Tighe&Bond
Engineers | Environmental Specialists

R-0298-4-01
May 5, 2016

Melanie A. Bachman
Acting Executive Director
Connecticut Siting Council
Ten Franklin Square
New Britain, CT 06051

**Re: PETITION NO. 1224**

Dear Ms. Bachman and Council Members:

On behalf of Woods Hill Solar, LLC (Woods Hill Solar), Tighe & Bond is providing additional information in response to the letter received from the Connecticut Siting Council (Council), dated April 25, 2016. Comments were provided by the Council in response to Petition No. 1224, submitted for the proposed construction of a 17.61 Megawatt AC Solar Photovoltaic Electric Generating facility located at 90 and 101 Woods Hill Road, in Pomfret, Connecticut. Comments are provided below in bold, followed by our response.

## Interrogatories

1. **Provide the specifications sheets for the proposed solar photovoltaic panels and for the proposed inverters.**

   The specific vendor of the PV panels has not yet been selected, but possible vendors include Tier 1 suppliers such as Yingli, Trina Solar, and Canadian Solar. Possible inverter models include Sunny Central 2200-US and the MVB-2200-US by SMA America, LLC. Specifications for potential panels, inverters and racking are attached.

2. **In general, in the case of fixed solar panels, does orienting your solar panels to the south provide a balance (in terms of sun exposure) between the sun rising in the east and setting in the west and ultimately result in optimizing (or attempting to maximize) your total annual energy production (in kilowatt-hours) and your capacity factor? Is it correct to say that the objective of the project, as proposed, is to maximize annual energy production in kilowatt-hours for economic and environmental benefits (e.g. reducing carbon emissions by causing traditional generation including fossil-fueled plants to "ramp down" as renewable power is added to the grid) as opposed to a solar plant designed for peak load shaving?**

   Yes. The project is designed for maximum energy production, environmental and economic benefits and also provides a significant amount of peak generation. Almost 70% of the output is peak power.

3. **Please provide the numbers that went into the EPA calculator provided in Tab Q. Given the amount of proposed tree clearing, what is the number of days, months, or years it would take to "break even" with carbon dioxide or when the carbon dioxide emissions reductions would <u>equal</u> the sequestration loss. (Data source: http://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references)**

   The EPA calculator has estimated that the project would offset the same amount of $CO_2$ as approximately 19.2 acres of US Forests in one year. Therefore, the 16 acres cleared for the project would take approximately ten months to be offset by the project. In developing these calculations, a project output of approximately 34,000 MWh per year was utilized.

4. **Does the Petitioner propose to install security fencing around any portion of the solar field? If so, please provide specifications.**

   There is no fencing proposed for the project other than around the equipment pads.

5. **What is the proposed height of the fence that would surround the electrical equipment? What is the proposed mesh size of the fence?**

   The fence will be 7 feet tall with 2.0 inch interwoven diamond mesh.

6. **Is there or could there be a battery storage system proposed?**

   At this time there is no battery storage system proposed or anticipated.

7. **Please provide the Federal Aviation Administration determination if it is available at this time.**

   Please see the attached FAA correspondence with regard to the determination of no hazard to air navigation issued April 12, 2016 for the project.

8. **Where is the nearest off-site residence located? Provide the distance, direction, and address of such off-site residence.**

   There are two residences located proximate to the proposed project; the first is located approximately 250' to the east of the Parcel B array, and approximately 125' to the northwest of the array on Parcel A. Planned vegetative screening to the southeast of this residence will limit visibility of the Parcel A portion of the project, and existing vegetation to the west of the residence will limit visibility of Parcel B. The second residence is located to the west of Parcel A and to the southeast of Parcel B. This residence is located approximately 125' from the nearest panels on Parcel A, and approximately 600' from the nearest panels on Parcel B. Planned vegetative screening to the east, southeast, and northwest of this residence will minimize visibility at this residence.

9. **Would the proposed project meet the applicable Department of Energy and Environmental Protection noise standards at the property boundaries? (Sources of noise might include but not be limited to inverters, transformers, etc.)**

Title 22a. Environmental Protection of the R.C.S.A. limits the noise level of a Class B emitters, such as the proposed project, to 62dBA at the property line of a Class B receptor (e.g. agriculture uses), and a nighttime limit of 45dBA at the property line of a Class A receptor (e.g. residential uses). The proposed project is predicted to meet these standards at its property boundaries, with the sole exception that it may reach 46dBA at its boundary with the two (2) existing residences on the project parcels. However, it will also meet the applicable DEEP noise standards at these residences (the residences described above in the response to comment #8). The project team has taken measures to reduce the impacts of the project from noise by situating the inverters and transformers central to the solar array in order to keep noise levels below DEEP standards at residences in the area.

**10. Has Woods Hill Solar (WHS) done any analysis to determine structural limits of snow accumulation on the solar panels and steel support structures, assuming heavy, wet snow? What accumulation of snow could the structures handle? Would WHS clear snow from the panels when it approached the limit?**

The structure will be designed to the 50 year snow load design criteria, which assumes a snow accumulation of 40 pounds per square foot (psf). This exceeds the expected snow load at the proposed project site.

**11. What is the status of the "Facilities and Transmission" studies that are part of the electrical interconnection as referred to on page 3-5 of the petition? Are there any additional steps/studies required before it enters into an Interconnection Agreement?**

The Facilities and Transmission studies are ongoing and are scheduled to be completed in the coming months. There are no other necessary studies expected to be needed. If necessary, an Interconnection Agreement can be entered into prior to the completion of the facilities and transmission studies.

**12. What is the electrical capacity of the Tracy Road Substation?**

RES has not been provided the precise available capacity of the Tracy Road Substation, but Eversource has confirmed in the Feasibility and System Impact Studies that there is adequate capacity at Tracy Road Substation for the project.

**13. What is the proposed route of the underground conduits from the proposed facility to the Eversource interconnection point?**

The underground conduits will follow the most direct route constructible from the inverter/transformers pads located throughout the site to the point of interconnection in the north of the project site.

**14. What is the proposed interconnection on Figure 5 behind Tab B connecting to? (i.e. line number, voltage, etc.)**

The proposed interconnection is to a 23kV express feeder located in the northern portion of the project. Eversource Energy will bring the express feeder to that point through its existing right of way from the Tracy Road 14M substation in Killingly.

**15. Page 3-2 of the Petition states that the 90 Woods Hill Road parcel would be referred to as Parcel B and the 101 Woods Hill Road parcel would be referred to as Parcel A. On page 3-3 of the Petition the bulleted items state that 90 Woods Hill Road is Parcel A and 101 Woods Hill Road is Parcel B. Please clarify which is referred to as Parcel A and which is referred to as Parcel B throughout the Petition.**

The 90 Woods Hill Road parcel is referred to as Parcel B and the 101 Woods Hill Road parcel is referred to as Parcel A. The reference on page 3-3 is incorrect. Also please note that the reference to the proposed vegetative screening on page 3-4 is incorrect. This statement should read: "Vegetation screening is proposed at two locations along Woods Hill Road on Parcel A and a third location is proposed within Parcel B."

**16. Given the location of the proposed site and the proximity to the Quinebaug River, what is the expected impact to Last Green Valley National Heritage Corridor?**

The Last Green Valley National Heritage corridor is defined by the Quinebaug and Shetucket Rivers systems. The area encompasses architecturally and culturally significant structures, attractions, villages and open spaces, including several in Pomfret Center; approximately 6 miles from the site. The Quinebaug River is located approximately 1.2 miles from the site. The proposed construction and associated clearing are not expected to affect the Quinebaug River, and similarly, we expect the project to have no impact to the Last Green Valley National Heritage Corridor. Additionally, one of the goals addressed in the *Vision 2020* plan produced by the Last Green Valley National Heritage Corridor encourages promoting green and renewable energy sources and energy conservation.

**17. Please provide the average percent slope of each parcel.**

The northern parcel (Parcel B) generally slopes to the northeast towards White Brook. Grades on the parcel range from fairly flat along the eastern property boundary to approximately 30% in the gully towards White Brook. The southern parcel (Parcel A) generally slopes to the south and east. Areas along the western property boundary are relatively flat and areas within the eastern utility easement approach 35%.

**18. Are ten inverters proposed for the project?**

Yes, ten (10) inverters are currently proposed for the project.

**19. What is the height of the proposed electrical equipment?**

As discussed in the response to comment #1, specific equipment vendors have not yet been selected, but potential inverter models include the Sunny Central 2200-US and the MVB-2200-US by SMA America, LLC. Potential inverter heights range from 6.9 feet to 7.6 feet.

**20. Page 6-1 of the petition states that the proposed racking will be designed to meet applicable local building codes for wind and snow loads. What is the wind threshold? What is the amount of snow accumulation designed for in the building codes?**

The 50 year, 3 second gust max wind speed, as defined in ASCE 7-10 is 117 MPH. We are proposing to classify this site as an exposure C and an occupancy category 1. All of those factors go into determining the maximum wind load that the structure will see. The 50 year maximum snow load for this location is defined by ASCE 7-10 as 40 psf. When designing the structure, the load combinations are calculated as outlined in ASCE 7-10 so that combined wind, snow, ice and seismic are all taken into account. A sample set of calculations is included in the responses to these interrogatories.

**21. What is the status of the Phase 1A Cultural Resources Assessment that the Connecticut SHPO requested as stated on page 6-4 of the Petition?**

Heritage Consultants, LLC (Heritage), has completed the Phase 1A Cultural Resources Assessment for the Woods Hill Road Solar Project. The Phase 1A field investigation was conducted on April 18, 2016. A Phase 1A summary report was completed on April 28, 2016. The report presents a description of the Areas of Potential Effect, the Phase 1A cultural resources assessment survey methodology, an archaeological assessment of the project area, and management recommendations for the project.

Background research and fieldwork associated with the survey revealed that the proposed impact areas are part of what was formerly known as Kingswood Manor. In addition, a review of previously identified cultural resources in the areas revealed that three archaeological sites are known in the vicinity, including two historic sites and one prehistoric occupation. One site contains evidence of an Early Woodland period occupation, a site type not often identified in Connecticut. Its presence suggests that other yet-to-be-identified prehistoric sites may exist in the area, and given the soil types noted on the subject property, it is possible such sites may be located within the proposed impact areas.

Based on these findings, Heritage recommends that a Phase 1B cultural resources reconnaissance survey of the proposed impact areas be conducted prior to construction. Due to the size of the property and potential prehistoric and historic sensitivity of the area, Heritage also recommends that an appropriate Scope of Work for the Phase 1B survey be formulated in consultation with the CT SHPO.

**22. What is the status of the vernal pool and plant survey? What is the estimated time for completion of such a survey?**

Davison Environmental, LLC (Eric Davison), has completed the vernal pool survey for the Woods Hill Road Solar Project. The fieldwork was conducted on April 1, 2016 with a follow-up dip-net survey completed on May 2, 2016. A summary report is currently being prepared for the project. Mr. Davison's fieldwork confirmed that the two "potential" vernal pools noted during the "off-season" and described in the Petition and Environmental Assessment (EA) report are, in fact, vernal pools. The cryptic vernal pools are embedded within Wetland 5 which straddles the easterly boundary of the southern parcel. No activity was observed in any of the other wetland areas that were delineated/ described in the Petition and EA report. None of the project area falls within either the Vernal Pool Envelope (VPE, 0 to 100 feet) or Critical Terrestrial Habitat (CTH, 100 to 750 feet) conservation zones of the vernal pools. Therefore, this project is compliant with *Best Development Practices, Conserving Pool-Breeding Amphibians in Residential and Commercial Developments in the Northeastern United States* (Calhoun and

Klemens, 2002, a.k.a. the BDP). The project will not negatively affect vernal pool wildlife in the two vernal pools identified.

Based on discussions with CT Department of Energy and Environmental Protection (DEEP) Wildlife Division staff, a survey for two plant species [Wild Blue Lupine (*Lupinus perennis)* and Wild Indigo (*Baptisia tinctoria*)] may not be required for the project because the proposed limit of tree clearing is located outside the Natural Diversity Data Base (NDDB) mapped polygon. Tighe & Bond has requested confirmation of this opinion in writing and will forward the letter to the CT Siting Council as soon as feasible.

**23. What is the distance and direction of the nearest Important Bird Area to the proposed site?**

The nearest Important Bird Area, Bafflin Sanctuary Complex, is located approximately 1 mile to the northwest of the proposed site.

**24. What effect would runoff from the drip edge of each row of solar panels have on the ground beneath it? Would channelization along the drip edge be expected? If not, why not?**

The project will convert existing agricultural uses to grass, which will result in less stormwater runoff than currently occurs on the site, based on USDA Technical Release (TR) 20 and 55 methodologies as previously provided in the Stormwater Report as the proposed vegetation will retain more water than that of existing conditions when fully stabilized. Until that time, temporary stabilization measures may be required as needed.

Channelization of stormwater flows along the drip edge of the panels is a potential concern prior to establishment of the final vegetation when topography runs perpendicular to the drip edge and slopes are in excess of 5%. Through much of the project, this is not a concern as the existing topography orientation and slope will not result in drip edge stormwater channelization.

Areas in which the existing topography runs perpendicular to the drip edge with slopes in excess of 5% exist within the westernmost portion of the project. These areas will be monitored throughout construction until vegetation is established and during routine system inspections to determine if additional measures are required. Small rills along the drip edge may develop; however the establishment of dense fescue grasses will assist in preventing erosion from occurring.

**25. Would the tree clearing be performed in stages (e.g. five acres at a time), or would the clearing all be performed together as one stage of construction? (Note: Connecticut Department of Energy and Environmental Protection "DEEP" General Permit for the Discharge of Stormwater and Dewatering Wastewasters Associated with Construction Activities states that, "Whenever possible, the site shall be phased to avoid the disturbance of over five acres at a time…")**

The site will be cleared at once during one stage of construction. However, the site was selected due to the minimal amount of necessary clearing and only 16 acres total of vegetative clearing are proposed. Further, please note that the areas proposed for clearing are not grouped together but are dispersed throughout the more than 100 acre project site. There is only one piece that exceeds 5 acres (by 3.5 acres) - all the rest are less than 5 acres per piece.

**26. Estimate the amounts of cut and fill in cubic yards.**

Cut and fill activities will result in a net balance of earth material (i.e. material removed will be used as fill and no materials will be removed or added to the site).

**27. What are the estimated construction days of the week and hours?**

RES anticipates construction hours Monday through Friday from 7:30am through 5pm.

**28. Has any analysis been conducted to determine structural limits of snow accumulation on the solar panels and steel support structures, assuming heavy, wet snow and or ice? What accumulation of snow could the structures handle? Would the Petitioner clear snow from the panels when it approached the limit?**

In addition to the responses above (please see Interrogatory 10 and 20), in general, it is not required that any snow clearing occur for structural reasons; however, snow may be cleared to maximize power production. This is a commercial consideration that is not required for structural integrity. Additionally, panels are designed with snow loads in mind as has been discussed in prior interrogatory responses.

29. **Would the installed solar panels require regular cleaning or other, similar, maintenance? How would this be accomplished?**

Regular cleaning of the panels is not anticipated at this time.

One original and 15 copies of this information packet are enclosed. At the Council's request, this information and the enclosures listed below are also being submitted electronically. If you have any additional questions, please do not hesitate to reach me by email at bangus@tighebond.com, or by phone at 413-875-1302.

Very truly yours,
**TIGHE & BOND, INC.**

Briony Angus

Briony Angus
Senior Project Manager/ Associate

Enclosures: FAA Letters re: Determination of No Hazard to Air Navigation
Equipment Specifications

Copy: Lee D. Hoffman, Esq., Pullman & Comley, LLC

# FAA Letters:

# Determination of No Hazard to Air Navigation

Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2016-ANE-654-OE

Issued Date: 04/12/2016

Jean Christy
Tighe & Bond, Inc.
53 Southampton Road
Westfield, MA 01085

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

| | |
|---|---|
| Structure: | Solar Panel Woods Hill Solar Point 1 |
| Location: | Pomfret, CT |
| Latitude: | 41-50-14.31N NAD 83 |
| Longitude: | 71-55-09.11W |
| Heights: | 358 feet site elevation (SE) |
| | 7 feet above ground level (AGL) |
| | 365 feet above mean sea level (AMSL) |

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed and maintained in accordance with FAA Advisory circular 70/7460-1 L.

This determination expires on 10/12/2017 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.
(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates , heights, frequency(ies) and power . Any changes in coordinates , heights, and frequencies or use of greater power will void this determination. Any future construction or alteration , including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

Any failure or malfunction that lasts more than thirty (30) minutes and affects a top light or flashing obstruction light, regardless of its position, should be reported immediately to (877) 487-6867 so a Notice to Airmen (NOTAM) can be issued. As soon as the normal operation is restored, notify the same number.

If we can be of further assistance, please contact our office at (404) 305-6531. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2016-ANE-654-OE.

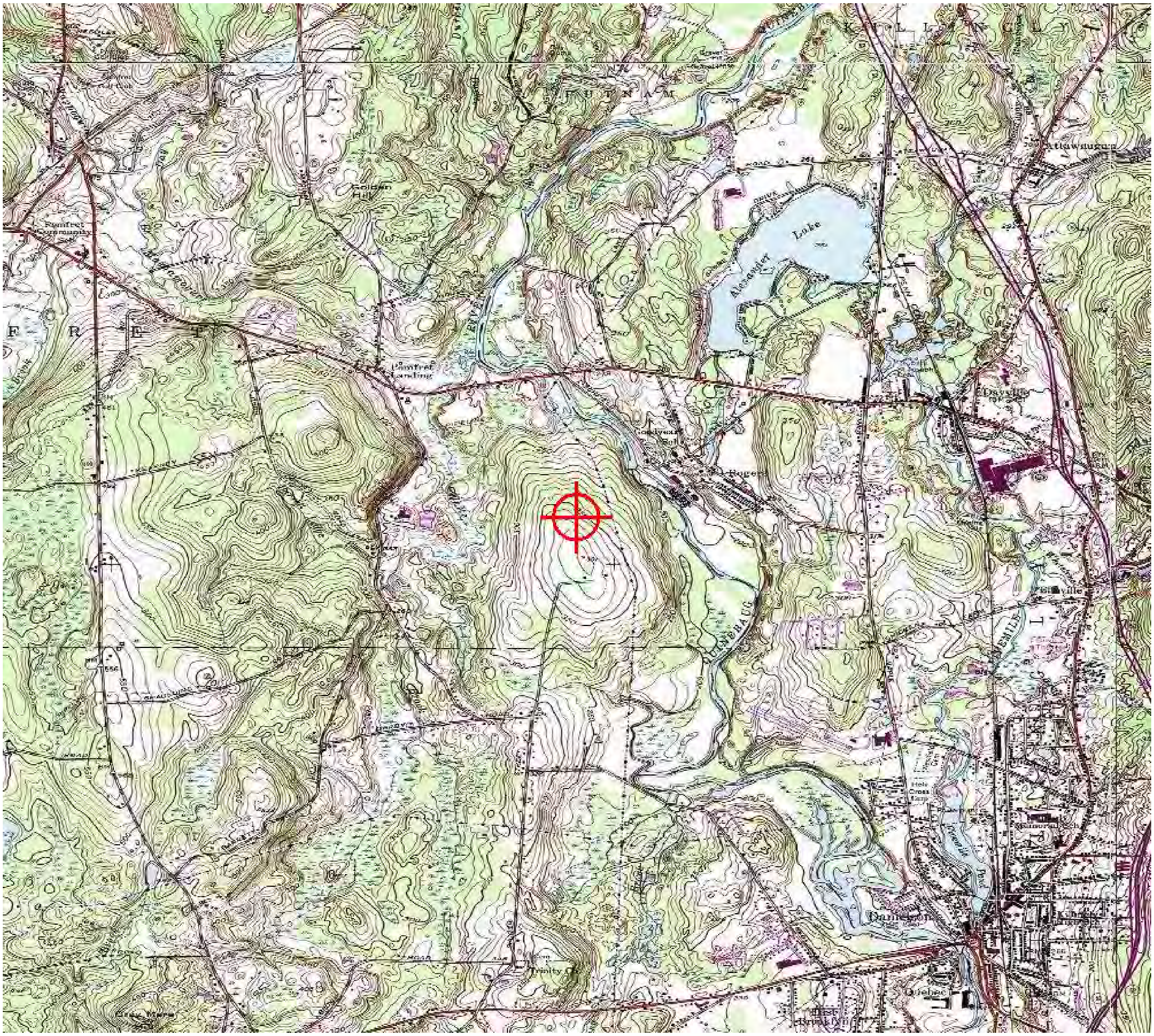
**Signature Control No: 285733426-288034826** ( DNE )
Darin Clipper
Specialist

Attachment(s)
Case Description
Map(s)

## Case Description for ASN 2016-ANE-654-OE

The project proposes to construct a 22 megawatt (DC) solar energy generation facility.

# TOPO Map for ASN 2016-ANE-654-OE



Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2016-ANE-655-OE

Issued Date: 04/12/2016

Jean Christy
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Westfield, MA 01085

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

| | |
|---|---|
| Structure: | Solar Panel Woods Hill Solar Point 2 |
| Location: | Pomfret, CT |
| Latitude: | 41-49-56.54N NAD 83 |
| Longitude: | 71-54-58.29W |
| Heights: | 370 feet site elevation (SE) |
| | 7 feet above ground level (AGL) |
| | 377 feet above mean sea level (AMSL) |

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed and maintained in accordance with FAA Advisory circular 70/7460-1 L.

This determination expires on 10/12/2017 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.
(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates , heights, frequency(ies) and power . Any changes in coordinates , heights, and frequencies or use of greater power will void this determination. Any future construction or alteration , including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

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This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

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If we can be of further assistance, please contact our office at (404) 305-6531. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2016-ANE-655-OE.

**Signature Control No: 285733427-288034825** ( DNE )
Darin Clipper
Specialist

Attachment(s)
Case Description
Map(s)

**Case Description for ASN 2016-ANE-655-OE**

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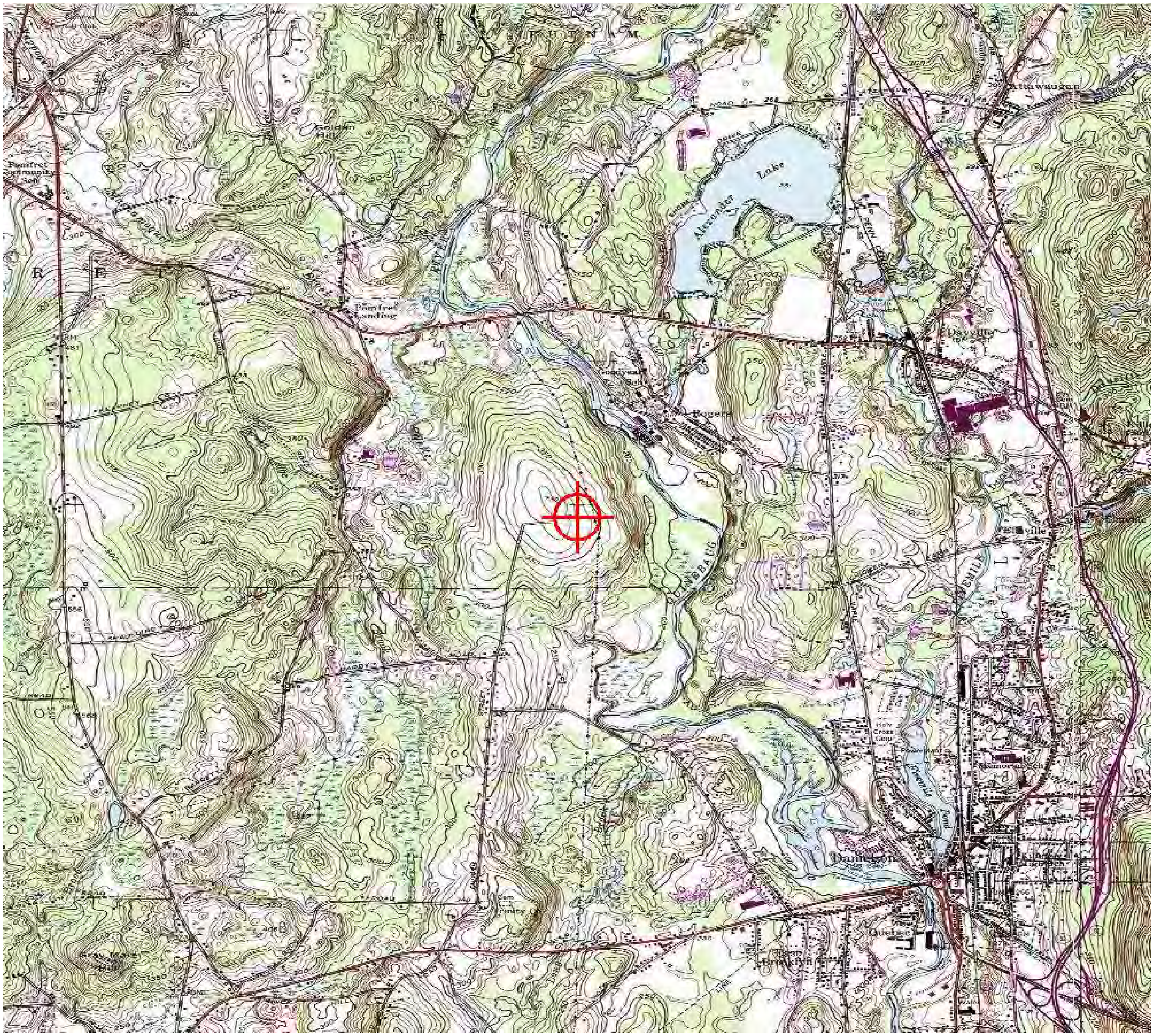

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| | |
|---|---|
| Structure: | Solar Panel Woods Hill Solar Point 3 |
| Location: | Pomfret, CT |
| Latitude: | 41-49-38.71N NAD 83 |
| Longitude: | 71-54-57.25W |
| Heights: | 309 feet site elevation (SE)<br>7 feet above ground level (AGL)<br>316 feet above mean sea level (AMSL) |

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed and maintained in accordance with FAA Advisory circular 70/7460-1 L.

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NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

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If we can be of further assistance, please contact our office at (404) 305-6531. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2016-ANE-656-OE.

**Signature Control No: 285733429-288034824** ( DNE )
Darin Clipper
Specialist

Attachment(s)
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Map(s)

# Case Description for ASN 2016-ANE-656-OE

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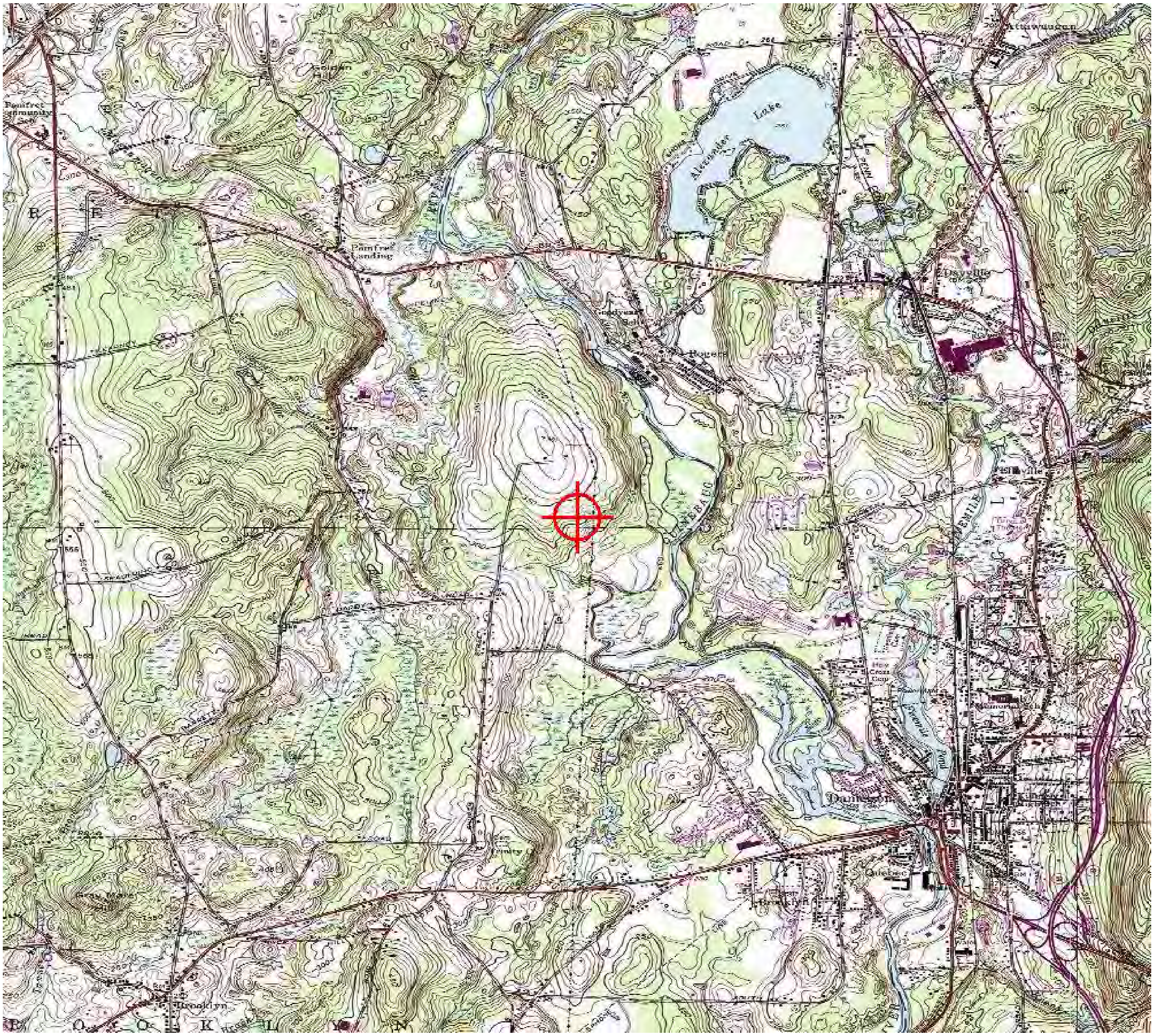

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The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

| | |
|---|---|
| Structure: | Solar Panel Woods Hill Solar Point 4 |
| Location: | Pomfret, CT |
| Latitude: | 41-49-37.70N NAD 83 |
| Longitude: | 71-55-09.45W |
| Heights: | 319 feet site elevation (SE) |
| | 7 feet above ground level (AGL) |
| | 326 feet above mean sea level (AMSL) |

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed and maintained in accordance with FAA Advisory circular 70/7460-1 L.

This determination expires on 10/12/2017 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.
(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates , heights, frequency(ies) and power . Any changes in coordinates , heights, and frequencies or use of greater power will void this determination. Any future construction or alteration , including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

Any failure or malfunction that lasts more than thirty (30) minutes and affects a top light or flashing obstruction light, regardless of its position, should be reported immediately to (877) 487-6867 so a Notice to Airmen (NOTAM) can be issued. As soon as the normal operation is restored, notify the same number.

If we can be of further assistance, please contact our office at (404) 305-6531. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2016-ANE-657-OE.

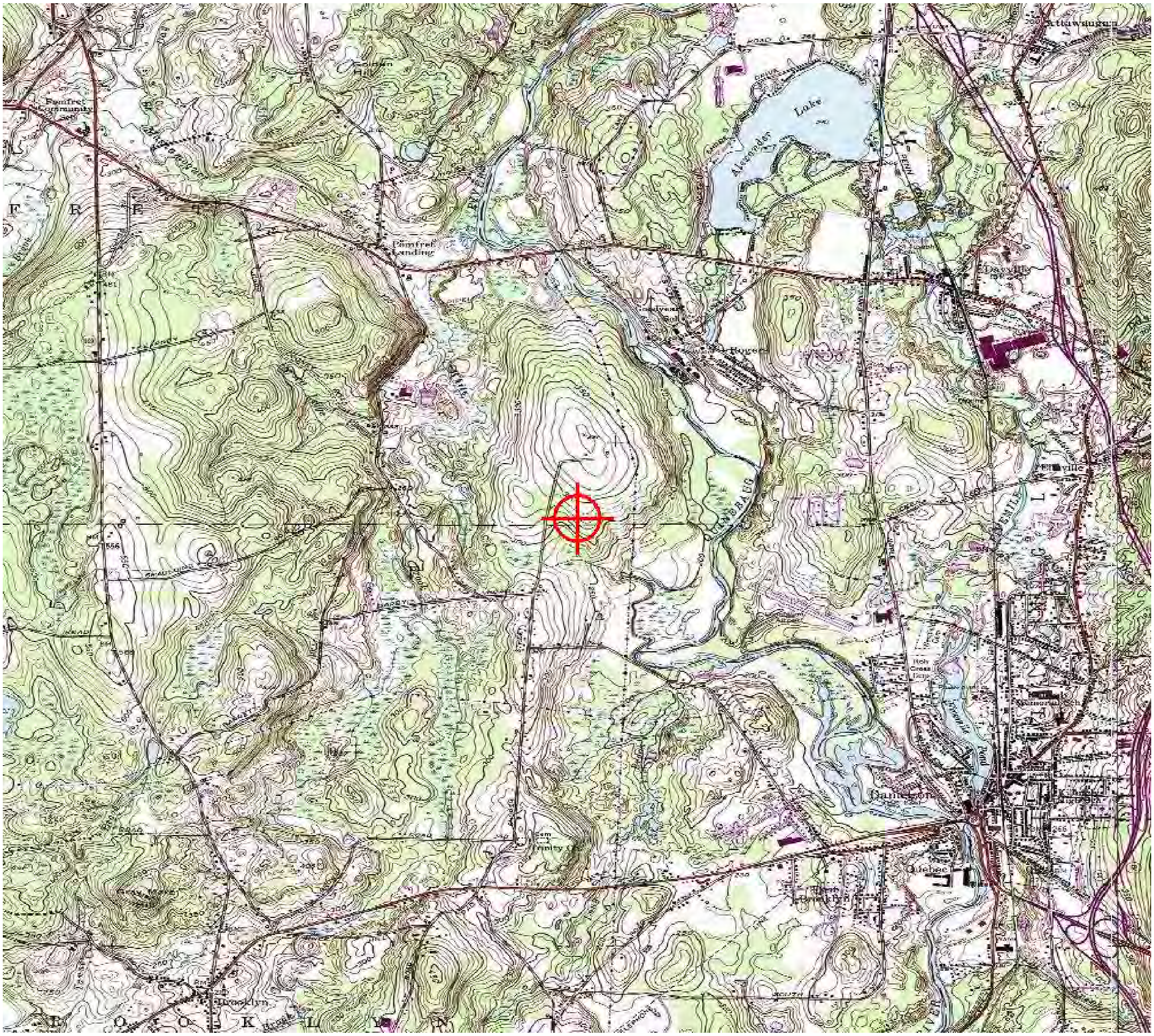
**Signature Control No: 285733430-288034823** ( DNE )
Darin Clipper
Specialist

Attachment(s)
Case Description
Map(s)

# Case Description for ASN 2016-ANE-657-OE

The project proposes to construct a 22 megawatt (DC) solar energy generation facility.

# TOPO Map for ASN 2016-ANE-657-OE



Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2016-ANE-658-OE

Issued Date: 04/12/2016

Jean Christy
Tighe & Bond, Inc.
53 Southampton Road
Westfield, MA 01085

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

| | |
|---|---|
| Structure: | Solar Panel Woods Hill Solar Point 5 |
| Location: | Pomfret, CT |
| Latitude: | 41-49-48.39N NAD 83 |
| Longitude: | 71-55-34.27W |
| Heights: | 292 feet site elevation (SE)<br>7 feet above ground level (AGL)<br>299 feet above mean sea level (AMSL) |

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
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If we can be of further assistance, please contact our office at (404) 305-6531. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2016-ANE-658-OE.

**Signature Control No: 285733431-288034822** ( DNE )

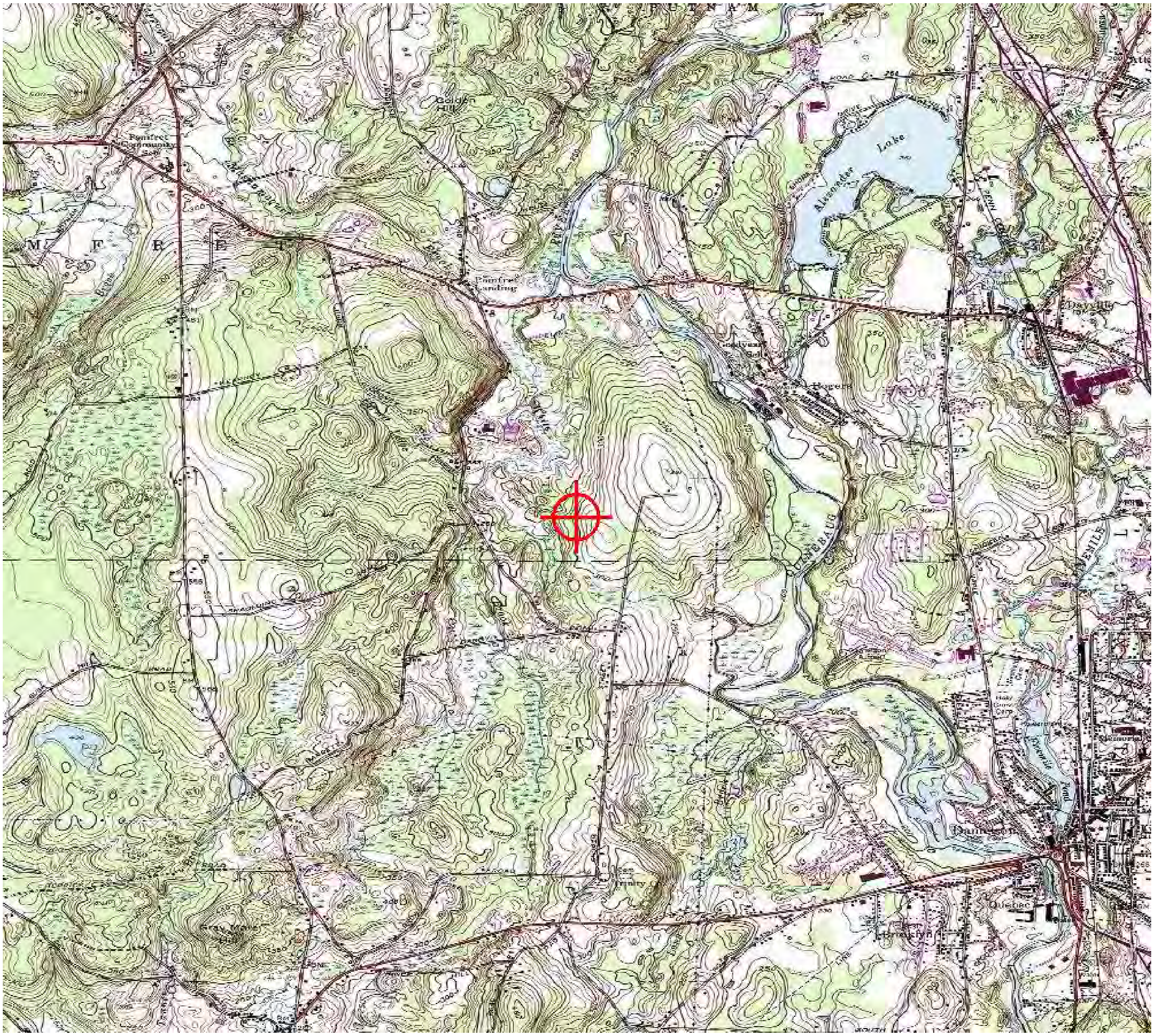
Darin Clipper
Specialist

Attachment(s)
Case Description
Map(s)

**Case Description for ASN 2016-ANE-658-OE**

The project proposes to construct a 22 megawatt (DC) solar energy generation facility.

## TOPO Map for ASN 2016-ANE-658-OE



Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2016-ANE-659-OE

Issued Date: 04/12/2016

Jean Christy
Tighe & Bond, Inc.
53 Southampton Road
Westfield, MA 01085

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

| | |
|---|---|
| Structure: | Solar Panel Woods Hill Solar Point 6 |
| Location: | Pomfret, CT |
| Latitude: | 41-50-11.65N NAD 83 |
| Longitude: | 71-55-21.92W |
| Heights: | 335 feet site elevation (SE)<br>7 feet above ground level (AGL)<br>342 feet above mean sea level (AMSL) |

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed and maintained in accordance with FAA Advisory circular 70/7460-1 L.

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If we can be of further assistance, please contact our office at (404) 305-6531. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2016-ANE-659-OE.

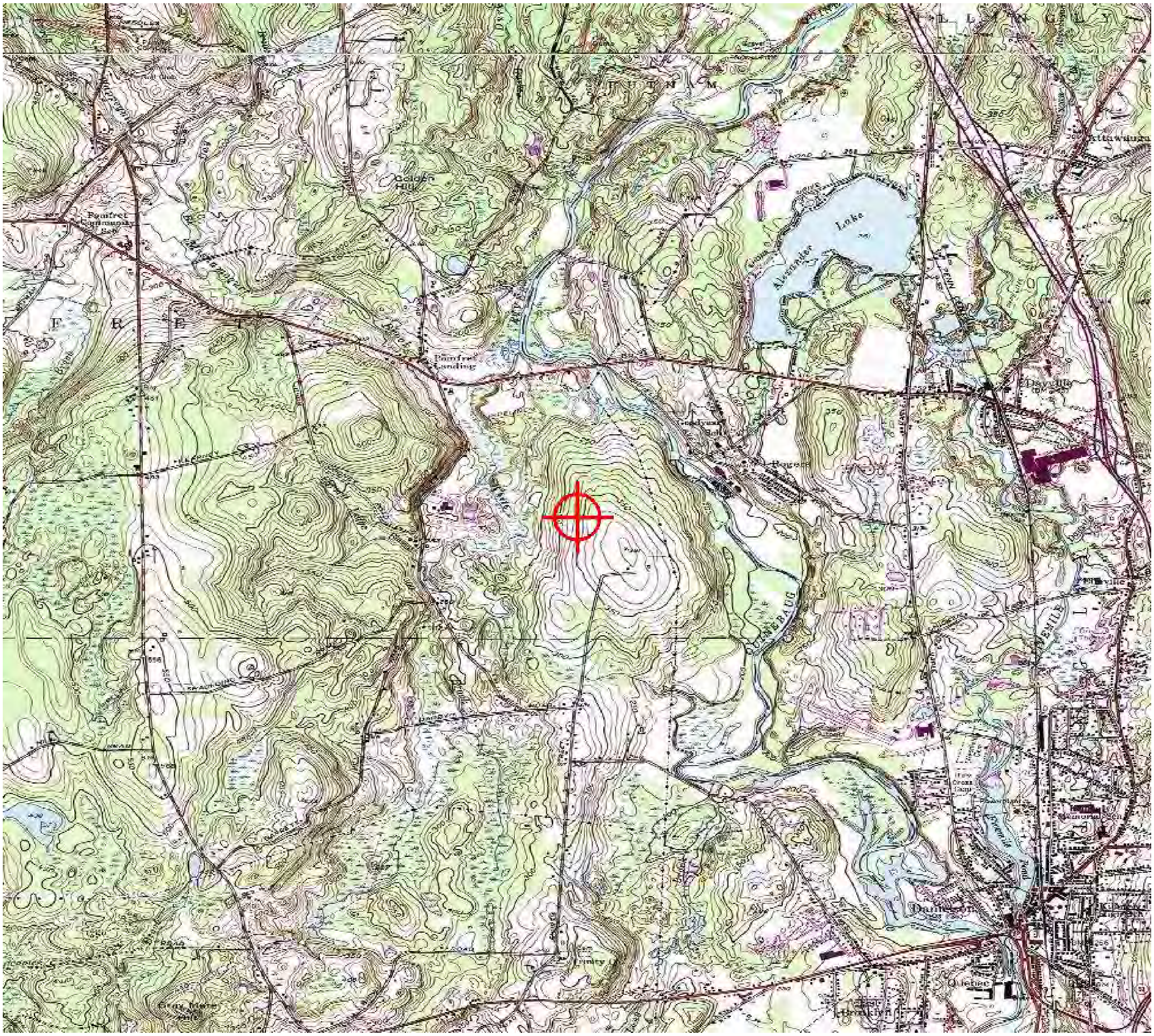
**Signature Control No: 285733435-288034827** ( DNE )
Darin Clipper
Specialist

Attachment(s)
Case Description
Map(s)

## Case Description for ASN 2016-ANE-659-OE

The project proposes to construct a 22 megawatt (DC) solar energy generation facility.

# TOPO Map for ASN 2016-ANE-659-OE



# Equipment Specifications

JA SOLAR

# JAP6

## -72/305-325/4BB

MULTICRYSTALLINE SILICON MODULE

## Key Features

- JA 4BB design module reduce cell series resistance and stress between cell interconnectors improves module reliability and module conversion efficiency
- High output, 16.51% highest conversion efficiency
- Designed for UL DC 1000V applications
- Anti-reflective and anti-soiling surface reduces power loss from dirt and dust
- Outstanding performance in low-light irradiance environments
- Excellent mechanical load resistance: Certified to withstand high wind loads (2400Pa) and snow loads (5400Pa)
- High salt and ammonia resistance certified by TÜV NORD

## JA Solar Holdings Co., Ltd.

JA Solar Holdings Co., Ltd. is a world-leading manufacturer of high-performance photovoltaic products that convert sunlight into electricity for residential, commercial, and utility-scale power generation. The company was founded on May 18, 2005, and was publicly listed on NASDAQ on February 7, 2007. JA Solar is one of the world's largest producers of solar cells and modules. Its standard and high-efficiency product offerings are among the most powerful and cost-effective in the industry.

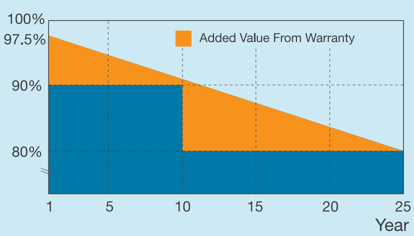
Add: NO.36, Jiang Chang San Road, Zhabei, Shanghai 200436, China
Tel: +86 21 6095 5888 / +86 21 6095 5999
Fax: +86 21 6095 5858 / +86 21 6095 5959
Email: sales@jasolar.com market@jasolar.com

## Reliable Quality

- Positive power tolerance: 0~+5W
- 100% EL double-inspection ensures modules are defects free
- Modules binned by current to improve system performance
- Potential Induced Degradation (PID) Resistant

## Superior Warranty

- 10-year product warranty
- 25-year linear power output warranty



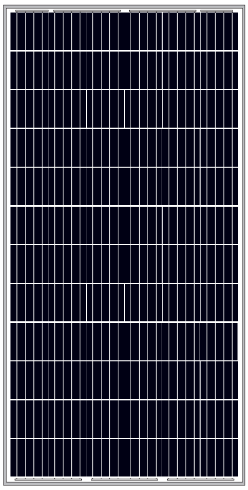

## Comprehensive Certificates

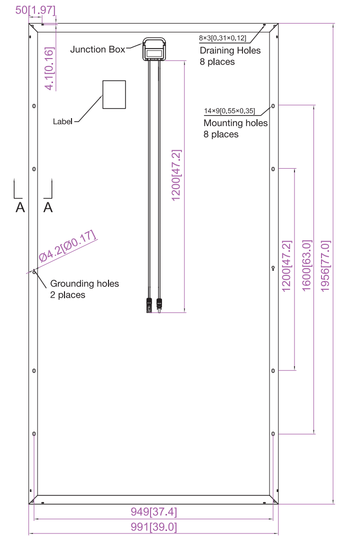
- IEC 61215, IEC 61730, UL1703, CEC Listed, MCS and CE
- ISO 9001: 2008: Quality management systems
- ISO 14001: 2004: Environmental management systems
- BS OHSAS 18001: 2007: Occupational health and safety management systems
- Environmental policy: The first solar company in China to complete Intertek's carbon footprint evaluation program and receive green leaf mark verification for our products

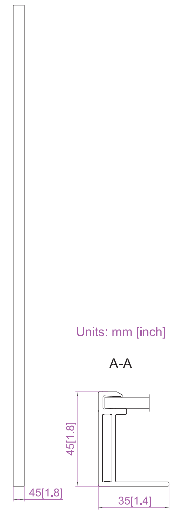
Specifications subject to technical changes and tests. JA Solar reserves the right of final interpretation.

# JAP6 -72/305-325/4BB

## Engineering Drawings






■ customized cable length available upon request

## MECHANICAL PARAMETERS

| | |
|---|---|
| Cell (mm) | Poly 156x156 |
| Weight (kg) | 26 (approx) |
| Glass Thickness | 4 mm |
| Dimensions (L×W×H) (mm) | 1956×991×45 |
| Cable Cross Section Size ($mm^2$) | 4 |
| No. of Cells and Connections | 72 (6×12) |
| Junction Box | IP67, 3 diodes |
| Connector | MC4 Compatible |
| Packaging Configuration | 23 Per Pallet |

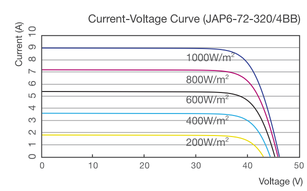
## WORKING CONDITIONS

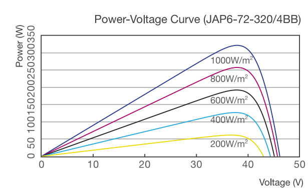
| | |
|---|---|
| Maximum System Voltage | DC 1000V (IEC) |
| Operating Temperature | -40℃~+85℃ |
| Maximum Series Fuse | 15A |
| Maximum Static Load, Front (e.g., snow and wind)<br>Maximum Static Load, Back (e.g., wind) | 5400Pa (112 lb/$ft^2$)<br>2400Pa (50 lb/$ft^2$) |
| NOCT | 45±2℃ |
| Application Class | Class A |

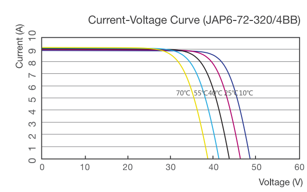
## ELECTRICAL PARAMETERS

| TYPE | JAP6-72-305/4BB | JAP6-72-310/4BB | JAP6-72-315/4BB | JAP6-72-320/4BB | JAP6-72-325/4BB |
|---|---|---|---|---|---|
| Rated Maximum Power at STC (W) | 305 | 310 | 315 | 320 | 325 |
| Open Circuit Voltage (Voc/V) | 45.37 | 45.66 | 45.95 | 46.22 | 46.48 |
| Maximum Power Voltage (Vmp/V) | 36.88 | 36.99 | 37.19 | 37.38 | 37.49 |
| Short Circuit Current (Isc/A) | 8.81 | 8.89 | 8.98 | 9.06 | 9.14 |
| Maximum Power Current (Imp/A) | 8.27 | 8.38 | 8.47 | 8.56 | 8.67 |
| Module Efficiency [%] | 15.73 | 15.99 | 16.25 | 16.51 | 16.77 |
| Power Tolerance (W) | -0~+5W | | | | |
| Temperature Coefficient of Isc (αIsc) | +0.058%/℃ | | | | |
| Temperature Coefficient of Voc (βVoc) | -0.330%/℃ | | | | |
| Temperature Coefficient of Pmax (γPmp) | -0.410%/℃ | | | | |
| STC | Irradiance 1000W/$m^2$, Cell Temperature 25℃, Air Mass 1.5 | | | | |

## I-V CURVE




## NOCT

| TYPE | JAP6-72-305/4BB | JAP6-72-310/4BB | JAP6-72-315/4BB | JAP6-72-320/4BB | JAP6-72-325/4BB |
|---|---|---|---|---|---|
| Max Power (Pmax) [W] | 221.43 | 225.06 | 228.69 | 232.32 | 235.95 |
| Open Circuit Voltage (Voc) [V] | 41.53 | 41.71 | 41.92 | 42.12 | 42.32 |
| Max Power Voltage (Vmp) [V] | 33.81 | 33.95 | 34.08 | 34.27 | 34.45 |
| Short Circuit Current (Isc) [A] | 6.95 | 7.01 | 7.06 | 7.12 | 7.18 |
| Max Power Current (Imp) [A] | 6.55 | 6.63 | 6.71 | 6.78 | 6.85 |
| Condition | Under Normal Operating Cell Temperature, Irradiance of 800 W/$m^2$, spectrum AM 1.5, ambient temperature 20℃, wind speed 1 m/s | | | | |

Electrical data in this catalog do not refer to a single module and they are not part of the offer. They only serve for comparison among different module types.

# SMA SERVICE FOR PV POWER PLANTS

EN

Successful Projects with Sunny Central System Solutions

# SMA SERVICE

## Top Performance and Maximum Yields

One thing is certain: PV power plants are investments in the future. Successful commissioning is an important milestone in your project. What remains crucial is the service lifecycle of your PV system.

### A Strong Team by Your Side

When service is needed, we are there for you immediately. Our SMA Service Line employees perform the initial error analyses and provide extensive telephone support. Thanks to our comprehensive service network, our team is available wherever service is needed, anywhere in the world and as quickly as possible. So you can be sure that your system will be back in operation quickly.

In addition to our reliable support, our team ensures that we tap the full potential of your PV power plant. Upon request, we also take on regular maintenance and real-time monitoring of your inverters.

### That's What We Call Service

Today, we can look back on more than 30 years of service experience. We want to continue to support and inspire you with our products and services, and the latest surveys show that we are succeeding. For the third consecutive time, SMA was selected as the most popular brand in the inverter industry.* According to the survey, what impresses SMA customers most of all is our outstanding, reliable service. Don't leave anything regarding your PV project to chance. Rely on the manufacturer expertise of SMA. For enhanced system reliability. For greater success.

*IMS Research 2012-2014


### We Are the Right Service Partner

✓ Comprehensive global service network: local presence, fast response times

✓ Professional support backed by many years of field experience

✓ Long-term availability of original parts

✓ Cost certainty from reliable spare parts inventory management

✓ Proactive service with intelligent error detection and remote updates

✓ Honored as the best service provider in the PV industry

# OUR SERVICES

## Full Service for the Entire System Lifecycle

Are you focused on optimal system performance and high yields? Do you want your system to be safely connected to the grid and to produce the desired output right away? Then SMA has the right services for you. Whether the issue is commissioning, preventative maintenance, extending the inverter warranty, spare parts management or repairs—we will support you throughout the entire life cycle of your PV power station and will see to it that your system generates maximum yields. Our service offer is the result of more than 30 years of experience in project support.

**SMA Operations & Maintenance**

Of course, you can also put the entire technical management of your power plant in our hands. With our Service Operations and Maintenance, we check daily whether your PV system is running as smoothly as possible. If challenges arise, our experts will drive to your plant on the very same day and immediately restore smooth operation.

For further information on this comprehensive service please refer to page 10 and 11.


SMA SERVICE
KS M 3481

# COMMISSIONING

## Superior System Performance Right from the Start

Professional commissioning is the key to a successful PV project. To ensure that your system is profitable long-term, it has to be connected to the grid safely and reliably and produce the optimal output right away.

During commissioning, our service experts check that your inverters and medium-voltage components are correctly installed and see to it that all necessary prerequisites for successful grid connection have been met. In addition, SMA adjusts the equipment settings, performs a thorough function test, and completes the commissioning with a grid-failure test.

All over the world, our customers trust the commissioning our service experts carry out. That's not surprising, because with an installed base of over 35 GW, we have the most practical experience in the industry. Our partners benefit from projects being completed on time, or even before the planned commercial commissioning.


**Advantages at a Glance:**

- Safe, proper commissioning of SMA components confirmed by SMA experts
- Stable, optimized operation of your PV system – from day one
- Prevention of consequential damages and fault-related downtime

# PREVENTATIVE MAINTENANCE

## Ensuring Maximum Operational Reliability

More power, greater efficiency, greater profitability: Regular maintenance improves the performance of your PV system and at the same time minimizes the risk of a potential system shutdown. Our SMA experts know your PV system inside and out and know how to keep your inverter at peak performance – even in difficult ambient conditions.

As part of this service, our service technicians carefully inspect your inverters and medium-voltage components, perform necessary updates and clean important equipment components. Careful error analyses and maintenance work round out the portfolio of services, making it possible to promptly counteract any potential power reduction.

Depending on the size of the system, annual SMA maintenance services include a 50-point inspection with a total of 17 function tests.

**Advantages at a Glance:**

- No unexpected malfunctions or hidden costs
- Adherence to maintenance intervals is ensured
- System downtime is prevented
- Yields are improved

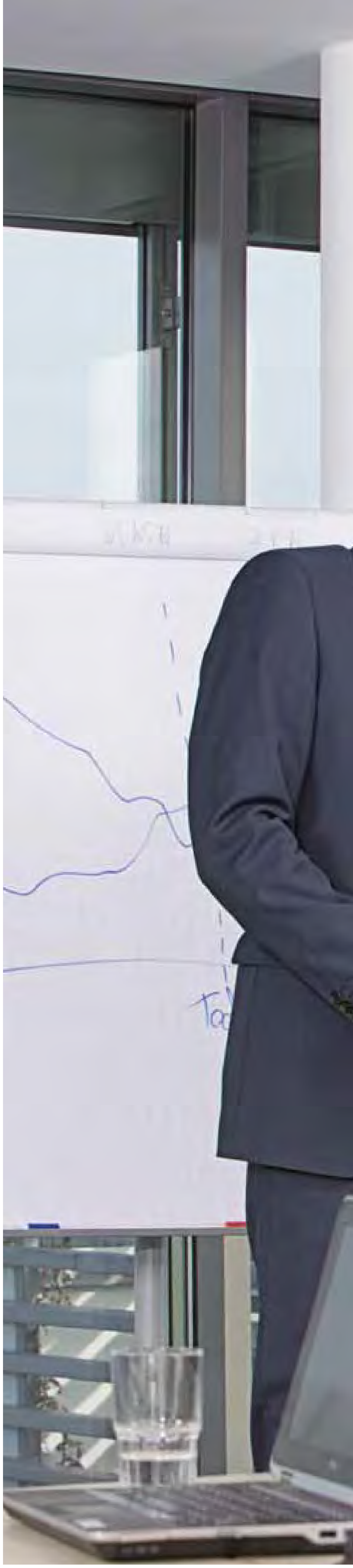
# EXTENDED WARRANTY

## Future-Proof Your Investment

Your goals: to maximize the profit of your PV system and minimize the risks. SMA supports you in this area, providing all inverters and medium voltage components with a five-year factory warranty. During this period we offer you maximum security. If service is needed, our service team will support you and analyze potential error messages by remote connection. If the issue can not be resolved by our Service Line, our technicians will come to your system and ensure that it resumes flawless operation. And if a component needs to be replaced, you will get it free of charge and as quickly possible.

An extended warranty* is a sensible choice and well worth it as it allows you to take advantage of this full service after the factory warranty ends. It protects you against unexpected costs and offers additional security by optimizing the internal rate of return for project developers, energy suppliers and system operators.

Not all extended warranties are created equal, compare SMA's Extended Warranty which includes all diagnostic services, repair labor and replacement parts. When you select the SMA Extended Warranty, you choose the stability of a guarantee backed by the most trusted brand in the business.



**Advantages at a Glance:**

- Optimization of the internal rate of return
- Excellent price certainty for entire service lifecycle of the equipment
- Quick resumption of system operation when service is needed
- Assured availability of replacement parts
- Highly qualified experts with many years of service experience

*Medium-voltage components are excluded from the extended warranty.

# SMA OPERATIONS & MAINTENANCE

## Managing Your PV System's Technical Operations

Even the best technology has to be checked periodically and needs extensive maintenance. Moreover, a properly maintained and serviced system can generate up to 30 percent better returns. SMA has the right offer for you.

With our SMA Operations & Maintenance Service, we offer full, comprehensive service. We manage all the technical operations of your PV system. This includes additional services such as thermal imaging and remote PV system monitoring, as well as module cleaning and vegetation control. After all, dirty modules, shadows and proliferation of plants pose a risk to optimal system operation and diminish your yields.

Put the technical operation of your system into the hands of experienced SMA experts and profit from optimal system performance, high yields and the assurance that your system is running smoothly, at all times.

## We offer the following two packages upon request:

### O&M Preventative

- Visual inspection of transformers, housing, inverters, wiring, racking and more
- Annual preventative inverter maintenance
- Detailed maintenance reports
- Thermoanalysis of electrical components to identify potential trouble spots
- Removal of vegetation and dirt from system components
- Remote monitoring with 24-hour customer support

### O&M Proactive

- All the advantages of the Preventative package
- DC wiring as well as maintenance and performance testing of electrical equipment
- Maintenance of racks
- Troubleshooting and calibration of energy meters
- Examination of error messages and immediate repairs up to a predefined amount
- Emergency service
- Spare parts inventory management
- Warranty administration

If preferred, you can also take advantage of additional individual services such as module cleaning and landscape maintenance around your PV system.

# SMA SOLAR MONITORING CENTER

## Keeping Close Track of Your Investment

Major investments require a high degree of security. For that reason, SMA keeps a close eye on your PV system. You profit from both our full-service protection and from a higher return on investment (ROI).

In our SMA Solar Monitoring Center, service experts remotely monitor your inverters in real time and make sure that your system functions as planned and your profits stay on track. For this, we use the most up-to-date technology to analyze power output and detect potential problems.

Because all relevant data is available to us in raw format, we can respond immediately and proactively, and take whatever steps are necessary. We resolve potential irregularities either directly by remote access or on site. In addition, in the case of abnormalities, we immediately get in touch with a contact person of your choice.

With SMA Remote Service you can sit back, relax, and concentrate on your business while SMA tends to your PV system and optimizes its performance. This service is included in SMA Operations & Maintenance Service. Upon request, remote monitoring can also be purchased separately.

70 MW PV-Power Plant in Kagoshima, Japan

# COMMISSIONED: JAPAN'S LARGEST PV POWER PLANT

## Service Team Successfully Handles All Challenges

The 70-megawatt system in Kagoshima is a good example of how important it is to have the right service partner at your side—someone with broad experience, who can respond to unexpected events in a flexible manner.

With an international service team hailing from Korea, Thailand, India and Germany, SMA provided substantial and active support during the construction of the PV system. The service technicians successfully handled all sorts of challenges, including a volcanic eruption and torrential rain with flooding and lightning strikes.

In 2013, the plant was commissioned on time, after only 13 months of construction. This success resulted in SMA securing the maintenance contract for the plant for the coming years. The facility will be managed by an SMA Service team located right in Japan, so the customer will always have a local contact person.

# OPERATIONS & MAINTENANCE IN CANADA

## Top Performance and Maximum Planning Security

About 130 SMA central inverters Sunny Central 800CP-US with a 98.7 percent degree of efficiency are currently operating in the 100-megawatt plant in Canada. The system, which is the largest PV power plant in Canada, is located in Haldimand County, Ontario.

Since 2014, SMA has been managing the entire technical operation, thereby guaranteeing smooth and continuous plant operation as well as top performance and maximum planning security.

SMA's comprehensive service covers both the inverters and the medium-voltage components, modules, racks, all wiring, as well as vegetation and system enclosure. The service includes repairs, device replacement, visual inspections and maintenance. Here, the focus is always on maximum efficiency and system profitability, even under unfavorable climate conditions.

MIX
Paper from responsible sources
Papier aus verantwortungsvollen Quellen
FSC® C044084

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SMA

SOCIAL MEDIA
www.SMA.de/Newsroom

www.SMA-Solar.com

# GeoPro
# Engineering Document Package

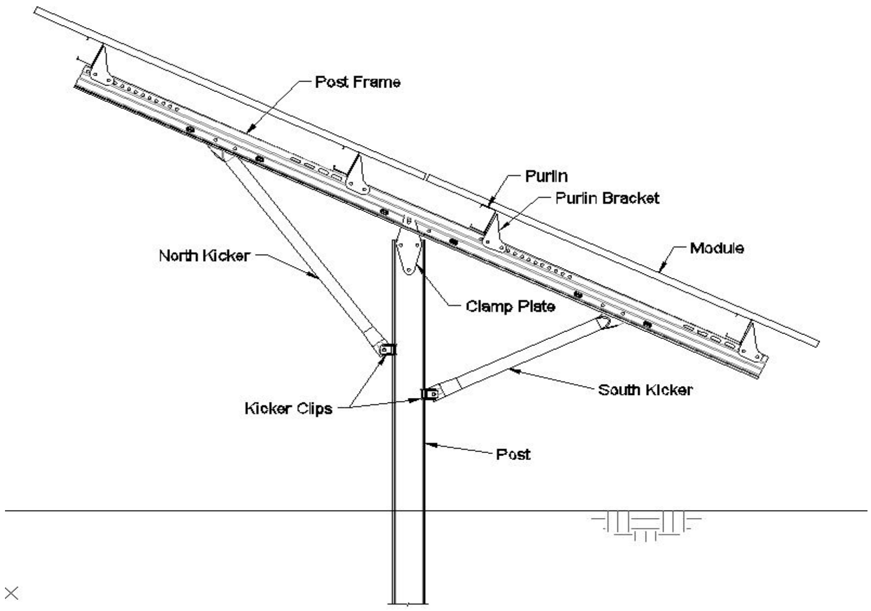
| | |
|---|---|
| Configuration: | 2-High Portrait<br>Centered W-Posts |
| Prepared for: | {ƶfl·Ǌ /ƶYǈl·yȅ |
| Project: | |
| Project No.: | -- |
| Print Date: | April 29, 2016 |
| Layout Revision Number: | R0 |

This Package Contains:

- SunLink GeoPro Structural Engineering Calculations
- Module datasheet for JA Solar JAP 72-315/3BB
- SunLink Layout Drawings
- Pile Load Test Report SLK16013

SUNLINK

## Table of Contents




## West Elevation: Component Names

| | | | | |
|---|---|---|---|---|
| **1.0** | **PROJECT INFORMATION** | | | |
| 1.1 | Sales Quote Number | -- | | |
| 1.2 | Sales Order Number | -- | | |
| 1.3 | Project Name | | | |
| 1.4 | Project Address | Plymouth, MA 02360 | | |
| 1.5 | Customer | | | |

| | | | | | References / Notes |
|---|---|---|---|---|---|
| **2.0** | **SITE INFORMATION** | | | | **References / Notes** |
| 2.1 | Occupancy Category | | I | | per customer's specification |
| 2.2 | Basic Wind Speed (3 sec gust) | V = | 115 | mph | |
| 2.3 | Wind Exposure Category | | C | | |
| 2.4 | Wind Site Topographic Effects | | no | | |
| 2.5 | Ground Snow Load | $p_g$ = | 25 | psf | |
| 2.6 | Min. Flat Roof Snow Load | $p_f$ = | 30 | psf | |
| 2.7 | Maximum E/W slope | | 0 | % | |
| 2.8 | Soil Site Class | | D | | |

| | | | | | |
|---|---|---|---|---|---|
| **3.0** | **MODULE INFORMATION** | | | | **References / Notes** |
| 3.1 | SunLink Module ID | | 71-179-08-004 | | |
| 3.2 | Manufacturer \| Model | | JA Solar JAP 72-315/3BB | | per customer's specification |
| 3.3 | Length | $L_{mod}$ = | 77.01 | in | |
| 3.4 | Width | $W_{mod}$ = | 39.02 | in | |
| 3.5 | Depth | $D_{mod}$ = | 1.77 | in | |
| 3.6 | Area | $A_{mod}$ = | 20.86 | $ft^2$ | |
| 3.7 | Weight | $W_{mod}$ = | 57.32 | lb | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **4.0** | **TABLE INFORMATION** | | | | | | | **Reference / Notes** |
| 4.1 | System tilt | Tilt = | 25.0 | deg | | | | |
| 4.2 | Leading edge | L.E. = | 30 | in | | | | |
| 4.3 | Array wind zone | **N Row** | **E/W Edge** | **N23 Rows** | **S Row** | **Interior** | | zones per SunLink wind tunnel report |
| 4.4 | Table Size (2 x _) | 6 | 6 | 6 | 6 | 6 | | |
| 4.5 | Table Length [in] | 238 | 238 | 238 | 238 | 238 | | |
| 4.6 | Post Spacing [in] | 139 | 139 | 139 | 139 | 139 | | |
| 4.7 | Post Size (W 6 x _) | W6x9 | W6x9 | W6x9 | W6x9 | W6x9 | | |
| 4.8 | Table weight [lb] | 1151 | 1151 | 1151 | 1151 | 1151 | | |

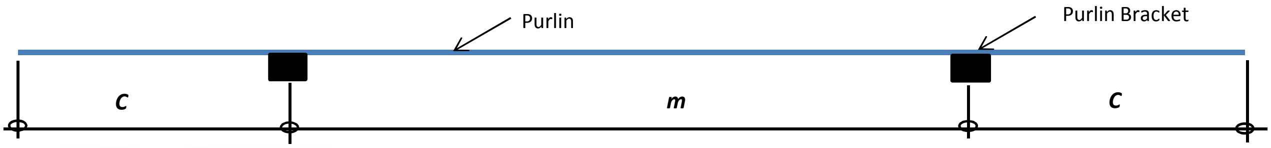
| | | | | | |
|---|---|---|---|---|---|
| **5.0** | **DESIGN PARAMETERS** | | | | **Reference / Notes** |
| **5.1** | **Wind** | | | | |
| 4.1.1 | Air Mass Density Constant | | 0.00256 | | |
| 4.1.2 | Velocity pressure exposure coeff. | $K_h$ = | 0.85 | - | ASCE 7-05 Figure 6-3 |
| 5.1.3 | Topographic factor | $K_{zt}$ = | 1.00 | - | See Line 2.4 above |
| 5.1.4 | Directionality factor | $K_d$ = | 0.85 | - | ASCE 7-05 Table 6-4 |
| 5.1.5 | Importance factor | I = | 0.77 | - | ASCE 7-05 Table 6-1 based on Line 2.1 |
| 5.1.6 | Basic velocity pressure | $q_h$ = | 18.83 | psf | |
| **5.2** | **Snow** | | | | |
| 5.2.1 | Thermal factor | $C_t$ = | 1.2 | - | ASCE 7-05 Table 7-3 (unheated) |
| 5.2.2 | Importance factor | I = | 0.8 | - | ASCE 7-05 Table 7-4 (Category II) |
| 5.2.3 | Roof slope factor | $C_s$ = | 0.85 | - | ASCE 7-05 Fig. 7-2 |

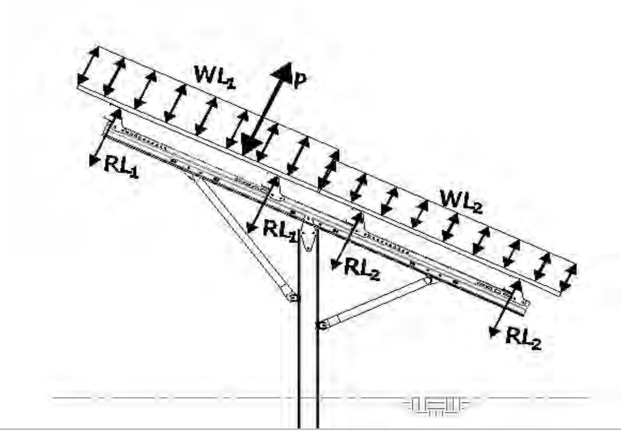
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5.2.4 | Array wind zone | | **N Row** | **E/W Edge** | **N23 Rows** | **S Row** | **Interior** | |
| 5.2.5 | Exposure factor | $C_e$ = | 0.9 | 0.9 | 1.00 | 0.90 | 1.00 | ASCE 7-05 Table 7-2 |
| 5.2.6 | Flat roof snow load [psf] | $p_f$ = | 15.12 | 30.00 | 30.00 | 30.00 | 30.00 | ASCE 7-05 Eq. 7-1; Pf = 0.7·Ce·Ct·I·pg |
| 5.2.7 | Sloped roof snow load [psf] | $p_s$ = | 25.38 | 25.38 | 25.38 | 25.38 | 25.38 | ASCE 7-05 Eq. 7-2 |
| 5.2.8 | Snow load per support frame [lb] | S = | 2880 | 2880 | 2880 | 2880 | 2880 | |

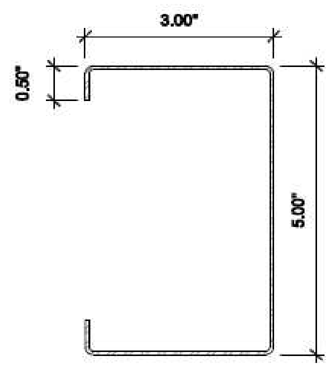
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **5.3** | **Seismic** | | | | | | | |
| 5.3.1 | Mapped short period spectral response factor | $S_S$ = | 0.240 | g | | | | USGS Seismic Parameters |
| 5.3.2 | Site coefficient | $F_a$ = | 1.60 | - | | | | USGS Seismic Parameters |
| 5.3.3 | Design short period spectral response factor | $S_{DS}$ = | 0.256 | g | | | | |
| 5.3.4 | Seismic importance factor | I = | 1.00 | - | | | | |
| 5.3.6 | Response modification factor | R = | 2.00 | - | | | | ASCE 7-05 Table 15.4-2 Inverted pendulum type |
| 5.3.7 | Seismic response coefficient | $C_s$ = | 0.128 | - | | | | ASCE 7-05 Eq. 12.8-2 |
| 5.3.8 | Seismic response coefficient | $C_s$ = | 0.128 | - | | | | ASCE 7-05 Eq. 15.4-1 (check min.) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5.3.9 | Array wind zone | | **N Row** | **E/W Edge** | **N23 Rows** | **S Row** | **Interior** | |
| 5.3.10 | Table size | | 2 x 6 | 2 x 6 | 2 x 6 | 2 x 6 | 2 x 6 | |
| 5.3.11 | Table weight per support frame [lb] | D = | 576 | 576 | 576 | 576 | 576 | Dead weight |
| 5.3.12 | W per per support frame [lb] | W = | 3456 | 3456 | 3456 | 3456 | 3456 | Dead weight + snow load (ASCE 7 15.5.3) |
| 5.3.13 | Seismic base shear per post [lb] | V = | 442 | 442 | 442 | 442 | 442 | ASCE 7-05 12.8-1 |

## 6.0 PURLINS




As is done for ASCE 7 monoslope open roof coefficients, wind loads are distributed using upper panel (WL1) and lower panel (WL2) uniform pressures that provide the correct design magnitude and eccentricity based on wind tunnel tests.

**16 ga. CFS Purlin**

### 6.1 Unfactored Purlin Loads

| Unfactored Purlin Loads | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|
| Table Size (2x_) | 6 | 6 | 6 | 6 | 6 | |
| Purlin Length | 19.83 | 19.83 | 19.83 | 19.83 | 19.83 | ft |
| Span length m = | 11.58 | 11.58 | 11.58 | 11.58 | 11.58 | ft |
| Cantilever Length c = | 4.13 | 4.13 | 4.13 | 4.13 | 4.13 | ft |
| Outer Support Moment : 1 plf line load | -0.103 | -0.103 | -0.103 | -0.103 | -0.103 | kip-in |
| Midspan Moment : 1 plf line load | 0.094 | 0.094 | 0.094 | 0.094 | 0.094 | kip-in |
| Inner Support Moment : 1 plf line load | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | kip-in |

| Wind Load (unfactored) | | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|---|
| **Uplift** | GCp | -0.9767 | -0.9902 | -0.9608 | -0.959975 | -0.775625 | |
| | Ecc | 0.633 | 0.656 | 0.688 | 0.694 | 0.681 | |
| pressure | p | -18.40 | -18.65 | -18.10 | -18.08 | -14.61 | psf |
| total load on table | P | -4.61 | -4.67 | -4.53 | -4.53 | -3.66 | kips |
| total load on upper panel | $P_U$ | -3.52 | -3.79 | -3.96 | -4.02 | -3.15 | kips |
| **dist. load per upper purlin** | **W_up_1** | **-89.39** | **-95.65** | **-99.95** | **-101.29** | **-79.53** | **plf** |
| total load on lower panel | $P_L$ | -1.08 | -0.88 | -0.57 | -0.51 | -0.50 | kips |
| **dist. load per lower purlin** | **W_up_2** | **-27.29** | **-22.07** | **-14.28** | **-12.84** | **-12.68** | **plf** |
| **Downpush** | GCp | 0.9558 | 0.9323 | 0.9123 | 0.8924125 | 0.54845 | |
| | Ecc | 0.405 | 0.345 | 0.405 | 0.350 | 0.419 | |
| pressure | p | 18.00 | 17.56 | 17.18 | 16.81 | 10.33 | psf |
| total load on table | P | 4.51 | 4.40 | 4.30 | 4.21 | 2.59 | kips |
| total load on upper panel | $P_U$ | 1.40 | 0.84 | 1.33 | 0.84 | 0.87 | kips |
| **dist. load per upper purlin** | **W_dn_1** | **35.23** | **21.06** | **33.62** | **21.22** | **22.01** | **plf** |
| total load on lower panel | $P_L$ | 3.11 | 3.56 | 2.97 | 3.37 | 1.71 | kips |
| **dist. load per lower purlin** | **W_dn_2** | **78.40** | **89.78** | **74.84** | **84.88** | **43.20** | **plf** |

| **Dead Load (unfactored)** | | **N Row** | **E/W Edge** | **N23 Rows** | **S Row** | **Interior** | |
|---|---|---|---|---|---|---|---|
| module (area) | Dma | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | |
| module (line) | Dml | 8.81 | 8.81 | 8.81 | 8.81 | 8.81 | plf |
| purlin (line) | Dp | 2.35 | 2.35 | 2.35 | 2.35 | 2.35 | plf |
| **vertical (line)** | **D** | **11.16** | **11.16** | **11.16** | **11.16** | **11.16** | |
| Dead Load Major Axis | Dx | 10.12 | 10.12 | 10.12 | 10.12 | 10.12 | plf |
| Dead Load Minor Axis | Dy | 4.72 | 4.72 | 4.72 | 4.72 | 4.72 | plf |

| **Snow Load (unfactored)** | | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|---|
| Snow Load | w_s | 25.38 | 25.38 | 25.38 | 25.38 | 25.38 | psf |
| Total Snow Load on Table | | 5.76 | 5.76 | 5.76 | 5.76 | 5.76 | kips |
| Total Snow Load per Purlin | S | 1440.06 | 1440.06 | 1440.06 | 1440.06 | 1440.06 | lb |
| **line load - snow -vert** | **W_S** | **72.61** | **72.61** | **72.61** | **72.61** | **72.61** | **plf** |
| line load - snow - Major Axis | W_Smajor | 65.81 | 65.81 | 65.81 | 65.81 | 65.81 | plf |
| line load - snow - Minor Axis | W_Sminor | 30.69 | 30.69 | 30.69 | 30.69 | 30.69 | plf |

**6.2 Purlin Demands**

| **Load Combo** | **Purlin** | **Axis** | **Value** | **N Row** | **E/W Edge** | **N23 Rows** | **S Row** | **Interior** | |
|---|---|---|---|---|---|---|---|---|---|
| Combo 1 | Upper | major | W | -133.91 | -143.93 | -150.81 | -152.96 | -118.14 | plf |
| 0.9D+1.6W | | | M | 13.85 | 14.88 | 15.59 | 15.82 | 12.22 | kip-in |
| | | | R | -1.33 | -1.43 | -1.50 | -1.52 | -1.17 | kip |
| | | minor | W | 4.25 | 4.25 | 4.25 | 4.25 | 4.25 | plf |
| | | | M | -0.44 | -0.44 | -0.44 | -0.44 | -0.44 | kip-in |
| | | | R | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | kip |
| | Lower | major | W | -34.55 | -26.21 | -13.74 | -11.44 | -11.18 | plf |
| | | | M | 3.57 | 2.71 | 1.42 | 1.18 | 1.16 | kip-in |
| | | | R | -0.34 | -0.26 | -0.14 | -0.11 | -0.11 | kip |
| | | minor | W | 4.25 | 4.25 | 4.25 | 4.25 | 4.25 | plf |
| | | | M | -0.44 | -0.44 | -0.44 | -0.44 | -0.44 | kip-in |
| | | | R | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | kip |
| Combo 2 | Upper | major | W | 101.41 | 78.74 | 98.84 | 79.00 | 80.25 | plf |
| 1.2D+1.6W+0.5S | | | M | -10.49 | -8.14 | -10.22 | -8.17 | -8.30 | kip-in |
| | | | R | 1.01 | 0.78 | 0.98 | 0.78 | 0.80 | kip |
| | | minor | W | 21.00 | 21.00 | 21.00 | 21.00 | 21.00 | plf |
| | | | M | -2.17 | -2.17 | -2.17 | -2.17 | -2.17 | kip-in |
| | | | R | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | kip |
| | Lower | major | W | 170.49 | 188.70 | 164.79 | 180.85 | 114.16 | plf |
| | | | M | -17.63 | -19.51 | -17.04 | -18.70 | -11.80 | kip-in |
| | | | R | 1.69 | 1.87 | 1.63 | 1.79 | 1.13 | kip |
| | | minor | W | 21.00 | 21.00 | 21.00 | 21.00 | 21.00 | plf |
| | | | M | -2.17 | -2.17 | -2.17 | -2.17 | -2.17 | kip-in |
| | | | R | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | kip |
| Combo 3 | Upper | major | W | 145.61 | 134.28 | 144.33 | 134.41 | 135.04 | plf |
| 1.2D+0.8W+1.6S | | | M | -15.06 | -13.88 | -14.92 | -13.90 | -13.96 | kip-in |
| | | | R | 1.44 | 1.33 | 1.43 | 1.33 | 1.34 | kip |
| | | minor | W | 54.76 | 54.76 | 54.76 | 54.76 | 54.76 | plf |
| | | | M | -5.66 | -5.66 | -5.66 | -5.66 | -5.66 | kip-in |
| | | | R | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | kip |
| | Lower | major | W | 180.15 | 189.26 | 177.30 | 185.33 | 151.99 | plf |
| | | | M | -18.63 | -19.57 | -18.33 | -19.16 | -15.72 | kip-in |
| | | | R | 1.79 | 1.88 | 1.76 | 1.84 | 1.51 | kip |
| | | minor | W | 54.76 | 54.76 | 54.76 | 54.76 | 54.76 | plf |
| | | | M | -5.66 | -5.66 | -5.66 | -5.66 | -5.66 | kip-in |
| | | | R | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | kip |

### 6.3 Purlin Capacity (CUFSM)

C5x3x16GA: CUFSM

| | | | |
|---|---|---|---|
| $\phi M_{nx}$ (+) = | 45.15 | kip-in | Top flange in compression |
| $\phi M_{nx}$ (-) = | 38.47 | kip-in | Bottom flange in compression |
| $\phi M_{ny}$ (+) = | 14.99 | kip-in | Right web in compression |
| $\phi M_{ny}$ (-) = | 15.01 | kip-in | Left web in compression |

### 6.4 Maximum DCRs

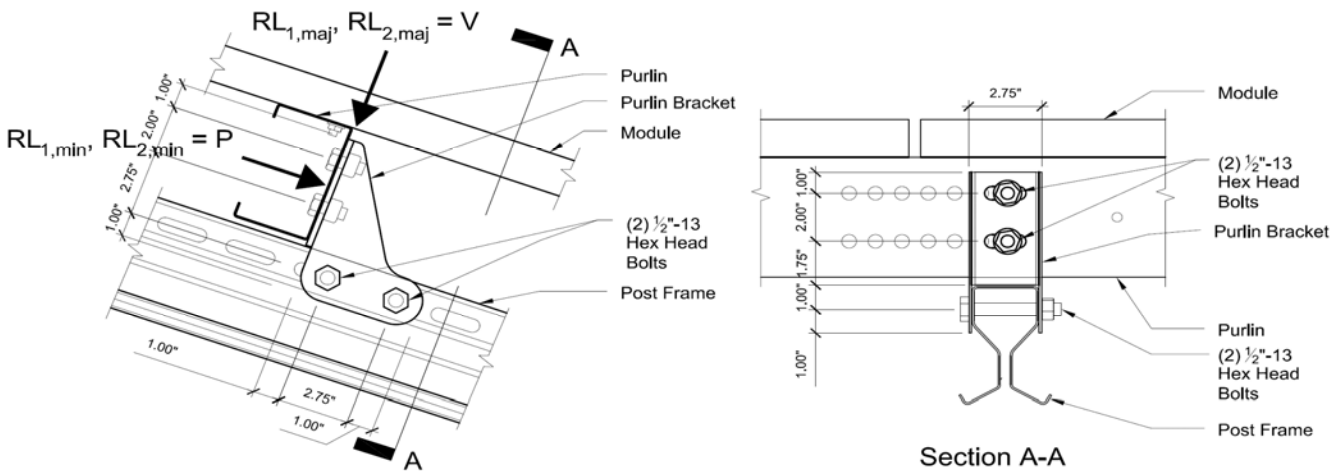
| | | Demand $M_u$ | Capacity $\phi M_n$ | D/C Ratio |
|---|---|---|---|---|
| Combo 1 | Upper, Major | 15.82 | 45.15 | 0.380 |
| | Upper, Minor | -0.44 | 15.01 | |
| Combo 3 | Lower, Major | -19.57 | 38.47 | 0.886 |
| | Lower, Minor | -5.66 | 15.01 | |

**NAS Eq. C5.2.2-3**

$$\frac{Mx}{\phi M_{nx}} + \frac{Mx}{\phi M_{ny}} \leq 1.0$$

where $\phi$ = 0.90

## 7.0 PURLIN BRACKET CONNECTIONS




### 7.1 Material & Section Properties

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| | Purlin | | | |
| 7.1.1 | Material = | A653 SS Gr. 50 Class 1 | | |
| 7.1.2 | $F_y$ = | 50 | ksi | |
| 7.1.3 | $F_u$ = | 65 | ksi | |
| 7.1.4 | t = | 0.0589 | in | 16 ga |
| | Purlin Bracket | | | |
| 7.1.5 | Material = | GB/T 2518 Property Gr. S350 | | |
| 7.1.6 | $F_y$ = | 50.8 | ksi | 350 MPa |
| 7.1.7 | $F_u$ = | 60.9 | ksi | 420 MPa |
| 7.1.8 | t = | 0.098 | in | 2.5 mm |
| 7.1.9 | l = | 3.67 | in. | Cross section length |
| 7.1.10 | $S_x$ = | 0.22 | $in.^3$ | Section modulus (each of 2 legs) |
| | Bolts | | | |
| 7.1.11 | Material = | A325 | | |
| 7.1.12 | $F_y$ = | 92.0 | ksi | Minimum yield stress |
| 7.1.13 | $F_u$ = | 120.0 | ksi | Tensile stress |
| 7.1.14 | $F_{nt}$ = | 90.0 | ksi | Nominal tensile stress |
| 7.1.15 | $F_{nv}$ = | 48.0 | ksi | Nominal shear stress |
| 7.1.16 | d = | 0.50 | in. | Bolt diameter |
| 7.1.17 | s = | 2.75 | in. | Bolt spacing |
| 7.1.18 | $L_c$ = | 1.44 | in. | Clear distance, Purlin to Bracket |
| 7.1.19 | $L_c$ = | 2.19 | in. | Clear distance, Bracket to Post Frame |
| | Post Frame | | | |
| 7.1.20 | Material = | GB/T 1591 Gr. Q345B | | |
| 7.1.21 | $F_y$ = | 50.8 | ksi | 350 MPa |
| 7.1.22 | $F_u$ = | 60.9 | ksi | 420 MPa |
| 7.1.23 | t = | 0.0787 | in. | 2 mm |

## 7.2 Purlin Reactions

LC1: Wind Uplift: 0.9D+1.6W

| Table Size 2x | Purlin length | Zone | RL1,maj | RL1,min | RL2,maj | RL2,min |
|---|---|---|---|---|---|---|
| - | ft | - | lb | lb | lb | lb |
| 6 | 19.833 | N. Row | -1319.2 | 42.1 | -342.7 | 42.1 |
| 6 | 19.833 | E&W Edges | -1427.3 | 42.1 | -259.9 | 42.1 |
| 6 | 19.833 | N.23 Rows | -1495.6 | 42.1 | -136.2 | 42.1 |
| 6 | 19.833 | S. Row | -1516.8 | 42.1 | -113.4 | 42.1 |
| 6 | 19.833 | Interior | -1171.6 | 42.1 | -110.9 | 42.1 |

LC2: Wind Downpush: 1.2D+1.6W+0.5S

| Table Size 2x | Purlin length | Zone | RL1,maj | RL1,min | RL2,maj | RL2,min |
|---|---|---|---|---|---|---|
| - | ft | - | lb | lb | lb | lb |
| 6 | 19.833 | N. Row | 1005.6 | 208.3 | 840.9 | 208.3 |
| 6 | 19.833 | E&W Edges | 780.8 | 208.3 | 898.1 | 208.3 |
| 6 | 19.833 | N.23 Rows | 980.2 | 208.3 | 822.9 | 208.3 |
| 6 | 19.833 | S. Row | 783.4 | 208.3 | 873.4 | 208.3 |
| 6 | 19.833 | Interior | 795.9 | 208.3 | 663.9 | 208.3 |

LC3: Snow: 1.2D+0.8W+1.6S

| Table Size 2x | Purlin length | Zone | RL1,maj | RL1,min | RL2,maj | RL2,min |
|---|---|---|---|---|---|---|
| - | ft | - | lb | lb | lb | lb |
| 6 | 19.833 | N. Row | 1444.0 | 543.0 | 1361.6 | 543.0 |
| 6 | 19.833 | E&W Edges | 1331.6 | 543.0 | 1390.2 | 543.0 |
| 6 | 19.833 | N.23 Rows | 1431.3 | 543.0 | 1352.6 | 543.0 |
| 6 | 19.833 | S. Row | 1332.9 | 543.0 | 1377.9 | 543.0 |
| 6 | 19.833 | Interior | 1339.1 | 543.0 | 1273.1 | 543.0 |

Maximum Connection Loads

| | | Value | | Units | Comment/Reference |
|---|---|---|---|---|---|
| | | **V** | **P** | - | Reaction |
| 7.2.1 | case 1 | -1.52 | 0.08 | kip | (case 1: max V, corresponding P) |
| 7.2.2 | case 2 | 1.44 | 1.09 | kip | (case 2: max P, corresponding V) |

**7.3 Purlin-to-Purlin Bracket Bolts**

| | | Case 1 | Case 2 | | |
|---|---|---|---|---|---|
| 7.3.1 | $V_u$ = | 1.52 | 1.44 | kip | (max V) |
| | Bearing Capacity due to Edge Distance in Purlin | | | | |
| 7.3.2 | e = | 1.00 | 1.00 | in | |
| 7.3.3 | $F_u/F_{sy}$ = | 1.20 | 1.20 | | |
| 7.3.4 | $\phi_v$ = | 0.70 | 0.70 | | |
| 7.3.5 | $\phi P_n$ = | 5.02 | 5.02 | kip | AISI Eq. E3.1-1 |
| | Rupture in net section of | | | | |
| 7.3.6 | $A_n$ = | 0.27 | 0.27 | $in.^2$ | net area of connected part |
| 7.3.7 | $F_t$ = | 60.92 | 60.92 | ksi | AISI Eq. E3.2-5, flat sheet connection, multiple bolts parallel to force |
| 7.3.8 | $\phi$ = | 0.65 | 0.65 | | |
| 7.3.9 | $\phi P_n$ = | 21.43 | 21.43 | kip | AISI Eq. E3.2-1, 2 bolts |
| | Bolt Bearing Capacity, Purlin | | | | |
| 7.3.10 | d/t = | 8.49 | 8.49 | | |
| 7.3.11 | C = | 3.00 | 3.00 | | AISI, Table E3.3.1-1 |
| 7.3.12 | $m_f$ = | 0.75 | 0.75 | | AISI, Table E3.3.1-2 |
| 7.3.13 | $\phi_v$ = | 0.60 | 0.60 | | |
| 7.3.14 | $\phi P_n$ = | 2.58 | 2.58 | kip | AISI Eq. E3.3.1-1, 2 bolts |
| | Bolt Bearing Capacity, Purlin Bracket | | | | |
| 7.3.10 | d/t = | 5.08 | 5.08 | | |
| 7.3.11 | C = | 3.00 | 3.00 | | AISI, Table E3.3.1-1 |
| 7.3.12 | $m_f$ = | 0.75 | 0.75 | | AISI, Table E3.3.1-2 |
| 7.3.13 | $\phi_v$ = | 0.60 | 0.60 | | |
| 7.3.14 | $\phi P_n$ = | 4.05 | 4.05 | kip | AISI Eq. E3.3.1-1, 2 bolts |
| | Shear, Bolt Capacity | | | | |
| 7.3.15 | $\phi_v$ = | 0.65 | 0.65 | | |
| 7.3.16 | $\phi V_n$ = | 12.25 | 12.25 | kip | $V_n = A_b F_{nv}$ |
| 7.3.17 | Controlling: | | | | |
| 7.3.18 | $\phi V_n$ = | 2.58 | 2.58 | kip | |
| 7.3.19 | DCR = | 0.587 | 0.559 | < 1, OK | |

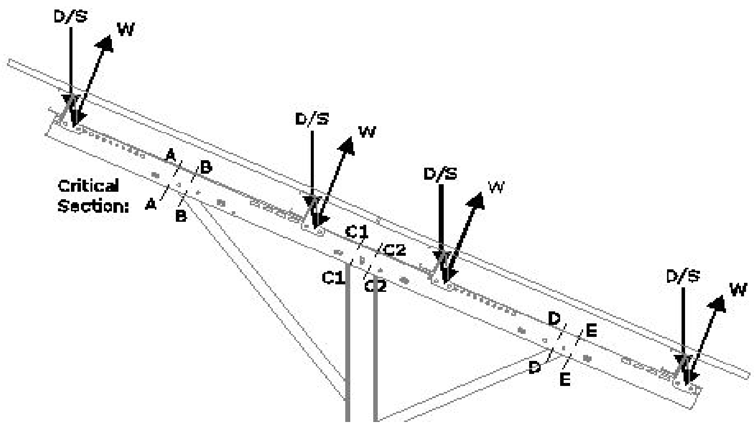
**7.4 Purlin Bracket Bending and Shear**

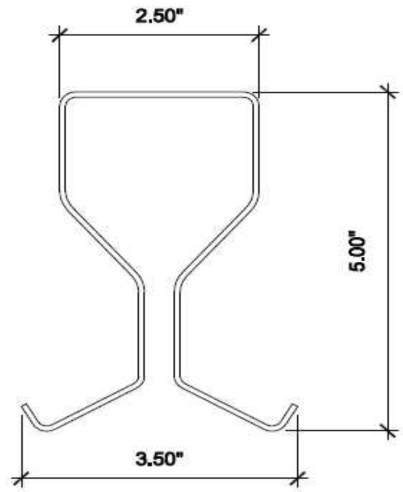
| | | | | | |
|---|---|---|---|---|---|
| | Shear Check | *Upper Purlin* | *Lower Purlin* | | |
| 7.4.1 | $V_u$ = | 0.08 | 1.09 | kip | (max P) |
| 7.4.2 | h/t = | 37.28 | 37.28 | | |
| 7.4.3 | $(Ek_v/F_y)^{1/2}$ = | 55.23 | 55.23 | | |
| 7.4.4 | $F_v$ = | 30.46 | 30.46 | ksi | |
| 7.4.5 | $A_w$= | 0.72 | 0.72 | $in.^2$ | (2 legs) |
| 7.4.6 | $\phi_v$ = | 0.95 | 0.95 | | |
| 7.4.7 | $\phi V_n$ = | 20.90 | 20.90 | kip | AISI, eq. C3.2.1-1 |
| 7.4.8 | DCR = | 0.004 | 0.052 | < 1, OK | |
| | Moment Check | | | | |
| 7.4.9 | $d_V$ = | 2.375 | 2.375 | in | V force offset distance from critical section |
| 7.4.10 | $d_P$ = | 2.75 | 2.75 | in | P force offset distance from critical section |
| 7.4.11 | $M_u$ = | 3.83 | 0.44 | kip-in | (max moment due to P and V combination) |
| 7.4.12 | $C_b$ = | 1.00 | 1.00 | | conservative assumption |
| 7.4.13 | $\phi_b$ = | 0.9 | 0.90 | | |
| 7.4.14 | $\phi M_n$ = | 20.18 | 20.18 | kip-in | AISI, eq. C3.1.1-1 (2 legs) |
| 7.4.15 | DCR = | 0.190 | 0.022 | < 1, OK | |
| | Combined Check | | | | |
| 7.4.16 | Combined DCR = | 0.190 | 0.056 | < 1, OK | AISI, eq. C3.3.2-1 |

### 7.5 Bolts to Post Frame

| | | Upper Purlin | Lower Purlin | | |
|---|---|---|---|---|---|
| 7.5.1 | $d_V$ = | 2.375 | 2.38 | in | |
| 7.5.2 | $d_P$ = | 3.75 | 3.75 | in | |
| 7.5.3 | $V_{up}$ = | 0.76 | 0.72 | kip | shear per bolt due to P |
| 7.5.4 | $V_{uv}$ = | 0.04 | 0.54 | kip | shear per bolt due to V |
| 7.5.5 | $M_u$ = | 3.92 | 0.64 | kip-in | moment due to eccentricity |
| 7.5.6 | $s_b$ = | 2.75 | 2.75 | in | bolt spacing |
| 7.5.7 | $R_u$ = | 1.42 | 0.23 | kip | shear per bolt due to force eccentricity, in direction V |
| 7.5.8 | $V_{unet}$ = | 1.65 | 1.06 | kip | net shear per bolt |
| | Shear, Spacing and Edge Distance | | | | |
| 7.5.9 | e = | 1.00 | 1.00 | in | |
| 7.5.10 | $F_u/F_{sy}$ = | 1.20 | 1.20 | | |
| 7.5.11 | $\phi_v$ = | 0.70 | 0.70 | | |
| 7.5.12 | $\phi P_n$ = | 6.72 | 6.72 | kip | AISI Eq. E3.1-1 (double shear) |
| | Rupture in net section | | | | |
| 7.5.13 | $A_n$ = | 0.23 | 0.23 | $in.^2$ | net area of connected part (per bolt) |
| 7.5.14 | $F_t$ = | 27.69 | 27.69 | ksi | AISI Eq. E3.2-4, flat sheet connection, bolts perpendicular to force |
| 7.5.15 | $\phi_v$ = | 0.65 | 0.65 | | |
| 7.5.16 | $\phi P_n$ = | 8.41 | 8.41 | kip | AISI Eq. E3.2-1, 2 bolts (double shear) |
| | Bearing Resistance, without Consideration of Bolt Hole Deformation | | | | |
| 7.5.17 | d/t = | 6.35 | 6.35 | | |
| 7.5.18 | C = | 3.00 | 3.00 | | AISI, Table E3.3.1-1 |
| 7.5.19 | $m_f$ = | 0.75 | 0.75 | | AISI, Table E3.3.1-2 |
| 7.5.20 | $\phi_v$ = | 0.60 | 1.60 | | |
| 7.5.21 | $\phi P_n$ = | 10.79 | 10.79 | kip | AISI Eq. E3.3.1-1, 2 bolts (double shear) |
| | Shear, Bolt Capacity | | | | |
| 7.5.22 | $\phi_v$ = | 0.65 | 0.65 | | |
| 7.5.23 | $\phi V_n$ = | 12.25 | 12.25 | kip | $V_n = A_b F_{nv}$ (double shear) |
| 7.5.24 | Controlling: | | | | |
| 7.5.25 | $\phi V_n$ = | 6.72 | 6.72 | kip | |
| 7.5.26 | DCR = | 0.246 | 0.158 | < 1, OK | |

## 8.0 POST FRAME




**CFS Post Frame** (2 mm)

Check Post Frames from all 5 wind zones by examining the DCRs at the possible critical sections A-A through E-E shown above using CFS.

Demands at all of the 5 locations for all of the wind zones are shown in the tables on the next page for the 3 critical load combinations; Wind up, Wind down, and Snow.

Reports from CFS follow.

### 8.1 Post Frame Forces at Each Critical Section:

8.1.1 Section A-A Cantilever near Post

| Zone | LC1: Wind Uplift: 0.9D+1.6W | | | LC2: Wind Downpush: 1.2D+1.6W+0.5S | | | LC3: Snow: 1.2D+0.8W+1.6S | | |
|---|---|---|---|---|---|---|---|---|---|
| | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip |
| N. Row | 0.04 | 26.12 | -1.32 | 0.21 | -18.78 | 1.01 | 0.54 | -25.82 | 1.44 |
| E&W Edges | 0.04 | 28.26 | -1.43 | 0.21 | -14.38 | 0.78 | 0.54 | -23.62 | 1.33 |
| N.23 Rows | 0.04 | 29.58 | -1.50 | 0.21 | -18.27 | 0.98 | 0.54 | -25.57 | 1.43 |
| S. Row | 0.04 | 29.99 | -1.52 | 0.21 | -14.41 | 0.78 | 0.54 | -23.64 | 1.33 |
| Interior | 0.04 | 23.23 | -1.17 | 0.21 | -14.66 | 0.80 | 0.54 | -23.76 | 1.34 |

8.1.2 Section B-B Center Span near Post

| Zone | LC1: Wind Uplift: 0.9D+1.6W | | | LC2: Wind Downpush: 1.2D+1.6W+0.5S | | | LC3: Snow: 1.2D+0.8W+1.6S | | |
|---|---|---|---|---|---|---|---|---|---|
| | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip |
| N. Row | 4.28 | 26.12 | 1.00 | -2.99 | -18.78 | -0.74 | -3.99 | -25.82 | -1.03 |
| E&W Edges | 4.62 | 28.26 | 1.07 | -2.28 | -14.38 | -0.58 | -3.63 | -23.62 | -0.95 |
| N.23 Rows | 4.83 | 29.58 | 1.12 | -2.91 | -18.27 | -0.72 | -3.94 | -25.57 | -1.02 |
| S. Row | 4.89 | 29.99 | 1.13 | -2.28 | -14.41 | -0.58 | -3.63 | -23.64 | -0.95 |
| Interior | 3.79 | 23.23 | 0.88 | -2.31 | -14.66 | -0.58 | -3.65 | -23.76 | -0.95 |

8.1.3 Section C-C Middle Center Span

| Zone | LC1: Wind Uplift: 0.9D+1.6W | | | LC2: Wind Downpush: 1.2D+1.6W+0.5S | | | LC3: Snow: 1.2D+0.8W+1.6S | | |
|---|---|---|---|---|---|---|---|---|---|
| | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy |
| N. Row | 4.32 | 3.18 | -0.32 | -2.78 | -0.84 | 0.26 | -3.44 | -0.28 | 0.42 |
| E&W Edges | 4.66 | 3.61 | -0.36 | -2.07 | -0.14 | 0.20 | -3.09 | 0.07 | 0.38 |
| N.23 Rows | 4.87 | 3.98 | -0.38 | -2.70 | -0.80 | 0.26 | -3.40 | -0.26 | 0.41 |
| S. Row | 4.93 | 4.08 | -0.39 | -2.08 | -0.18 | 0.21 | -3.09 | 0.05 | 0.39 |
| Interior | 3.84 | 3.14 | -0.30 | -2.10 | -0.54 | 0.22 | -3.10 | -0.13 | 0.39 |

8.1.4 Section D-D Center Span near Kicker

| Zone | LC1: Wind Uplift: 0.9D+1.6W | | | LC2: Wind Downpush: 1.2D+1.6W+0.5S | | | LC3: Snow: 1.2D+0.8W+1.6S | | |
|---|---|---|---|---|---|---|---|---|---|
| | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip |
| N. Row | 0.47 | 7.93 | -0.27 | -1.65 | -20.89 | 0.88 | -2.94 | -34.80 | 1.49 |
| E&W Edges | 0.32 | 5.96 | -0.17 | -1.77 | -22.25 | 0.95 | -3.00 | -35.48 | 1.53 |
| N.23 Rows | 0.10 | 3.04 | -0.04 | -1.62 | -20.47 | 0.86 | -2.93 | -34.59 | 1.48 |
| S. Row | 0.06 | 2.47 | -0.01 | -1.72 | -21.68 | 0.93 | -2.98 | -35.19 | 1.52 |
| Interior | 0.08 | 2.43 | -0.03 | -1.36 | -16.72 | 0.71 | -2.80 | -32.71 | 1.41 |

8.1.5 Section E-E Cantilever near Kicker

| Zone | LC1: Wind Uplift: 0.9D+1.6W | | | LC2: Wind Downpush: 1.2D+1.6W+0.5S | | | LC3: Snow: 1.2D+0.8W+1.6S | | |
|---|---|---|---|---|---|---|---|---|---|
| | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip | P kip | Mx kip-in | Vy kip |
| N. Row | -0.04 | 7.93 | 0.34 | -0.21 | -20.89 | -0.84 | -0.54 | -34.80 | -1.36 |
| E&W Edges | -0.04 | 5.96 | 0.26 | -0.21 | -22.25 | -0.90 | -0.54 | -35.48 | -1.39 |
| N.23 Rows | -0.04 | 3.04 | 0.14 | -0.21 | -20.47 | -0.82 | -0.54 | -34.59 | -1.35 |
| S. Row | -0.04 | 2.47 | 0.11 | -0.21 | -21.68 | -0.87 | -0.54 | -35.19 | -1.38 |
| Interior | -0.04 | 2.43 | 0.11 | -0.21 | -16.72 | -0.67 | -0.54 | -32.71 | -1.27 |

## 8.2 Capacity Checks using CFS v.7.0.0

### 8.2.1 Section A - A Uplift

Report: GeoPro-P Post Frame ADM Redbrook.sct 4/17/2015 3:44:32 PM

Member Check - 2010 North American Specification - US (LRFD)

```
Material Type: A653 SS Grade 50/1, Fy=50 ksi
Design Parameters:
Lx          2.000 ft      Ly          2.000 ft      Lt          2.000 ft
Kx          2.0000        Ky          1.0000        Kt          1.0000
Cbx         1.6667        Cby         1.0000        ex          0.0000 in
Cmx         1.0000        Cmy         1.0000        ey          0.0000 in
Braced Flange: None       kφ              0 k
Red. Factor, R: 0         Lm         20.000 ft

Loads:            P          Mx          Vy         My          Vx
                 (k)       (k-in)        (k)      (k-in)        (k)
Entered         0.040      29.990      -1.520      0.000       0.000
Applied         0.040      29.990      -1.520      0.000       0.000
Strength       42.682      58.268      11.362     21.949       8.452

Effective section properties at applied loads:
Ae          1.1140 in^2   Ixe         3.2076 in^4   Iye         0.8545 in^4
                          Sxe(t)      1.3225 in^3   Sye(l)      0.4878 in^3
                          Sxe(b)      1.2948 in^3   Sye(r)      0.4878 in^3

Interaction Equations
NAS Eq. C5.2.2-1   (P, Mx, My)  0.001 + 0.515 + 0.000 = 0.516 <= 1.0
NAS Eq. C5.2.2-2   (P, Mx, My)  0.001 + 0.515 + 0.000 = 0.516 <= 1.0
NAS Eq. C3.3.2-1      (Mx, Vy)     Sqrt(0.265 + 0.018)= 0.532 <= 1.0
NAS Eq. C3.3.2-1      (My, Vx)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0
```

### 8.2.2 Section A - A Downpush

Report: GeoPro-P Post Frame ADM Redbrook.sct 4/17/2015 3:44:32 PM

Member Check - 2010 North American Specification - US (LRFD)

```
Material Type: A653 SS Grade 50/1, Fy=50 ksi
Design Parameters:
Lx          2.000 ft      Ly          2.000 ft      Lt          2.000 ft
Kx          2.0000        Ky          1.0000        Kt          1.0000
Cbx         1.6667        Cby         1.0000        ex          0.0000 in
Cmx         1.0000        Cmy         1.0000        ey          0.0000 in
Braced Flange: None       kφ              0 k
Red. Factor, R: 0         Lm         20.000 ft

Loads:            P          Mx          Vy         My          Vx
                 (k)       (k-in)        (k)      (k-in)        (k)
Entered         0.540     -25.820       1.440      0.000       0.000
Applied         0.540     -25.820       1.440      0.000       0.000
Strength       42.682      58.268      11.362     21.949       8.452

Effective section properties at applied loads:
Ae          1.1140 in^2   Ixe         3.2076 in^4   Iye         0.8545 in^4
                          Sxe(t)      1.3225 in^3   Sye(l)      0.4878 in^3
                          Sxe(b)      1.2948 in^3   Sye(r)      0.4878 in^3

Interaction Equations
NAS Eq. C5.2.2-1   (P, Mx, My)  0.013 + 0.444 + 0.000 = 0.456 <= 1.0
NAS Eq. C5.2.2-2   (P, Mx, My)  0.011 + 0.443 + 0.000 = 0.454 <= 1.0
NAS Eq. C3.3.2-1      (Mx, Vy)     Sqrt(0.196 + 0.016)= 0.461 <= 1.0
NAS Eq. C3.3.2-1      (My, Vx)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0
```

8.2.3 **Section B - B Uplift**

Report: GeoPro-P Post Frame ADM Redbrook.sct 4/17/2015 3:44:32 PM

Member Check - 2010 North American Specification - US (LRFD)

```
Material Type: A653 SS Grade 50/1, Fy=50 ksi
Design Parameters:
Lx          3.250 ft      Ly          2.290 ft      Lt          2.290 ft
Kx         1.0000         Ky         1.0000         Kt         1.0000
Cbx        1.7899         Cby        2.5190         ex         0.0000 in
Cmx        1.0000         Cmy        1.0000         ey         0.0000 in
Braced Flange: None       kϕ              0 k
Red. Factor, R: 0         Lm         20.000 ft

Loads:          P         Mx         Vy         My         Vx
               (k)      (k-in)       (k)      (k-in)       (k)
Entered       4.890     29.990     1.130      0.000      0.000
Applied       4.890     29.990     1.130      0.000      0.000
Strength     40.787     58.268    11.362     21.949      8.452

Effective section properties at applied loads:
Ae         1.1140 in^2    Ixe        3.2076 in^4    Iye        0.8545 in^4
                          Sxe(t)     1.3225 in^3    Sye(l)     0.4878 in^3
                          Sxe(b)     1.2948 in^3    Sye(r)     0.4878 in^3

Interaction Equations
NAS Eq. C5.2.2-1   (P, Mx, My)  0.120 + 0.519 + 0.000 = 0.639 <= 1.0
NAS Eq. C5.2.2-2   (P, Mx, My)  0.099 + 0.515 + 0.000 = 0.614 <= 1.0
NAS Eq. C3.3.2-1      (Mx, Vy)     Sqrt(0.265 + 0.010)= 0.524 <= 1.0
NAS Eq. C3.3.2-1      (My, Vx)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0
```

8.2.4 **Section B - B Downpush**

Report: GeoPro-P Post Frame ADM Redbrook.sct 4/17/2015 3:44:32 PM

Member Check - 2010 North American Specification - US (LRFD)

```
Material Type: A653 SS Grade 50/1, Fy=50 ksi
Design Parameters:
Lx          3.250 ft      Ly          2.290 ft      Lt          2.290 ft
Kx         1.0000         Ky         1.0000         Kt         1.0000
Cbx        1.7899         Cby        2.5190         ex         0.0000 in
Cmx        1.0000         Cmy        1.0000         ey         0.0000 in
Braced Flange: None       kϕ              0 k
Red. Factor, R: 0         Lm         20.000 ft

Loads:          P         Mx         Vy         My         Vx
               (k)      (k-in)       (k)      (k-in)       (k)
Entered      -3.990    -25.820    -1.030      0.000      0.000
Applied      -3.990    -25.820    -1.030      0.000      0.000
Strength     52.333     58.268    11.362     21.949      8.452

Effective section properties at applied loads:
Ae         1.1140 in^2    Ixe        3.2076 in^4    Iye        0.8545 in^4
                          Sxe(t)     1.3225 in^3    Sye(l)     0.4878 in^3
                          Sxe(b)     1.2948 in^3    Sye(r)     0.4878 in^3

Interaction Equations
NAS Eq. C5.1.2-1   (Mx, My, T)  0.434 + 0.000 + 0.076 = 0.510 <= 1.0
NAS Eq. C5.1.2-2   (Mx, My, T)  0.443 + 0.000 - 0.076 = 0.367 <= 1.0
NAS Eq. C3.3.2-1      (Mx, Vy)     Sqrt(0.196 + 0.008)= 0.452 <= 1.0
NAS Eq. C3.3.2-1      (My, Vx)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0
```

8.2.5 **Section D - D Downpush**

Report: GeoPro-P Post Frame ADM Redbrook.sct 4/17/2015 3:44:32 PM

Member Check - 2010 North American Specification - US (LRFD)

```
Material Type: A653 SS Grade 50/1, Fy=50 ksi
Design Parameters:
Lx        3.590 ft     Ly         2.250 ft     Lt         2.250 ft
Kx        1.0000       Ky         1.0000       Kt         1.0000
Cbx       1.4613       Cby        2.6172       ex         0.0000 in
Cmx       1.0000       Cmy        1.0000       ey         0.0000 in
Braced Flange: None    kϕ             0 k
Red. Factor, R: 0      Lm         20.000 ft

Loads:          P          Mx         Vy         My         Vx
               (k)       (k-in)      (k)       (k-in)      (k)
Entered      -3.000     35.480      1.530      0.000      0.000
Applied      -3.000     35.480      1.530      0.000      0.000
Strength     52.333     58.268     11.362     21.949      8.452

Effective section properties at applied loads:
Ae        1.1140 in^2  Ixe        3.2076 in^4  Iye        0.8545 in^4
                       Sxe(t)     1.3225 in^3  Sye(l)     0.4878 in^3
                       Sxe(b)     1.2948 in^3  Sye(r)     0.4878 in^3

Interaction Equations
NAS Eq. C5.1.2-1  (Mx, My, T)  0.609 + 0.000 + 0.057 = 0.666 <= 1.0
NAS Eq. C5.1.2-2  (Mx, My, T)  0.609 + 0.000 - 0.057 = 0.552 <= 1.0
NAS Eq. C3.3.2-1     (Mx, Vy)     Sqrt(0.371 + 0.018)= 0.624 <= 1.0
NAS Eq. C3.3.2-1     (My, Vx)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0
```

8.2.6 **Section E - E Downpush**

Report: GeoPro-P Post Frame ADM Redbrook.sct 4/17/2015 3:44:32 PM

Member Check - 2010 North American Specification - US (LRFD)

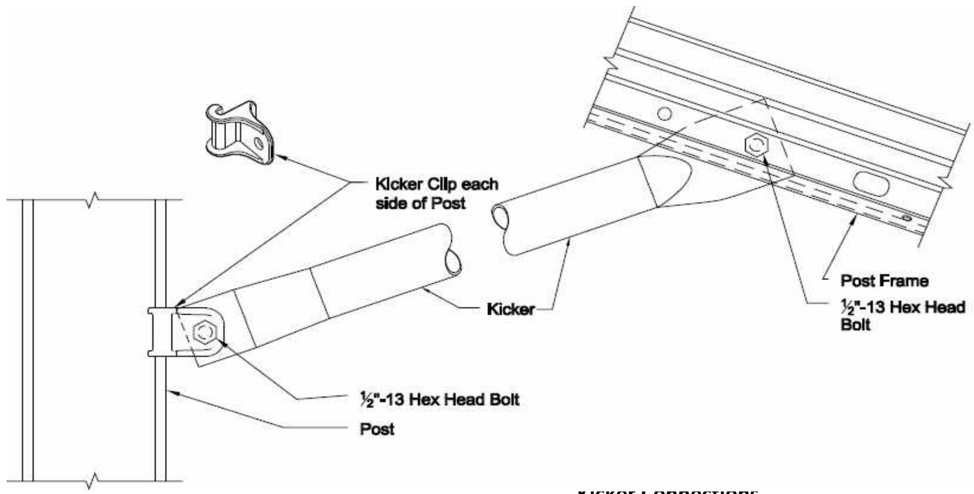
```
Material Type: A653 SS Grade 50/1, Fy=50 ksi
Design Parameters:
Lx        2.040 ft     Ly         2.040 ft     Lt         2.040 ft
Kx        2.0000       Ky         1.0000       Kt         1.0000
Cbx       1.6667       Cby        1.0000       ex         0.0000 in
Cmx       1.0000       Cmy        1.0000       ey         0.0000 in
Braced Flange: None    kϕ             0 k
Red. Factor, R: 0      Lm         20.000 ft

Loads:          P          Mx         Vy         My         Vx
               (k)       (k-in)      (k)       (k-in)      (k)
Entered      -0.540     35.480     -1.390      0.000      0.000
Applied      -0.540     35.480     -1.390      0.000      0.000
Strength     52.333     58.268     11.362     21.949      8.452

Effective section properties at applied loads:
Ae        1.1140 in^2  Ixe        3.2076 in^4  Iye        0.8545 in^4
                       Sxe(t)     1.3225 in^3  Sye(l)     0.4878 in^3
                       Sxe(b)     1.2948 in^3  Sye(r)     0.4878 in^3

Interaction Equations
NAS Eq. C5.1.2-1  (Mx, My, T)  0.609 + 0.000 + 0.010 = 0.619 <= 1.0
NAS Eq. C5.1.2-2  (Mx, My, T)  0.609 + 0.000 - 0.010 = 0.599 <= 1.0
NAS Eq. C3.3.2-1     (Mx, Vy)     Sqrt(0.371 + 0.015)= 0.621 <= 1.0
NAS Eq. C3.3.2-1     (My, Vx)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0
```

## 9.0 KICKERS




Kicker Connections

### 9.1 Material & Section Properties

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| 9.1.1 | Post Frame | | | |
| 9.1.2 | Material = | GB/T 1591 Gr. Q345B | | |
| 9.1.3 | $F_y$ = | 50.8 | ksi | Miminum yield stress |
| 9.1.4 | $F_u$ = | 60.9 | ksi | Tensile stress |
| 9.1.5 | t = | 0.0787 | in. | thickness |
| 9.1.6 | Kicker | | | |
| 9.1.7 | Material = | Q345-B PER GB/T 1591-2008 | | |
| 9.1.8 | $F_y$ = | 50.0 | ksi | GB/R 3091-2008 Table 3; Miminum yield stress |
| 9.1.9 | $F_u$ = | 68.2 | ksi | GB/R 3091-2008 Table 3; Tensile stress |
| 9.1.10 | t = | 0.098 | in. | Wall thickness |
| 9.1.12 | tflat = | | | |
| 9.1.13 | $a_{top}$ = | 0.720 | in. | minimum extension beyond bearing end of top pin |
| 9.1.14 | $a_{bot}$ = | 0.460 | in. | minimum extension beyond bearing end of bottom pin |
| 9.1.15 | E = | 29000.00 | ksi | Modulus of Elasticity |
| 9.1.16 | $L_{north}$ = | 52.00 | in. | length of North Kicker from pin to pin |
| 9.1.17 | $L_{south}$ = | 38.00 | in. | length of South Kicker from pin to pin |
| 9.1.18 | d_outer = | 2.36 | in. | outer diameter |
| 9.1.19 | d_inner = | 2.17 | in. | inner diameter |
| 9.1.20 | r = | 0.80 | in. | radius of gyration |
| 9.1.21 | Kicker Clip | | | |
| 9.1.22 | Material = | GB/T 1348 Gr. QT600-3 | | |
| 9.1.23 | $F_y$ = | 46.4 | ksi | AISC 13 Table 2-3; Miminum yield stress |
| 9.1.24 | $F_u$ = | 72.5 | ksi | AISC 13 Table 2-3; Tensile stress |
| 9.1.25 | t = | 0.220 | in. | thickness at bolt hole |
| 9.1.26 | Bolts | | | |
| 9.1.27 | Material = | A325 | | |
| 9.1.28 | $F_y$ = | 92.0 | ksi | Minimum yield stress |
| 9.1.29 | $F_u$ = | 120.0 | ksi | Tensile stress |
| 9.1.30 | $F_{nt}$ = | 90.0 | ksi | Nominal tensile stress |
| 9.1.31 | $F_{nv}$ = | 48.0 | ksi | Nominal shear stress |
| 9.1.32 | d = | 0.50 | in. | Bolt diameter |
| 9.1.33 | $A_b$ = | 0.196 | $in.^2$ | Cross section area of bolt |

**9.2 Max Factored Forces in North Kicker**

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| 9.2.1 | $R_x$ = | 3.274 | kip | Max factored Kicker reaction - horizontal |
| 9.2.2 | $R_Z$ = | 4.447 | kip | Max factored Kicker reaction - vertical |

**9.3 North Kicker-to-Post Frame Connection**

Limit State of Bolt Bearing on Kicker

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| 9.3.1 | $\phi$ = | 0.75 | | AISC 13th J3.10 - Bearing Strength |
| 9.3.2 | $\phi R_N$ = | 10.06 | kip | $\phi \cdot 2.0 \cdot d \cdot t \cdot F_u$ (Equation J3-6c) |
| 9.3.3 | $R_u$ = | 5.523 | kip | $\sqrt{(R_x^2 + R_Z^2)}$ |
| 9.3.4 | D/C = | 0.549 | | OK |

Limit State of Bolt Bearing on Post Frame

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| 9.3.5 | $\phi$ = | 0.65 | | AISI NACFSS 2012 |
| 9.3.6 | d/t = | 6.35 | | bolt dia / thickness ratio |
| 9.3.7 | C = | 3 | | Bearing Factor - Table E3.3.1-1 |
| 9.3.8 | $m_f$ = | 1 | | Modification Factor - Table E3.3.1-2 |
| 9.3.9 | $\phi R_N$ = | 9.35 | kip | = $\phi \cdot C \cdot mf \cdot d \cdot 2t \cdot F_u$ ( Eq E3.3.1-1) - 2 sides of Post Frame |
| 9.3.10 | $R_u$ = | 5.523 | kip | $\sqrt{(R_x^2 + R_Z^2)}$ |
| 9.3.11 | D/C = | 0.590 | | OK |

Limit State of Bolt Shear (Top Bolt)

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| 9.3.12 | $\phi$ = | 0.75 | | AISC 13th J3.6 Shear Strength |
| 9.3.13 | $\phi R_N$ = | 14.14 | kip | 2(double shear)*$\phi$*$F_{nv}$*$A_b$ (Equation J3-1) |
| 9.3.14 | $R_u$ = | 5.523 | kip | $\sqrt{(R_x^2 + R_Z^2)}$ |
| 9.3.15 | D/C = | 0.391 | | OK |

**9.4 North Kicker-to-Kicker Clip Connection Strength Check**

Limit State of Bolt Bearing on Kicker Clip

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| 9.4.1 | $\phi$ = | 0.75 | | AISC 13th J3.10 - Bearing Strength |
| 9.4.2 | $\phi R_N$ = | 35.90 | kip | $\phi \cdot 3.0 \cdot d \cdot t \cdot F_u$ (Equation J3-6b) |
| 9.4.3 | $R_u$ = | 5.523 | kip | $\sqrt{(R_x^2 + R_Z^2)}$ |
| 9.4.4 | D/C = | 0.154 | | OK |

| | | | | |
|---|---|---|---|---|
| **9.5** | **North Kicker Strut (Compression) D/C Ratio Check** | | | |
| | <u>Demand to Capacity Relationship</u> | | | |
| 9.5.1 | $\phi$ = | 0.90 | | AISC 13th J3.10 - Bearing Strength |
| 9.5.2 | kL/r = | 64.91 | | where k = 1 |
| 9.5.3 | $4.71\cdot\sqrt{(E/F_y)}$ = | 113.39 | | AISC 13th E3 equation E3 |
| 9.5.4 | $F_e$= | 67.93 | ksi | elastic critical buckling stress (Equation E3-4) |
| 9.5.5 | $F_{cr}$ = | 36.76 | ksi | flexural buckling stress (Equation E3-2 or E3-3) |
| 9.5.6 | $A_g$ = | 0.70 | $in^2$ | gross cross sectional area |
| 9.5.7 | $\phi P_n$ = | 23.16 | kip | nominal compressive strength (Equation E3-1) |
| 9.5.8 | $P_u$ = | 5.523 | kip | max factored compression in North Kicker |
| 9.5.9 | D/C = | 0.238 | | OK |

| | | | | |
|---|---|---|---|---|
| **9.6** | **North Kicker Tie (Tension) D/C Ratio Check** | | | |
| | <u>Demand to Capacity Relationship</u> | | | |
| 9.6.1 | $\phi_{t,gross}$ = | 0.90 | | AISC 13th Equation D2-1 - Yielding in Gross Section |
| 9.6.2 | $A_g$ = | 0.70 | $in^2$ | gross cross sectional area |
| 9.6.3 | $\phi_{t,gross}P_{n,gross}$ = | 31.52 | kip | $\phi_{t,gross}\cdot F_y\cdot A_g$ (AISC 13th Equation D2-1 - Yielding in Gross Section) |
| 9.6.4 | $b_{eff}$ = | 1.024 | in | $2\cdot t + 0.63$ in |
| 9.6.5 | $\phi_{t,net}$ = | 0.75 | | AISC 13th Equation D5-1 - Tensile Rupture in Net Effective Area |
| 9.6.6 | $\phi_{t,net}P_{n,net}$ = | 20.61 | kip | $\phi_{t,net}\cdot 2\cdot t\cdot b_{eff}\cdot F_u$ (AISC 13th Equation D5-1 - Tensile Rupture in Net Effective Area) |
| 9.6.7 | $A_{sf}$ = | 0.382 | $in^2$ | $2\cdot t\cdot(a+d/2)$ |
| 9.6.8 | $\phi_{sf}$ = | 0.75 | | AISC 13th Equation D5-2 - Shear Rupture in Net Effective Area |
| 9.6.9 | $\phi_{sf}P_{n,sf}$ = | 11.71 | kip | $\phi_{sf}\cdot 0.6\cdot F_u\cdot A_{sf}$ (AISC 13th Equation D5-2 - Shear Rupture in Net Effective Area) |
| 9.6.10 | $P_u$ = | -5.160 | kip | max factored tension in North Kicker |
| 9.6.11 | D/C = | 0.440 | | OK |

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| **9.7** | **Max Factored Forces in South Kicker** | | | |
| 9.7.1 | $R_x$ = | 3.459 | kip | Max factored Kicker reaction - horizontal |
| 9.7.2 | $R_Z$ = | 1.609 | kip | Max factored Kicker reaction - vertical |
| **9.8** | **South Kicker-to-Post Frame Connection** | | | |
| | Limit State of Bolt Bearing on Kicker | | | |
| 9.8.1 | $\phi$ = | 0.75 | | AISC 13th J3.10 - Bearing Strength |
| 9.8.2 | $\phi R_N$ = | 10.06 | kip | $\phi \cdot 2.0 \cdot d \cdot t \cdot F_u$ (Equation J3-6c) |
| 9.8.3 | $R_u$ = | 3.815 | kip | $\sqrt{( R_x^2 + R_Z^2 )}$ |
| 9.8.4 | D/C = | 0.379 | | OK |
| | Limit State of Bolt Bearing on Post Frame | | | |
| 9.8.5 | $\phi$ = | 0.65 | | AISI NACFSS 2012 |
| 9.8.6 | d/t = | 6.35 | | bolt dia / thickness ratio |
| 9.8.7 | C = | 3 | | Bearing Factor - Table E3.3.1-1 |
| 9.8.8 | $m_f$ = | 0.75 | | Modification Factor - Table E3.3.1-2 |
| 9.8.9 | $\phi R_N$ = | 7.01 | kip | = $\phi \cdot C \cdot mf \cdot d \cdot 2t \cdot F_u$ ( Eq E3.3.1-1) - 2 sides of Post Frame |
| 9.8.10 | $R_u$ = | 3.815 | kip | $\sqrt{( R_x^2 + R_Z^2 )}$ |
| 9.8.11 | D/C = | 0.544 | | OK |
| | Limit State of Bolt Shear (Top Bolt) | | | |
| 9.8.12 | $\phi$ = | 0.75 | | AISC 13th J3.6 Shear Strength |
| 9.8.13 | $\phi R_N$ = | 14.14 | kip | 2(double shear)*$\phi$*$F_{nv}$*$A_b$ (Equation J3-1) |
| 9.8.14 | $R_u$ = | 3.815 | kip | $\sqrt{( R_x^2 + R_Z^2 )}$ |
| 9.8.15 | D/C = | 0.270 | | OK |
| **9.9** | **South Kicker-to-Kicker Clip Connection Strength Check** | | | |
| | Limit State of Bolt Bearing on Kicker Clip | | | |
| 9.9.1 | $\phi$ = | 0.75 | | AISC 13th J3.10 - Bearing Strength |
| 9.9.2 | $\phi R_N$ = | 35.90 | kip | $\phi \cdot 3.0 \cdot d \cdot t \cdot F_u$ (Equation J3-6b) |
| 9.9.3 | $R_u$ = | 3.815 | kip | $\sqrt{( R_x^2 + R_Z^2 )}$ |
| 9.9.4 | D/C = | 0.106 | | OK |

**9.10 South Kicker Strut (Compression) D/C Ratio Check**

Demand to Capacity Relationship

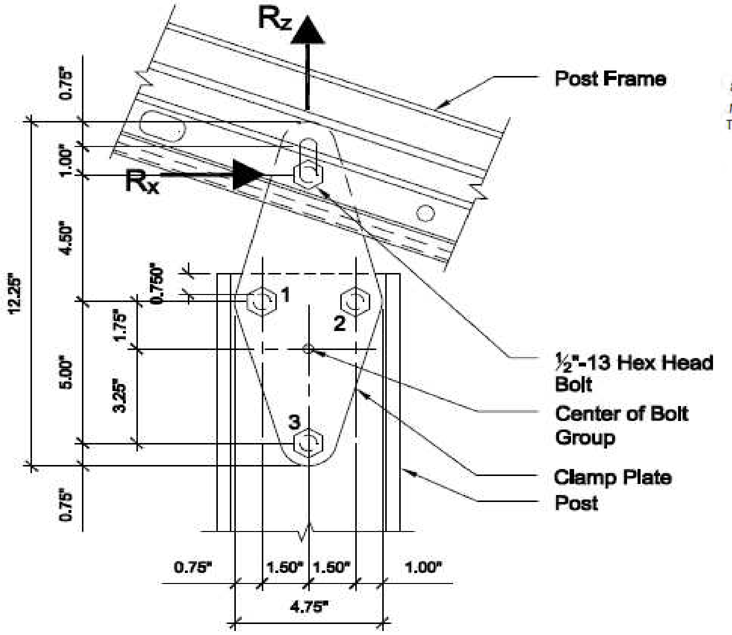
| | | | | |
|---|---|---|---|---|
| 9.10.1 | $\phi$ = | 0.90 | | AISC 13th J3.10 - Bearing Strength |
| 9.10.2 | kL/r = | 47.43 | | where k = 1 |
| 9.10.3 | $4.71 \cdot \sqrt{(E/F_y)}$ = | 113.39 | | AISC 13th E3 equation E3 |
| 9.10.4 | $F_e$= | 127.21 | ksi | elastic critical buckling stress (Equation E3-4) |
| 9.10.5 | $F_{cr}$ = | 42.44 | ksi | flexural buckling stress (Equation E3-2 or E3-3) |
| 9.10.6 | $A_g$ = | 0.70 | $in^2$ | gross cross sectional area |
| 9.10.7 | $\phi P_n$ = | 26.74 | kip | nominal compressive strength (Equation E3-1) |
| 9.10.8 | $P_u$ = | 0.794 | kip | max factored compression in South Kicker |
| 9.10.9 | D/C = | 0.030 | | OK |

**9.11 South Kicker Tie (Tension) D/C Ratio Check**

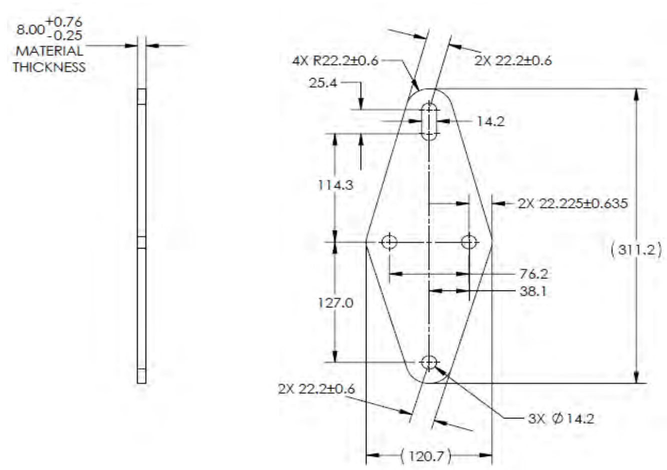
Demand to Capacity Relationship

| | | | | |
|---|---|---|---|---|
| 9.11.1 | $\phi_{t,gross}$ = | 0.90 | | AISC 13th Equation D2-1 - Yielding in Gross Section |
| 9.11.2 | $A_g$ = | 0.70 | $in^2$ | gross cross sectional area |
| 9.11.3 | $\phi_{t,gross}P_{n,gross}$ = | 31.52 | kip | $\phi_{t,gross} \cdot F_y \cdot A_g$ (AISC 13th Equation D2-1 - Yielding in Gross Section) |
| 9.11.4 | $b_{eff}$ = | 1.024 | in | $2 \cdot t + 0.63$ in |
| 9.11.5 | $\phi_{t,net}$ = | 0.75 | | AISC 13th Equation D5-1 - Tensile Rupture in Net Effective Area |
| 9.11.6 | $\phi_{t,net}P_{n,net}$ = | 20.61 | kip | $\phi_{t,net} \cdot 2 \cdot t \cdot b_{eff} \cdot F_u$ (AISC 13th Equation D5-1 - Tensile Rupture in Net Effective Area) |
| 9.11.7 | $A_{sf}$ = | 0.382 | $in^2$ | $2 \cdot t \cdot (a+d/2)$ |
| 9.11.8 | $\phi_{sf}$ = | 0.75 | | AISC 13th Equation D5-2 - Shear Rupture in Net Effective Area |
| 9.11.9 | $\phi_{sf}P_{n,sf}$ = | 11.71 | kip | $\phi_{sf} \cdot 0.6 \cdot F_u \cdot A_{sf}$ (AISC 13th Equation D5-2 - Shear Rupture in Net Effective Area) |
| 9.11.10 | $P_u$ = | -3.815 | kip | max factored tension in South Kicker |
| 9.11.11 | D/C = | 0.326 | | OK |

## 10.0 CLAMP PLATE CONNECTION CALCULATION




Clamp Plate Connection




Clamp Plate Detail

### 10.1 Material Properties and Dimensions

| | Variable | Value | Units | Comment/Reference |
|---|---|---|---|---|
| | Post Frame | | | |
| | Material = | GB/T 1591 Gr. Q345B | | |
| 10.1.1 | $F_y$ = | 50.8 | ksi | Miminum yield stress |
| 10.1.2 | $F_u$ = | 60.9 | ksi | Minimum tensile stress |
| 10.1.3 | t = | 0.0787 | in | thickness |
| | Clamp Plate | | | |
| | Material = | Q345-B PER GB/T 1591-2008 | | |
| 10.1.4 | $F_y$ = | 50.0 | ksi | Miminum yield stress |
| 10.1.5 | $F_u$ = | 68.2 | ksi | Minimum tensile stress |
| 10.1.6 | t = | 0.3150 | in | thickness |
| 10.1.7 | $l_c$ = | 0.594 | in | clear distance to edge |
| | Post | | | |
| | Material = | ASTM A992 | | |
| 10.1.8 | $F_y$ = | 50.0 | ksi | AISC 13 Table 2-3; Miminum yield stress |
| 10.1.9 | $F_u$ = | 65.0 | ksi | AISC 13 Table 2-3; Tensile stress |
| | $t_w$ | | | web thickness may vary - see below |
| | $l_c$ = | 0.719 | in | clear distance to top of post |

Bolts

| | | | | |
|---|---|---|---|---|
| | Material = | A325 | | |
| 10.1.10 | $F_y$ = | 92.0 | ksi | Minimum yield stress |
| 10.1.11 | $F_u$ = | 120.0 | ksi | Tensile stress |
| 10.1.12 | $F_{nt}$ = | 90.0 | ksi | Nominal tensile stress |
| 10.1.13 | $F_{nv}$ = | 48.0 | ksi | Nominal shear stress |
| 10.1.14 | d = | 0.50 | in. | Bolt diameter |
| 10.1.15 | $A_b$ = | 0.196 | $in.^2$ | Cross section area of bolt |

**10.2 Connection Demands - Shear at Post Frame Post**

| | **N Row** | **E/W Edge** | **N23 Rows** | **S Row** | **Interior** | Zones per SunLink BLWT Report |
|---|---|---|---|---|---|---|
| Post size W6 x _ | W6x9 | W6x9 | W6x9 | W6x9 | W6x9 | |
| web thickness | 0.170 | 0.170 | 0.170 | 0.170 | 0.170 | in |
| LC 1 - Rx | 3.808 | 4.236 | 4.653 | 4.791 | 3.721 | kips |
| LC 1 - Rz | -1.325 | -1.481 | -1.637 | -1.688 | -1.314 | |
| LC 1 - Ru | 4.032 | 4.49 | 4.93 | 5.08 | 3.95 | Load Case 1 - Resultant Bolt Shear |
| LC 2 - Rx | -0.920 | -0.061 | -0.839 | -0.125 | -0.478 | kips |
| LC 2 - Rz | 0.128 | -0.177 | 0.088 | -0.152 | -0.026 | |
| LC 2 - Ru | 0.929 | 0.187 | 0.844 | 0.197 | 0.479 | Load Case 2 - Resultant Bolt Shear |
| LC 3 - Rx | 0.120 | 0.550 | 0.221 | 0.518 | 0.402 | kips |
| LC 3 - Rz | -0.490 | -0.643 | -0.569 | -0.631 | -0.626 | |
| LC 3 - Ru | 0.504 | 0.846 | 0.610 | 0.816 | 0.744 | Load Case 3 - Resultant Bolt Shear |

### 10.3 Clamp Plate-to-Post Frame Connection Strength Check

| | | | | |
|---|---|---|---|---|
| 10.3.1 | $\phi =$ | 0.75 | - | AISC 13th J3.10 - Bearing Strength |
| 10.3.2 | $\phi R_{N1} =$ | 9.57 | kip | $\phi \cdot 1.0 \cdot L_C \cdot t \cdot F_u$ (Equation J3-6c) |
| 10.3.3 | $\phi R_{N2} =$ | 16.10 | kip | $\phi \cdot 2.0 \cdot d \cdot t \cdot F_u$ (Equation J3-6c) |
| 10.3.4 | $\phi R_N =$ | 9.57 | kip | Minimum of 2 possible conditions per the two equations above |
| 10.3.5 | $R_u =$ | 5.080 | kip | max. factored shear demand - Section 10.2 above |
| 10.3.6 | D/C = | 0.531 | - | OK |

<u>Limit State of Bolt Bearing on Post Frame</u>

| | | | | |
|---|---|---|---|---|
| 10.3.7 | $\phi =$ | 0.65 | - | AISI NACFSS 2012 |
| 10.3.8 | d/t = | 6.35 | | bolt dia / thickness ratio |
| 10.3.9 | C = | 3 | | Bearing Factor - Table E3.3.1-1 |
| 10.3.10 | mf = | 0.75 | | Modification Factor - Table E3.3.1-2 |
| 10.3.11 | $\phi R_N =$ | 7.01 | kip | $= \phi \cdot C \cdot mf \cdot d \cdot 2t \cdot F_u$ ( Eq E3.3.1-1) - 2 sides of Post Frame |
| 10.3.12 | $R_u =$ | 5.080 | kip | max. factored shear demand - Section 10.2 above |
| 10.3.13 | D/C = | 0.724 | - | OK |

<u>Limit State of Bolt Shear</u>

| | | | | |
|---|---|---|---|---|
| 10.3.14 | $\phi =$ | 0.75 | | AISI NACFSS 2012 E3.4 (Appendix A) |
| 10.3.15 | $\phi R_N =$ | 7.07 | | $= \phi \cdot A_b \cdot F_{nt}$ ( Eq E3.4-1) |
| 10.3.16 | D/C = | 0.719 | - | OK |

## 10.4 Clamp Plate-to-Post: Calculate Demands on Bolts

Properties of 3-bolt group (see sketch above):

| | x | z |
|---|---|---|
| Bolts 1 & 2 | 1.5 | 1.75 |
| Bolt 3 | 0 | 3.25 |

Ix = 16.6875 in2
Iz = 4.5 in2
Iy = 21.1875 in2

Calculate bolt forces:

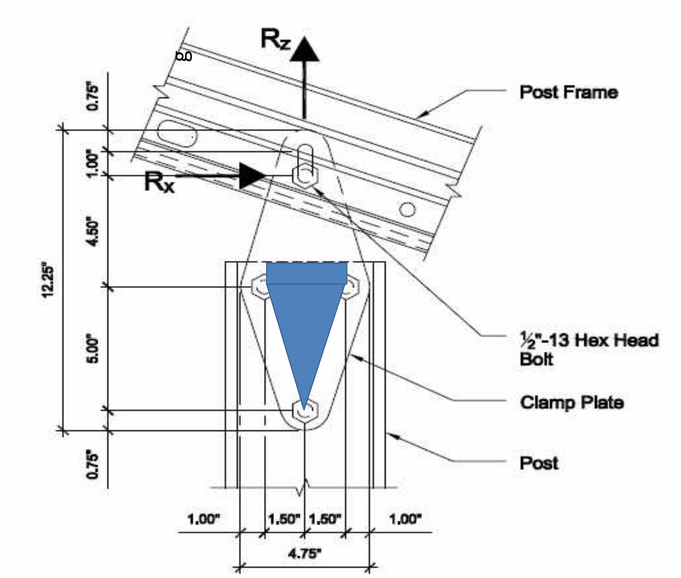
| | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|
| arm_z | 7.250 | 7.250 | 7.250 | 7.250 | 7.250 | in |
| **LC1: Wind Uplift: 0.9D+1.6W** | | | | | | |
| Rx | 3.808 | 4.236 | 4.653 | 4.791 | 3.721 | kip |
| Rz | -1.325 | -1.481 | -1.637 | -1.688 | -1.314 | kip |
| My = Rx·arm_z | 27.608 | 30.711 | 33.734 | 34.735 | 26.977 | kip |
| Bolts 1 & 2 | | | | | | |
| Vx | 3.550 | 3.949 | 4.337 | 4.466 | 3.469 | kip |
| Vz | -0.442 | -0.494 | -0.546 | -0.563 | -0.438 | kip |
| V | 3.577 | 3.979 | 4.371 | 4.501 | 3.496 | kip |
| Bolt 3 | | | | | | |
| Vx | -3.617 | -4.024 | -4.420 | -4.551 | -3.534 | kip |
| Vz | -0.442 | -0.494 | -0.546 | -0.563 | -0.438 | kip |
| V | 3.644 | 4.054 | 4.453 | 4.585 | 3.561 | kip |
| **LC2: Wind Downpush: 1.2D+1.6W+0.5S** | | | | | | |
| Rx | -0.920 | -0.061 | -0.839 | -0.125 | -0.478 | kip |
| Rz | 0.128 | -0.177 | 0.088 | -0.152 | -0.026 | kip |
| My = Rx·arm_z | -6.670 | -0.442 | -6.083 | -0.906 | -3.466 | kip |
| Bolts 1 & 2 | | | | | | |
| Vx | -0.858 | -0.057 | -0.782 | -0.117 | -0.446 | kip |
| Vz | 0.043 | -0.059 | 0.029 | -0.051 | -0.009 | kip |
| V | 0.859 | 0.082 | 0.783 | 0.127 | 0.446 | kip |
| Bolt 3 | | | | | | |
| Vx | 0.874 | 0.058 | 0.797 | 0.119 | 0.454 | kip |
| Vz | 0.043 | -0.059 | 0.029 | -0.051 | -0.009 | kip |
| V | 0.875 | 0.083 | 0.797 | 0.129 | 0.454 | kip |
| **LC3: Snow: 1.2D+0.8W+1.6S** | | | | | | |
| Rx | 0.120 | 0.550 | 0.221 | 0.518 | 0.402 | kip |
| Rz | -0.490 | -0.643 | -0.569 | -0.631 | -0.626 | kip |
| My = Rx·arm_z | 0.870 | 3.988 | 1.602 | 3.756 | 2.915 | kip |
| Bolts 1 & 2 | | | | | | |
| Vx | 0.112 | 0.513 | 0.206 | 0.483 | 0.375 | kip |
| Vz | -0.163 | -0.214 | -0.190 | -0.210 | -0.209 | kip |
| V | 0.198 | 0.556 | 0.280 | 0.527 | 0.429 | kip |
| Bolt 3 | | | | | | |
| Vx | -0.114 | -0.522 | -0.210 | -0.492 | -0.382 | kip |
| Vz | -0.163 | -0.214 | -0.190 | -0.210 | -0.209 | kip |
| V | 0.199 | 0.565 | 0.283 | 0.535 | 0.435 | kip |

### 10.5 Clamp Plate-to-Post Connection Strength Check

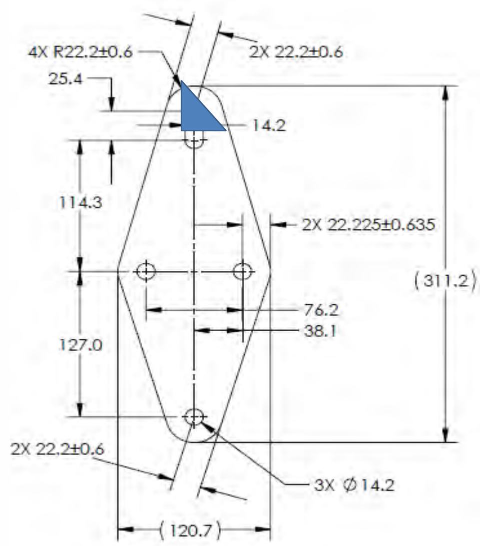
Limit State of Bolt Bearing on Post

| | N Row | E/W Edge | N23 Rows | S Row | Interior | | |
|---|---|---|---|---|---|---|---|
| tw = | 0.170 | 0.170 | 0.170 | 0.170 | 0.170 | in. | Post web thickness |
| $l_c$ = | 0.719 | | | | | in. | clear distance to top of post |
| d = | 0.50 | | | | | in. | bolt diameter |
| $\phi$ = | 0.75 | | | | | - | AISC 13th J3.10 - Bearing Strength |
| $\phi R_{N1}$ = | 8.93 | 8.93 | 8.93 | 8.93 | 8.93 | kip | $\phi \cdot 1.5 \cdot l_c \cdot t \cdot F_u$ (Equation J3-6b) |
| $\phi R_{N2}$ = | 12.43 | 12.43 | 12.43 | 12.43 | 12.43 | kip | $\phi \cdot 3 \cdot d \cdot t \cdot F_u$ (Equation J3-6b) |
| $\phi R_N$ = | 8.93 | 8.93 | 8.93 | 8.93 | 8.93 | kip | Minimum of $\phi R_{N1}$ & $\phi R_{N2}$ |
| $R_u$ = | 3.644 | 4.054 | 4.453 | 4.585 | 3.561 | kip | Bolt 3 - LC 1 governs |
| D/C = | 0.408 | 0.454 | 0.498 | 0.513 | 0.399 | | |

## 10.6 Block Shear Checks




Potential Block for Block Shear on Post




Potential Block for Block Shear on Clamp Plate

### 10.6.1 Limit State of Block Shear Rupture of Post

$\phi$ = 0.75 - AISC 13th J4-5

| | N Row | E/W Edge | N23 Rows | S Row | Interior | | |
|---|---|---|---|---|---|---|---|
| $A_{gv}$ = | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | in.$^2$ | Gross area subject to shear |
| $A_{nt}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | in.$^2$ | Net area subject to tension = 0 |
| $A_{nv}$ = | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | in.$^2$ | Net area subject to shear |
| $U_{bs}$ = | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | - | AISC 13th J4-3 |
| $R_{N1}$ = | 34.22 | 34.22 | 34.22 | 34.22 | 34.22 | kip | $0.6F_uA_{nv} + U_{bs}F_uA_{nt}$ |
| $R_{N2}$ = | 30.60 | 30.60 | 30.60 | 30.60 | 30.60 | kip | $0.6F_yA_{gv} + U_{bs}F_uA_{nt}$ |
| $\phi R_N$ = | 45.90 | 45.90 | 45.90 | 45.90 | 45.90 | kip | $\phi$(2 sides)*min($R_{N1}$, $R_{N2}$) |
| $R_u$ = | 5.080 | 5.080 | 5.080 | 5.080 | 5.080 | - | sqrt( $R_X^2 + R_Z^2$ ) |
| D/C = | 0.111 | 0.111 | 0.111 | 0.111 | 0.111 | - | OK |

### 10.6.2 Limit State of Block Shear Rupture of Clamp Plate

| | | | |
|---|---|---|---|
| $\phi$ = | 0.75 | - | AISC 13th J4-5 |
| $A_{gv}$ = | 0.43 | in.$^2$ | Gross area subject to shear = (.75"+1"/2)*(t) |
| $A_{nt}$ = | 0.19 | in.$^2$ | Net area subject to tension = (22.2mm-0.5*14.2mm)*(t) |
| $A_{nv}$ = | 0.15 | in.$^2$ | Net area subject to shear = (.75"-0.5*0.56")*(t) |
| $U_{bs}$ = | 0.50 | - | |
| $R_{N1}$ = | 12.56 | kip | $0.6F_uA_{nv} + U_{bs}F_uA_{nt}$ |
| $R_{N2}$ = | 19.50 | kip | $0.6F_yA_{gv} + U_{bs}F_uA_{nt}$ |
| $\phi R_N$ = | 18.84 | kip | 2(sides)*minimum of 2 possible conditions |
| $R_u$ = | 5.080 | kip | max demand |
| D/C = | 0.270 | - | OK |

## 10.7 Clamp Plate Capacity Checks

**LC4: Seismic 1.2D + 0.2S + 1E**

| | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|
| $R_x$ = | 0.950 | 0.950 | 0.950 | 0.950 | 0.950 | kip |
| $R_z$ = | 0.574 | 0.574 | 0.574 | 0.574 | 0.574 | kip |
| $R_y$ = | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | kip |

**Check stresses on net section at upper bolts in post:**

| | | | |
|---|---|---|---|
| $A_{net}$ = | 1.14 | in2 | |
| $Z_{xx}$ = | 0.090 | in3 | about weak axis |
| $Z_{yy}$ = | 1.248 | in3 | |
| r = | 0.0909 | in | |
| arm = L = | 5.5 | in | |
| k = | 1 | (cons.) | |
| kL/r = | 60.49 | | |
| 4.71·√(E/Fy) = | 113.39 | | |
| $F_e$ = | 78.22 | ksi | |
| $F_{cr}$ = | 38.28 | ksi | |
| $\phi_b = \phi_c$ = | 0.90 | | |
| $P_c = \phi_c \cdot F_{cr} \cdot A_{net}$ = | 39.41 | kip | |
| $M_{cx}$ = | 4.06 | kip·in | |
| $M_{cy}$ = | 56.22 | kip·in | |

| | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|
| $P_r$ = | 0.574 | 0.574 | 0.574 | 0.574 | 0.574 | kip |
| $P_r/P_c$ = | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | |
| $M_{rx}$ = | 2.433 | 2.433 | 2.433 | 2.433 | 2.433 | kip·in |
| $M_{ry}$ = | 5.226 | 5.226 | 5.226 | 5.226 | 5.226 | kip·in |
| Interaction | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | < 1 OK AISC 360-05 Eq. H1-1b |

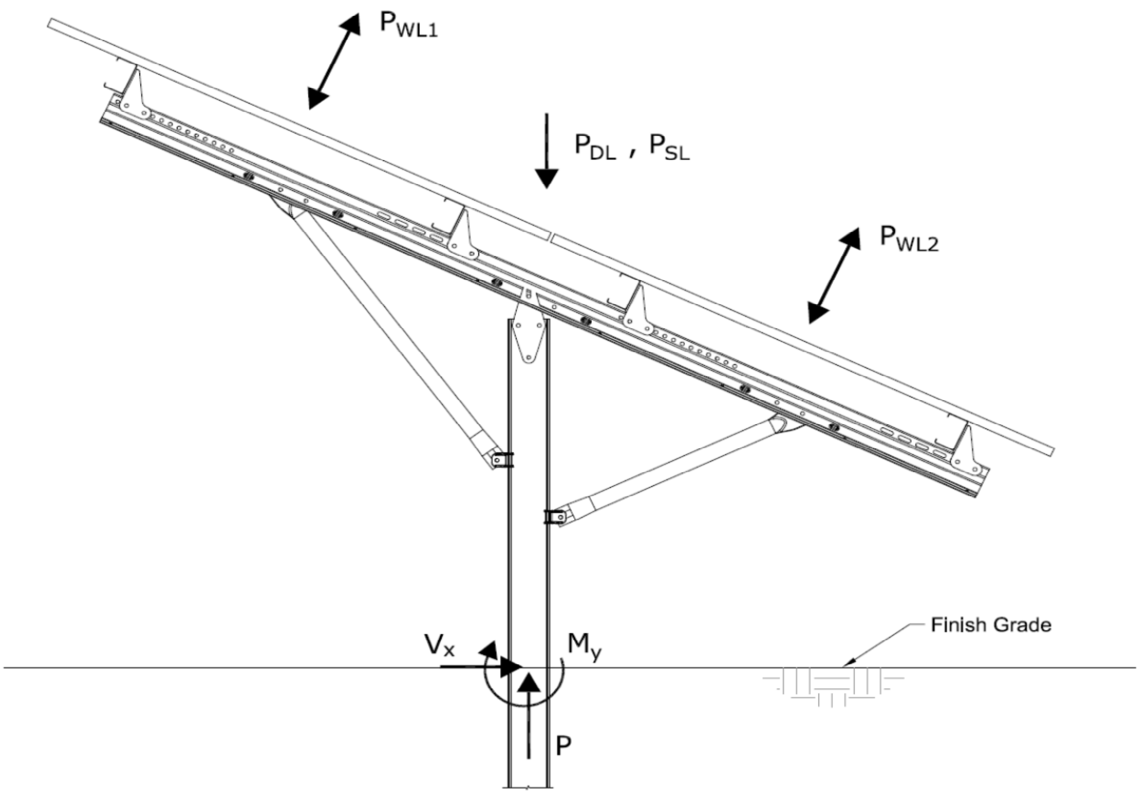
**LC2: Wind Downpush: 1.2D+1.6W+0.5S**

| | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|
| $R_x$ = | -0.920 | -0.061 | -0.839 | -0.125 | -0.478 | kip |
| $R_z$ = | 0.128 | -0.177 | 0.088 | -0.152 | -0.026 | kip |

**Check compressive stress assuming net section at upper boltfor full height:**

| | N Row | E/W Edge | N23 Rows | S Row | Interior | |
|---|---|---|---|---|---|---|
| $P_r$ = | 0.128 | -0.177 | 0.088 | -0.152 | -0.026 | kip |
| $P_r/P_c$ = | 0.003 | -0.004 | 0.002 | -0.004 | -0.001 | |
| $M_{ry}$ = | -5.060 | -0.336 | -4.615 | -0.688 | -2.629 | kip·in |
| Interaction | 0.092 | 0.004 | 0.083 | 0.010 | 0.046 | < 1 OK AISC 360-05 Eq. H1-1b |

## 11.0 POSTS



**Post demands at 1' below grade:**

| 11.1 Unfactored Post Load Demands | N. Row | E/W Edge | N23 Rows | S. Row | Interior | | References / Notes |
|---|---|---|---|---|---|---|---|
| Table Size (2x) | 6 | 6 | 6 | 6 | 6 | | Array zone |
| **Dead (D)** | | | | | | | |
| Axial demand P = | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | kip | |
| Major axis moment demand $M_Y$ = | 2.69 | 2.69 | 2.69 | 2.69 | 2.69 | kip-in | |
| **Snow (S)** | | | | | | | |
| Axial demand P = | 2.88 | 2.88 | 2.88 | 2.88 | 2.88 | kip | |
| Major axis moment demand $M_Y$ = | 14.83 | 14.83 | 14.83 | 14.83 | 14.83 | kip-in | |
| **Wind - Uplift (W)** | | | | | | | |
| Axial demand P = | -2.09 | -2.12 | -2.05 | -2.05 | -1.66 | kip | |
| Major axis shear demand $V_x$ = | 0.97 | 0.99 | 0.96 | 0.96 | 0.77 | kip | |
| Major axis moment demand $M_Y$ = | 110.09 | 120.32 | 127.87 | 129.98 | 101.43 | kip-in | |
| **Wind - Downpush (W)** | | | | | | | |
| Axial demand P = | 2.04 | 1.99 | 1.95 | 1.91 | 1.17 | kip | |
| Major axis shear demand $V_x$ = | -0.95 | -0.93 | -0.91 | -0.89 | -0.55 | kip | |
| Major axis moment demand $M_Y$ = | -27.17 | -5.78 | -25.94 | -7.19 | -18.39 | kip-in | |
| **Seismic (E)** | | | | | | | |
| Major axis shear demand $V_x$ = | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | kip | $V = C_s*W$ |
| Minor axis shear demand $V_Y$ = | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | kip | $V = C_s*W$ |
| Major axis moment demand $M_Y$ = | 33.12 | 33.12 | 33.12 | 33.12 | 33.12 | kip-in | $V_X*d_{\text{panel c.g. to ground}}$ |
| Minor axis moment demand $M_x$ = | 33.12 | 33.12 | 33.12 | 33.12 | 33.12 | kip-in | $V_Y*d_{\text{panel c.g. to ground}}$ |

| 11.2 ASD Factored Post Load Combinations | N. Row | E/W Edge | N23 Rows | S. Row | Interior | | Array zone |
|---|---|---|---|---|---|---|---|
| **1D+1S** | | | | | | | |
| Axial demand P = | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | kip | |
| Major axis moment demand $M_Y$ = | 17.52 | 17.52 | 17.52 | 17.52 | 17.52 | kip-in | |
| **1D+1W** | | | | | | | |
| Axial demand P = | 2.56 | 2.51 | 2.47 | 2.43 | 1.69 | kip | |
| Major axis shear demand $V_x$ = | -0.95 | -0.93 | -0.91 | -0.89 | -0.55 | kip | |
| Major axis moment demand $M_Y$ = | -24.49 | -3.09 | -23.25 | -4.50 | -15.70 | kip-in | |
| **1D+0.75W+0.75S** | | | | | | | |
| Axial demand P = | 4.21 | 4.18 | 4.14 | 4.11 | 3.56 | kip | |
| Major axis shear demand $V_x$ = | -0.71 | -0.70 | -0.68 | -0.67 | -0.41 | kip | |
| Major axis moment demand $M_Y$ = | -6.57 | 9.47 | -5.64 | 8.42 | 0.02 | kip-in | |
| **0.6D+1W** | | | | | | | |
| Axial demand P = | -1.77 | -1.80 | -1.74 | -1.74 | -1.34 | kip | |
| Major axis shear demand $V_x$ = | 0.97 | 0.99 | 0.96 | 0.96 | 0.77 | kip | |
| Major axis moment demand $M_Y$ = | 111.70 | 121.93 | 129.49 | 131.60 | 103.04 | kip-in | |
| **1D+0.7E** | | | | | | | |
| Axial demand P = | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | kip | |
| Minor axis shear demand $V_Y$ = | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | kip | |
| Minor axis moment demand $M_x$ = | 23.18 | 23.18 | 23.18 | 23.18 | 23.18 | kip-in | |
| **1D+0.525E+0.75S** | | | | | | | |
| Axial demand P = | 2.68 | 2.68 | 2.68 | 2.68 | 2.68 | kip | |
| Minor axis shear demand $V_Y$ = | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | kip | |
| Minor axis moment demand $M_x$ = | 17.39 | 17.39 | 17.39 | 17.39 | 17.39 | kip-in | |

**11.3 LRFD Factored Post Load Combinations**

| | N. Row | E/W Edge | N23 Rows | S. Row | Interior | |
|---|---|---|---|---|---|---|
| **1.2D + 0.8W + 1.6S** | | | | | | |
| Axial demand P = | 6.87 | 6.83 | 6.79 | 6.76 | 6.17 | kip |
| Major axis shear demand $V_x$ = | -1.52 | -1.49 | -1.45 | -1.42 | -0.87 | kip |
| Major axis moment demand $M_Y$ = | 5.22 | 22.33 | 6.21 | 21.21 | 12.25 | kip-in |
| **0.9D + 1.6W** | | | | | | |
| Axial demand P = | -2.87 | -2.92 | -2.82 | -2.81 | -2.18 | kip |
| Major axis shear demand $V_x$ = | 1.56 | 1.58 | 1.53 | 1.53 | 1.24 | kip |
| Major axis moment demand $M_Y$ = | 178.56 | 194.93 | 207.02 | 210.39 | 164.71 | kip-in |
| **1.2D + 1.6W + 0.5S** | | | | | | |
| Axial demand P = | 5.33 | 5.25 | 5.19 | 5.12 | 3.94 | kip |
| Major axis shear demand $V_x$ = | -1.52 | -1.49 | -1.45 | -1.42 | -0.87 | kip |
| Major axis moment demand $M_Y$ = | -32.84 | 1.39 | -30.86 | -0.86 | -18.78 | kip-in |
| **1.2D + 0.2S + 1E** | | | | | | |
| Axial demand P = | 1.20 | 1.20 | 1.20 | 1.20 | 1.20 | kip |
| Major axis shear demand $V_x$ = | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | kip |
| Major axis moment demand $M_Y$ = | 39.31 | 39.31 | 39.31 | 39.31 | 39.31 | kip-in |
| Major axis shear demand $V_Y$ = | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | kip |
| Minor axis moment demand $M_x$ = | 33.12 | 33.12 | 33.12 | 33.12 | 33.12 | kip-in |

**11.4 Post Capacity Check**

| | | N. Row | E/W Edge | N23 Rows | S. Row | Interior | |
|---|---|---|---|---|---|---|---|
| | **Check Post Size:** | **W6x9** | **W6x9** | **W6x9** | **W6x9** | **W6x9** | |
| | KL/r | 145.73 | 145.73 | 145.73 | 145.73 | 145.73 | |
| | $F_e$ | 13.48 | 13.48 | 13.48 | 13.48 | 13.48 | |
| | $P_c$ | 31.68 | 31.68 | 31.68 | 31.68 | 31.68 | |
| | $M_{cx}$ | 280.27 | 280.27 | 280.27 | 280.27 | 280.27 | |
| | $M_{cy}$ | 51.33 | 51.33 | 51.33 | 51.33 | 51.33 | |
| 0.9D + 1.6W | AISC Eq. H1-1b: | 0.68 | 0.74 | 0.78 | 0.80 | 0.62 | < 1.0 OK |
| 1.2D + 0.8W + 1.6S | AISC Eq. H1-1b: | 0.13 | 0.19 | 0.13 | 0.18 | 0.14 | < 1.0 OK |
| 1.2D + 1.6W + 0.5S | AISC Eq. H1-1b: | 0.20 | 0.09 | 0.19 | 0.08 | 0.13 | < 1.0 OK |
| 1.2D + 0.2S + 1E | AISC Eq. H1-1b: | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | < 1.0 OK |
| | | O.K. | O.K. | O.K. | O.K. | O.K. | |

**11.5 Foundation Capacity**

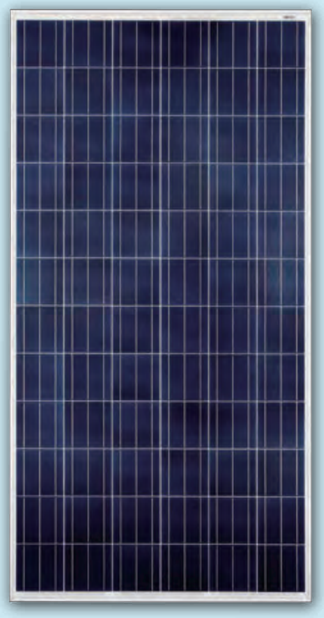
Pile embedment per Pile Load Test Report SLK16013

JA SOLAR

# JAP6

## 72/300-320/3BB

MULTICRYSTALLINE SILICON MODULE



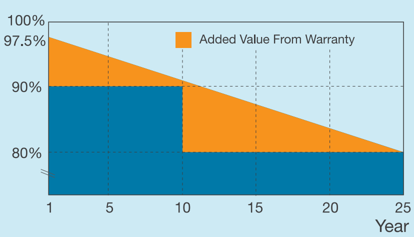
## JA Solar Holdings Co., Ltd.

JA Solar Holdings Co., Ltd. is a world-leading manufacturer of high-performance photovoltaic products that convert sunlight into electricity for residential, commercial, and utility-scale power generation. The company was founded on May 18, 2005, and was publicly listed on NASDAQ on February 7, 2007. JA Solar is one of the world's largest producers of solar cells and modules. Its standard and high-efficiency product offerings are among the most powerful and cost-effective in the industry.

Add: NO.36, Jiang Chang San Road, Zhabei, Shanghai 200436, China
Tel: +86 21 6095 5888 / +86 21 6095 5999
Fax: +86 21 6095 5858 / +86 21 6095 5959
Email: sales@jasolar.com market@jasolar.com

## Superior Warranty

- 10-year product warranty
- 25-year linear power output warranty




## Key Features

- Multicrystalline modules designed for commercial and solar farm grid-tied applications
- High output, 16.51% highest conversion efficiency
- Designed for IEC DC 1000V applications
- Anti-reflective and anti-soiling surface reduces power loss from dirt and dust
- Outstanding performance in low-light irradiance environments
- Excellent mechanical load resistance: Certified to withstand high wind loads (2400Pa) and snow loads (5400Pa)
- High salt and ammonia resistance certified by TÜV NORD

## Reliable Quality

- Positive power tolerance: 0~+5W
- 100% EL double-inspection ensures modules are defects free
- Modules binned by current to improve system performance
- Potential Induced Degradation (PID) Resistant

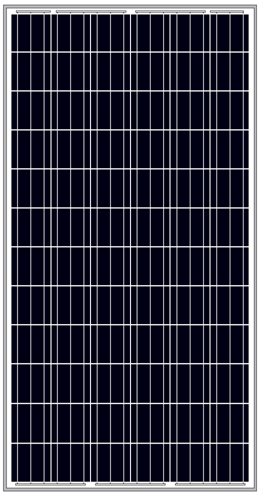
## Comprehensive Certificates

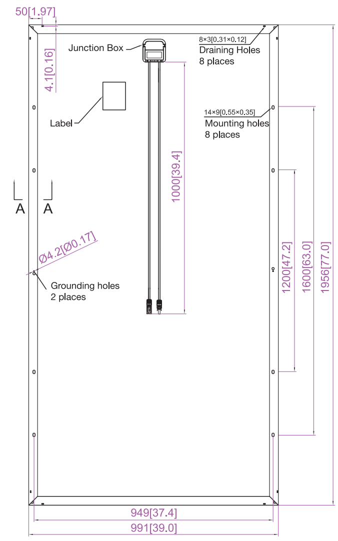
- IEC 61215, IEC 61730, UL1703, CEC Listed, MCS and CE
- ISO 9001: 2008: Quality management systems
- ISO 14001: 2004: Environmental management systems
- BS OHSAS 18001: 2007: Occupational health and safety management systems
- Environmental policy: The first solar company in China to complete Intertek's carbon footprint evaluation program and receive green leaf mark verification for our products

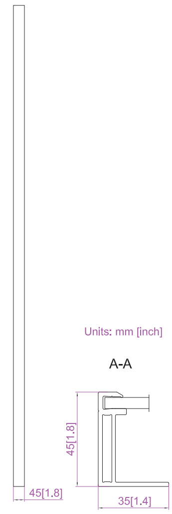
# JAP6 72/300-320/3BB

JA SOLAR

## Engineering Drawings






customized cable length available upon request

## MECHANICAL PARAMETERS

| | |
|---|---|
| Cell (mm) | Poly 156x156 |
| Weight (kg) | 26 (approx) |
| Glass Thickness | 4 mm |
| Dimensions (L×W×H) (mm) | 1956×991×45 |
| Cable Cross Section Size ($mm^2$) | 4 |
| No. of Cells and Connections | 72 (6×12) |
| Junction Box | IP67, 3 diodes |
| Connector | MC4 Compatible |
| Packaging Configuration | 23 Per Pallet |

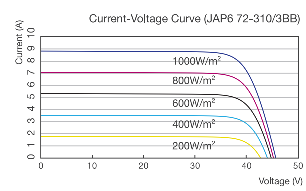
## WORKING CONDITIONS

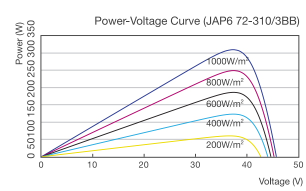
| | |
|---|---|
| Maximum System Voltage | DC 1000V (IEC) |
| Operating Temperature | -40℃~+85℃ |
| Maximum Series Fuse | 15A |
| Maximum Static Load, Front (e.g., snow and wind)<br>Maximum Static Load, Back (e.g., wind) | 5400Pa (112 lb/$ft^2$)<br>2400Pa (50 lb/$ft^2$) |
| NOCT | 45±2℃ |
| Application Class | Class A |

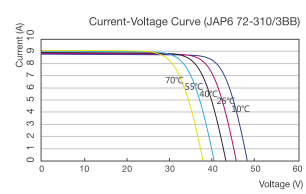
## ELECTRICAL PARAMETERS

| TYPE | JAP6 72-300/3BB | JAP6 72-305/3BB | JAP6 72-310/3BB | JAP6 72-315/3BB | JAP6 72-320/3BB |
|---|---|---|---|---|---|
| Rated Maximum Power at STC (W) | 300 | 305 | 310 | 315 | 320 |
| Open Circuit Voltage (Voc/V) | 45.20 | 45.35 | 45.45 | 45.60 | 45.82 |
| Maximum Power Voltage (Vmp/V) | 36.41 | 36.71 | 37.00 | 37.28 | 37.56 |
| Short Circuit Current (Isc/A) | 8.73 | 8.79 | 8.85 | 8.91 | 9.03 |
| Maximum Power Current (Imp/A) | 8.24 | 8.31 | 8.38 | 8.45 | 8.52 |
| Module Efficiency [%] | 15.48 | 15.73 | 15.99 | 16.25 | 16.51 |
| Power Tolerance (W) | -0~+5W | | | | |
| Temperature Coefficient of Isc (αIsc) | +0.058%/℃ | | | | |
| Temperature Coefficient of Voc (βVoc) | -0.330%/℃ | | | | |
| Temperature Coefficient of Pmax (γPmp) | -0.410%/℃ | | | | |
| STC | Irradiance 1000W/$m^2$, Module Temperature 25℃, Air Mass 1.5 | | | | |

## I-V CURVE



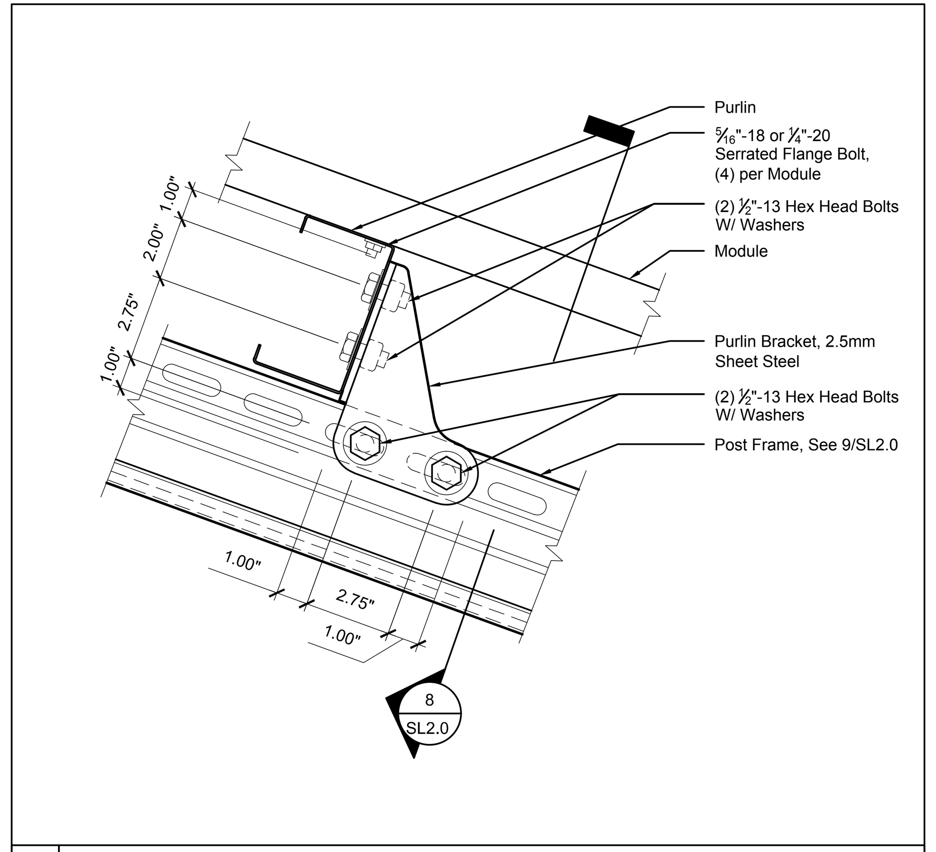



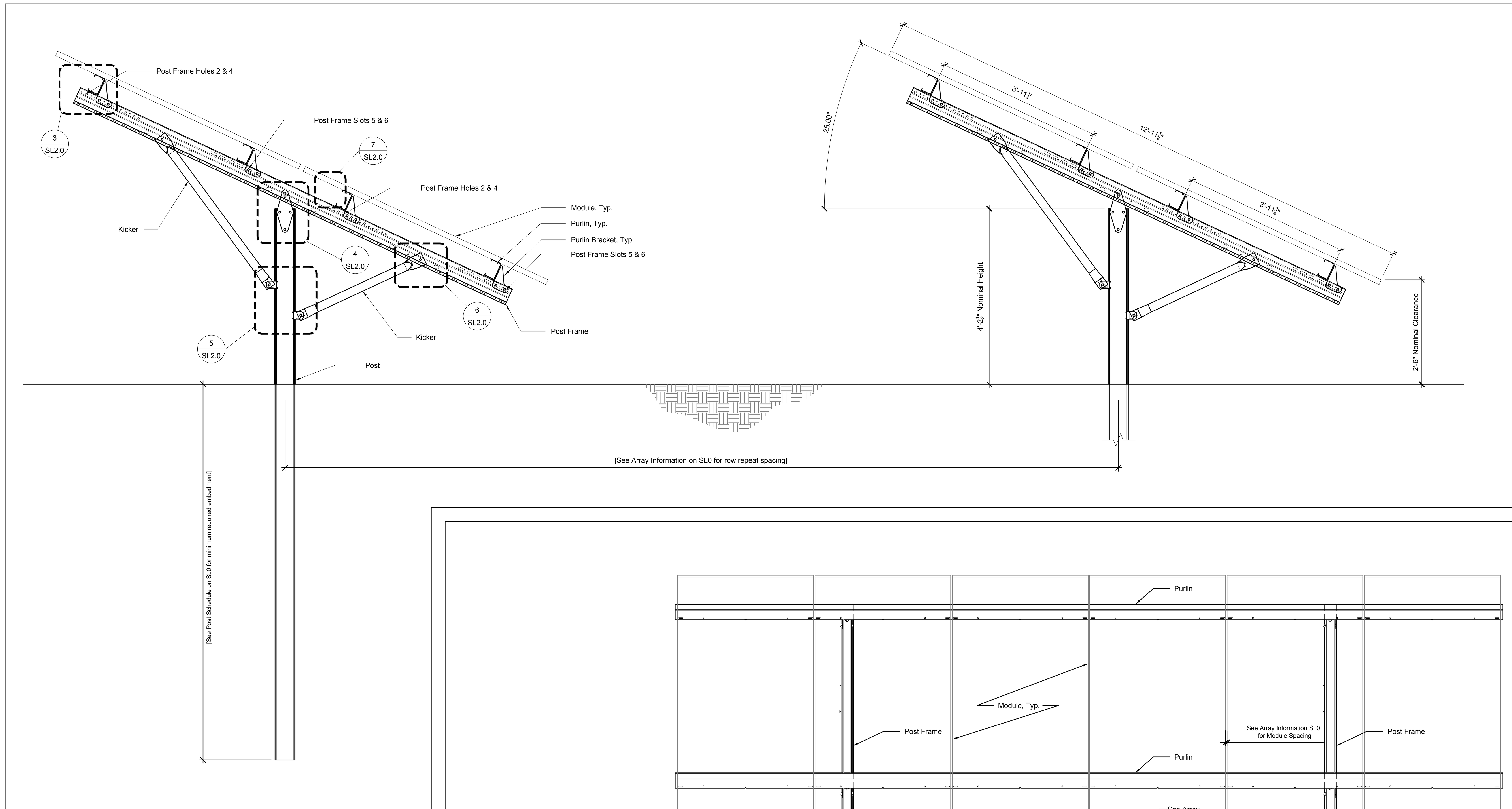

## NOCT

| TYPE | JAP6 72-300/3BB | JAP6 72-305/3BB | JAP6 72-310/3BB | JAP6 72-315/3BB | JAP6 72-320/3BB |
|---|---|---|---|---|---|
| Max Power (Pmax) [W] | 217.80 | 221.43 | 225.06 | 228.69 | 232.32 |
| Open Circuit Voltage (Voc) [V] | 42.31 | 42.47 | 42.58 | 42.63 | 42.78 |
| Max Power Voltage (Vmp) [V] | 33.77 | 33.91 | 34.05 | 34.08 | 34.28 |
| Short Circuit Current (Isc) [A] | 6.89 | 6.93 | 6.99 | 7.06 | 7.16 |
| Max Power Current (Imp) [A] | 6.45 | 6.53 | 6.61 | 6.71 | 6.78 |
| Condition | Under Normal Operating Cell Temperature, Irradiance of 800 W/$m^2$, spectrum AM 1.5, ambient temperature 20℃, wind speed 1 m/s | | | | |

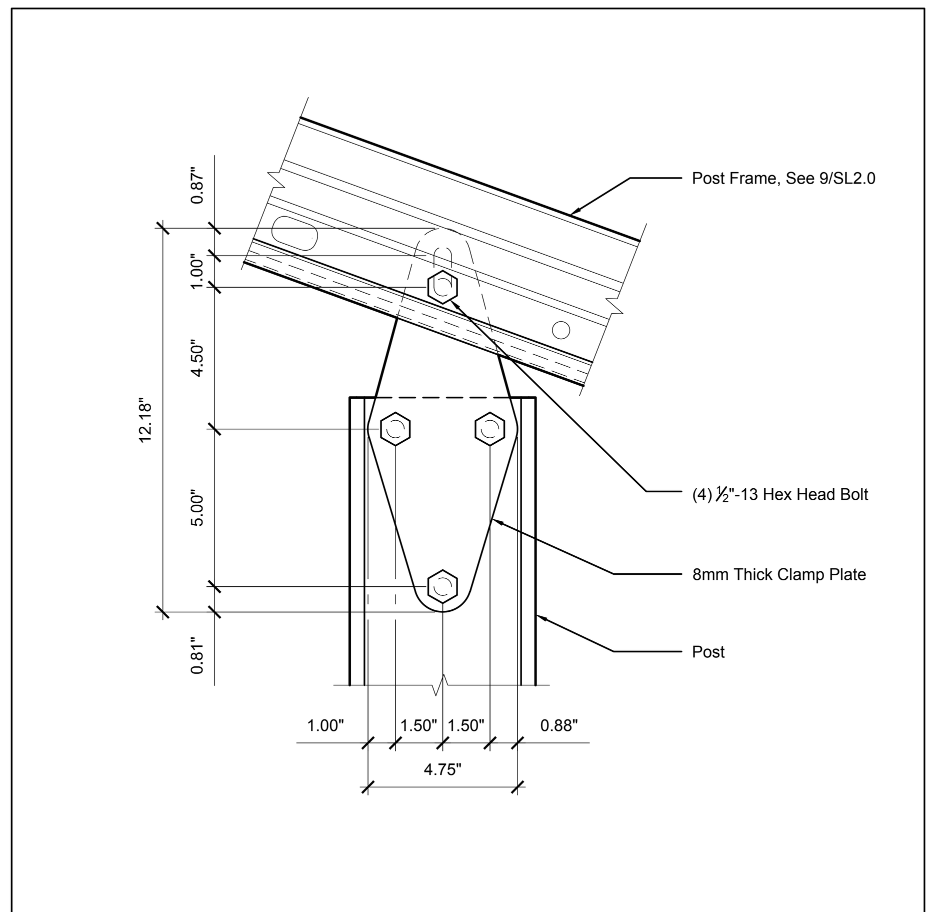
Electrical data in this catalog do not refer to a single module and they are not part of the offer. They only serve for comparison among different module types.



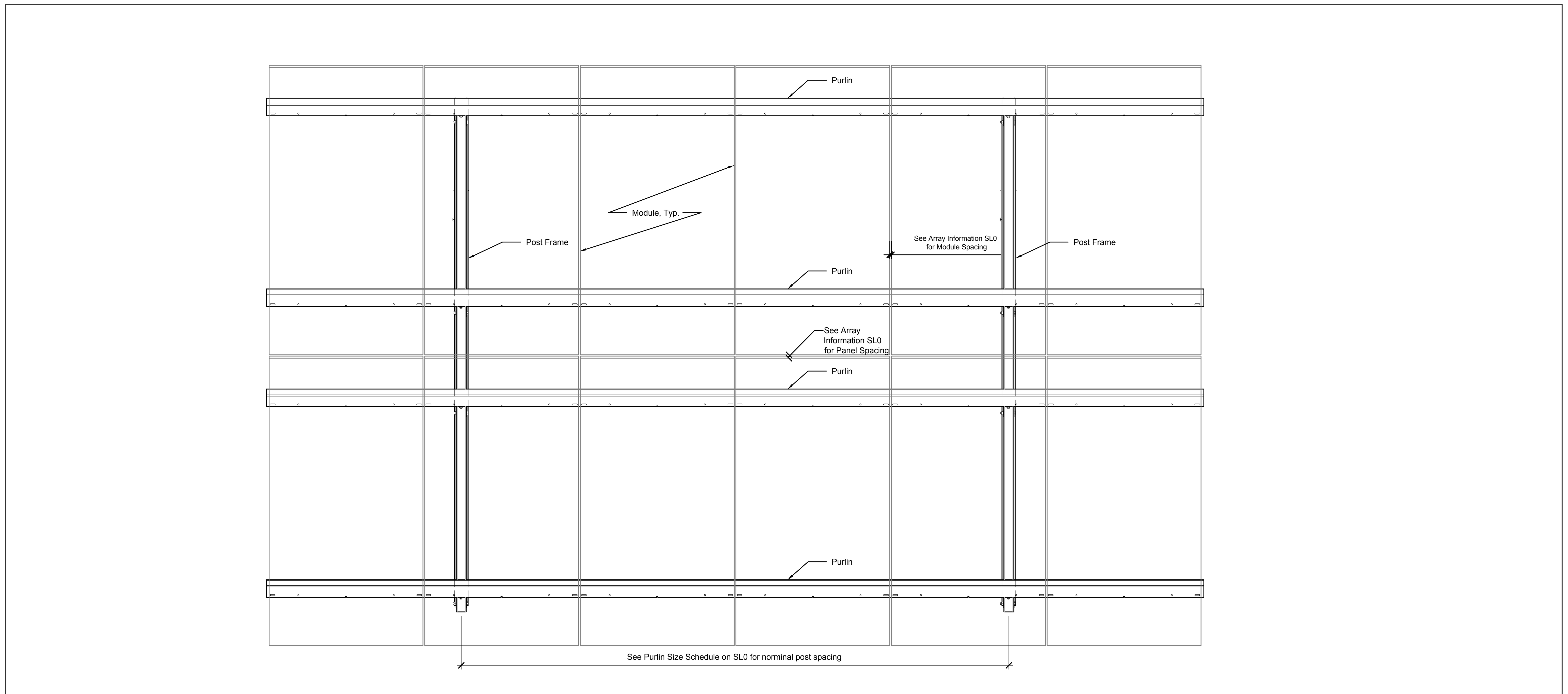

3 Purlin Bracket to Purlin and Post Frame Connections Scale: 3" = 1'-0"



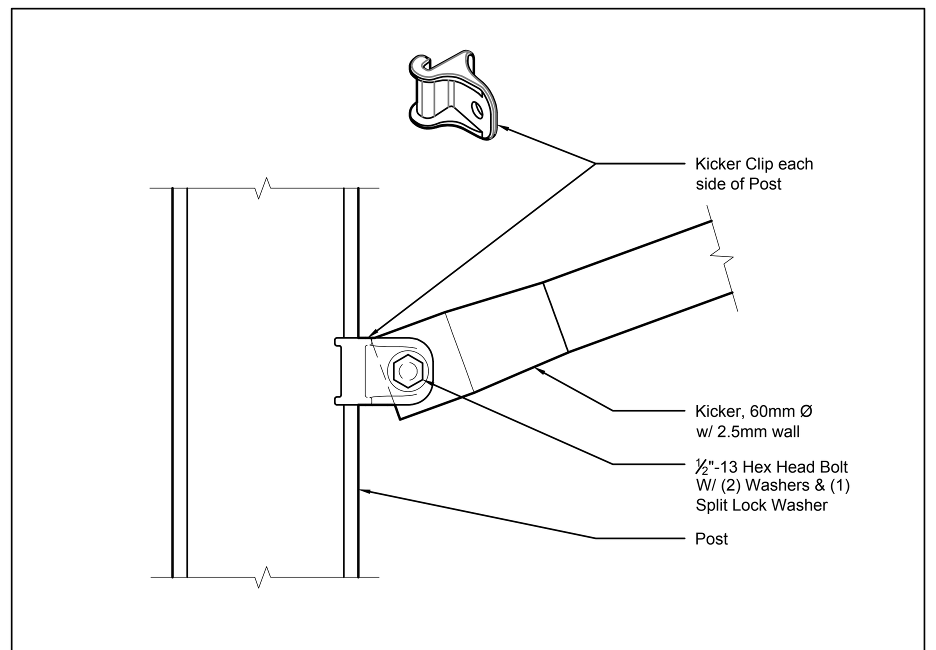

1 Section - Typical Table Assemblies Scale: 3/4" = 1'-0"



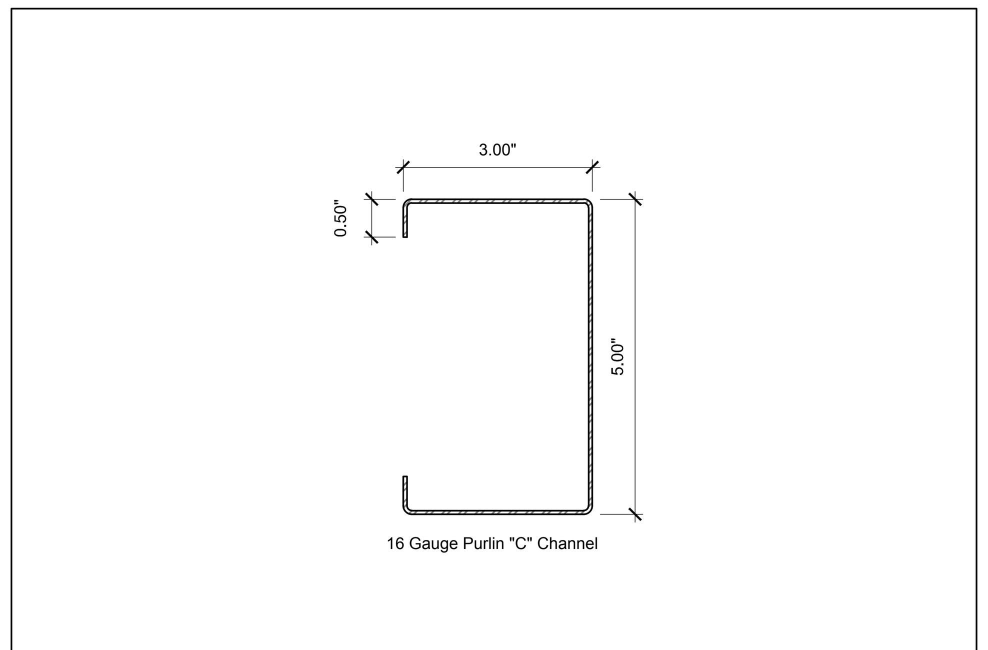

4 Post to Post Frame Connection Scale: 3" = 1'-0"



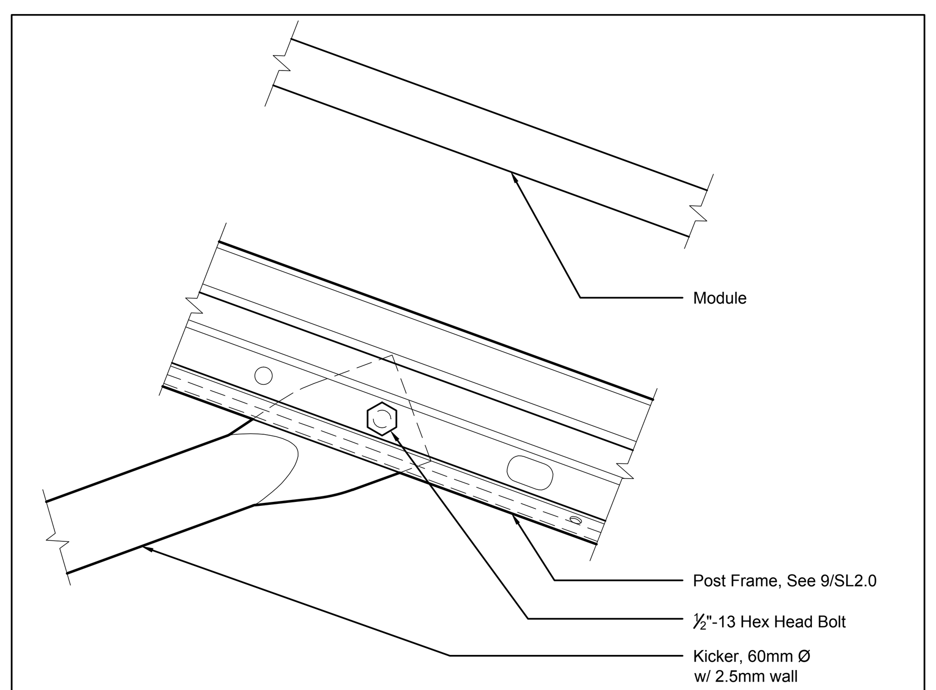

2 Plan - Typical Table Layout Scale: 3/4" = 1'-0"



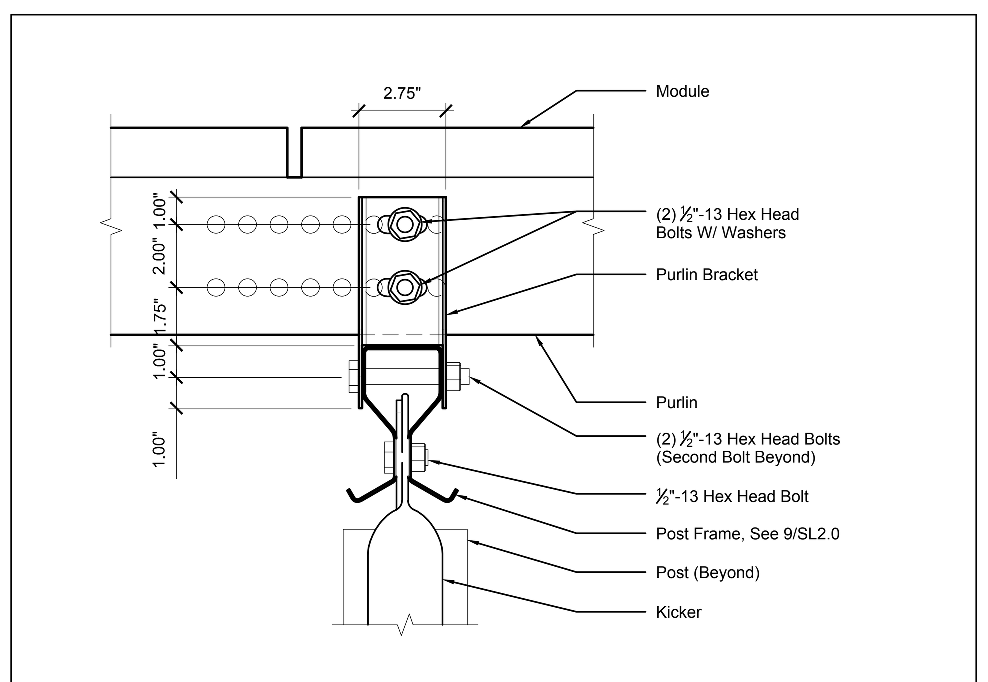

5 Post to Kicker Connection Scale: 3" = 1'-0"



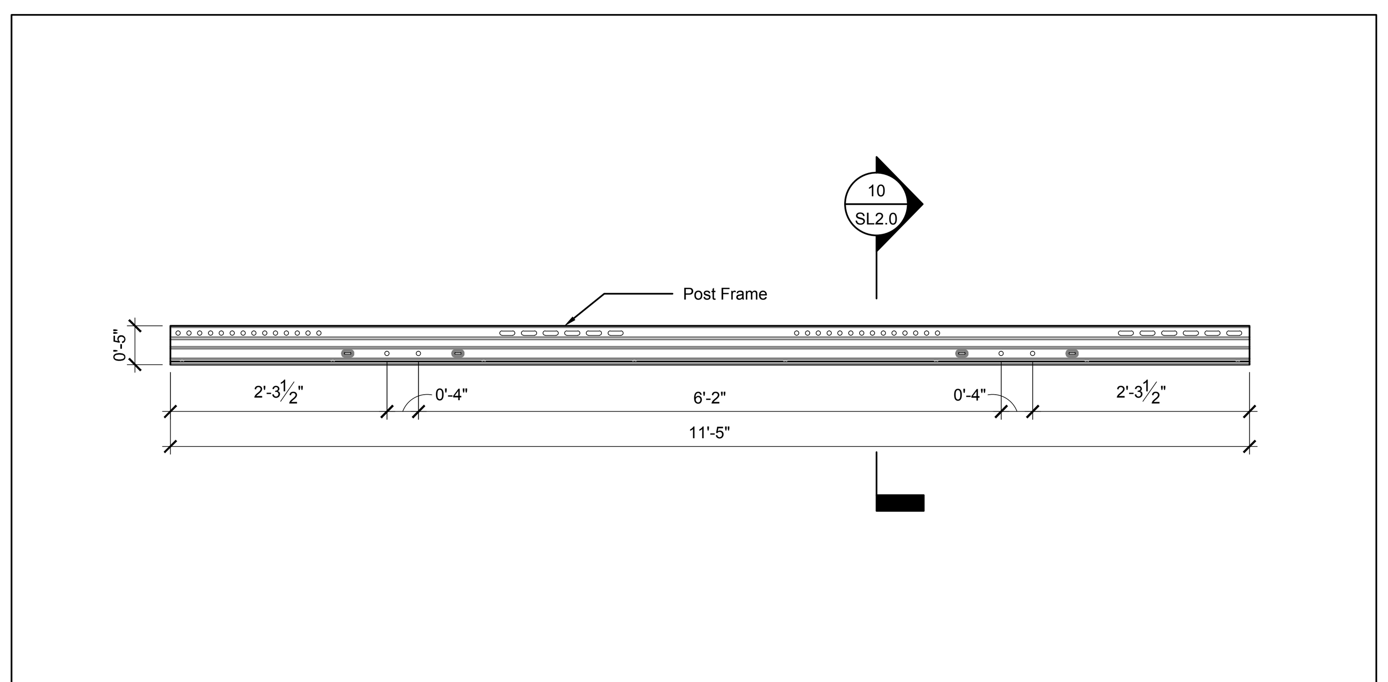

7 Purlin Section Scale: 6" = 1'-0"



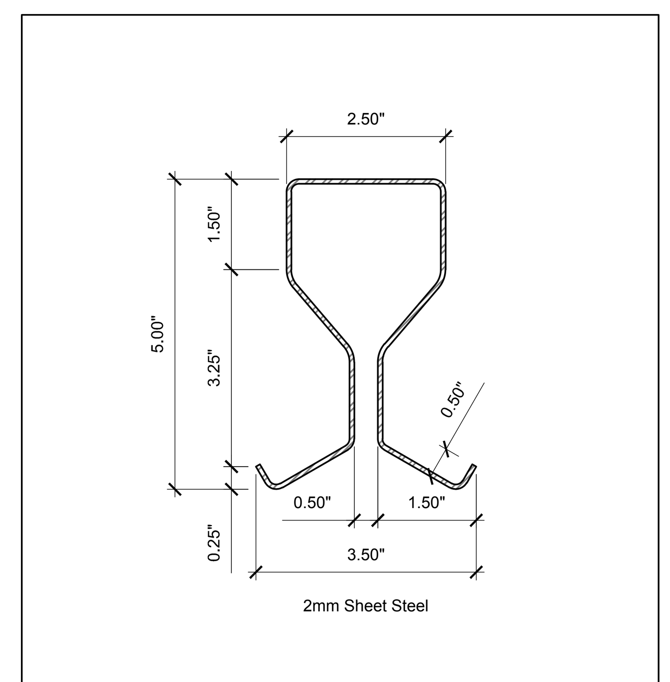

6 Kicker to Post Frame Connection Scale: 3" = 1'-0"



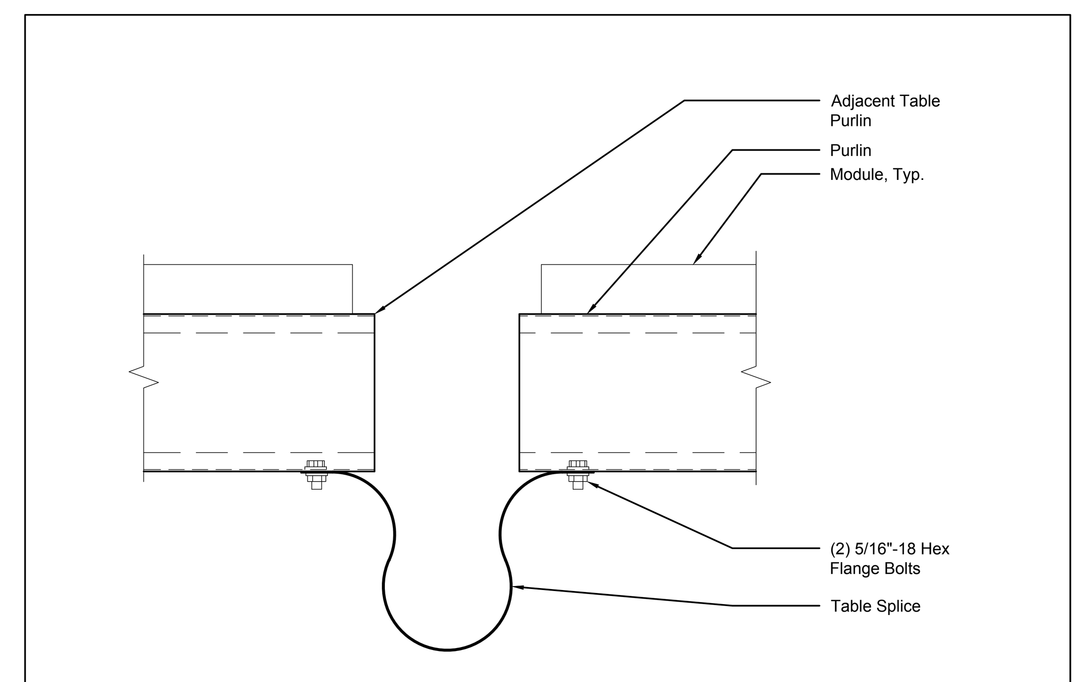

8 Post Frame to Purlin Bracket and Kicker Connections Scale: 3" = 1'-0"




9 Post Frame Scale: 3/4" = 1'-0"




10 Post Frame Section Scale: 6" = 1'-0"




11 Table Splice Scale: 3" = 1'-0"

| Issue | Description | Date | Drawn By | Checked By |
| --- | --- | --- | --- | --- |
| R0 | Preliminary Layout with JA Solar 315 at 25 degrees | 04-26-16 | MW | - |
| R1 | Layout revised with 2x6 tables | 04-29-16 | MW | - |

**SUNLINK CORPORATION**
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**WWW.SUNLINK.COM**



SUNLINK
PV ARRAY MOUNTING SYSTEMS

| | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Customer: xxx. | GeoPro | Module: JA Solar JAP6 72-315/3BB | | No. of Tables: 1,494 | Sheets: n of 1 |
| Project: Axxx | | Tilt Angle: 25 | Wattage: 315 | No. of Modules: 17,640 | Issue: R1 |
| Location: d Plymouth, MA 02360 | Quote Reference No. | DC String Length: 18 | No. of Strings: 980 | Power Output (DC): 5,556.60 kW | Sheet Number: SL2.0 |
| | Sales Order No. | Sheet Title: Details for GeoPro with Post Foundation | | | |

# GEOTECHNICAL LOAD TESTING FOR PHOTOVOLTAIC SYSTEM INSTALLATION

SLK16013

PREPARED FOR

SUNLINK

1010 B Street, Suite 400
San Rafael, CA 94901

415.925.9650
sales@sunlink.com
**SunLink.com**

THE POWER OF WHAT'S POSSIBLE

April 20, 2016

Attn:

**RE:**

**Geotechnical Load Testing**

**Plymouth, MA**
**SLK16013**

Dear,

SunLink is pleased to present the findings from the geotechnical load testing services provided for the proposed ground-mounted photovoltaic system located near Plymouth, MA. This report presents the on-site observations, results of the pile load testing, and summary of laboratory results for soil classification and corrosion potential.

We appreciate the opportunity to provide the geotechnical load testing services necessary for this project. If you have any questions about this report or any of our testing and design services, please do not hesitate to contact us.

Sincerely,

SunLink Corporation
1010 B Street
San Rafael, CA

COMMONWEALTH OF MASSACHUSETTS
DANIEL CRAIG SMITH
CIVIL
No. 46735
REGISTERED PROFESSIONAL ENGINEER

JDS CONSULTING & DESIGN

**ENGINEERING REVIEW BY:**
JDS CONSULTING & DESIGN, PLLC
P.O. Box 80755
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WWW.JDSDESIGNONLINE.COM
PROJECT NO: EBS160043

# TABLE OF CONTENTS

# EXECUTIVE SUMMARY

SunLink has completed the geotechnical load testing for the proposed Project located near Plymouth, MA. The scope of work included site observations, pile load testing, shallow test pits for subsurface observations, and laboratory soil analyses for classification and corrosion potential. Based on the site observations and results of the load testing program, we conclude that the site is suitable for the proposed ground-mount solar development. The following geotechnical considerations were identified:

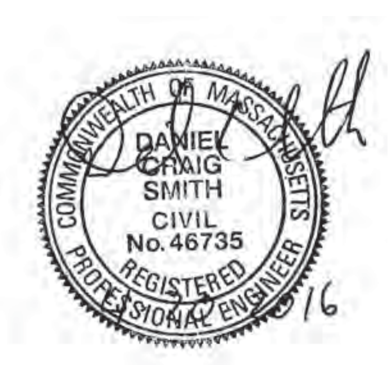
- Subsurface conditions are relatively consistent across the area proposed for development. In general, approximately 1 ft of topsoil was encountered. The topsoil was underlain by sand to the termination of the test pits.

- Groundwater was encountered in shallow test pits.

- Pile load testing was performed at 9 locations across the site. Results from vertical and lateral load testing indicate sufficient capacity at the depths tested for the proposed SunLink ground-mount system design. The proposed embedment depth based on field testing results and safe working design loads (3.01 kips vertically and 0.67 kips laterally) is 9 ft.

- Foundation piles were not refused, tilted, or twisted during installation for load testing. Potential obstructions such as cobbles were observed in test pits after load testing.

The executive summary should be used in conjunction with the entire report. The report must be read in its entirety for a comprehensive understanding of the results and recommendations contained herein.

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PROJECT NO: EBS160043

# SCOPE OF WORK

The services performed for this site investigation included site reconnaissance and subsequent advancement of test piles at the project site to observe soil conditions and test for axial load capacity and lateral load capacity for support of photovoltaic panels. SunLink provided the test methods, procedures, and equipment for the site investigation. The purpose of this scope of work is to acquire and present soil load test data to be used by SunLink and SunLink's consultants to determine the type and dimensions of SunLink provided foundations used to support the photovoltaic system.

# SITE CONDITIONS

The project site consists of 5 areas bisected by an access road. Each area was covered by forest. Testing was therefore performed adjacent to the access road in each area. Testing was performed at a sufficient distance from the road to ensure results are representative of undisturbed soil. The ground surface is rough and undulates in each area. Surface conditions are moderately firm and organic debris and vegetative cover.

# LOAD TESTING PROCEDURES

Test piles with profile W6x9 were advanced by SunLink using a rubber tracked GAYK HRE 1000 hydraulic ram. The test piles were advanced between 8 ft and 10 ft below the ground surface. Locations of the test piles can be seen on a general site image in Appendix A.

SunLink performed a vertical pull-out capacity test for each advanced test pile using a 10-ton hydraulic jack connected to a hydraulic pull cylinder. The hydraulic pull cylinder was used to pull upward on a chain connected to the test pile with a bolt. A dial indicator was placed on a tripod on the opposite side of the hydraulic jack. The indicator measured vertical displacement from the top of a magnet attached to the test pile. The vertical displacement in inches was measured and recorded at 20 bar pressure increments from 0 to 240 bars or failure defined as vertical displacement in excess of 1.0 in. The maximum pull-out pressure is defined as the pressure attained immediately before the pile-soil interface failed and excessive movement of the pile began. These data are presented in Appendix B.

SunLink also performed a lateral load capacity test for each advanced test pile by positioning the GAYK parallel to the embedded pile. The hydraulic jack was oriented horizontally between the GAYK and the test pile. A dial indicator was placed on a tripod on the opposite side of the hydraulic jack at the bottom of the test pile to measure the horizontal displacement in inches. The horizontal displacement was measured and recorded at 20 bar pressure increments from 0 to 140 bars or failure as defined as lateral displacement in excess of 1.0 in. The heights of the hydraulic jack and the dial indicator were also measured. These data are presented in Appendix B.

The test piles were removed from the ground after the completion of the testing. The soils observed within each test pit were recorded.

# SUBSURFACE CONDITIONS

## SOIL CONDITIONS

The observed soil profiles at the project site extend to depths of approximately 10 ft below the ground surface. Soil conditions at each pile location are assumed to be representative of soil conditions in the direct vicinity of the respective pile. A summary of the observed strata is shown in Table 1.

### TABLE 1: OBSERVED SOIL PROFILE.

| DESCRIPTION | APPROXIMATE DEPTH TO BOTTOM OF STRATUM (FT) | MATERIAL ENCOUNTERED |
| --- | --- | --- |
| Stratum 1 | 1.0 | Topsoil |
| Stratum 2 | 10 ft | Sand |

## GROUNDWATER CONDITIONS

Groundwater was observed at the time of testing in the shallow test pits. However, seasonal and weather variations, as well as other factors, may potentially affect groundwater conditions during construction.

# RESULTS

## FIELD TESTING

Results of the vertical pull-out capacity and lateral load capacity tests are provided in Appendix B.

# DISCUSSION AND RECOMMENDATIONS

The structural analysis of the proposed solar arrays yields the maximum design loads the system may be subjected to. Based on the system design, the ultimate design loads, both vertical and lateral, are 6.02 kips and 1.34 kips, respectively. The test pile is loaded to the ultimate design loads and the respective displacement is measured to determine the vertical and lateral load capacities. Displacements greater than 1.0 in are considered not conforming to the predetermined design criteria and a pile is retested in the immediate vicinity to obtain further data. The safe working loads are determined by applying a factor of safety of 2.0 to the ultimate design loads, yielding a vertical and lateral safe working load of 3.01 kips and 0.67 kips, respectively. The testing loads are approximated to the ultimate design load in order to prove an approximated FOS of 2.0 in the field.

Piles were tested at 9 locations on the project site, for vertical pull-out capacity and lateral load capacity. The piles were tested either 1 day or 2 days after installation. All tests showed displacements less than 1.0 in when ultimate design loads were applied vertically and laterally. Based on these results, the recommended embedment depth is 9 ft provided that the maximum axial forces, as shown in the system design, do not exceed the safe working design load of 3.01 kips vertically and 0.67 kips laterally.

Subsurface soil conditions are loose near the ground surface and moderately firm at depth in areas proposed for construction. All test piles advanced without obstruction and obstructions were not observed when removing the test piles. Potential for obstructions during installation is low.

The recommended embedment depths for piles supporting photovoltaic panels are based on current site conditions. Filling, grading, and vegetation removal at the project site may alter or disturb current soil conditions and render these data and recommendations invalid. If soils conditions are disturbed or change due to project site modifications prior to, during, or after pile installation contact SunLink immediately.

# LIMITATIONS

This Geotechnical Investigation Report was generated exclusively for SunLink Corporation, 1010 B Street, San Rafael, CA, which holds any and all rights to this report. All results presented in this report were obtained with the proprietary pile profile manufactured by SunLink. Extrapolation of the data for use with different profile geometries manufactured by others may lead to false assumptions for design calculations. In case you are using this report for design calculations you are rendering yourself liable to prosecution in accordance with the nondisclosure agreement between SunLink and its clients.

This report was prepared for the exclusive use of SunLink Corporation and their authorized agents for the construction for a proposed solar panel system, located at the SunLink worksite.

Recommendations contained in this report are based on field observations, subsurface explorations, laboratory tests and present knowledge of the proposed construction as described in this report. Soil conditions may vary between or beyond the points explored. If soil or groundwater conditions are encountered during construction that differ from those described herein, SunLink Corporation should be notified immediately to allow for a review or supplementary recommendations.

The findings, conclusions, and recommendations in this report are presented in a manner consistent with the standards of care and skill ordinarily exercised by members of this profession practicing under similar conditions at the time and location of the services. No warranty or other commitment, expressed or implied, is made.

# APPENDIX A

Area Image
Test Pile Locations


Figure 1: Aerial view of test locations.

# APPENDIX B

Lateral Load Capacity Test Data

Vertical Pull-out Capacity Test Data

# Pile Load Testing Summary

Project: ADM Redbrook
Project ID: SLK16013
Project Location: Plymouth, MA

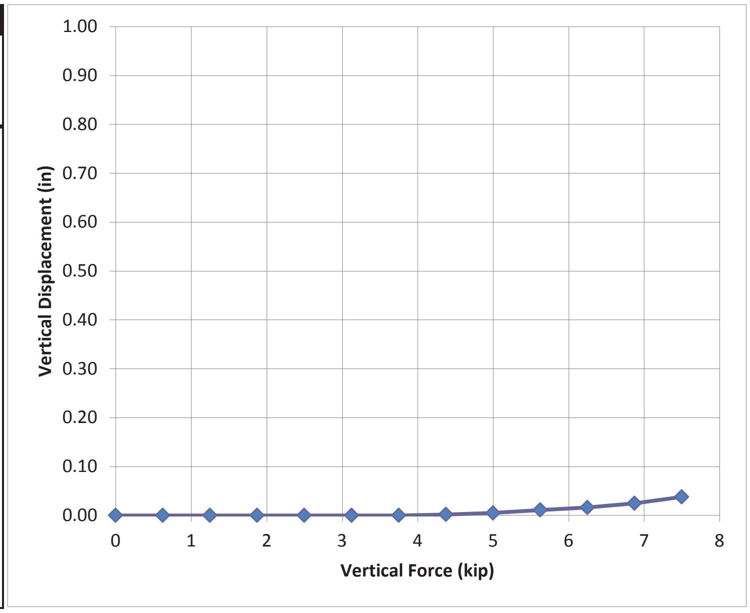
| Test Location | Pile Section | Embedment Depth (ft) | Installation Time (sec) | Maximum Axial Pressure (Bar) | Notes |
|---|---|---|---|---|---|
| 1a | W6x9 | 8 | 35 | 240 | |
| 1b | W6x9 | 10 | 54 | 240 | |
| 2 | W6x9 | 10 | 35 | 240 | |
| 3 | W6x9 | 10 | 37 | 240 | |
| 4 | W6x9 | 10 | 73 | 240 | |
| 5 | W6x9 | 9 | 73 | 240 | |
| 6 | W6x9 | 10 | 73 | 240 | |
| 7 | W6x9 | 10 | 36 | 240 | |
| 8 | W6x9 | 9 | 42 | 240 | |
| 9 | W6x9 | 9 | 38 | 240 | |

# Pile Load Test Results

| | | | |
|---|---|---|---|
| Test Location: | TP1a | Project: | ADM Redbrook |
| Latitude (N): | 41.83640 | Project ID: | SLK16013 |
| Longitude (W): | -70.61226 | Date Installed: | 4/7/2016 |
| Embedment Depth (ft): | 8 | Date Tested: | 4/8/2016 |

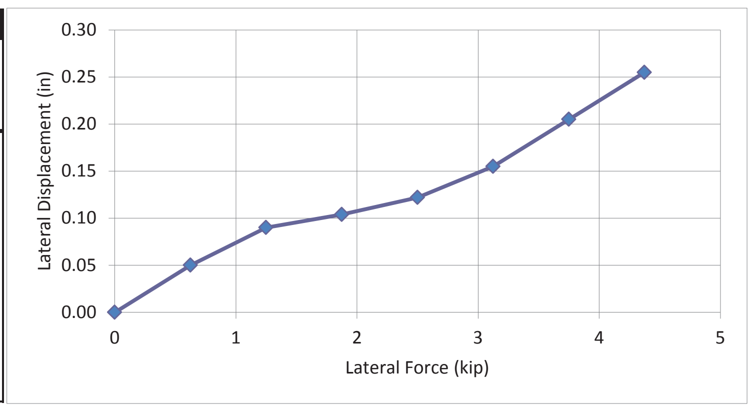
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.00 |
| 80 | 2.50 | 0.00 |
| 100 | 3.12 | 0.00 |
| 120 | 3.75 | 0.00 |
| 140 | 4.37 | 0.00 |
| 160 | 5.00 | 0.01 |
| 180 | 5.62 | 0.01 |
| 200 | 6.25 | 0.02 |
| 220 | 6.87 | 0.03 |
| 240 | 7.50 | 0.04 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.05 |
| 40 | 1.25 | 0.09 |
| 60 | 1.87 | 0.10 |
| 80 | 2.50 | 0.12 |
| 100 | 3.12 | 0.16 |
| 120 | 3.75 | 0.21 |
| 140 | 4.37 | 0.26 |



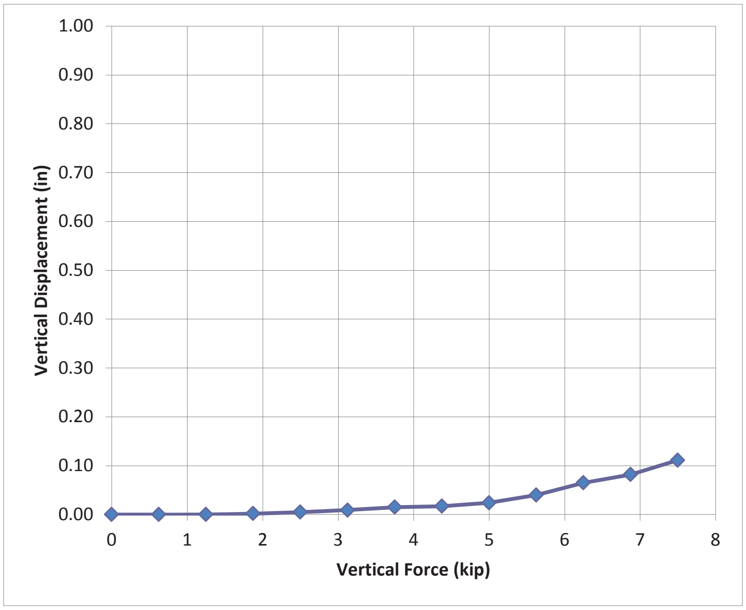
# Pile Load Test Results

| | |
|---|---|
| Test Location: | TP1b |
| Latitude (N): | 41.83640 |
| Longitude (W): | -70.61226 |
| Embedment Depth (ft): | 8 |

| | |
|---|---|
| Project: | ADM Redbrook |
| Project ID: | SLK16013 |
| Date Installed: | 4/7/2016 |
| Date Tested: | 4/8/2016 |

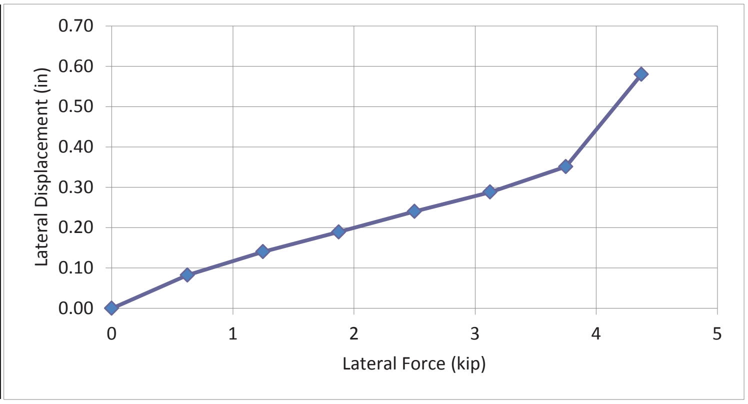
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.00 |
| 80 | 2.50 | 0.01 |
| 100 | 3.12 | 0.01 |
| 120 | 3.75 | 0.02 |
| 140 | 4.37 | 0.02 |
| 160 | 5.00 | 0.02 |
| 180 | 5.62 | 0.04 |
| 200 | 6.25 | 0.07 |
| 220 | 6.87 | 0.08 |
| 240 | 7.50 | 0.11 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.08 |
| 40 | 1.25 | 0.14 |
| 60 | 1.87 | 0.19 |
| 80 | 2.50 | 0.24 |
| 100 | 3.12 | 0.29 |
| 120 | 3.75 | 0.35 |
| 140 | 4.37 | 0.58 |

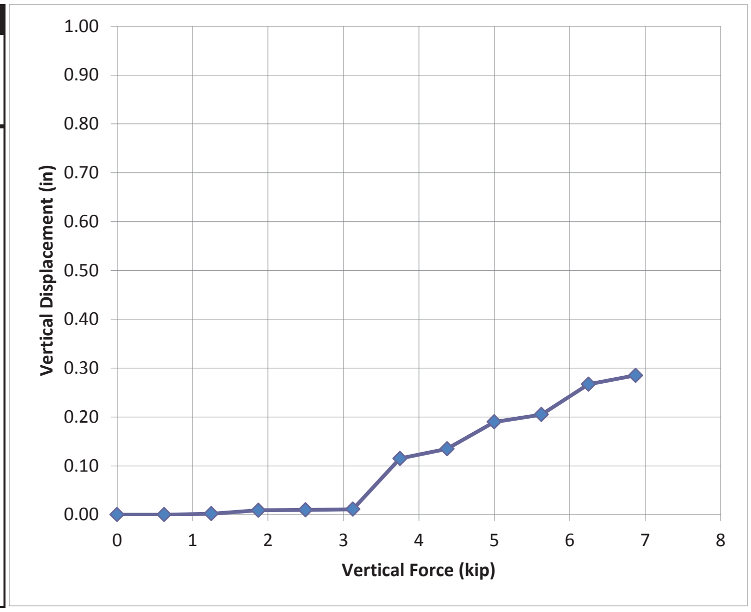


Pile Load Test Results

| | | | |
|---|---|---|---|
| Test Location: | TP2 | Project: | ADM Redbrook |
| Latitude (N): | 41.83678 | Project ID: | SLK16013 |
| Longitude (W): | -70.61159 | Date Installed: | 4/7/2016 |
| Embedment Depth (ft): | 10 | Date Tested: | 4/8/2016 |

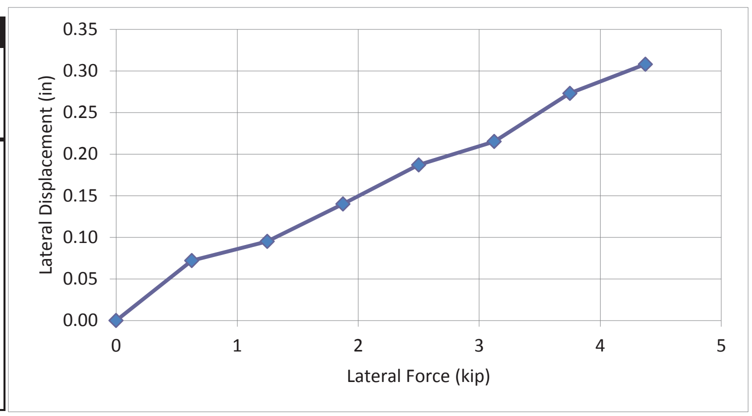
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.01 |
| 80 | 2.50 | 0.01 |
| 100 | 3.12 | 0.01 |
| 120 | 3.75 | 0.12 |
| 140 | 4.37 | 0.14 |
| 160 | 5.00 | 0.19 |
| 180 | 5.62 | 0.21 |
| 200 | 6.25 | 0.27 |
| 220 | 6.87 | 0.29 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.07 |
| 40 | 1.25 | 0.10 |
| 60 | 1.87 | 0.14 |
| 80 | 2.50 | 0.19 |
| 100 | 3.12 | 0.22 |
| 120 | 3.75 | 0.27 |
| 140 | 4.37 | 0.31 |

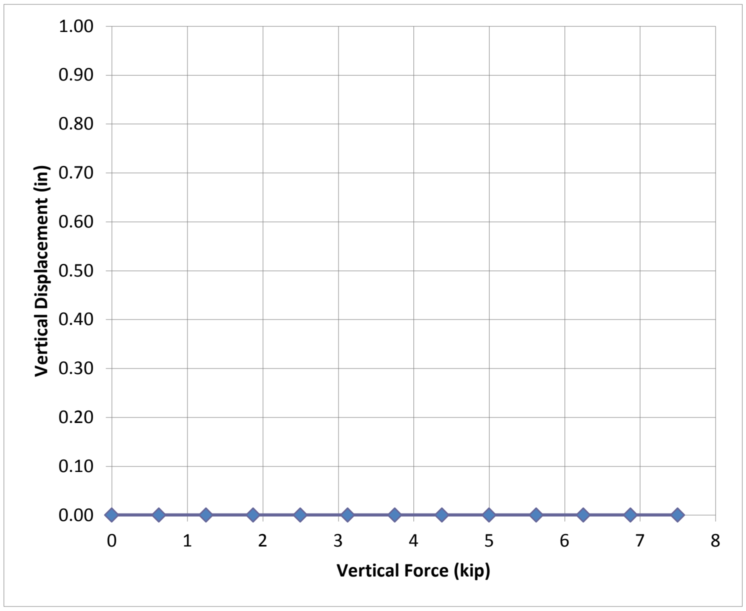


| | |
|---|---|
| Test Location: | TP3 |
| Latitude (N): | 41.83604 |
| Longitude (W): | -70.61129 |
| Embedment Depth (ft): | 10 |

| | |
|---|---|
| Project: | ADM Redbrook |
| Project ID: | SLK16013 |
| Date Installed: | 4/7/2016 |
| Date Tested: | 4/8/2016 |

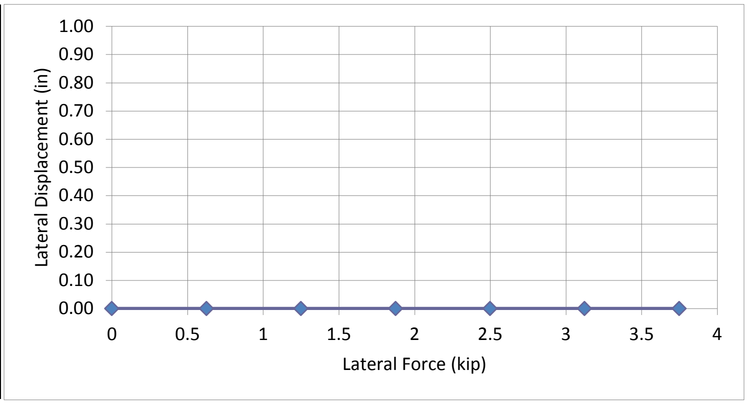
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.00 |
| 80 | 2.50 | 0.00 |
| 100 | 3.12 | 0.00 |
| 120 | 3.75 | 0.00 |
| 140 | 4.37 | 0.00 |
| 160 | 5.00 | 0.00 |
| 180 | 5.62 | 0.00 |
| 200 | 6.25 | 0.00 |
| 220 | 6.87 | 0.00 |
| 240 | 7.50 | 0.00 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | NR |
| 20 | 0.62 | NR |
| 40 | 1.25 | NR |
| 60 | 1.87 | NR |
| 80 | 2.50 | NR |
| 100 | 3.12 | NR |
| 120 | 3.75 | NR |
| 140 | 4.37 | NR |



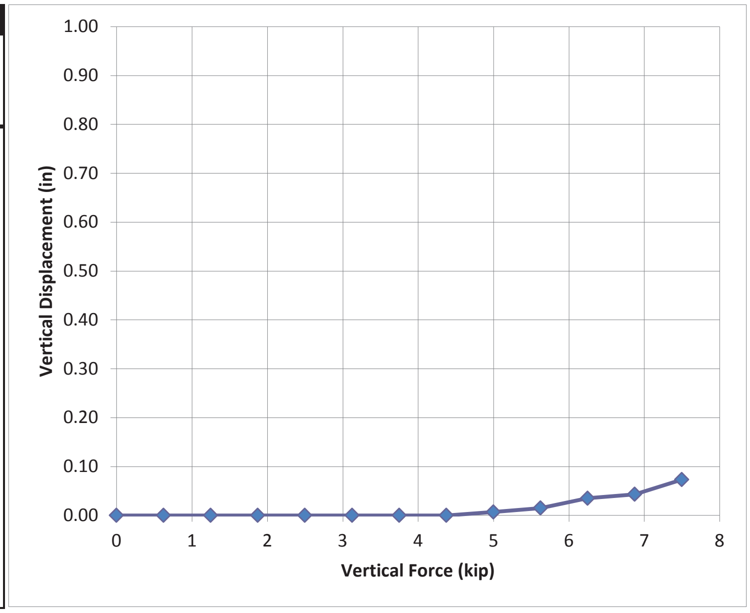
Pile Load Test Results

Test Location: TP4
Latitude (N): 41.83555
Longitude (W): -70.61171
Embedment Depth (ft): 8

Project: ADM Redbrook
Project ID: SLK16013
Date Installed: 4/7/2016
Date Tested: 4/9/2016

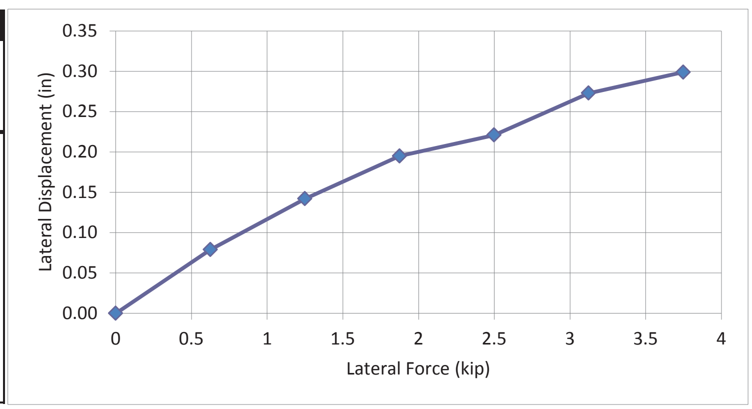
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.00 |
| 80 | 2.50 | 0.00 |
| 100 | 3.12 | 0.00 |
| 120 | 3.75 | 0.00 |
| 140 | 4.37 | 0.00 |
| 160 | 5.00 | 0.01 |
| 180 | 5.62 | 0.02 |
| 200 | 6.25 | 0.04 |
| 220 | 6.87 | 0.04 |
| 240 | 7.50 | 0.07 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.08 |
| 40 | 1.25 | 0.14 |
| 60 | 1.87 | 0.20 |
| 80 | 2.50 | 0.22 |
| 100 | 3.12 | 0.27 |
| 120 | 3.75 | 0.30 |
| 140 | 4.37 | 0.33 |

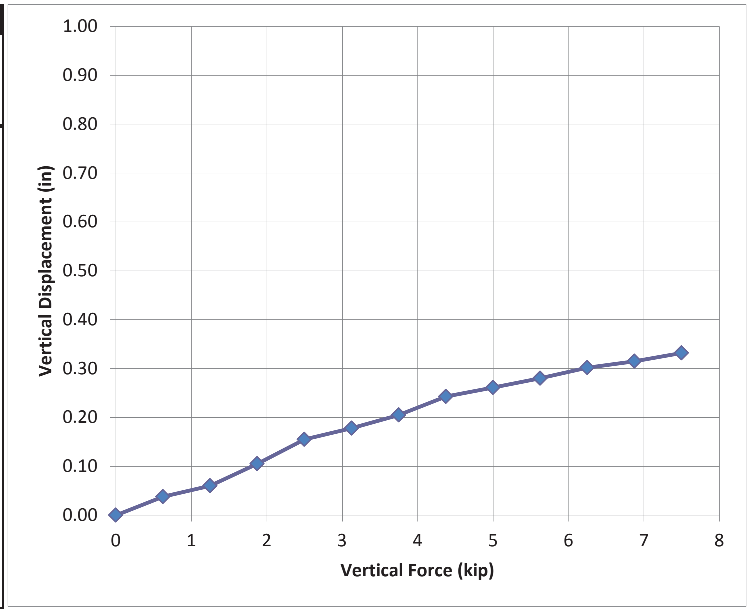


Pile Load Test Results

| | | | |
|---|---|---|---|
| Test Location: | TP5 | Project: | ADM Redbrook |
| Latitude (N): | 41.83504 | Project ID: | SLK16013 |
| Longitude (W): | -70.61162 | Date Installed: | 4/7/2016 |
| Embedment Depth (ft): | 9 | Date Tested: | 4/9/2016 |

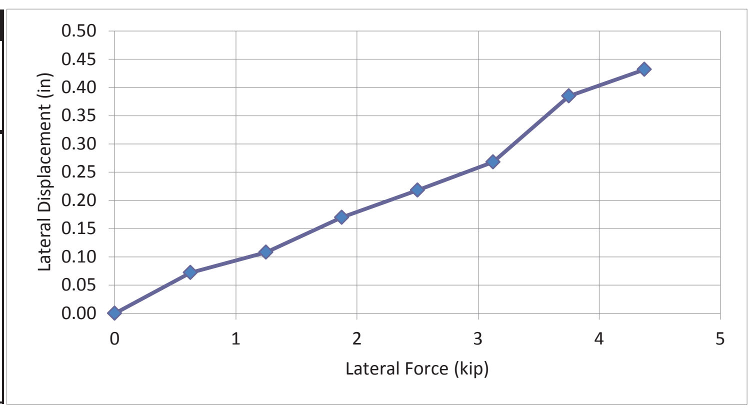
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.04 |
| 40 | 1.25 | 0.06 |
| 60 | 1.87 | 0.11 |
| 80 | 2.50 | 0.16 |
| 100 | 3.12 | 0.18 |
| 120 | 3.75 | 0.21 |
| 140 | 4.37 | 0.24 |
| 160 | 5.00 | 0.26 |
| 180 | 5.62 | 0.28 |
| 200 | 6.25 | 0.30 |
| 220 | 6.87 | 0.32 |
| 240 | 7.50 | 0.33 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.07 |
| 40 | 1.25 | 0.11 |
| 60 | 1.87 | 0.17 |
| 80 | 2.50 | 0.22 |
| 100 | 3.12 | 0.27 |
| 120 | 3.75 | 0.39 |
| 140 | 4.37 | 0.43 |



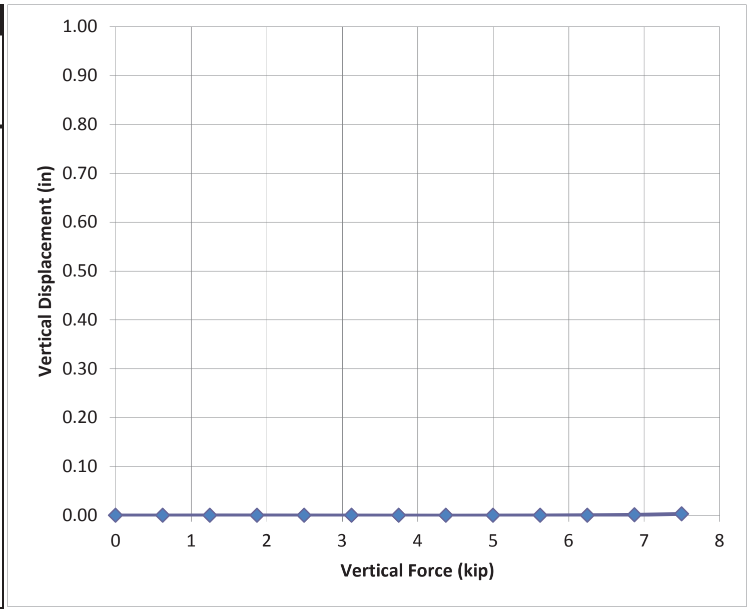
# Pile Load Test Results

Test Location: TP6
Latitude (N): 41.83275
Longitude (W): -70.61131
Embedment Depth (ft): 10

Project: ADM Redbrook
Project ID: SLK16013
Date Installed: 4/7/2016
Date Tested: 4/9/2016

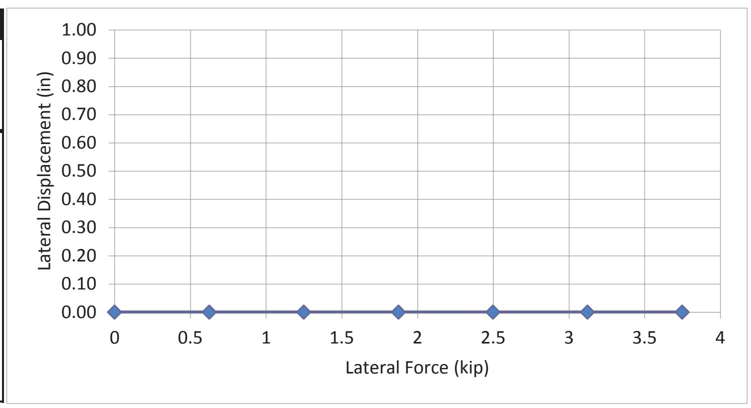
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.00 |
| 80 | 2.50 | 0.00 |
| 100 | 3.12 | 0.00 |
| 120 | 3.75 | 0.00 |
| 140 | 4.37 | 0.00 |
| 160 | 5.00 | 0.00 |
| 180 | 5.62 | 0.00 |
| 200 | 6.25 | 0.00 |
| 220 | 6.87 | 0.00 |
| 240 | 7.50 | 0.00 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | NR |
| 20 | 0.62 | NR |
| 40 | 1.25 | NR |
| 60 | 1.87 | NR |
| 80 | 2.50 | NR |
| 100 | 3.12 | NR |
| 120 | 3.75 | NR |
| 140 | 4.37 | NR |

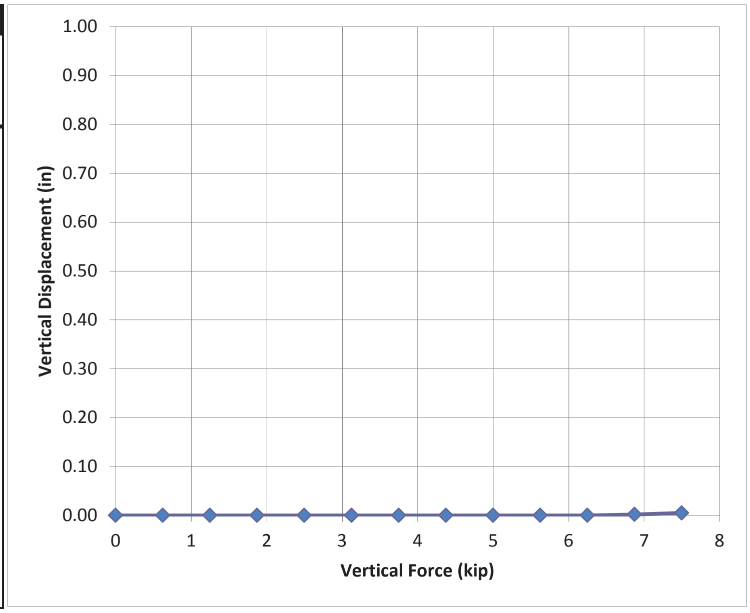


# Pile Load Test Results

| | | | |
|---|---|---|---|
| Test Location: | TP7 | Project: | ADM Redbrook |
| Latitude (N): | 41.8321 | Project ID: | SLK16013 |
| Longitude (W): | -70.61141 | Date Installed: | 4/7/2016 |
| Embedment Depth (ft): | 10 | Date Tested: | 4/9/2016 |

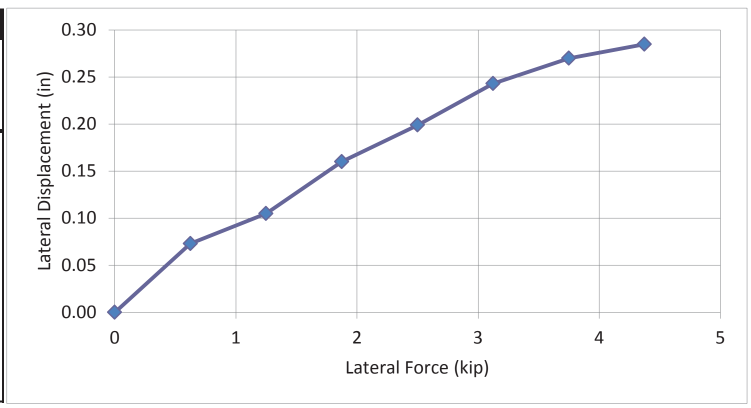
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.00 |
| 80 | 2.50 | 0.00 |
| 100 | 3.12 | 0.00 |
| 120 | 3.75 | 0.00 |
| 140 | 4.37 | 0.00 |
| 160 | 5.00 | 0.00 |
| 180 | 5.62 | 0.00 |
| 200 | 6.25 | 0.00 |
| 220 | 6.87 | 0.00 |
| 240 | 7.50 | 0.01 |




**Lateral Results**

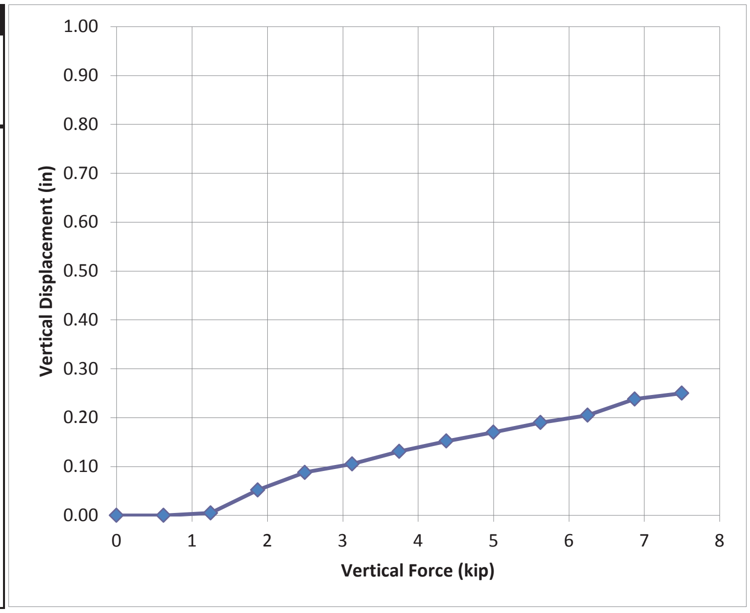
| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.07 |
| 40 | 1.25 | 0.11 |
| 60 | 1.87 | 0.16 |
| 80 | 2.50 | 0.20 |
| 100 | 3.12 | 0.24 |
| 120 | 3.75 | 0.27 |
| 140 | 4.37 | 0.29 |



| | | | |
|---|---|---|---|
| Test Location: | TP8 | Project: | ADM Redbrook |
| Latitude (N): | 41.83189 | Project ID: | SLK16013 |
| Longitude (W): | -70.61245 | Date Installed: | 4/7/2016 |
| Embedment Depth (ft): | 9 | Date Tested: | 4/9/2016 |

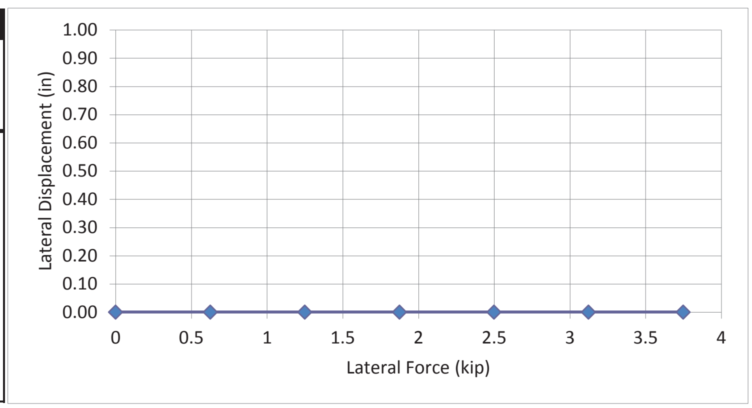
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.01 |
| 60 | 1.87 | 0.05 |
| 80 | 2.50 | 0.09 |
| 100 | 3.12 | 0.11 |
| 120 | 3.75 | 0.13 |
| 140 | 4.37 | 0.15 |
| 160 | 5.00 | 0.17 |
| 180 | 5.62 | 0.19 |
| 200 | 6.25 | 0.21 |
| 220 | 6.87 | 0.24 |
| 240 | 7.50 | 0.25 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | NR |
| 20 | 0.62 | NR |
| 40 | 1.25 | NR |
| 60 | 1.87 | NR |
| 80 | 2.50 | NR |
| 100 | 3.12 | NR |
| 120 | 3.75 | NR |
| 140 | 4.37 | NR |

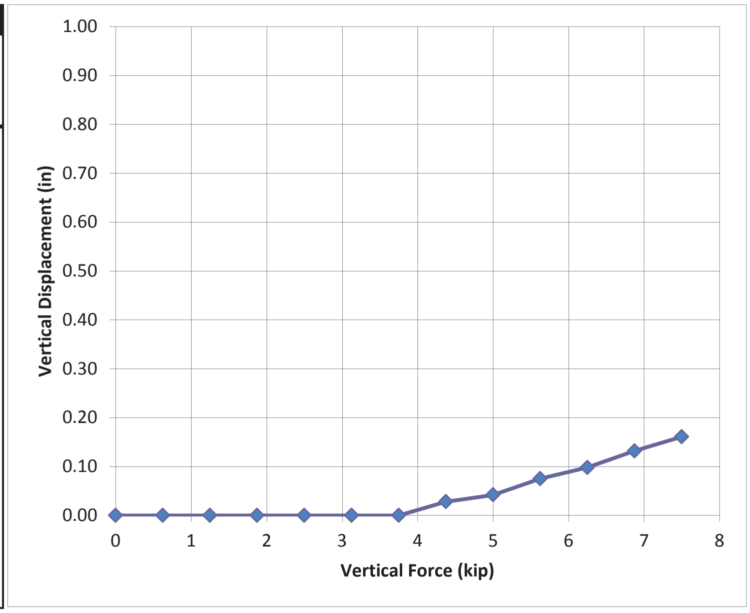


| | |
|---|---|
| Test Location: | TP9 |
| Latitude (N): | 41.83275 |
| Longitude (W): | -70.61237 |
| Embedment Depth (ft): | 9 |

| | |
|---|---|
| Project: | ADM Redbrook |
| Project ID: | SLK16013 |
| Date Installed: | 4/7/2016 |
| Date Tested: | 4/9/2016 |

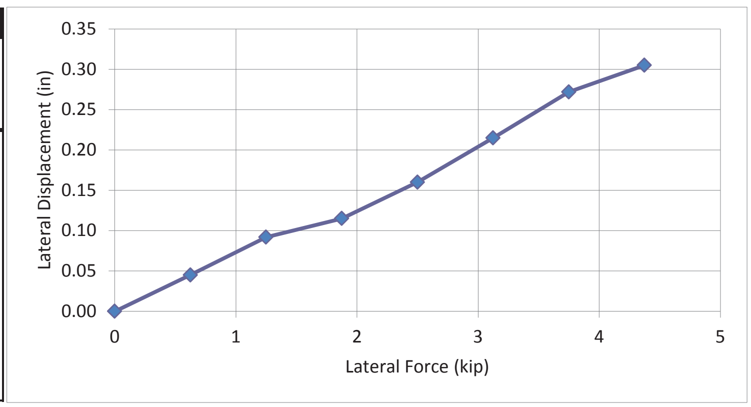
**Tension Results**

| Vertical Force (ft-lb) | Vertical Force (kip) | Vertical Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.00 |
| 40 | 1.25 | 0.00 |
| 60 | 1.87 | 0.00 |
| 80 | 2.50 | 0.00 |
| 100 | 3.12 | 0.00 |
| 120 | 3.75 | 0.00 |
| 140 | 4.37 | 0.03 |
| 160 | 5.00 | 0.04 |
| 180 | 5.62 | 0.08 |
| 200 | 6.25 | 0.10 |
| 220 | 6.87 | 0.13 |
| 240 | 7.50 | 0.16 |




**Lateral Results**

| Vertical Force (ft-lb) | Lateral Force (kip) | Lateral Displacement (in) |
|---|---|---|
| 0 | 0 | 0.00 |
| 20 | 0.62 | 0.05 |
| 40 | 1.25 | 0.09 |
| 60 | 1.87 | 0.12 |
| 80 | 2.50 | 0.16 |
| 100 | 3.12 | 0.22 |
| 120 | 3.75 | 0.27 |
| 140 | 4.37 | 0.31 |



# APPENDIX C

Site Photos


Figure 2: View of the setup used to measure axial tension.

Figure 3: View of the setup used to measure shear capacity.

Figure 5: View of the project site looking north and west.