3.1 through 3.4 above shall use the Wind Tunnel Procedure in ASCE 7 and Section 3.6 below of this document to establish design wind loads.

3.6 Wind Tunnel Procedure

When utilizing the wind tunnel procedure in ASCE 7 Chapter 31 to develop wind loads for solar PV arrays, the wind tunnel model shall properly model the wind flow environment in accordance with ASCE 7 Sections 31.2 and 31.6, and in accordance with the requirements in ASCE 49, "Wind Tunnel Testing for Buildings and Other Structures," and SEAOC PV2 Section 7.2.

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- **Modeling:** When developing generalizable wind loads for rooftop solar PV arrays, the wind tunnel model shall include to-scale the array configuration and layouts placed on the roof of a building that properly models the rooftop wind flow environment. The model shall include various building features that affect the wind flow environment on the roof. The testing and instrumentation shall be designed to determine the wind load effects in different roof zones (e.g., corner, edge, center, etc.). Modeling site-specific buildings is not necessary; rather, generic models with buildings large enough in plan area to capture the wind flow environment over different roof zones may be used.
- **Instrumentation:** Wind tunnel testing shall use an arrangement of pressure taps or other instrumentation methodology sufficient to establish design wind forces on solar panels and the variation of such forces as a function of effective wind area.
- **Results:** Wind tunnel results shall not be extrapolated to other panel geometry, panel inclination angle, panel row spacing, panel elevation above roof surface, or other roof shape types (e.g., gable, hip, barrel, flat, etc.) that were not part of the wind tunnel study. For moderate changes in panel angle, row spacing, or other parameters, reasonable interpolation between two or more tests is permitted. The limitations of any wind tunnel study, such as the range of array and building geometry parameters that were tested, shall be clearly reported along with the results. The wind tunnel results shall provide wind loads for the design of each structural element of the panel support system, such as by providing design wind pressures as a function of effective wind area. The wind tunnel results shall be provided in a format that is compatible with ASCE 7 (e.g., GC factors) that can be adjusted for site and buildings characteristics (i.e., exposure, building height, wind speed, etc.).

3.6.1 Minimum Wind Pressure for Wind Tunnel Procedure

The minimum design wind loads based on a wind tunnel study for solar panel systems shall comply with this section.

3.6.1.1 Rooftop Solar Panels for Buildings

For solar panel systems that meet the limitations and geometry requirements defined in Sections 3.1.1 and 3.1.2 above, the minimum design wind load based on a wind tunnel study shall be in accordance with ASCE 7 Section 31.6.1.1 and need not comply with the minimum wind pressure of 16 psf per ASCE 7 Section 30.2.2. The minimum design wind load in ASCE 7 Section 31.6.1.1 shall be based on ASCE 7 Section 29.4.4, not Figure 29.4-7, in accordance with SEAOC PV2 Section 7.2.1.

3.6.1.2 Minimum Loads for the Main Wind Force Resisting System

Determined by wind tunnel testing shall be limited in accordance with ASCE 7 Section 31.4.4.

3.6.1.3 Minimum Pressures for Components and Cladding

Determined by wind tunnel testing shall be limited in accordance with ASCE 7 Section 31.4.4.

3.6.1.4 Other Systems

Other systems, as described in Section 3.5 above, shall comply with the minimum design wind loads as determined above for rooftop solar panel systems when based on a wind tunnel study. Limits lower than these minimums are subject to an independent peer review per Section 3.6.2 below and/or approval of DSA.

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3.6.2 Wind Tunnel Study Peer Review

The independent peer review is an objective, technical review by knowledgeable reviewer(s) experienced in performing wind tunnel studies on buildings and similar systems, in properly simulated atmospheric boundary layers. Peer review shall be performed in accordance with ASCE 7 Section 31.6.1.2 and SEAOC PV2 Section 7.2.6.

DSA may require an independent peer review of a wind tunnel study in accordance with this section, depending on complexity and suitability of the study and qualifications of the wind tunnel laboratory. DSA will require an independent peer review of a wind tunnel study where wind load values lower than the minimums are being used, only where specifically allowed in this Section 3.6 or when utilizing a ballasted system per Section 5.2 below. Once a particular wind tunnel study has been peer reviewed and found acceptable, it need not be peer reviewed for subsequent projects provided the applicability and findings are appropriate for such projects.

The peer review shall be completed before substantial portions of the design and/or analysis work will be reviewed by DSA.

3.6.2.1 Peer Reviewer Qualifications

Minimum qualifications and terms of employment for the peer reviewer shall be as follows:

- The peer reviewer shall be independent from the wind tunnel laboratory that performed the study and prepared the report and shall bear no conflict of interest.
- The peer reviewer shall be acceptable to DSA.
- The peer reviewer shall have technical expertise in the application of wind tunnel studies on buildings similar to that being reviewed.
- The peer reviewer shall have experience in performing or evaluating boundary layer wind tunnel studies and shall be familiar with the technical issues and regulations governing the wind tunnel procedure in ASCE 7 as it is applied to systems similar to solar PV arrays that use generalized wind tunnel data for design.

3.6.2.2 Peer Reviewer Responsibilities

The peer reviewer shall review the wind tunnel report, including, but not limited to, data collection methods, data analysis, boundary layer modeling, array and building modeling, resulting wind loads and their relationship to effective wind area, conversion of data into GC values, and conditions of applicability of results to different buildings types, array geometry, etc. The peer reviewer shall prepare a written report to the client. Such a report shall include, at a minimum, statements regarding the following:

- Scope of peer review with limitations defined.
- The status of the wind tunnel study at time of review.
- Conformance of the wind tunnel study with the requirements of ASCE 7 Section 31.2, ASCE 49, and SEAOC PV2 Section 7.2.6.
- Presentation of the conclusions of the reviewer identifying any areas that need further review, investigation and/or clarification.
- Recommendations.
- Whether in the reviewer's opinion, the wind loads derived from the wind tunnel study are in conformance with ASCE 7 for the intended use(s).

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3.7 Other Wind Design Considerations

3.7.1 Computational Fluid Dynamics (CFD)

CFD is not recognized by ASCE 7 as an acceptable method to develop wind loads, and therefore is not acceptable to DSA.

3.7.2 Solar PV Wind Load Applied to Main Wind Force-Resisting System (MWFRS)

For solar PV systems installed on buildings, the MWFRS shall be designed to include the wind load from the solar PV panels, except solar PV systems flush-mounted to the roof. When calculating the contributing wind load from the solar PV panels, the effective wind area may be assumed to be the total area of solar arrays on the building. The increase of wind load on the MWFRS of existing buildings shall be evaluated per CAC Section 4-309.

4. SEISMIC DESIGN REQUIREMENTS

The seismic anchorage design of solar panels and support frame systems attached to buildings shall be based on the requirements in CBC Section 1613A and ASCE 7 Chapter 13. Seismic coefficients for roof-mounted (attached) solar panel systems shall be for “Other mechanical or electrical components” in ASCE 7 Table 13.6-1 ($a_p = 1$, $R_p = 1.5$), unless otherwise substantiated in consideration of SEAOC PV1 “Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays.”

Ground-mounted support frame systems shall be based on the requirements in CBC Section 1613A, and ASCE 7 Chapter 12 with seismic coefficients of the applicable building frame system in Table 12.2-1.

4.1 Friction

Friction due to gravity cannot be used to resist seismic loads in combination with attachments as allowed in SEAOC PV1 Section 4, unless shake table testing or nonlinear response history analysis is performed. Testing or analysis must be similar to that described in SEAOC PV1 Section 9, demonstrating satisfactory load sharing between friction and attachments, subject to the peer review requirements in Section 5.2.4 below.

4.2 Ballasted Solar Panel Systems

Shall be designed for seismic forces and displacements in accordance with ASCE 7 Section 13.6.12 Exceptions. Ballasted systems that resist seismic forces by friction alone shall be designed in accordance with Section 5.2 below.

4.3 Solar Carports, Covered Walkways, and Other Freestanding Ground Supported Systems

The seismic design of the seismic force-resisting system of solar carports, walkways, and other freestanding ground supported systems sheltering any use or occupancy shall be based on ASCE 7 Chapter 12 and additional requirements in IR PC-7.

5. REQUIREMENTS FOR SOLAR SYSTEMS ATTACHED TO STANDING SEAM METAL ROOFS (SSMR), BALLASTED SYSTEMS AND BIPV

5.1 Solar PV Panels Supported on SSMR

When solar panels are attached directly to SSMR, the attachment of SSMR panels to the roof structure shall be verified per Section 5.1.1 below to demonstrate that the SSMR panel-to-structure attachment is capable of resisting the imposed loads from the solar panel system. The attachment device of the solar support frame system to the SSMR shall be identified and

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verified per Section 5.1.2 below. Quality control testing on the field installed connections shall be performed per Section 5.1.3 below.

5.1.1 SSMR Panel Attachment to Structure

5.1.1.1 On New Metal Roofs

Provide structural calculations to demonstrate that the SSMR panel-to-structure attachment is capable of resisting the imposed design loads from the solar panel system.

Panel clip values shall be based on a valid evaluation report per IR A-5 or testing per ASTM E1592 or Factory Mutual (FM) 4474 as specified in CBC Section 1504.3.2.

The attachment of standing seam metal roof (SSMR) panels to the roof structure shall be detailed on the plans, including special detailing within areas of discontinuities (edges, ridge, corners, etc.).

5.1.1.2 On Existing Metal Roofs

Provide structural calculations to establish the sliding and uplift design loads imposed by the solar panel system on the SSMR for verification of the SSMR panel-to-structure attachments.

On roofs with slopes greater than or equal to 7 degrees, the sliding capacity of the existing SSMR panel attachments to the roof substrate shall be determined by existing construction documents, roof panel removal, or by other acceptable means (e.g., removal of ridge cap, etc.). For verification by panel removal, one panel for every 3000 sq. ft. of roof area and not less than a minimum of three locations per building shall be removed to verify the attachment method and shall be shown on the submitted plans. Except when the roof is subject to snow load, the sliding capacity need not be evaluated if the new sliding load from seismic and wind forces on the solar panel system is less than the displaced design live load sliding component.

The uplift capacity of existing SSMR panels to resist factored design uplift loads will be verified through the field installation quality control testing indicated in Sections 5.1.3 and 5.1.3.2 below. This testing may be performed after plan approval, and/or during installation of solar panel support frames, if each solar PV racking beam is connected to every crossing seam. Otherwise, the testing utilizing the specified solar support frame fastening devices shall be conducted with the results provided to DSA prior to plan approval.

5.1.2 Solar PV Panel Attachment to SSMR Panels

The components of the solar PV support frame system, including system or unique seam connecting devices (e.g., S-5! clamps, AceClamp, etc.) and their attachment to the SSMR panels, shall be specified and detailed on the plans. Structural calculations shall be provided for the support framing, anchors and anchor reactions, except that calculations for prefabricated rack-mounted frame and/or anchor systems justified by an evaluation report in accordance with IR A-5 need not be provided (see also Section 1.1.4 above). Product information (model number, manufacturer, etc.), evaluation or test report in accordance with Section 5.1.2.1 below, and installation procedure (i.e., torque, retightening of set screws, etc.) of the seam connecting devices shall be specified.

5.1.2.1 Validation of Seam Connecting Devices

The uplift and lateral (sliding) design values of the connecting devices (e.g., S-5! clamps, AceClamp, etc.) between the panel array and the SSMR shall be based on either of the following:

- A valid evaluation report per IR A-5.

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- Tests performed by a third-party testing agency conforming to the requirements of IR A-5 Section 3.3.

The evaluation report or tests performed by the third-party for validation of the connecting devices shall satisfy requirements noted in Sections 5.1.2.1.1 through 5.1.2.1.4 below. Test data must be for the same metal panel system (i.e., profile, manufacturer and gauge) used for the project.

5.1.2.1.1 The connecting device shall be tested for uplift and lateral load parallel to the seam; see Photograph #1 in Appendix B below for uplift test. The load rate shall be per ICC-ES AC428 Section 3.2.5.

5.1.2.1.2 The failure criteria shall be the disengagement of the connecting device from the standing seam or the cracking of the standing seam, whichever occurs first.

5.1.2.1.3 A minimum of four tests are required for each direction for each metal panel system, and the allowable design value shall be the average of the four tests with a safety factor of 3 or higher.

5.1.2.1.4 The design values must be verified and submitted to DSA plan review prior to plan approval. Where previous test data is not available for installations on the existing metal panel system, the testing shall be fully detailed on the approved plans and the test results shall be submitted and approved by DSA prior to installation.

5.1.3 Field Installation Quality Control Testing

All testing shall be performed by a DSA accepted Laboratory Evaluation Acceptance (LEA) laboratory approved by the Architect or Structural Engineer of Record (SEOR) and DSA for the project. The Project Inspector or designated Special Inspector shall observe the installation of all connecting devices to the seams. The approved plans shall clearly indicate the testing requirements. The load rate shall be per ICC-ES AC428 Section 3.2.5. The solar field test report shall include the number of tests performed at each building in each wind zone, any failures during testing, and any noticeable deformation after testing.

5.1.3.1 On New Roof

Field tests are required to verify proper installation of the seam connecting device. After all the connecting devices have been installed, test a minimum of 20 consecutive devices to twice the maximum allowable stress design (ASD) wind uplift load tributary to the connecting device based on the wind pressure at areas of discontinuity such as roof edges and ridges. If there is no failure in 20 consecutive tests, test 10 percent of the remaining installed connecting devices. If failure occurs before 20 consecutive successful tests are completed, then additional tests shall be performed until 20 consecutive successful tests are completed, then continue at a rate of 10 percent on the remaining installed devices. See Photograph #1 in Appendix B below which illustrates this testing.

5.1.3.2 On Existing Roof

Field tests are required to verify both the uplift capacity of the connection of the SSMR panel-to-structure attachment and proper installation of the seam connecting device.

5.1.3.2.1 Initial testing shall consist of a total of five group tests spread throughout the roof zones. Each group test will consist of three (minimum) adjacent connecting devices on the same seam. These devices shall be pull tested simultaneously to 1.67 times the maximum design wind load (ASD) on each device based on the pressure coefficients for the roof zones (1, 2 or 3) in which the connection is located. If the three devices for one group test straddle

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multiple roof zones, each device shall be pulled to the test load which correlates to the zone in which the device is located.

5.1.3.2.2 The reaction from the pull test shall bridge over at least one seam on each side of the tested seam. See Photograph #2 in Appendix B below which illustrates this testing.

5.1.3.2.3 After the initial five successful group tests, continue testing groups of three adjacent connecting devices at a rate of 10 percent of the remaining connections. If failure occurs during the initial five group tests continue testing until five consecutive successful tests of the similar configuration are performed, then continue at a rate of 10 percent of the remaining connections. These five consecutive successful tests are not counted as part of the 10 percent on the remaining connections.

5.1.3.2.4 If failure occurs on any of the remaining setups, additional group tests shall be performed until five consecutive successful group tests are performed. These five consecutive successful tests are not counted as part of the 10 percent on the remaining connections.

5.1.3.2.5 Test locations shall be selected by the design professional in responsible charge for the solar system anchorage and support and shall be distributed over the roof area to capture the various roof pressure zones.

5.2 Ballasted Solar PV Systems

Ballasted solar PV arrays rely on their weight and ballast to resist the wind uplift forces, while friction between the array supports and the roof surface resist seismic forces. Gravity design requirements are indicated in Section 2 above. Wind load design requirements are indicated in Section 3 above. Seismic design requirements are indicated in Section 4.2 above.

5.2.1 Conditions for Use

Ballasted arrays are only permitted when all the following conditions are met:

5.2.1.1 The maximum roof slope at the location of the array is less than or equal to 1:20 slope (2.9 degrees) per ASCE 7 Section 13.6.12. Where justified by testing and analysis and a peer review is conducted in accordance with Section 5.2.3 below, the maximum roof slope for buildings assigned to Seismic Design Category D may be less than or equal to 1:12 slope (4.8 degrees) per ASCE 7 Section 13.6.12 Exception #7.

5.2.1.2 The height above the roof surface to the center of mass of the solar array is less than the smaller of 36 inches and half the least plan dimension of the supporting base of the basket.

5.2.1.3 The roof shall not be subject to significant ice, snow or frost considering the seismicity at the site. For the purposes of determining this, it will be acceptable to consider it as not significant if the lowest average monthly low temperature (LAML T) for any month in the city the building is located and the seismicity at the site comply with any of the following limits:

- Any roof where $S_{Ds} < 0.5$.
- Any roof where the LAML T $\geq 32^{\circ}\text{F}$ and $S_1 < 0.75$.
- Any roof where LAML T $\geq 35^{\circ}\text{F}$.

Appendix C lists major California cities and the LAML T.

5.2.2 Requirements to Accommodate Seismic Displacements

For ballasted arrays, the accommodation of seismic displacement shall be afforded by providing the minimum separation determined in accordance with ASCE 7 Section 13.6.12 Exceptions #2 and #6 to allow sliding.

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5.2.2.1 Each separate array shall be interconnected as an integral unit and have the strength as indicated in ASCE 7 Section 13.6.12. Elements of the array that are not interconnected as specified shall be considered structurally separate and shall be provided with the required minimum separation. The interconnection force shall be resisted by continuous members along each row of ballasts in both orthogonal directions or equivalent means and not through the solar panels unless the panels have been tested for such loading. The elements resisting the interconnection force shall be evaluated separately in tension and compression, as well as bending where load transfer is required between continuous members.

5.2.2.2 Friction testing per SEAOC PV1 Section 8 shall be conducted where required to determine the seismic displacements.

5.2.3 Effective Wind Area

5.2.3.1 For wind uplift, the effective wind area (EWA) shall be validated by the SEOR for the solar panel support system, based on principles of mechanics and testing submitted to DSA for review and approval. The out-of-plane load sharing capabilities of the modules and interconnection assemblies shall be resisted by continuous members or equivalent means and not through the solar panels. Per ASCE 7 Section C26.2, if the support system for the solar array has adequate strength, stiffness, and interconnectedness to span across a support or ballast point, the EWA can be correspondingly increased, provided that strengths are not governed by brittle failure and that the deformation of the array is evaluated and does not result in adverse performance. The vertical deflection that the array is allowed to undergo shall also be validated by the SEOR. If a wind tunnel study is used, it shall also be validated by the wind tunnel engineer. It should be noted that smaller deflection limits typically require consideration of smaller EWA.

In lieu of calculations or testing, prescriptive EWA factors may be used as a function of module area without justification or additional analysis as noted below:

- EWA Factor = 1 for corner modules.
- EWA Factor = 1.5 for edge modules.
- EWA Factor = 4 for interior modules located one panel from edge.
- EWA Factor = 6 for interior modules located more than one panel from edge.

5.2.3.2 For sliding, the EWA of an array may be taken as the entire solar panel area of the array for each array that is interconnected as an integral unit with continuous members in both directions as noted in Section 5.2.1 above. For arrays that do not comply with the above interconnection requirements, the EWA to evaluate sliding shall be taken equal to the area of one module.

5.2.4 Peer Review Requirements

DSA may require an independent peer review when the seismic displacements are determined by nonlinear response history analysis or shake table testing depending on complexity of the analysis and availability of staff qualified to perform such review. If seismic displacements are less than 50 percent of the values indicated in the prescriptive design seismic displacements indicated in ASCE 7 Section 13.6.12, then an independent peer review must be performed. The peer reviewer shall be approved by DSA and the peer review shall comply with California Existing Building Code (CEBC), Section 322.

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5.2.5 Other Considerations

Ballasted solar PV systems shall not cause excessive sagging of the roof resulting in water ponding. They shall also not block or impede drainage flows to any overflow drains and scuppers as a result of the movement of the array imposed by the seismic displacements.

The electrical systems and other items attached to arrays shall be flexible and designed to accommodate the required minimum separation in a manner that meets code life-safety performance requirements. Details of providing slackness or movement capability to electrical wiring shall be included on the approved drawings for the solar installation in accordance with ASCE 7 Section 13.6.12, Exception #5.

5.3 BIPV Roof Covering Systems

BIPV roof covering systems shall be in accordance with CBC Section 1507.18, and their anchorage to the structure shall be subject to the design requirements described in Sections 2, 3 and 4 above.

Adhered PV panels may be accepted if test and analysis data, and quality control and assurance program are submitted to demonstrate compliance with ICC-ES AC365 "Acceptance Criteria for Building-Integrated Photovoltaic (BIPV) Roof Covering Systems." Tests shall be performed by an accredited third-party testing agency or a valid evaluation report per IR A-5 may be submitted.

If any BIPV system is anticipated or being considered for use on a project, a preliminary meeting with DSA will be required. The local DSA Regional Office should be contacted early in the design phase of the project.

6. ACCESS COMPLIANCE, FIRE AND LIFE SAFETY AND ELECTRICAL REQUIREMENTS

In addition to the above structural design requirements, the following requirements apply:

6.1 Access Compliance

Projects which consist only of solar alteration work installed on existing buildings and which are accessed only by ladders, catwalks or narrow passages and frequented only by maintenance personnel do not trigger accessibility code requirements or DSA accessibility review. See CBC Sections 11B-203.4 and 11B-203.5 for detailed requirements, and *IR 11B-6: Mechanical Only Projects Exempt from Accessibility Review*.

New shade structures, lunch shelters, canopies and carports incorporating solar panels will require access compliance review. Please refer to *IR 11B-9: Accessibility Requirements for Solar Photovoltaic Systems at School Sites*, for CBC accessibility requirements related to these structures.

6.2 Fire-Life Safety Requirements

DSA Fire and Life Safety (FLS) provides the following for clarification and to address issues that have arisen during plan review. For purposes of application, ground-mounted structures supporting PV solar arrays are considered 'buildings' as defined in CBC Chapter 2 ("Any structure used or intended for supporting or sheltering any use or occupancy"). Design and construction of ground-mounted PV solar arrays shall comply with CBC and California Fire Code (CFC) requirements, and as modified herein. Those ground-mounted systems with no occupancy/use underneath are considered equipment structures designed in compliance with CBC and CFC requirements, and Section 6.2.3 below.

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When located within a designated Very High Fire Hazard Severity Zone (VHFHSZ) PV panels shall be tested and listed to UL 1703 and UL 2703.

6.2.1 Ground-Mounted PV Arrays with Use Underneath

The following requirements are applicable for ground-mounted PV arrays with use underneath.

6.2.1.1 PV support framework and panels shall not be located in, or extend into, dedicated fire apparatus access roadways. Support framework and PV arrays may extend above and over designated fire lanes when a minimum 13'-6" vertical clearance is provided and there is no encroachment affecting the fire apparatus required turning radius.

6.2.1.2 PV equipment supported by non-combustible framing installed in locations dedicated for building frontage used for area increases per CBC Section 506, shall be limited in size and may be allowed on a case by case basis. Maximum area that may be allowed for such systems shall not exceed 1/3 of the horizontal projected area of each frontage.

6.2.1.3 For the purpose of determining the Risk Category, an occupant load shall be calculated per CBC Section 1004, Table 1004.5 as applicable, and the load indicated on the drawings.

6.2.1.4 When constructed in parking lots, the design shall provide unobstructed openings equal to or greater than 70 percent to allow smoke and heat to freely vent vertically. The highest point of the PV panels shall be 10 feet or more above the ground and shall have a minimum vertical clearance underneath of 6'-8" (8'-2" when installed above accessible parking spaces). When constructed above designated fire lanes, a minimum 13'-6" vertical clearance shall be provided.

6.2.1.5 Access to a public way or safe dispersal area shall not be obstructed by the system or system framing. (CBC Sections 452.1.3 and 1028.5)

6.2.1.6 PV systems installed above outdoor assembly areas such as amphitheaters, bleachers or grandstand seating (occupancy Group A-5) shall not impede the free ventilation provisions associated with 'smoke-protected seating'.

6.2.1.7 PV systems installed on a riser framework above the roof assembly shall be tested to UL 1703 Standards.

6.2.2 Specific Requirements for Open-Sided, High Profile Ground-Mounted PV Installations Above Parking Areas

For the purposes of this IR, "open-sided, high profile ground-mounted PV installation" means:

- The highest point of the panels is 10 feet or more from the ground.
- Meets the minimum 6' -8" clearance requirement below with a use underneath (minimum 8'-2" clearance when installed above accessible parking spaces).
- When installed above designated fire lanes, has a minimum vertical clearance of 13'-6".
- Structure has unobstructed openings throughout to allow heat and gases to escape and constitute a minimum of 70 percent of the area within perimeter of the solar array.
- PV systems installed over parking spaces may be located adjacent to property lines when of non-combustible construction.

6.2.2.1 The following code requirements are not applicable:

- Fire Extinguishers per CFC Section 906; Exit Signs per CBC Section 1013; Emergency Lighting per CBC Section 1008.

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- Automatic Fire Sprinkler System (not required for Group S-2 open parking garages and Group U open parking garages for private vehicles).
- PV systems installed over both parking spaces and drive aisles may be designed as either a Group S-2 or Group U occupancy. The proposed design shall comply with the applicable CBC provisions based on the occupancy classification.

6.2.3 Specific Requirements for Ground-Mounted PV Installations with No Use Underneath

Design and construction of ground-mounted PV installations with no use underneath are considered equipment structures and shall comply with the CBC, CFC and the following:

- Shall not be constructed within dedicated side yards (frontage) used for allowable area determination of new or existing buildings.

Exception: PV arrays supported on non-combustible framing may be installed in dedicated frontage areas when the size does not exceed 1/3 of the horizontal projected area of the frontage space.

- Shall not be located in dedicated fire apparatus access roadways.
- When of non-combustible construction, may be located proximal to property lines (real or imaginary).
- Shall be fenced around the perimeter to prohibit general access.
- Fence shall include a gate for maintenance personnel and emergency access.
- Gate shall be equipped with a security type 'break-away' lock or be of the 'Knox Lock' type, or other locking system as approved by the local fire authority.
- When located in a 'field', a minimum 10-foot clearance around the perimeter free from vegetation shall be provided and maintained.

6.3 Electrical Requirements

All provisions found in the California Electric Code (CEC) for PV systems shall apply. These CEC provisions include, but are not limited to, Articles 250, 310, 690 and 705. Appendix A of this IR provides an example of a PV system grounding.

The interconnection, operating and metering requirements for generation facilities which are to be connected to a utility's distribution system, over which the California Public Utilities Commission (CPUC) has jurisdiction, shall comply with Rule 21. The School District must be the named customer on the utility account whether connection is through the school house meter or a separate meter dedicated to the proposed project.

6.4 Guard Requirements

The guard requirements for mechanical equipment near roof edges in CBC Section 1015.6 do not apply to solar panel arrays.

7. SOLAR PROJECT SUBMITTAL REQUIREMENTS

All projects involving installation of PV or solar thermal systems shall have a California licensed or registered architect or structural engineer in general responsible charge per CAC Section 4-316. Applications for project review shall be submitted to the applicable DSA Regional Office, following the normal process for project submittal. Form *DSA-3: Project Submittal Checklist* is a guide to the information required for a complete submittal.

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In addition to the above requirements, the following items are also required for a complete submittal for DSA review:

7.1 Construction plans and specifications shall be signed and stamped by the architect or structural engineer in general responsible charge per *IR A-19: Design Professional's Signature and Seal (Stamp) on Construction Documents*. The architect or structural engineer in general responsible charge may use construction plans and specifications prepared by the manufacturer's California registered engineer provided the requirements of *IR A-18: Use of Construction Documents Prepared by Other Professionals*, are met.

7.2 The plans and specifications shall include all solar system requirements identified in Section 1.2 above, including anchorage or restraint details of the panels, BOS equipment, support structures, and foundations. Fully detail all support frame and anchor system components (e.g., rails, connectors, angles, stanchions, trays, expansion joints, etc.) on the plans.

7.3 Calculations to verify that the primary structure will support the additional vertical and lateral loads from the panels and BOS equipment. Provide calculations verifying that roof deflection will not cause ponding, and calculations for the racking system components, attachment to the structure, other structural connections necessary to resist the applicable loads.

7.4 Submit wind tunnel, shake table and friction test reports, non-linear time history analysis, and other reports and calculations, as applicable.

REFERENCES:

- California Education Code, Section 17282.5
- 2019 California Code of Regulations (CCR) Title 24
 - Part 1: California Administrative Code (CAC)
 - Part 2: California Building Code (CBC), Sections 1609A, and 1613A
 - Part 3: California Electrical Code (CEC), Articles 250, 310, 690 and 705
- Structural Engineers Association of California (SEAOC)
 - SEAOC PV1-2012: "Structural Seismic Requirements and Commentary for Rooftop Solar PV Arrays"
 - SEAOC PV2-2017: "Wind Design for Solar Arrays"
 - SEAOC PV3-2019: "Gravity Design for Rooftop Solar Photovoltaic Arrays"
- Underwriter Laboratories (UL)
 - UL 1703: Standard for Flat-Plate Photovoltaic Modules and Panels (2015)
 - UL 2703: Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels (2015)

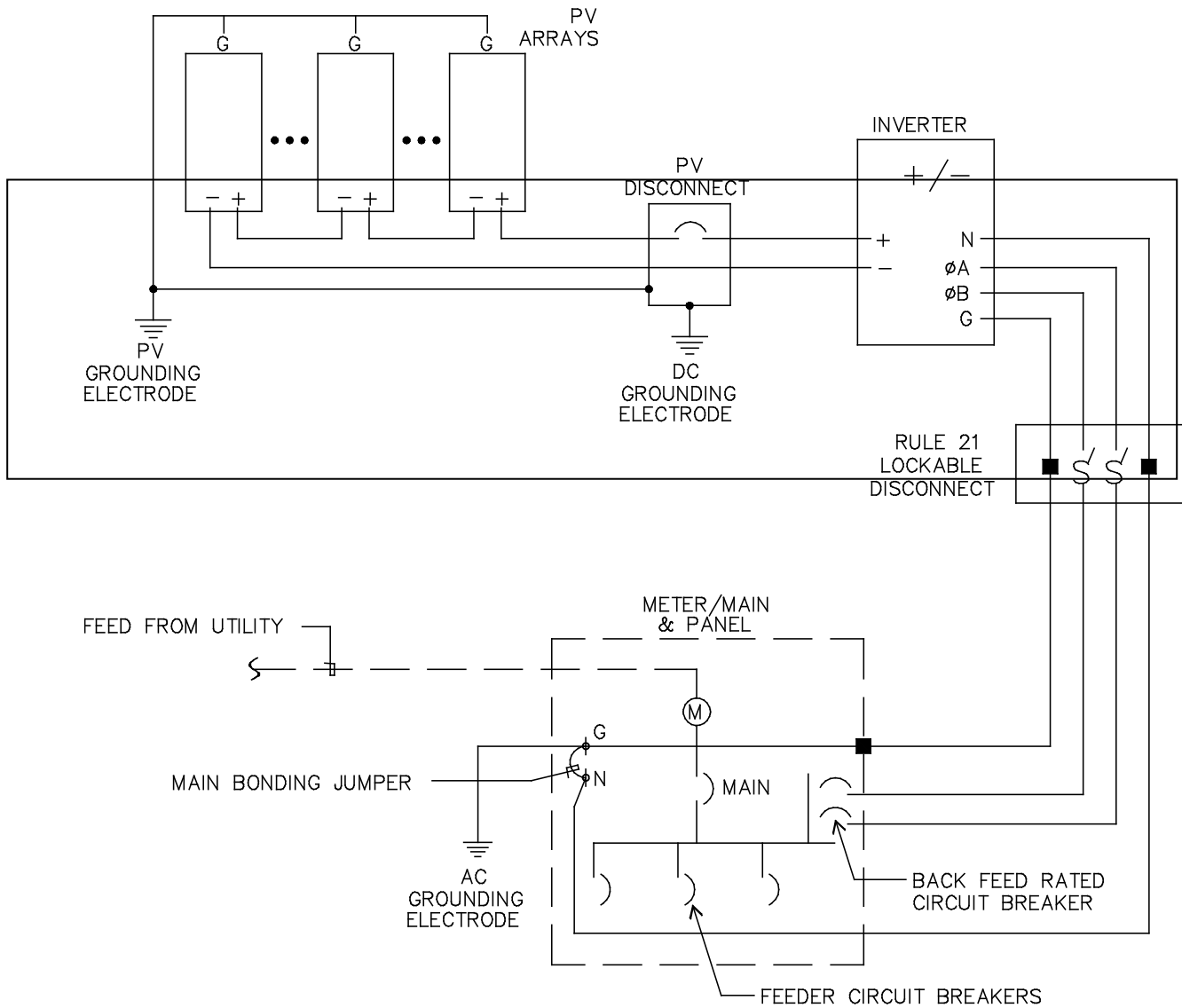
This IR is intended for use by DSA staff and by design professionals to promote statewide consistency for review and approval of plans and specifications as well as construction oversight of projects within the jurisdiction of DSA, which includes State of California public schools (K–12), community colleges and state-owned or state-leased essential services buildings. This IR indicates an acceptable method for achieving compliance with applicable codes and regulations, although other methods proposed by design professionals may be considered by DSA.

This IR is subject to revision at any time. Please check DSA's website for currently effective IRs. Only IRs listed on the webpage at www.dgs.ca.gov/dsa/publications at the time of project application submittal to DSA are considered applicable.

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APPENDICES

Appendix A: Example of PV System Grounding

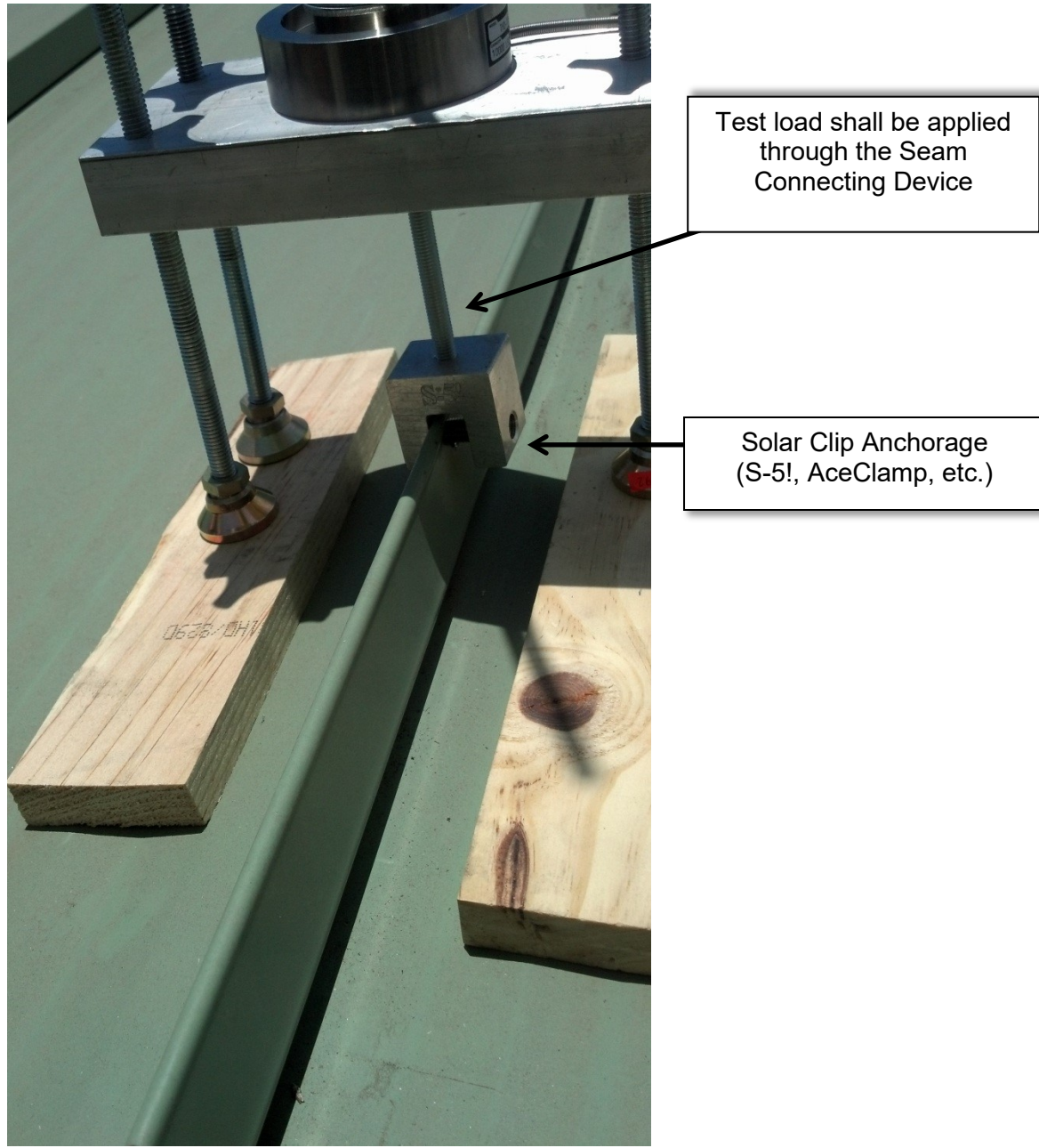


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Appendix B: Standing Seam Metal Roof Testing

Photograph #1: Example of Test Apparatus

- (1) Validate the capacity values of the Seam Connecting Device to be utilized for design as required per Section 5.1.2.1 above.
- (2) Field Installation Quality Control Test of installed Device on a New Roof per Section 5.1.3.1 above.



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Photograph #2: Example of Field Installation Quality Control Test on Existing Roof as required per Section 5.1.3.2 above.



Test apparatus to bridge over adjacent seam on each side.

Stand outside of the area that is being tested so as not to alter the test results.

Test load shall be applied through the Seam Connecting Devices.

Seam Connecting Devices (S-5!, AceClamp, etc.) are to be installed at the locations shown on the approved plans.

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REQUIREMENTS****Appendix C: Lowest Average Monthly Low Temperature**

City	Lowest Average Monthly Low Temp. (°F)
Bakersfield	39
Big Bear	21
Chico	35
Fresno	38
Hesperia	31
Lake Arrowhead	30
Los Angeles	47
Mammoth	20
Modesto	40
Palm Spring	44
Palmdale	34
Redding	36
Ridgecrest	31
Sacramento	38
San Francisco	46
San Luis Obispo	43
Santa Rosa	39
Truckee	15

*Source: www.weather.com