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IronRidge
28357 Industrial Boulevard
Hayward, CA 94545

July 1, 2019


Attn: Mr. Corey Geiger, VP New Markets, IronRidge Inc.

Subject: Ground Mounting System – Structural Analysis – 4 Module (XR1000)

Dear Sir:

We have analyzed the subject ground mounted structure and determined that it is in compliance with the applicable sections of the following Reference Documents:

Codes: ASCE/SEI 7-10 Min. Design Loads for Buildings & Other Structures
ASCE/SEI 7-16 Min. Design Loads for Buildings & Other Structures
International Building Code, 2015 Edition
International Building Code, 2018 Edition
Other: AC428, Acceptance Criteria for Modular Framing Systems Used to Support PV Modules, dated Effective November 1, 2012 by ICC-ES
Aluminum Design Manual, 2015 Edition
IronRidge Exhibit EX-0001

The structure is a simple column (pier) and beam (cross pipe) system. The piers & cross pipes are ASTM A53 Grade B standard weight (schedule 40) steel pipes or Allied Mechanical Tubing. Please refer to Exhibit EX-0001 for approved pipe geometry and material properties. The tops of the piers are connected in the E-W direction by the cross pipes which cantilever over and extend past the end piers. The cross pipes are connected by proprietary IronRidge XR1000 Rails spanning up and down the slope which cantilever over and extend past the top and bottom cross pipes. There are typically two rails per column of modules. The modules are clamped to the rails by the IronRidge Module Mounting Clamps as shown in the attached Exhibit.

Gravity loads are transferred to the piers and foundations by the rails and cross pipes acting as simple beams. For lateral loads the system is either a cantilever structure or, when diagonal braces are provided, a braced frame. The effect of seismic loads (for all design categories A-F) have been determined to be less than the effect due to wind loads in all load conditions and combinations.

The pier spacing in the N-S direction is 7'-6". The pier spacing in the E-W direction is selected from load tables determined by the structural design for the specified slope, wind load, and snow load. The governing criteria for the pier spacing is either the spanning capacity of the cross pipes or the cantilever capacity of the pier. Simplified Load Tables 1A-F & 2A-F are included herein for reference.

More comprehensive information covering all load combinations is available at the IronRidge website, IronRidge.com.

| Table 2B - MAXIMUM PIER SPACING (in) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3" Unbraced Pipe Frame | Snow | Slope (deg) | | | | | | | | | |
| Wind Speed & Exposure Category | psf | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
| 100 mph Exposure C | 0 | 212 | 217 | 186 | 181 | 171 | 163 | 139 | 117 | 100 | 85 |
| | 10 | 191 | 194 | 176 | 174 | 170 | 163 | 139 | 117 | 100 | 85 |
| | 20 | 165 | 167 | 155 | 154 | 153 | 153 | 139 | 117 | 100 | 85 |
| | 30 | 155 | 156 | 147 | 146 | 146 | 147 | 139 | 117 | 100 | 85 |
| | 40 | 142 | 143 | 136 | 135 | 137 | 139 | 139 | 117 | 100 | 85 |
| | 50 | 131 | 131 | 127 | 127 | 129 | 131 | 134 | 117 | 100 | 85 |
| | 60 | 121 | 121 | 120 | 119 | 122 | 125 | 129 | 117 | 100 | 85 |
| 105 mph Exposure C | 0 | 204 | 178 | 162 | 148 | 137 | 134 | 126 | 107 | 91 | 77 |
| | 10 | 186 | 178 | 162 | 148 | 137 | 134 | 126 | 107 | 91 | 77 |
| | 20 | 162 | 164 | 152 | 148 | 137 | 134 | 126 | 107 | 91 | 77 |
| | 30 | 152 | 154 | 144 | 143 | 137 | 134 | 126 | 107 | 91 | 77 |
| | 40 | 140 | 141 | 134 | 133 | 134 | 134 | 126 | 107 | 91 | 77 |
| | 50 | 130 | 131 | 125 | 125 | 126 | 129 | 126 | 107 | 91 | 77 |
| | 60 | 121 | 121 | 118 | 118 | 120 | 123 | 126 | 107 | 91 | 77 |
| 110 mph Exposure C | 0 | 196 | 202 | 171 | 166 | 157 | 150 | 115 | 97 | 83 | 70 |
| | 10 | 182 | 185 | 167 | 164 | 157 | 150 | 115 | 97 | 83 | 70 |
| | 20 | 159 | 161 | 149 | 147 | 145 | 145 | 115 | 97 | 83 | 70 |
| | 30 | 150 | 152 | 141 | 140 | 139 | 140 | 115 | 97 | 83 | 70 |
| | 40 | 138 | 139 | 131 | 130 | 131 | 132 | 115 | 97 | 83 | 70 |
| | 50 | 128 | 130 | 123 | 123 | 124 | 126 | 115 | 97 | 83 | 70 |
| 120 mph Exposure C | 0 | 183 | 188 | 159 | 154 | 145 | 132 | 97 | 82 | 69 | 59 |
| | 10 | 174 | 177 | 158 | 154 | 145 | 132 | 97 | 82 | 69 | 59 |
| | 20 | 153 | 155 | 142 | 140 | 138 | 132 | 97 | 82 | 69 | 59 |
| | 30 | 145 | 147 | 136 | 134 | 133 | 132 | 97 | 82 | 69 | 59 |
| | 40 | 134 | 136 | 127 | 126 | 126 | 126 | 97 | 82 | 69 | 59 |
| | 50 | 125 | 127 | 119 | 119 | 120 | 121 | 97 | 82 | 69 | 59 |
| 130 mph Exposure C | 0 | 171 | 175 | 148 | 143 | 135 | 112 | 82 | 70 | 59 | 50 |
| | 10 | 166 | 169 | 148 | 143 | 135 | 112 | 82 | 70 | 59 | 50 |
| | 20 | 147 | 150 | 136 | 134 | 131 | 112 | 82 | 70 | 59 | 50 |
| | 30 | 140 | 142 | 130 | 129 | 127 | 112 | 82 | 70 | 59 | 50 |
| | 40 | 130 | 132 | 122 | 121 | 121 | 112 | 82 | 70 | 59 | 50 |
| | 50 | 122 | 124 | 116 | 115 | 115 | 112 | 82 | 70 | 59 | 50 |
| 140 mph Exposure C | 0 | 160 | 165 | 138 | 134 | 126 | 97 | 71 | 60 | 51 | 43 |
| | 10 | 158 | 162 | 138 | 134 | 126 | 97 | 71 | 60 | 51 | 43 |
| | 20 | 142 | 145 | 130 | 128 | 125 | 97 | 71 | 60 | 51 | 43 |
| | 30 | 135 | 138 | 125 | 123 | 121 | 97 | 71 | 60 | 51 | 43 |
| | 40 | 127 | 128 | 118 | 117 | 116 | 97 | 71 | 60 | 51 | 43 |
| | 50 | 119 | 121 | 112 | 111 | 111 | 97 | 71 | 60 | 51 | 43 |
| 150 mph Exposure C | 0 | 150 | 155 | 130 | 126 | 118 | 84 | 62 | 52 | 44 | 38 |
| | 10 | 150 | 154 | 130 | 126 | 118 | 84 | 62 | 52 | 44 | 38 |
| | 20 | 137 | 140 | 125 | 123 | 118 | 84 | 62 | 52 | 44 | 38 |
| | 30 | 131 | 133 | 120 | 118 | 116 | 84 | 62 | 52 | 44 | 38 |
| | 40 | 123 | 125 | 114 | 113 | 111 | 84 | 62 | 52 | 44 | 38 |
| 160 mph Exposure C | 0 | 142 | 146 | 122 | 118 | 107 | 74 | 54 | 46 | 39 | 33 |
| | 10 | 142 | 146 | 122 | 118 | 107 | 74 | 54 | 46 | 39 | 33 |
| | 20 | 132 | 135 | 120 | 117 | 107 | 74 | 54 | 46 | 39 | 33 |
| | 30 | 127 | 129 | 116 | 114 | 107 | 74 | 54 | 46 | 39 | 33 |
| | 40 | 119 | 121 | 110 | 108 | 107 | 74 | 54 | 46 | 39 | 33 |

Notes: see page 14

Notes for Tables 1 & 2:

1. Span = Indicated region denotes the requirement for (3) three XR1000 rails.

   Span = Indicated region denotes special requirements for XR1000 rails – contact IronRidge.

2. Cross pipe splices not permitted in outer 2/3 of end spans, or the middle 1/3 of interior spans based on the installed attachment spacing ($L_{install}$). See Figure A
3. End cantilever span of pipe rails (max) = 0.40 x maximum span ($L_{max}$) from above tables. See Figure A
4. When installations occur on a N-S grade, the design slope of the array shall be determined as the slope relative to level ground. Code required topographic effects have not been considered. Topographic (Wind) Factor = 1.0 (no topographic effects)
5. Dead Load (Weight) = 3 psf
6. Maximum PV Module Dimension = 80”

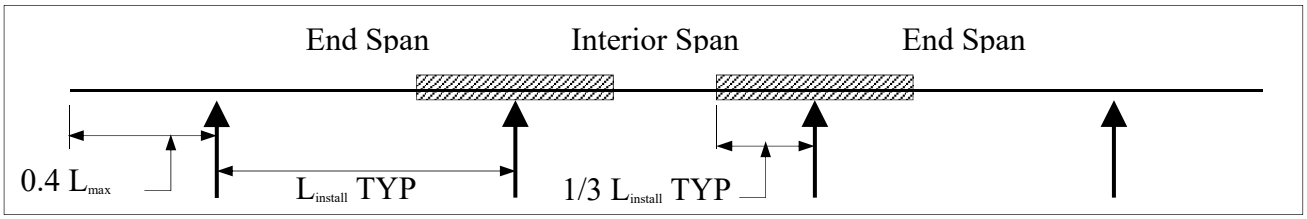



Figure A

$L_{max}$ = Maximum pier spacing provided in the tables above for the project design criteria

$L_{install}$ = Actual installed pier spacing

= Indicates region of the pipe rail where splice may be installed

To avoid potential problems from the effects of thermal expansion, a maximum total continuous cross pipe length of 100 ft is recommended.

Notes for CAMO module clamp installation:

1. Single module installation (“orphan modules”) shall not be permitted with the ground mount system when CAMO clamp is used. Reference Figure 1 on following page for “Orphan Module” installation.

2. CAMO clamps will function within a module’s design load ratings. Be sure the specific module being used with the CAMO clamp meets the dimensional requirements shown in Figure 2 on the following page, is a module listed in IronRidge’s installation manual, and that the module selected is suitable for the environmental conditions of a particular project.

| Soil Class 4 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Table 4B - MINIMUM FOUNDATION DEPTHS (in)** | | | | | | | | | | | |
| **3" Pipe Frame Unbraced** | Pier Dia (in) | Slope (deg) | | | | | | | | | |
| Wind Speed & Exposure Category | | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
| 100 mph Exposure C | 12 | 42 | 48 | 54 | 60 | 72 | 84 | 90 | 90 | 90 | 90 |
| | 16 | 36 | 36 | 42 | 54 | 66 | 72 | 78 | 78 | 78 | 78 |
| | 20 | 36 | 36 | 42 | 48 | 60 | 66 | 72 | 72 | 72 | 72 |
| | 24 | 36 | 36 | 36 | 48 | 54 | 60 | 66 | 66 | 66 | 66 |
| 105 mph Exposure C | 12 | 42 | 48 | 48 | 60 | 66 | 78 | 90 | 90 | 90 | 90 |
| | 16 | 36 | 36 | 42 | 54 | 60 | 72 | 78 | 78 | 78 | 78 |
| | 20 | 36 | 36 | 42 | 48 | 54 | 66 | 72 | 72 | 72 | 72 |
| | 24 | 36 | 36 | 36 | 42 | 54 | 60 | 66 | 66 | 66 | 66 |
| 110 mph Exposure C | 12 | 48 | 54 | 54 | 66 | 78 | 84 | 90 | 90 | 90 | 90 |
| | 16 | 36 | 42 | 48 | 54 | 66 | 78 | 78 | 78 | 78 | 78 |
| | 20 | 36 | 36 | 42 | 54 | 60 | 72 | 72 | 72 | 72 | 72 |
| | 24 | 36 | 36 | 36 | 48 | 54 | 66 | 66 | 66 | 66 | 66 |
| 120 mph Exposure C | 12 | 54 | 60 | 60 | 72 | 78 | 90 | 90 | 90 | 90 | 90 |
| | 16 | 42 | 48 | 48 | 60 | 72 | 78 | 78 | 78 | 78 | 78 |
| | 20 | 36 | 36 | 42 | 54 | 66 | 72 | 72 | 72 | 72 | 72 |
| | 24 | 36 | 36 | 42 | 48 | 60 | 66 | 66 | 66 | 66 | 66 |
| 130 mph Exposure C | 12 | 54 | 66 | 66 | 78 | 84 | 90 | 90 | 90 | 90 | 90 |
| | 16 | 42 | 48 | 54 | 60 | 72 | 78 | 78 | 78 | 78 | 78 |
| | 20 | 36 | 42 | 42 | 54 | 66 | 72 | 72 | 72 | 72 | 72 |
| | 24 | 36 | 36 | 42 | 54 | 60 | 66 | 66 | 66 | 66 | 66 |
| 140 mph Exposure C | 12 | 60 | 72 | 72 | 84 | 84 | 90 | 90 | 90 | 90 | 90 |
| | 16 | 48 | 54 | 54 | 66 | 72 | 78 | 78 | 78 | 78 | 78 |
| | 20 | 36 | 42 | 48 | 60 | 66 | 72 | 72 | 72 | 72 | 72 |
| | 24 | 36 | 36 | 42 | 54 | 66 | 66 | 66 | 66 | 66 | * |
| 150 mph Exposure C | 12 | 66 | 78 | 78 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 16 | 48 | 60 | 60 | 66 | 78 | 78 | 78 | 78 | 78 | 78 |
| | 20 | 42 | 48 | 48 | 60 | 72 | 72 | 72 | 72 | 72 | * |
| | 24 | 36 | 42 | 42 | 54 | 66 | 66 | 66 | 66 | * | * |
| 160 mph Exposure C | 12 | 72 | 84 | 84 | 96 | 96 | 90 | 90 | 90 | 90 | 90 |
| | 16 | 54 | 60 | 60 | 72 | 78 | 78 | 78 | 78 | 78 | 78 |
| | 20 | 42 | 48 | 48 | 60 | 72 | 72 | 72 | 72 | * | * |
| | 24 | 36 | 42 | 48 | 54 | 66 | 66 | 66 | * | * | * |

Notes: see page 52

Notes for Tables 3 & 4:

1. Concrete Weight = 145 pcf / f'c = 2500 psi
2. Provide Air Entraining Admixture for freeze and thaw cycles as required for colder climates.
3. Skin Friction per 2018 IBC & 2015 IBC 1810.3.3.1.4 & 5
4. Top 1'-0" of soil neglected for Skin Friction
5. Snow Load = 0 psf – tabulated values are conservative for Snow Loads > 0 psf
6. * indicates special foundation required. Contact IronRidge
7. Resistance to corrosion and/or sulfate attack, along with possible adverse effects due to expansive soils has not been considered in these foundation recommendations. SML Engineers assumes no liability with regard to these items.
8. Soil classification is to be determined and verified by the end user of this certification letter.

The analysis assumes that the array, including the connections and associated hardware, are installed in a workmanlike manner in accordance with the IronRidge Ground Mount Installation Manual and generally accepted standards of construction practice. Verification of PV Module capacity to support the loads associated with the given array shall be the responsibility of the Contractor or Owner and not IronRidge or Starling Madison Lofquist.

Please feel free to contact me at your convenience if you have any questions.

Respectfully yours,

Tres Warner, P.E.
Design Division Manager


Tres J Warner

Digitally signed by Tres J Warner
DN: c=US, o=Starling Madison Lofquist Inc, ou=A01427D00000165B5A5D9AF0000718D, cn=Tres J Warner
Date: 2019.06.30 10:25:48 -07'00'

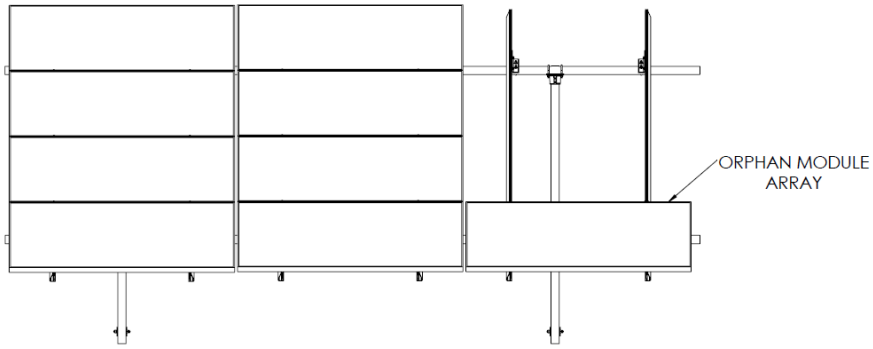



Figure 1: Orphan Module Installation

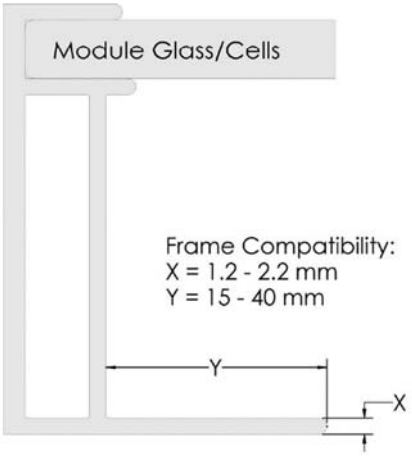



Figure 2: CAMO Clamp Module Frame Dimensional Requirements

Foundation Requirements

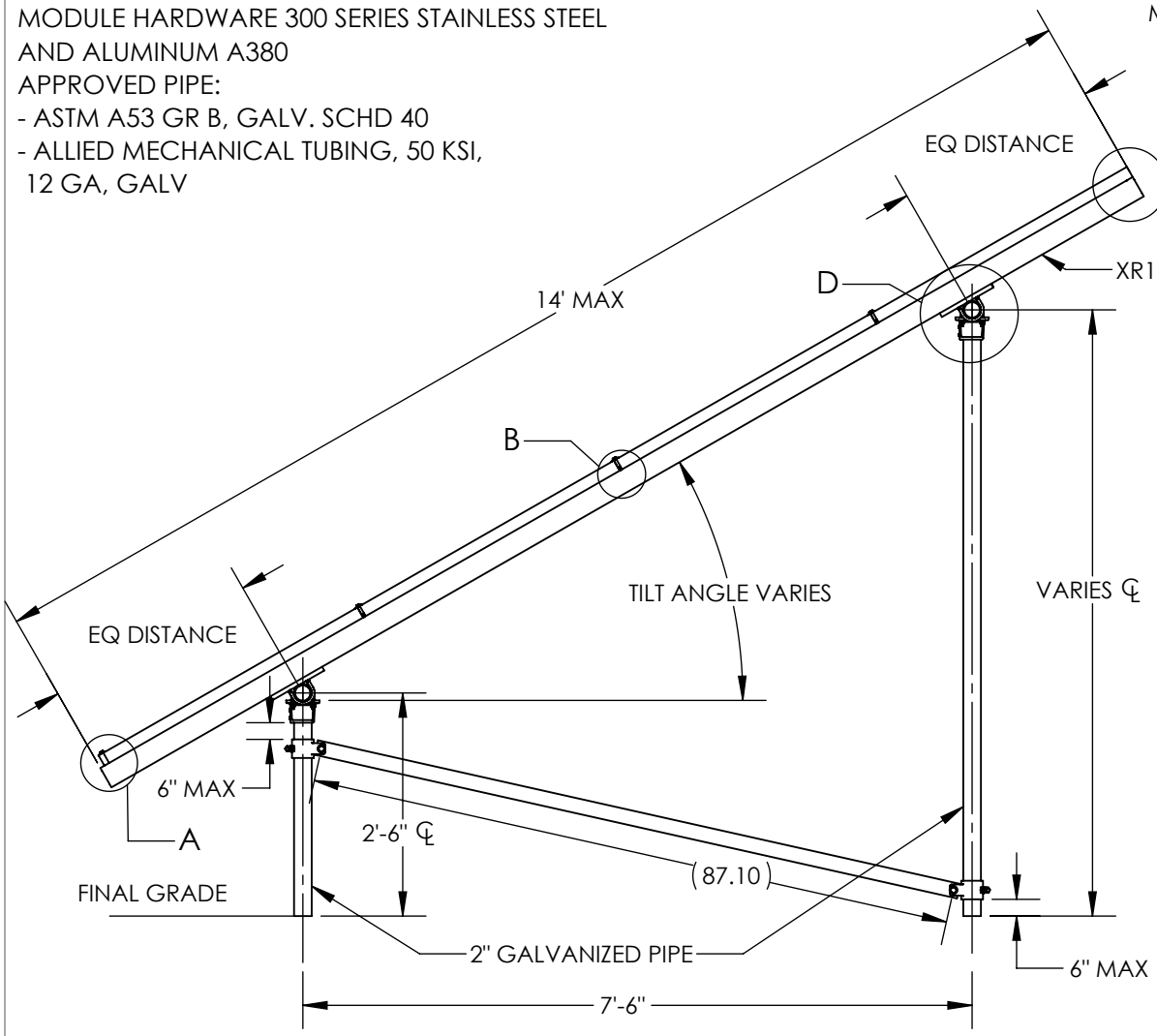
The foundation requirements for a cast-in-place drilled concrete pier system and for each soil class 2, 3, & 4 may be obtained from the tables below. The soil class is noted at the top of the tables. For each soil class Tables 3A-3F and 4A-4F are provided for the 2in and 3in systems respectively. These tables are based on the piers being installed at their maximum allowable spacing. For spacing values less than maximum and for loads cases with snow > 0 psf, the requirements can be determined by using the online Design Assistant at IronRidge.com.

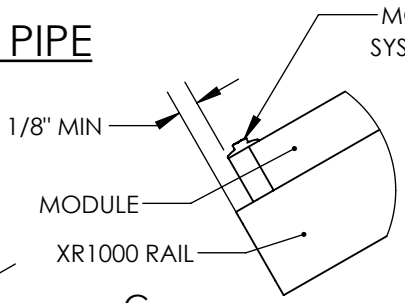
**EXHIBIT: EX-0001**

# 4 MODULE ROWS, 2" PIPE

10/16/2018

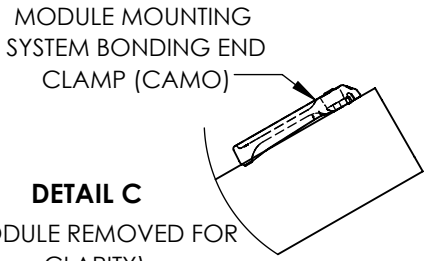
DESIGN CRITERIA & MATERIAL SPECIFICATIONS:
PER ASCE 7-10/WIND LOADING
MAXIMUM MODULE WEIGHT IS 3 psf
ALUMINUM XR1000 RAIL
MODULE HARDWARE 300 SERIES STAINLESS STEEL AND ALUMINUM A380
APPROVED PIPE:
- ASTM A53 GR B, GALV. SCHD 40
- ALLIED MECHANICAL TUBING, 50 KSI, 12 GA, GALV



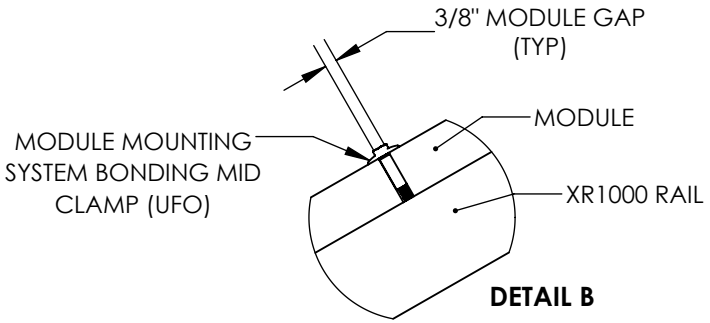




**DETAIL A**

**OR**

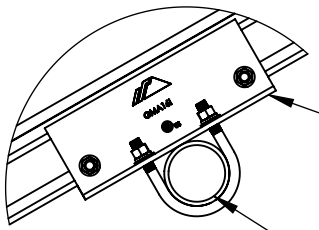



**DETAIL C**
(MODULE REMOVED FOR CLARITY)




**DETAIL B**

| APPROVED 2" PIPE | |
|---|---|
| - ALLIED MECHANICAL TUBING<br>- 50 ksi YIELD STRENGTH<br>- GALVANIZED (ALLIED FLOCOAT, GATORSHIELD, OR HOT DIPPED)<br>TOP CAP SET SCREW INSTALL TORQUE: 11 ft*lbs | ALLIED MECH. TUBING, 12 GA<br>.109 in<br>2.375 in |
| - ASTM A53 GR B<br>- 35 ksi YIELD STRENGTH<br>- HOT DIPPED GALVANIZED<br>TOP CAP SET SCREW INSTALL TORQUE: 20 ft*lbs | SCHD. 40 PIPE<br>.154 in<br>2.375 in |



XR1000 RAIL CONNECTION DETAIL TO HORIZONTAL CROSS PIPE (CONNECTOR, RAIL SGA 2")

**DETAIL D**

CROSS PIPE

| | | |
|---|---|---|
| DRAWN | TC | 10/16/2018 |
| CHECKED | -- | -- |
| ENG APPR. | -- | -- |
| MFG APPR. | -- | -- |
| Q.A. | -- | -- |

DIMENSIONS ARE IN INCHES.
TOLERANCES:
.XX: +/- .030
XXX: +/- .010
ANGLES: +/- 1°

IRONRIDGE

GROUND MOUNT SYSTEM 2" PIER, 4 SOLAR MODULE ROWS

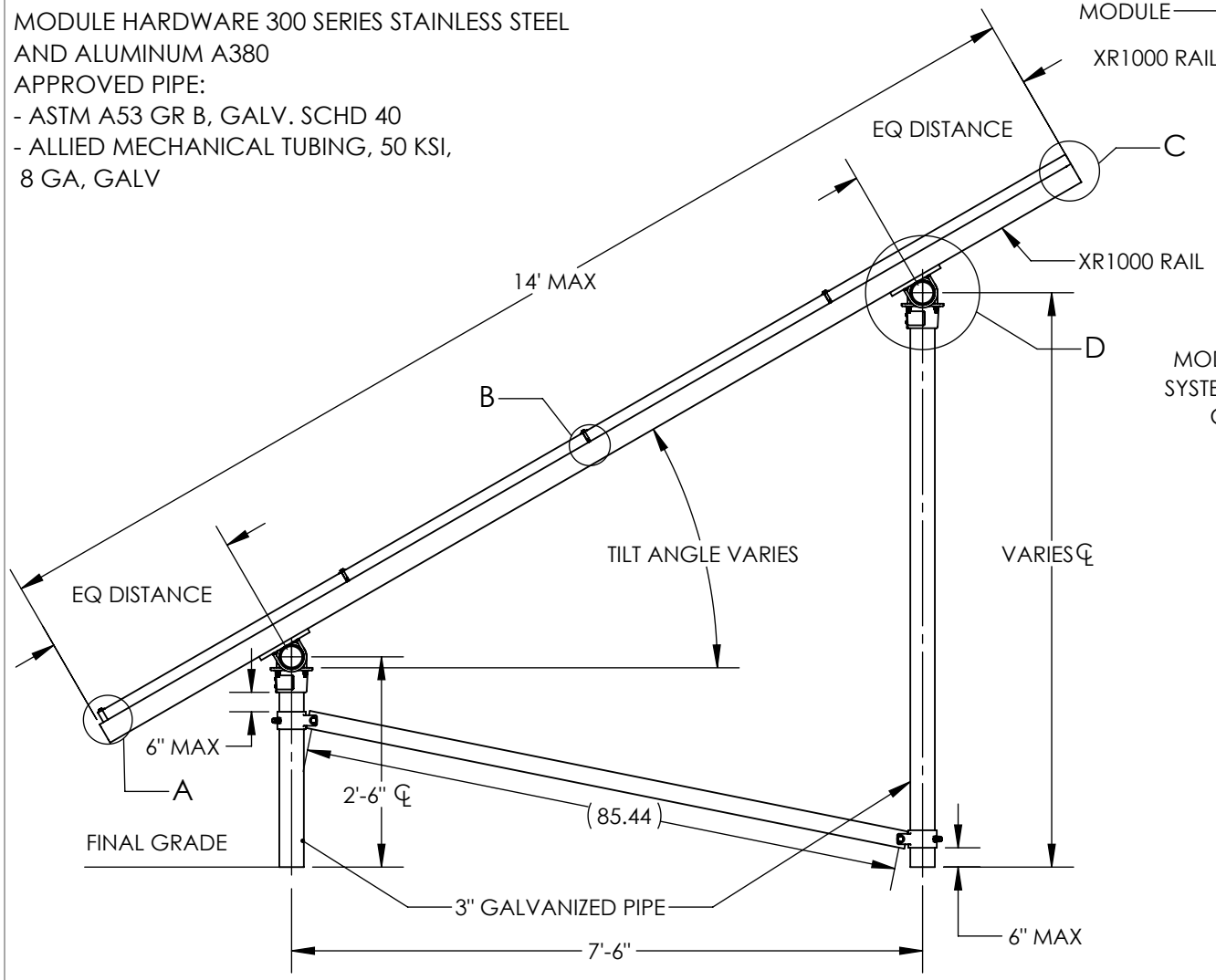
| SIZE | DWG. NO. | REV. |
|---|---|---|
| A | EX-0001 | B |
| SCALE:1:25 | WEIGHT: | SHEET 1 OF 5 |

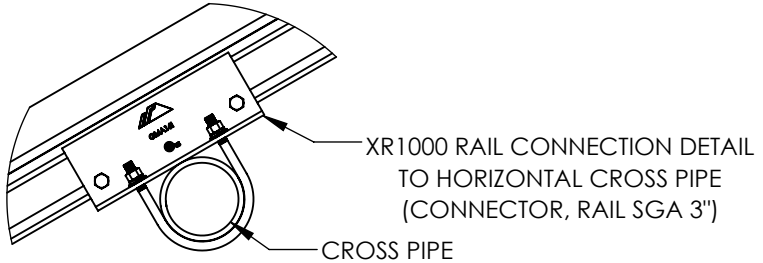
# EXHIBIT: EX-0001

10/16/2018

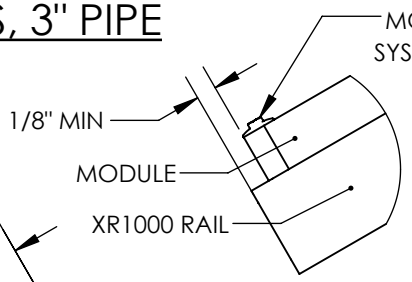
DESIGN CRITERIA & MATERIAL SPECIFICATIONS:
PER ASCE 7-10/WIND LOADING
MAXIMUM MODULE WEIGHT IS 3 psf
ALUMINUM XR1000 RAIL
MODULE HARDWARE 300 SERIES STAINLESS STEEL AND ALUMINUM A380
APPROVED PIPE:
- ASTM A53 GR B, GALV. SCHD 40
- ALLIED MECHANICAL TUBING, 50 KSI, 8 GA, GALV

## 4 MODULE ROWS, 3" PIPE



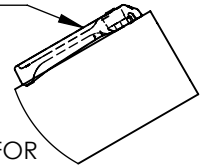

**DETAIL D**




**DETAIL A**

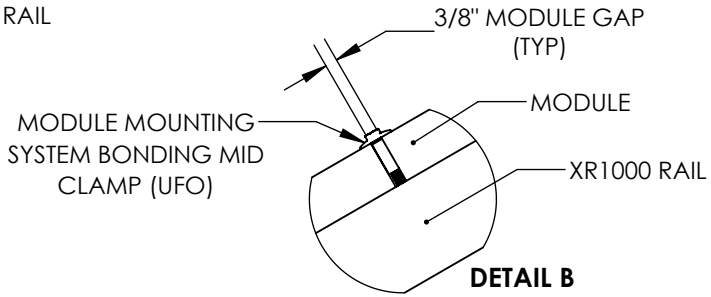
**OR**

MODULE MOUNTING SYSTEM BONDING END CLAMP (CAMO)

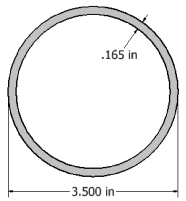
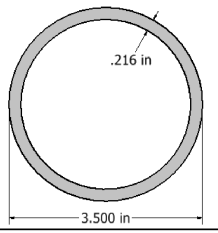


**DETAIL C**

(MODULE REMOVED FOR CLARITY)




**DETAIL B**

| APPROVED 3" PIPE | |
|---|---|
| - ALLIED MECHANICAL TUBING<br>- 45 ksi YIELD STRENGTH<br>- GALVANIZED (ALLIED FLOCOAT, GATORSHIELD, OR HOT DIPPED)<br><br>TOP CAP SET SCREW INSTALL TORQUE: 16 ft*lbs | **ALLIED MECH. TUBING, 8 GA**<br>  |
| - ASTM A53 GR B<br>- 35 ksi YIELD STRENGTH<br>- HOT DIPPED GALVANIZED<br><br>TOP CAP SET SCREW INSTALL TORQUE: 20 ft*lbs | **SCHD. 40 PIPE**<br>  |

IRONRIDGE

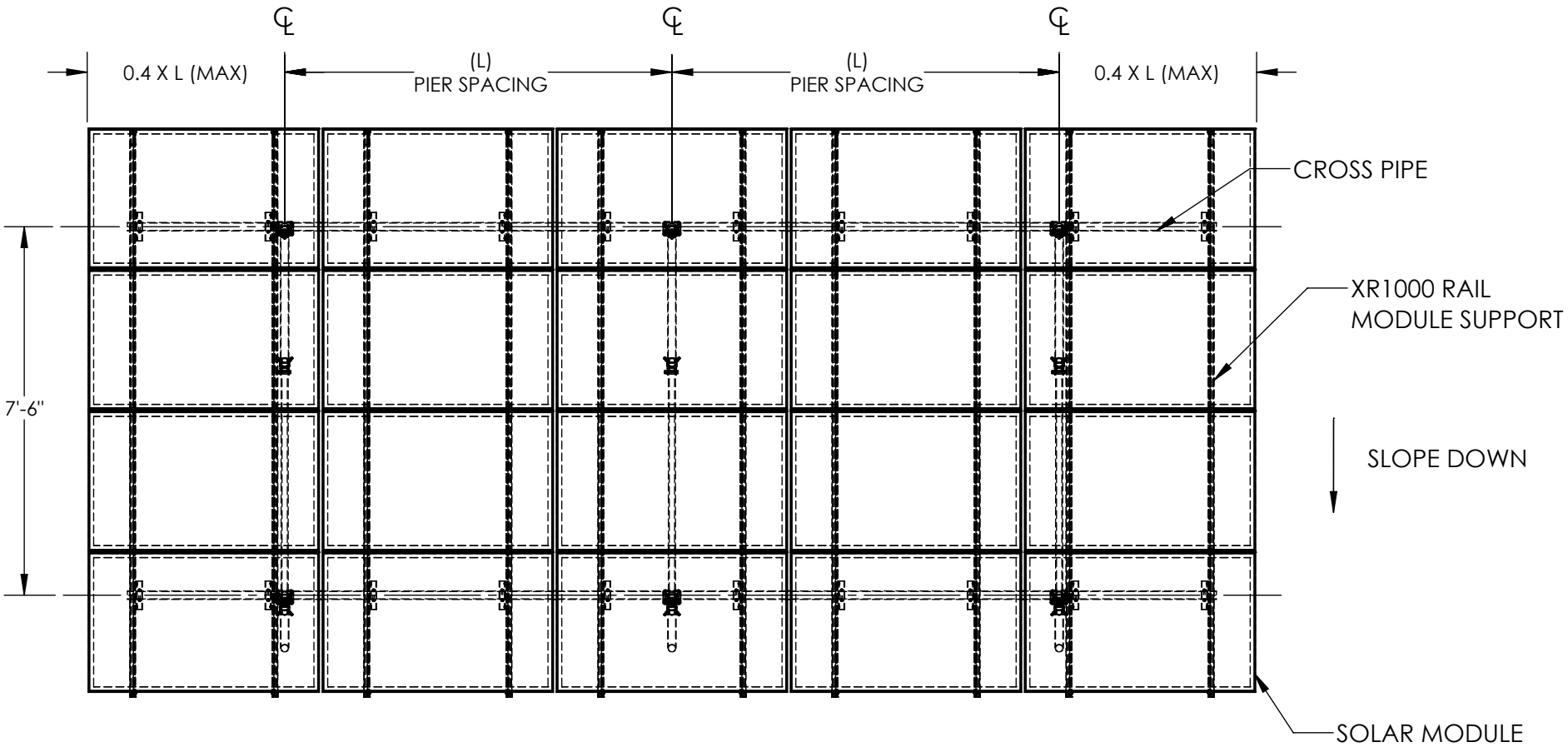
GROUND MOUNT SYSTEM 3" PIER, 4 SOLAR MODULE ROWS

| SIZE | DWG. NO. | REV. |
|---|---|---|
| A | EX-0001 | B |
| SCALE:1:25 | WEIGHT: | SHEET 2 OF 5 |

**EXHIBIT: EX-0001**

10/16/2018

# PLAN VIEW (6 PIER LAYOUT SHOWN)




IRONRIDGE

GROUND MOUNT SYSTEM, 4 SOLAR MODULE ROWS

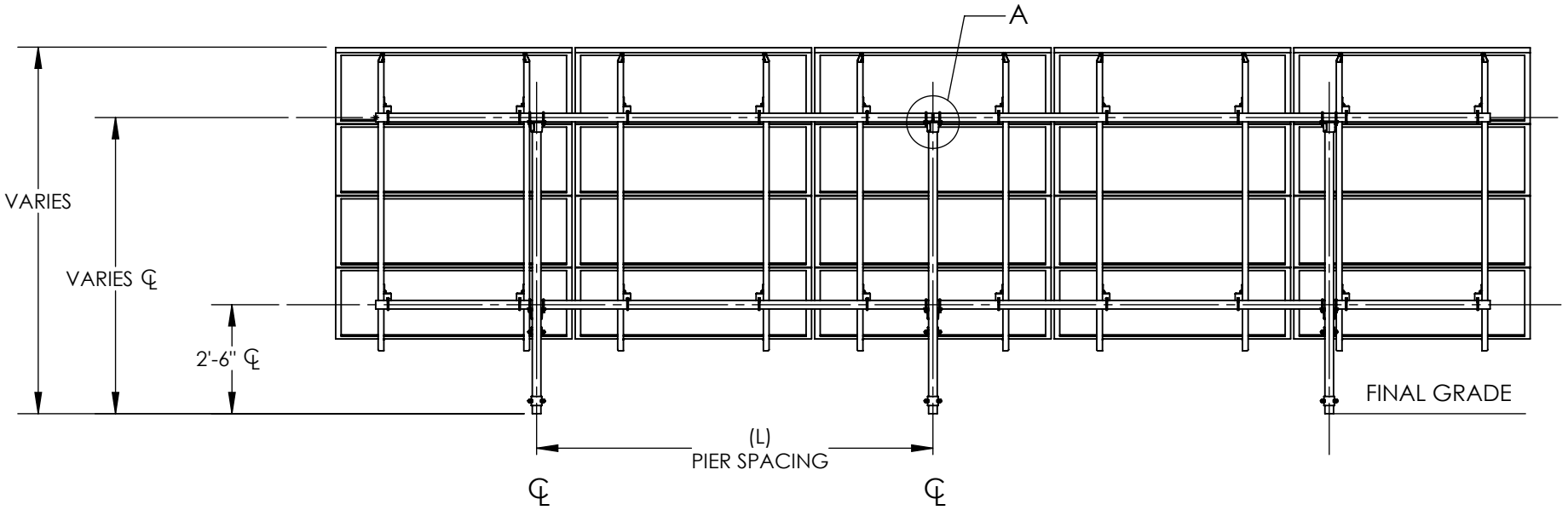
| SIZE | DWG. NO. | REV. |
|---|---|---|
| A | EX-0001 | B |

| SCALE:1:25 | WEIGHT: | SHEET 3 OF 5 |
|---|---|---|

**EXHIBIT: EX-0001**

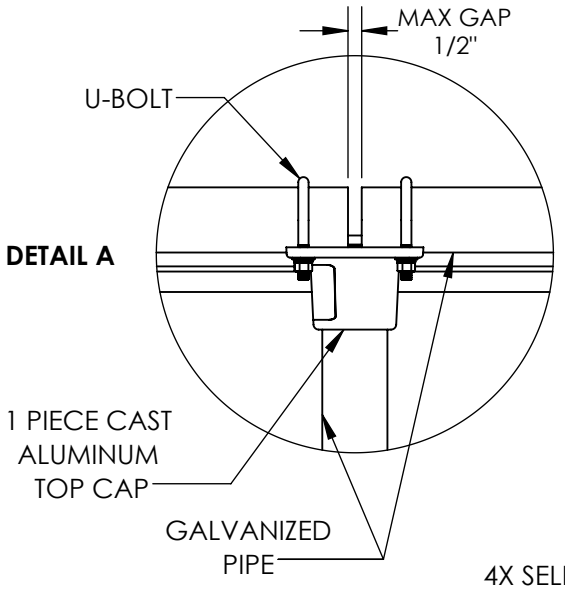
10/16/2018

# NORTH VIEW



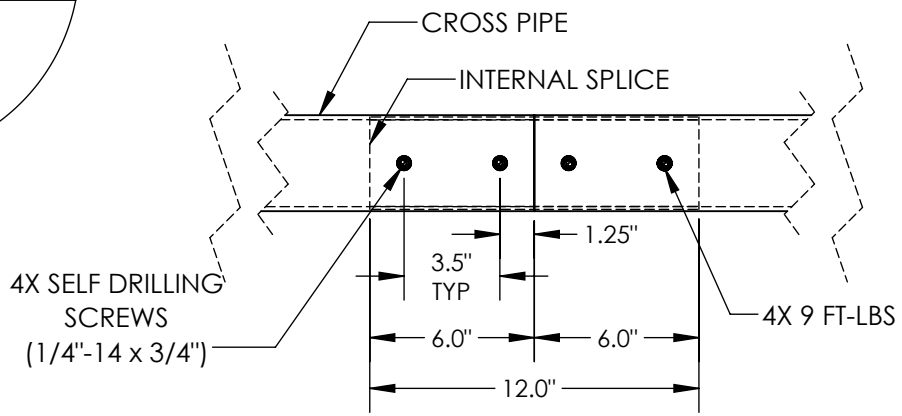

# SPLICING CROSS PIPE

## ALLIED MECHANICAL TUBE OR SCH. 40 PIPE SPLICE

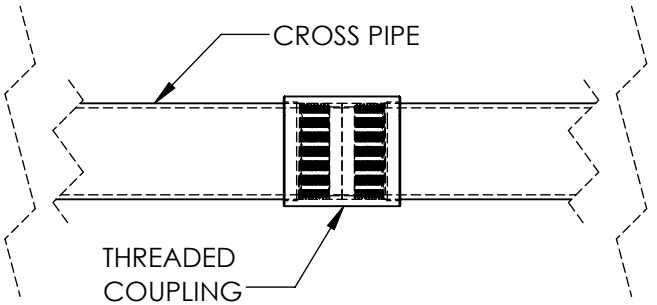



| Mechanical Tube Size of the Structure | Splice Tube Size |
|---|---|
| 2.375" OD, 12 Gauge | 2.000" OD, 9 Gauge, Minimum 12" Long |
| 3.500" OD, 8 Gauge | 3.000" OD, 12 Gauge, Minimum 12" Long |

## ALLIED MECHANICAL TUBE SPLICE




## SCH. 40 PIPE SPLICE




IRONRIDGE

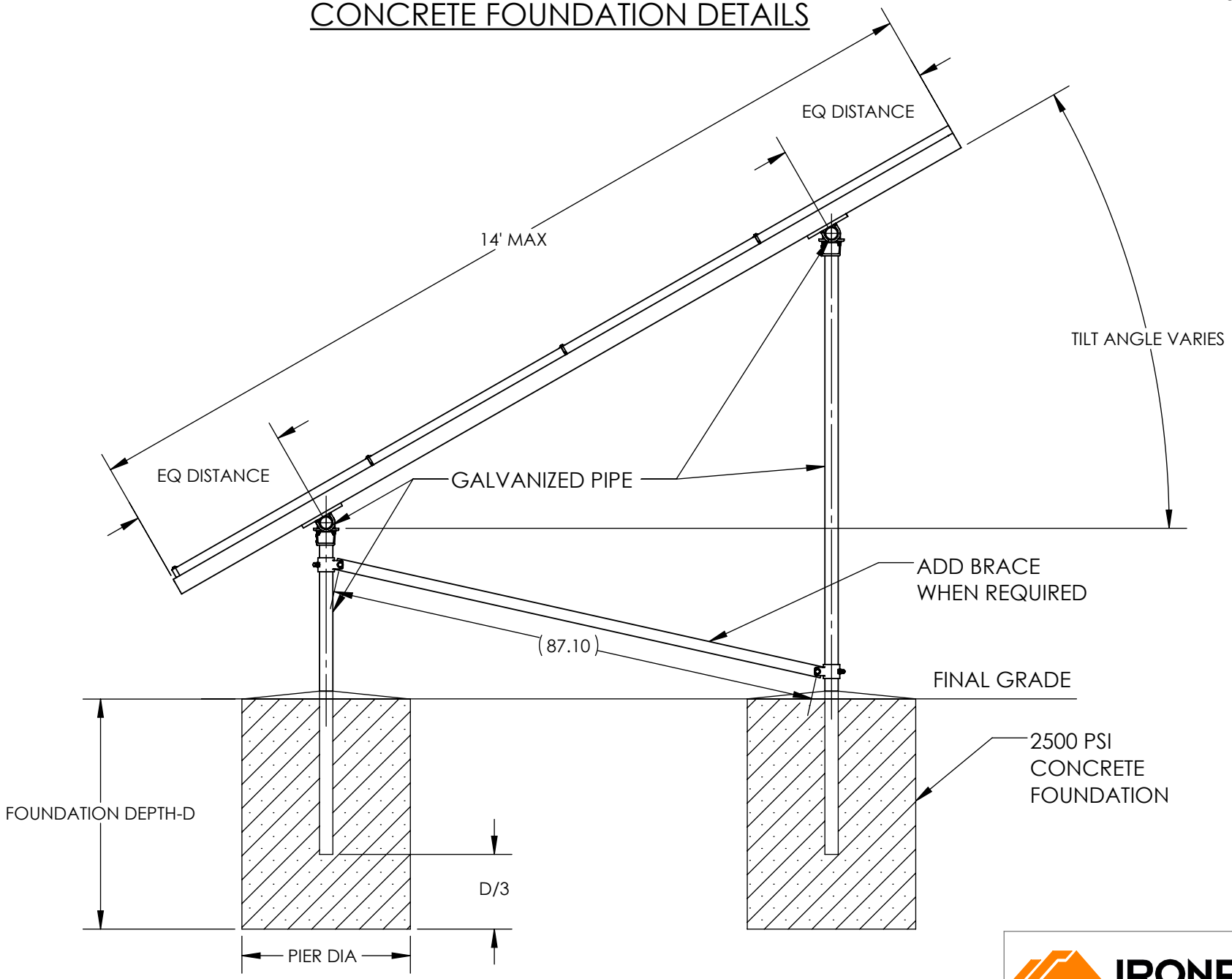
GROUND MOUNT SYSTEM, 4 SOLAR MODULE ROWS

| SIZE | DWG. NO. | REV. |
|---|---|---|
| A | EX-0001 | B |
| SCALE:1:25 | WEIGHT: | SHEET 4 OF 5 |

**EXHIBIT: EX-0001**

10/16/2018

# CONCRETE FOUNDATION DETAILS




NOTE:
THE ATTACHED SPAN TABLES ARE BASED ON USING DRILLED CAST-IN-PLACE CONCRETE PIER FOUNDATION SYSTEM. OTHER FOUNDATION SYSTEMS (EG. SCREW ANCHORS, DRIVEN PIERS) ARE PERMISSIBLE BUT MAY REQUIRE ADDITIONAL BRACING AND/OR REDUCED SPAN. PLEASE CONTACT IRONRIDGE FOR MORE INFORMATION.

IRONRIDGE

GROUND MOUNT SYSTEM, 4 SOLAR MODULE ROWS

| SIZE | DWG. NO. | REV. |
|---|---|---|
| A | EX-0001 | B |
| SCALE:1:25 | WEIGHT: | SHEET 5 OF 5 |