The Simple Solar Racking Solution™

Engineering Details & Sample Documents

Sollega

Table of Contents

The Simple Solar Racking Solution™

FastRack 510™

The simple solar racking solution for flat roof or ground mount PV installations.

- 5º or 10º mounting solution
- Simple, modular, one piece design
- Universal design compatible with all framed modules
- Fully ballasted , heat welded, anchored and hybrid options
- Roof friendly with round edges and low point loads
- One size bolt with all top down connections
- Injection molded with Ultramid® by BASF
- Engineering and ballast layout services available
- UL 1703 Class "A" Type 1 Module
- UL 467 Integrated grounding
- 100% Recyclable

Easy to install:

1. Position FastRacks
2. Add Ballast and Clamps
3. Attach Modules

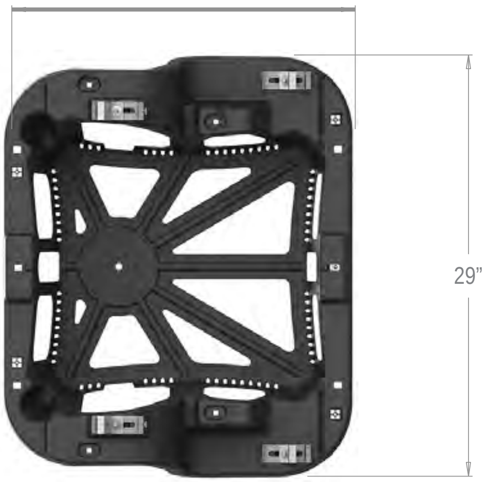
Sollega Inc.

Toll free: 855-725-RACK (7225) | info@ sollega.com | www.sollega. com

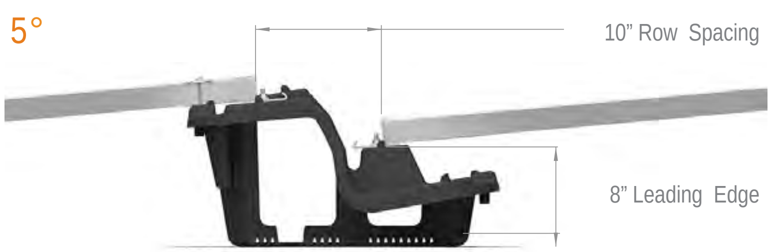
Sollega™

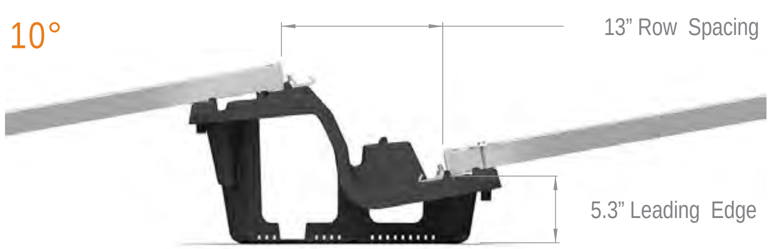
The Simple Solar Racking Solution™

FastRack510™



Tilt Angle	5°	10°
Row Spacing	10” (254 mm)	13” (330 mm)
Leading Edge	8” (203 mm)	5.3” (135 mm)
Compatible Modules	All framed modules 31” - 44” in width (787 mm and 1117 mm)	
Weight	4.75 lbs. (2.15 kg)	
Ballast Requirements	4” x 8” x 16” Roof Paver (31.5 lbs each) based on ASTM Designation C1491 – 01a.	
Material	BASF Ultramid® glass reinforced nylon	
Module Orientation	Landscape, Portrait	
Wind Load Criteria	Meets ASCE 7-10 up to 165 mph	
UL Certification	UL 1703: Class 'A' Type 1 Module, UL467	
Warranty	25 Year Limited Warranty	
Dimensions	(LxWxH) 24.25 x 29 x 14” 616 x 737 x 356mm	
Disassembly	Simple disassembly and 100% recyclable content	
Patent	Patented design: US	





Sollega Inc.   Toll free: 855-725-RACK (7225) | info@ sollega.com | www.sollega. com

Proudly Made in America

Ultramid® for the Solar Industry

Ultramid® polyamide from BASF has a proven performance record in construction and outdoor applications. It is also used extensively in automotive, material handling and household products applications.

BASF has many decades of experience with engineering plastics for outdoor applications. Extensive testing has shown that the mechanical properties of Ultramid® change nominally when exposed to extreme weather conditions although there is some slight graying of the component after the initial UV exposure.

BASF has developed a specific grade of Ultramid® optimized for the requirements of the solar industry having the following properties:

- High strength and rigidity
- Very good impact strength
- Good elastic properties
- Outstanding UV stability
- High temperature stability
- High resistance to chemicals
- Dimensional stability
- Low creep
- Exceptional sliding friction
- Simple processing
- Excellent for injection mold

These properties translate to product durability, weather resistance and outstanding mechanics to the various applications.

The specific glass fiber reinforced Ultramid® 8233G HS BK-106 used in the Sollega FastRack FR510 is heat stabilized and UV weather resistant. It is designed for injection molding with excellent mold flow qualities. It offers excellent strength, stiffness, high temperature performance and dimensional stability. This balance of engineering properties in combination with excellent processing ability make it ideal for roof top solar PV. It is a direct metal replacement, resulting in an overall lower cost per watt and weight reduction for rooftop solar PV.

Figure 1 represents a field study field study of UV exposure on automotive component demonstrating the tensile strength retention over a fourteen year service life. Even at extreme combinations of high temperature and humidity, typical conditions for solar PV, Ultramid® shows high resilience of mechanical properties.

Sollega FastRack FR510 Solar PV Racking is reinforced with Ultramid®

BASF
The Chemical Company

For **more information** on Ultramid® for Solar applications, visit www.plasticsportal.com

Sollega™

FastRack is a product of Sollega. Learn more at: sollega.com

Ultramid® is a registered trademark of BASF SE.

UV Exposed Automotive Component Strength Study

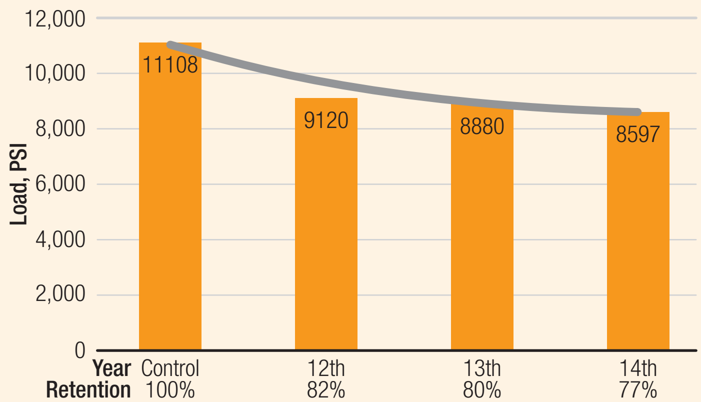


Fig. 1: Tensile strength retention over years of service. Actual UV exposed glass fiber reinforced Ultramid® automotive component.

Modulus Vs. Temperature – Ultramid® 8233G HS BK-106

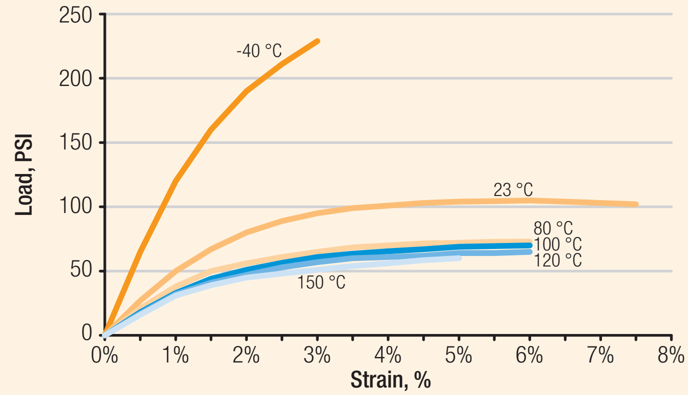


Fig. 2: Stress / strain diagram for Ultramid® with high glass fiber content, at 23 °C and 80 °C.

The Sollega FastRack 510 using Ultramid® 8233G HS BK-106 exceeds all requirements set by UL2703. These requirements include:

- UL 746C - Ultramid® 8233G HS BK-106 glass reinforced nylon well exceeds this requirement by maintaining 98% of its physical properties after 1,000 hours of Xenon arc testing.
- UL 746C - Ultramid® 8233G HS BK-106 glass reinforced nylon well exceeds this requirement by maintaining 85% of its physical properties after water exposure and immersion conditioning.
- UL2703 Section 7.4 - Minimum Relative Temperature Index (RTI) Mechanical without Impact value of 95°C. Ultramid® 8233G HS BK-106 glass reinforced nylon well exceeds its requirement by having a RTI value of 140°C.

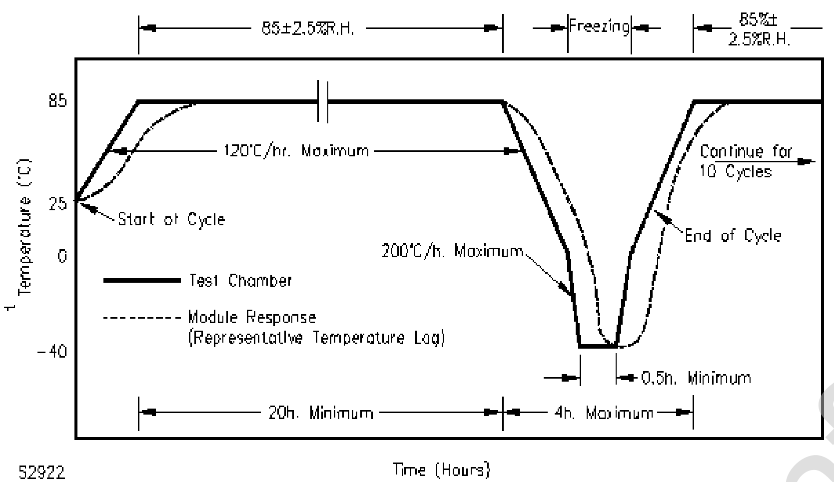
PHYSICAL	**ISO TEST METHOD**	**PROPERTY VALUE**	
Density, g/cm	1183	1.39	
Moisture %	62		
(24 hour)		1.1	
(50% RH)		1.8	
(Saturation)		6.4	
MECHANICAL	**ISO TEST METHOD**	**DRY**	**CONDITIONED**
Tensile Moculus, MPa	527		
40 °C		10,400	11,500
23 °C		10,500	7,700
80 °C		4,660	4,600
121 °C		4,015	4,200
Tensile stress at break, MPa	527		
-40 °C		210	215
23 °C		155	100
80 °C		85	70
121 °C		70	80
Tensile strain at break, %	527		
23 °C		2	6
Flexural Strength, MPa	178		
23 °C		225	–
Flexural Modulus, MPa23 °C	176		
23 °C		8,700	–
IMPACT	**ISO TEST METHOD**	**DRY**	**CONDITIONED**
Izod Notched Impact, kJ/m²	180		
23 °C		8.5	–
-40 °C		6	–
Charpy Notched, kJm²	179		
23 °C		8	–
-30 °C		5.5	–
Charpy Unnotched, kJ/m²	170		
23 °C		55	–
THERMAL	**ISO TEST METHOD**	**DRY**	**CONDITIONED**
Melting Point, °C	3146	220	–
HDT A, C	75	205	–
HDT B, C	75	215	–
ELECTRICAL	**ISO TEST METHOD**	**DRY**	**CONDITIONED**
Volume Resistivity	IEC 60093	>1#13	–

Table 1. Material Properties of Ultramid® 8233-G HS BK-106.

UL2703
Humidity-Freezing Cycle Test Results

150 years

BASF
We create chemistry



UL2703 Humidity-Freezing Cycle Test Procedure:

18.5 Each cycle is to consist of:

a) A transition in the test chamber temperature from 25°C to 85°C (77°F to 185°F);

b) A dwell at 85°C for 20 h minimum.

c) A transition from 85°C to minus 40°C (minus 40°F);

d) A dwell at minus 40°C for 30 minutes minimum; and

e) A transition from minus 40°C to 25°C. When the temperature is 0°C (32°F) or above, the temperature transitions of the test chamber with respect to time are not to be greater than 120°C/h (216°F/h). When the temperature is less than 0°C, the temperature transitions of the test chamber with respect to time are not to be greater than 200°C/h (360°F/h). The total time for the transitions and the minus 40°C dwell together is not to exceed 4 h. If the 25°C temperature is the start or end of the 10 cycles, any nominal room temperature in the range 15°C to 30°C (59°F to 86°F) may be used. The total cycle time is not to exceed 24 h.

18.6 The humidity of the chamber air when the chamber air temperature is 85°C (185°F) is to be 85 ±2.5 percent relative humidity. During all temperature transitions the chamber air is to be isolated from the outside air (no make-up air) to allow condensing water vapor to freeze in the module or panel.

Property	Ultramid® 8233G HS bk-106
Dry-as- Molded Property	
Tensile Strength, MPa	169
Elongation, %	2.4
Flexural strength, MPa	243
Flexural Modulus, MPa	10000
Charpy notched, kJ/m^2	8
Charpy Nonotch kJ/m^2	55
Property after Conditioning (humidity/freeze as per UL 2703)	
Tensile Strength, MPa	88
Elongation, %	6.3
Flexural strength, MPa	140
Flexural Modulus, MPa	5500
Charpy notched, kJ/m^2	21
Charpy Nonotch kJ/m^2	82
% Property Retention	
Tensile Strength	52%
Elongation	260%
Flexural strength	57%
Flexural Modulus	55%
Charpy notched	260%
Charpy Nonotch	150%

Component - Plastics [guide info] E36632

BASF CORP

1609 BIDDLE AVE, WYANDOTTE MI 48192-3729

8233GHS (f1)(t2)

Polyamide 6 (PA6), "Capron or Ultramid", furnished as pellets

Color	Min Thk (mm)	Flame Class	HWI	HAI	RTI Elec	RTI Imp	RTI Str
BK	1.5	HB	1	0	140	115	140
	3.0	HB	1	0	140	120	140

Comparative Tracking Index (CTI): 1

Inclined Plane Tracking (IPT): -

Dielectric Strength (kV/mm): 29

Volume Resistivity (10^x ohm-cm): 13

High-Voltage Arc Tracking Rate (HVTR): 1

High Volt, Low Current Arc Resis (D495): 6

Dimensional Stability (%): 0.3

(f1) - Suitable for outdoor use with respect to exposure to Ultraviolet Light, Water Exposure and Immersion in accordance with UL 746C.

(t2) - Represents glow wire temperature 750C tested in accordance with IEC 60695-2-13

ANSI/UL 94 small-scale test data does not pertain to building materials, furnishings and related contents. ANSI/UL 94 small-scale test data is intended solely for determining the flammability of plastic materials used in the components and parts of end-product devices and appliances, where the acceptability of the combination is determined by UL.

Report Date: 1994-01-27

Last Revised: 2015-02-11

c UL us

IEC and ISO Test Methods

Test Name	Test Method	Units	Thk (mm)	Value
Flammability	IEC 60695-11-10	Class (color)	1.5	HB75 (BK)
			3.0	HB40 (BK)
Glow-Wire Flammability (GWFI)	IEC 60695-2-12	C	1.5	960
			3.0	960
Glow-Wire Ignition (GWIT)	IEC 60695-2-13	C	1.5	750
			3.0	750
IEC Comparative Tracking Index	IEC 60112	Volts (Max)	-	-
IEC Ball Pressure	IEC 60695-10-2	C	-	-
ISO Heat Deflection (1.80 MPa)	ISO 75-2	C	-	-
ISO Tensile Strength	ISO 527-2	MPa	-	-
ISO Flexural Strength	ISO 178	MPa	-	-
ISO Tensile Impact	ISO 8256	kJ/m^2	-	-
ISO Izod Impact	ISO 180	kJ/m^2	-	-
ISO Charpy Impact	ISO 179-2	kJ/m^2	-	-

Sollega FastRack Solar Panel Mount FEA Report

BASF Contact - Matthew Parkinson
BASF Analyst - Prasanna Kondapalli & Praphulla Chandra
Date Prepared - 01/20/2014

BASF
The Chemical Company

Summary

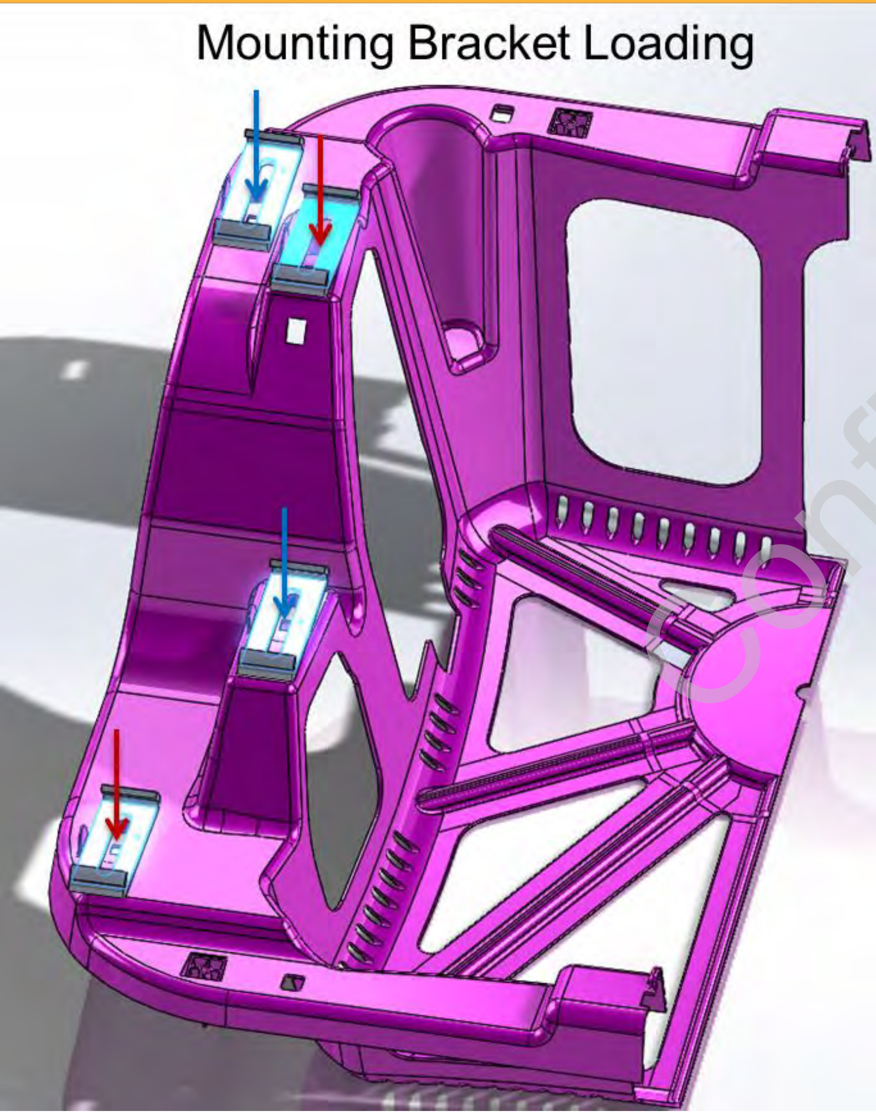
- Objective
  - To design a Solar Panel Mount that can support a total load of 1000lb without material failure, while minimizing mass.
  - Material used: Ultramid® 8233G HS (conditioned, at 23°C).
- Result
  - Under the 1000lb loading, Ultrasim® results predict that the part will pass, with a reasonable factor of safety.

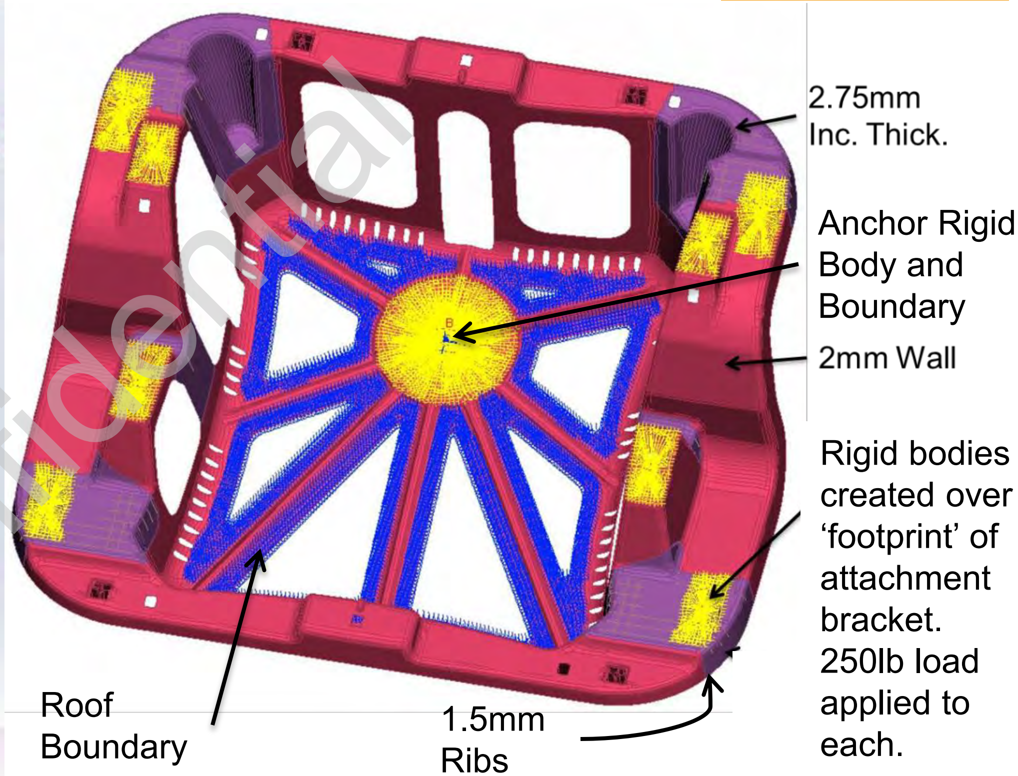
Analysis Details / Assumptions

BASF
The Chemical Company

- A non-linear Ultrasim® analysis was carried using a midplane model.
- Ribs were modeled as being a uniform 1.5mm thick, and did not account for taper.
- Two independent load cases were analyzed, with a 1000lb load applied at the 10° and the 5° mounting locations.
- The displacement plots were obtained under a 250lb total load.
- Two boundary conditions were applied for both load cases:
  - A boundary was applied on the nodes in contact with the roof to prevent their motion in the vertical direction.
  - A rigid body was applied to the central anchor mount to simulate the anchor. The rigid body was held in all degrees of freedom.
- The analysis assumed conditioned material properties at 23°C.
- Units used for this analysis:
  - mm / s / ton / MPa

Panel Mounting Condition

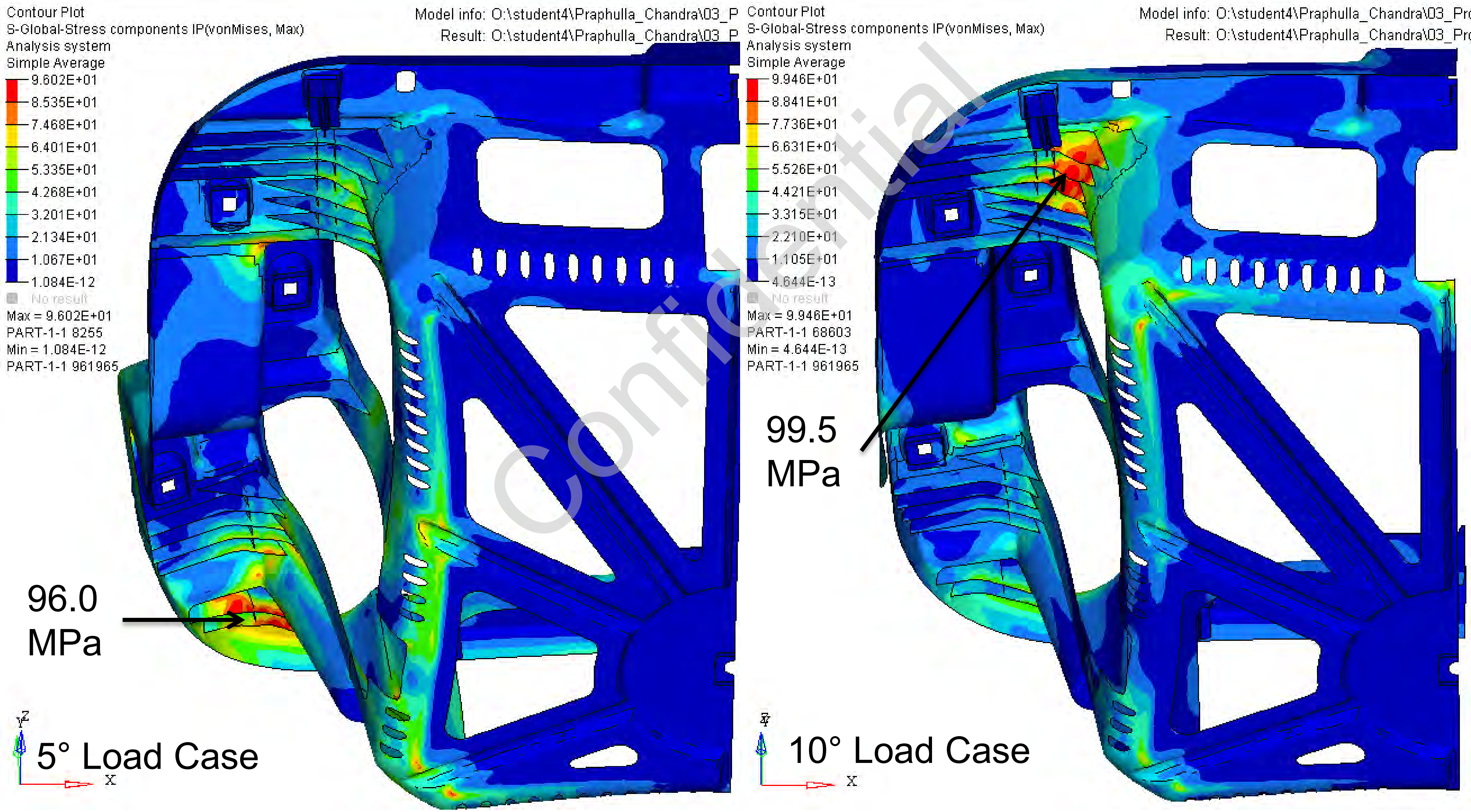




Color	Load Case	Load Applied
Blue	5º	4*250lb
Red	10º	4*250lb

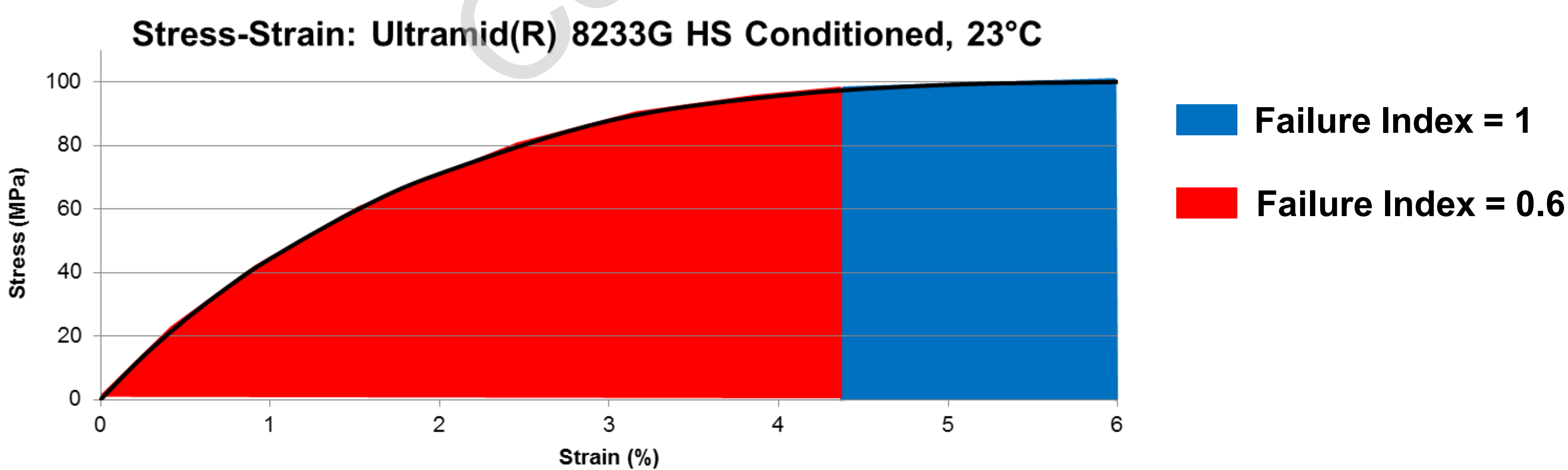
FEA RESULTS

Isotropic Analysis
Total Load Applied: 1000lb



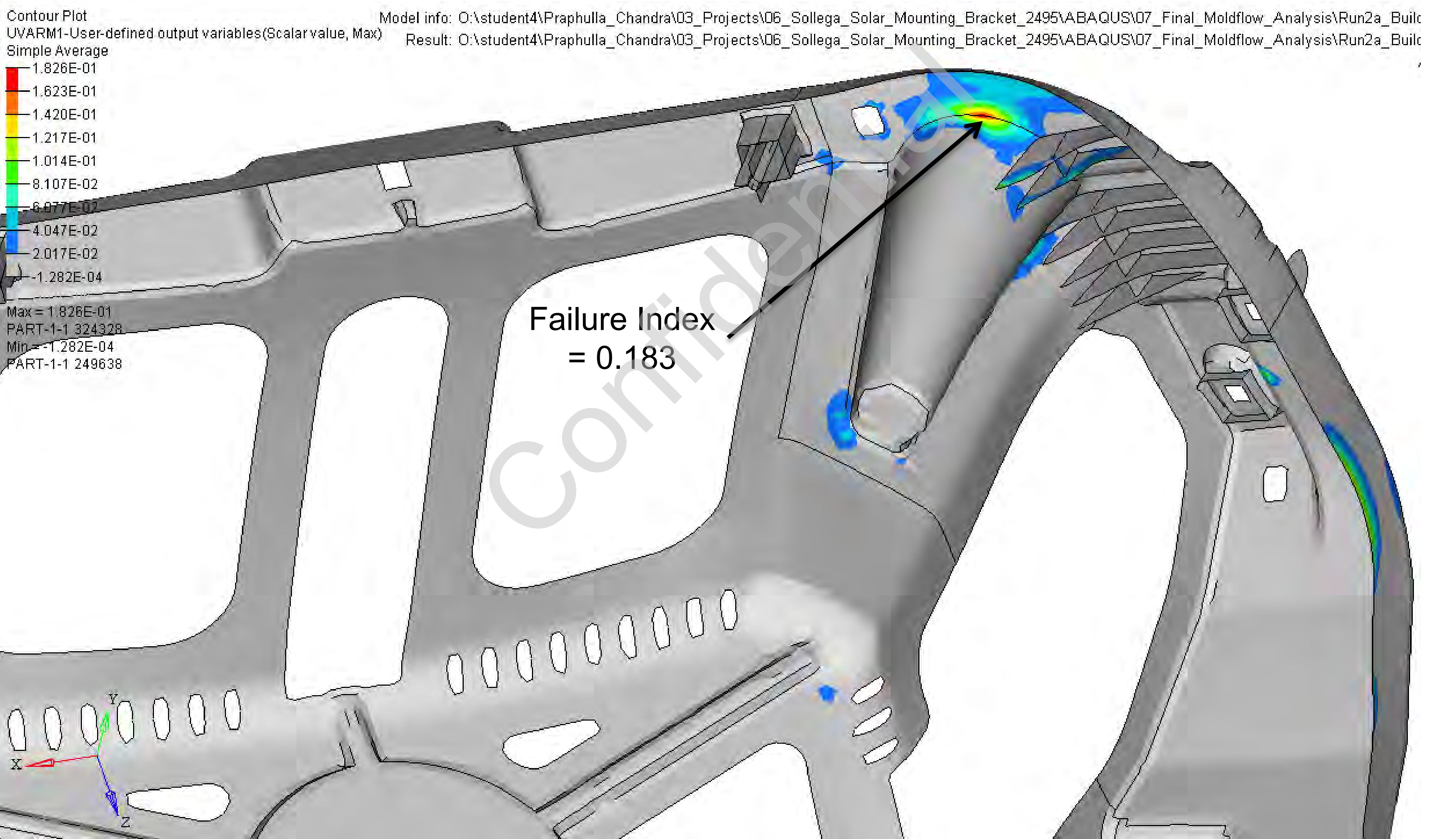
Interpreting Ultrasim® Results

- The following analyses were performed using Ultrasim®. The plots show the failure index at each element.
- The failure index is a scale from 0 to 1, with a value of 1 showing failure. It is defined as the strain energy stored per element divided by the energy for failure at that element.
- As shown by the plot below, even a fairly high stress can correspond to a relatively low failure index. Therefore, we recommend an upper limit for the failure index of 0.6.



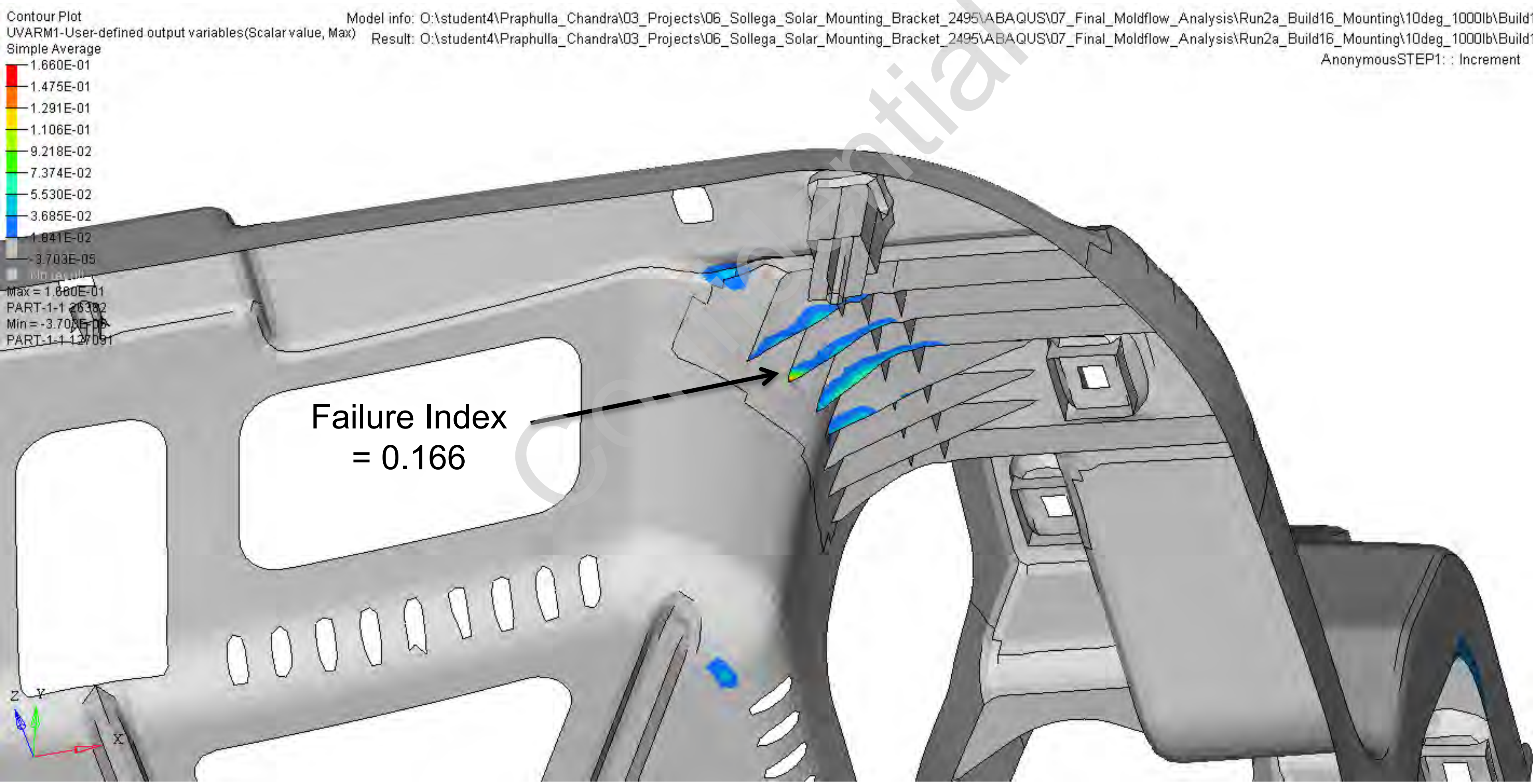
Ultrasim® Analysis: 5° Load Case
Total Load Applied: 1000lb

BASF
The Chemical Company



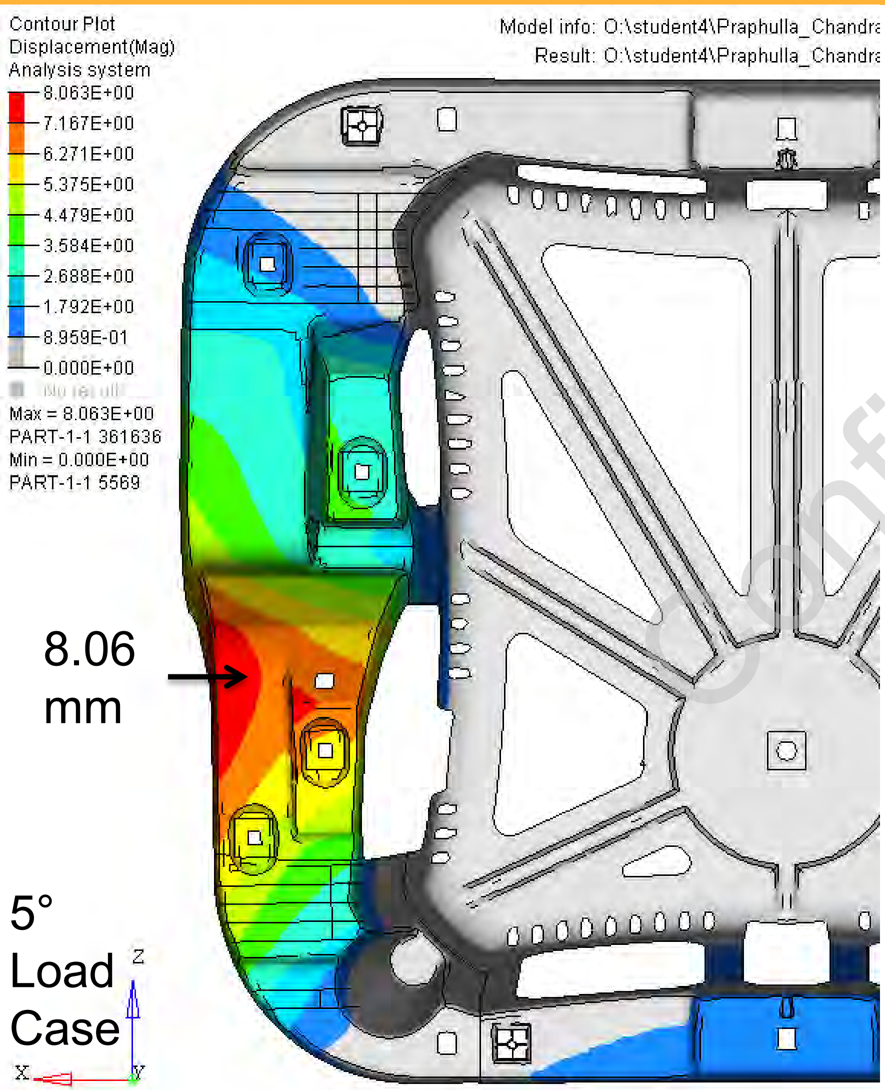
Ultrasim® Analysis: 10° Load Case
Total Load Applied: 1000lb

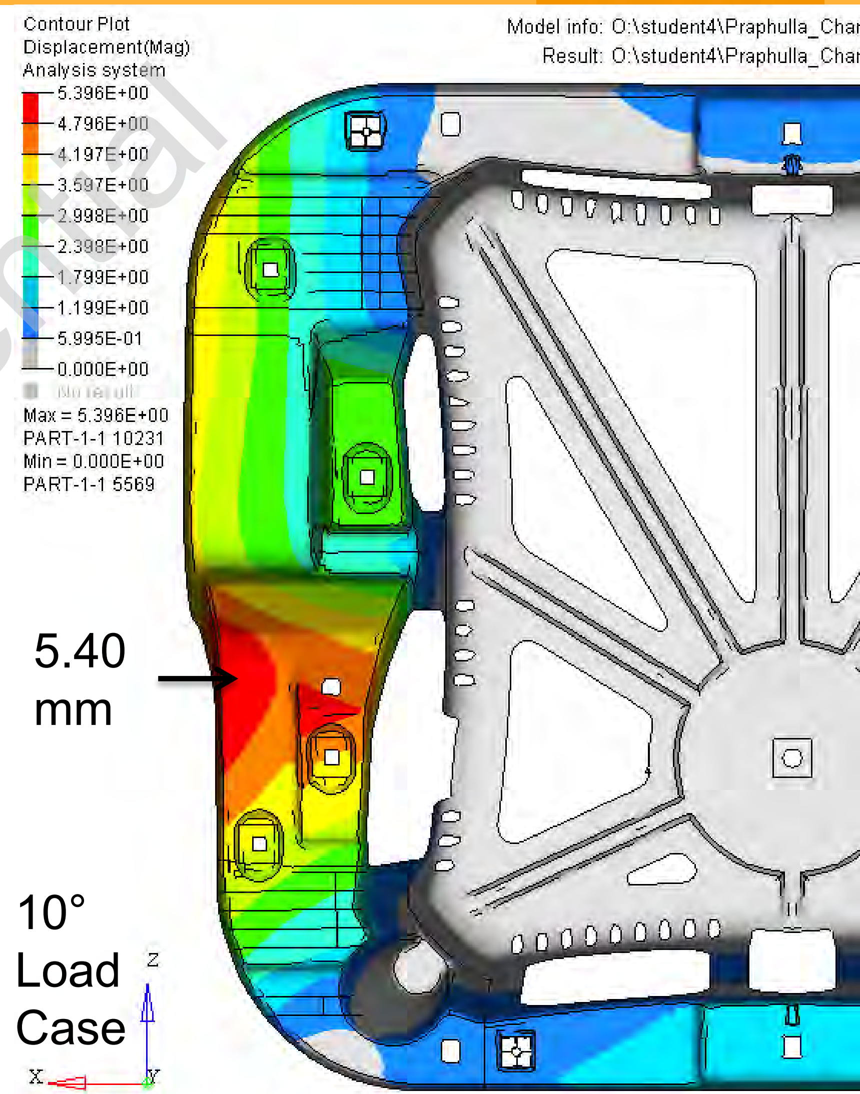
BASF
The Chemical Company



Ultrasim® Analysis: Displacement Plots
Total Load Applied: 250lb

BASF
The Chemical Company



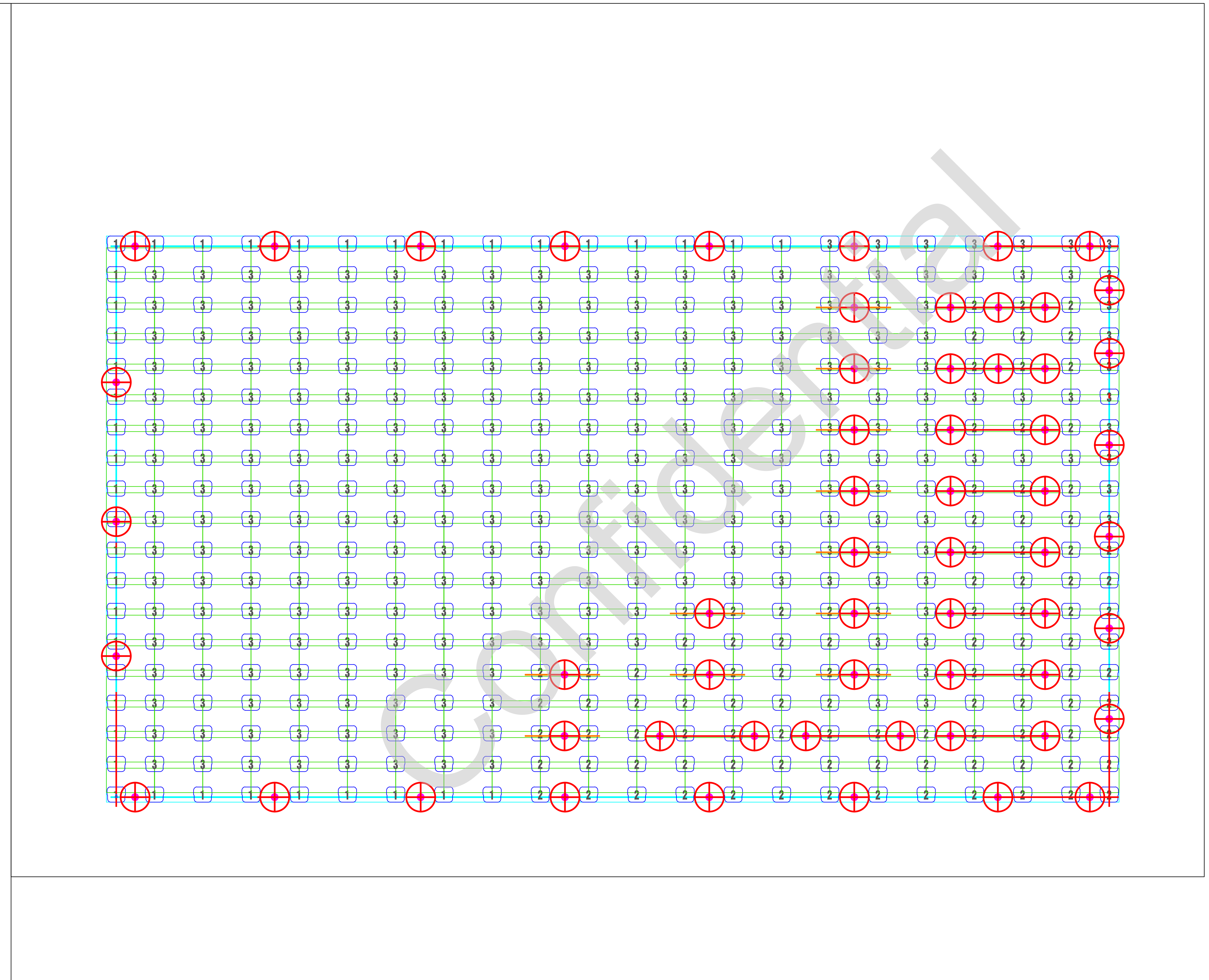


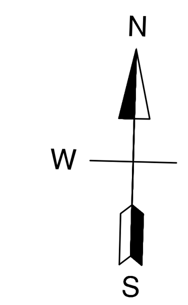
Conclusions

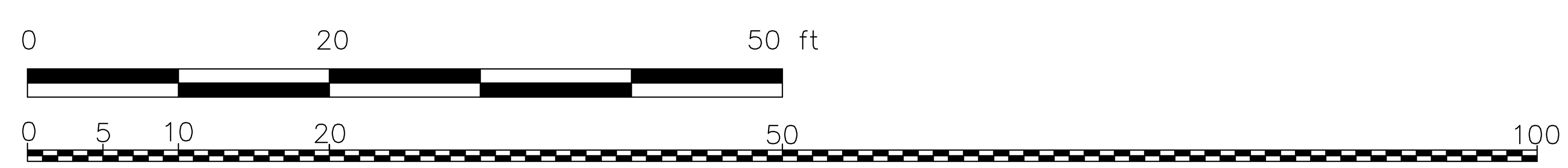
BASF
The Chemical Company

- Ultrasim® results are able to account for fiber orientation in the material model, and thus are better at predicting material failure at locations where the fiber is highly oriented, such as in the ribs of the part.
- This analysis assumed a constant rib thickness of 1.5mm and was not performed with the ribs' tooling draft which creates a 1.0mm thickness at the tip of the ribs. However, the safety factor is scaled to account for this rib thickness reduction.
- Although the 5° load case shows a higher failure index, due to the rib taper from tooling draft, the front ribs under the 10° load case are more likely to fail. Under this load case, scaling the safety factor linearly with the rib thickness, the safety factor is 2.41.
- S.F.=2.41 is a sufficient safety factor to allow for the creep, thermal cycling and weathering degradation that the part will experience.

Racking Layout







1/8”=1’0”

SEE S2.0 AND S3.0 FOR SOLLEGA ANCHOR, PANEL, AND CORNER SUPPORT ATTACHMENT DETAILS

PROJECT SPECIFICATIONS	
Project ID	Final Layout
Roof Height (ft)	40
Wind Speed ASCE 7-10 (mph)	110
Exposure Factor	B
Azimuth (deg.)	178
Installation Method	Pull Clamps
Modules (#)	378
Module Type (W)	340
Module Size (LxWxD) (in)	77.17x39.37x1.81
Module Weight (lbs)	44.8
System Size (kW-DC)	128.5
Total FastRacks (#)	418
Wind Screens (#)	21
Roof Anchors (#)	57
Row Spacing (in)	51.74
Tilt Angle (deg.)	10
Total CMU Blocks (#)	1,069
Total Non-ballast Weight (lb)	19,006
Total Ballast Weight (lb)	32,070
Total System Weight (lb)	51,076
Total Load per Array Area (psf)	4.73

PROJECT INFO.	
Location	
Installer	
Contact	
Email	
Phone	

NOTES	
3 / S2.0	Windscreens
2,7 / S2.0	Roof Anchor
1–4 / S3.0	20’ Strut 15’ Strut 10’ Strut 5’ Strut
5A,5B / S3.0	Splice Kits

Ballast Required (#CMU blocks)

FASTRACK 510

= Ballast Per FastRack

CMU: 30 lb , 4”x8”x16”

Sollega™

Sollega West: 415-648-1299
2480 Mission St, Ste 107B, San Francisco, CA 94110
www.Sollega.com

FOR INTERNAL USE ONLY

DRAWING INFO.

REV #	Description	Drawn	Approved	M/D/Y

Date & Time	4/28/2016 3:12 PM
Sheet Name	S1.0

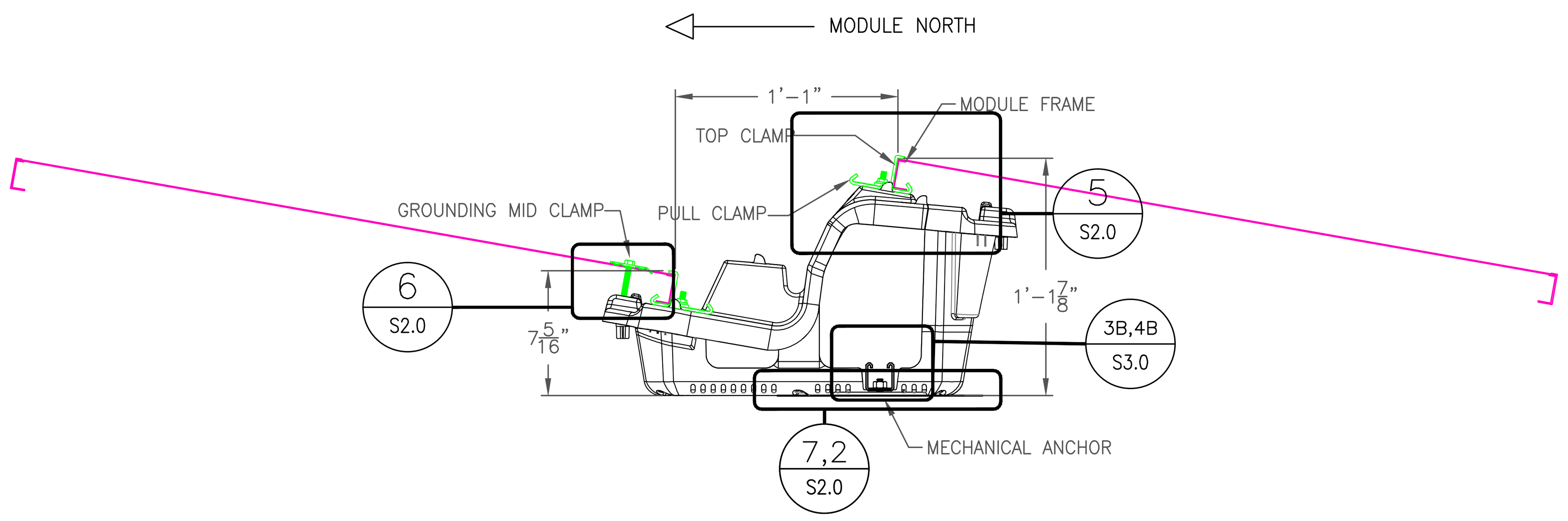
Sollega™

Sollega: 415-648-1299
2480 Mission Street, Ste. 107B, San Francisco, CA 94110
www.Sollega.com

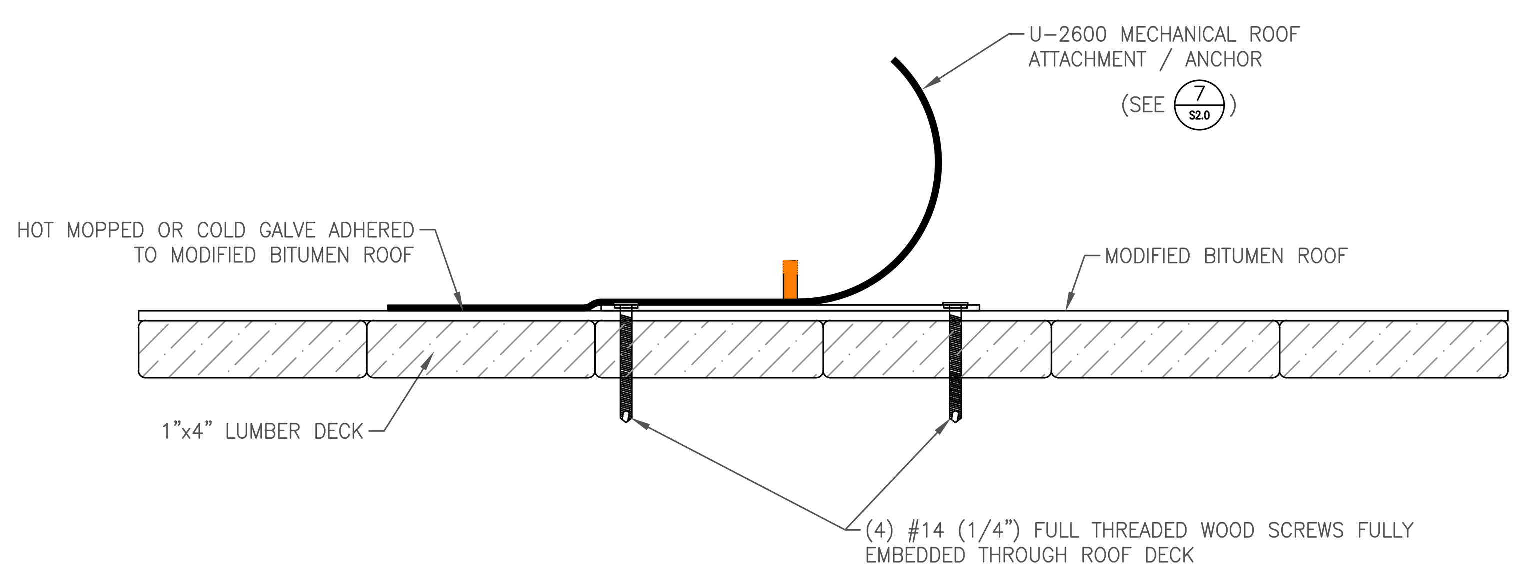
NOTES

PROJECT INFO	
Location	
Installer	
Main Contact	
Email	
Phone	

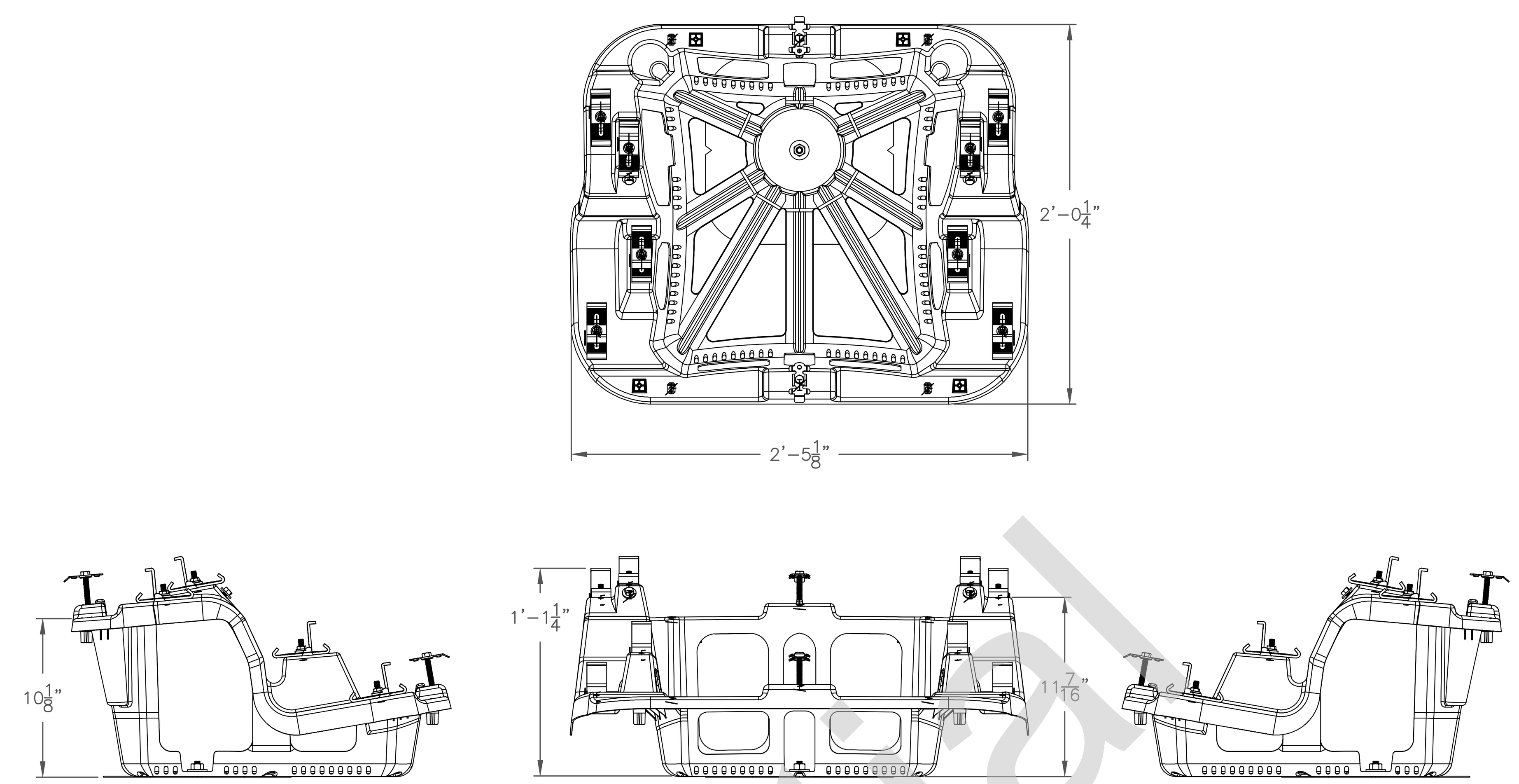
DRAWING INFO.	
Date & Time	
Prepared/Approved by	
Sheet Name	



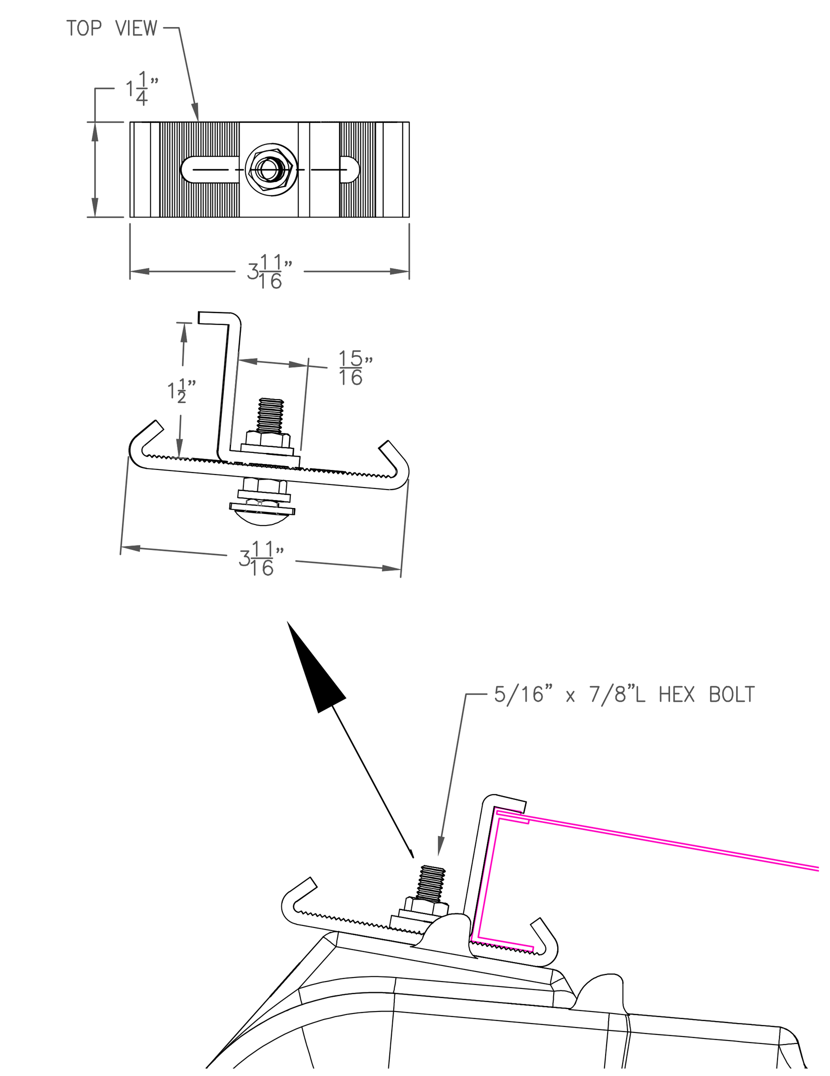
1 S2.0 MODULE ATTACHMENT DETAIL
SCALE: 1-1/2" = 1'-0"



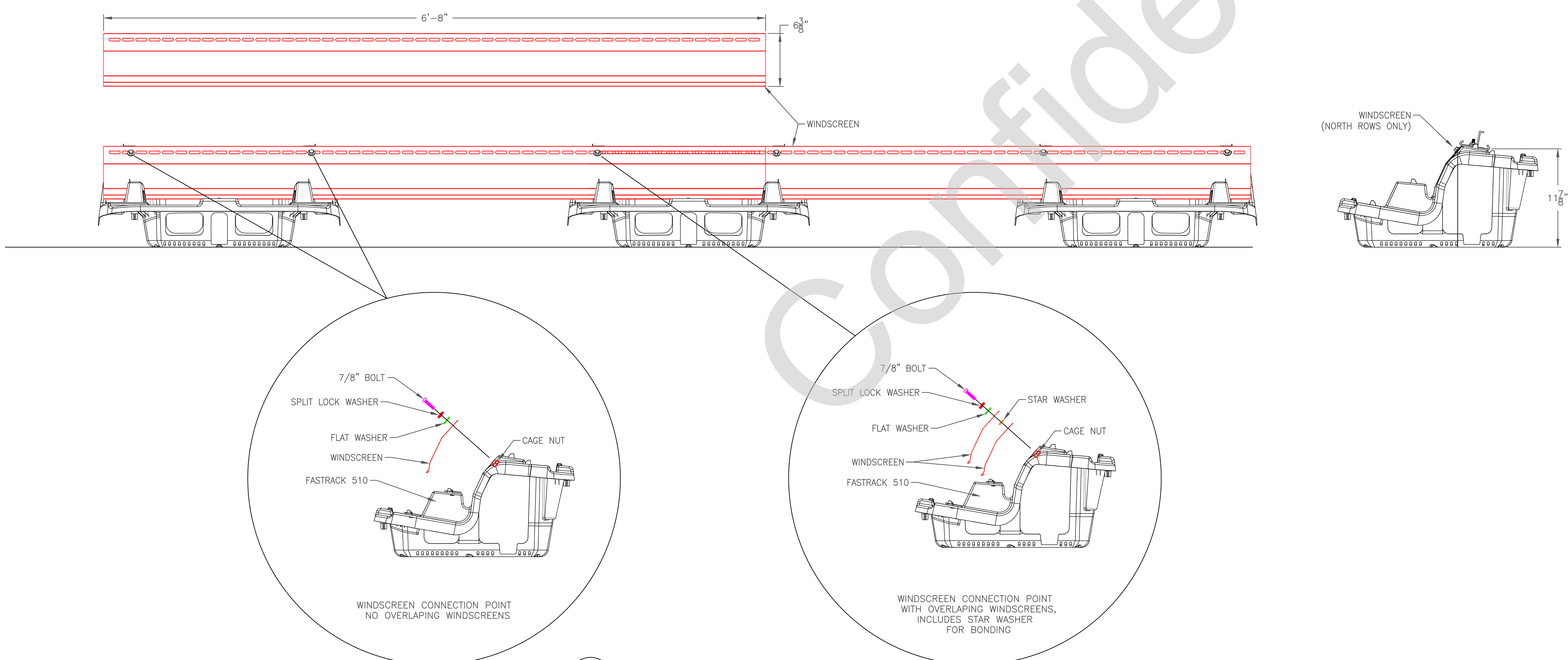
2 S2.0 ROOF ANCHOR ATTACHEMENT DETAIL
SCALE: NTS



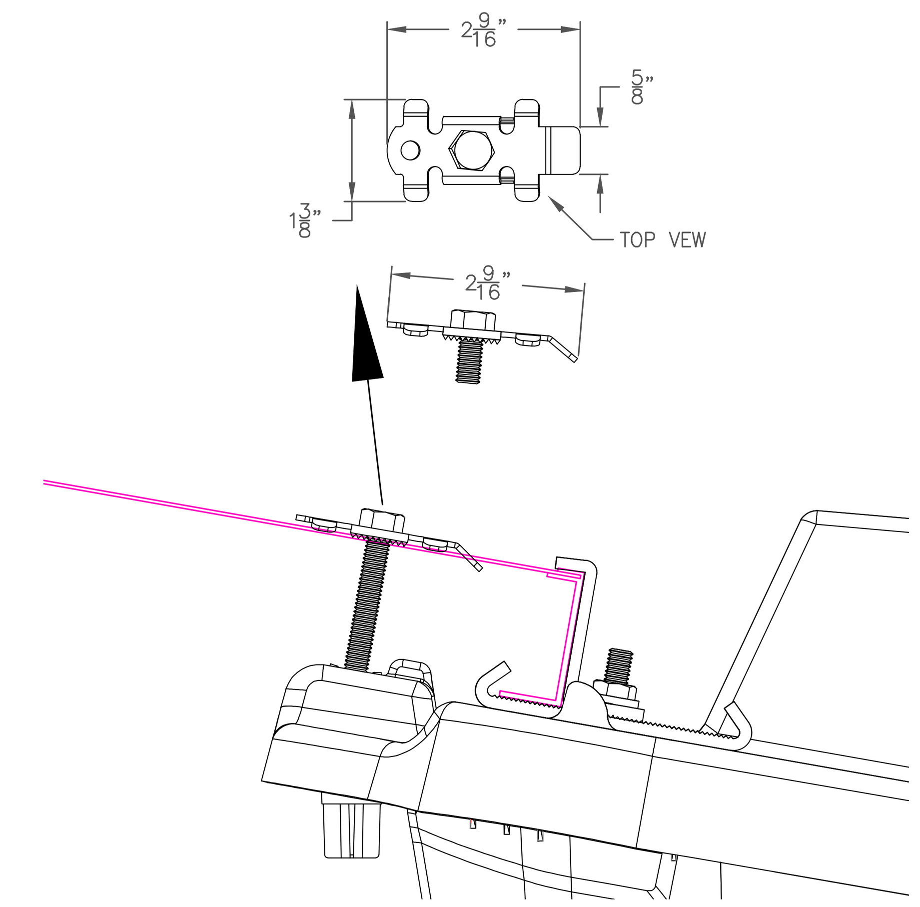
4 S2.0 SOLLEGA FAST RACK 510 (FR510)
SCALE: 1-1/2" = 1'-0"



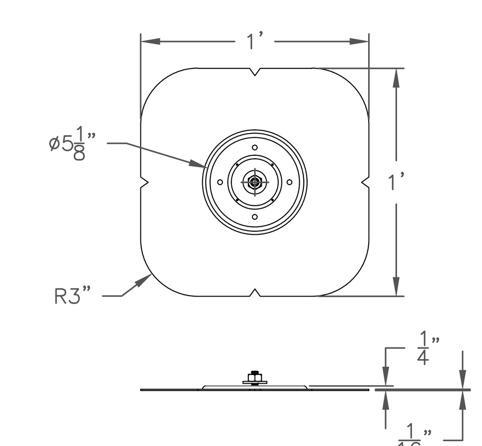
5 S2.0 CLAMP DETAIL
SCALE: 6" = 1'-0"



3 S2.0 WINDSCREEN DETAIL
SCALE: 1-1/2" = 1'-0"



6 S2.0 MID CLAMP DETAIL
SCALE: 6" = 1'-0"



SEE 2 S2.0 FOR FASTENER DETAILS AND ROOF DECK ELEVATION

7 S2.0 MECHANICAL ANCHOR DETAIL
SCALE: 1-1/2" = 1'-0"

Sollega™
Sollega: 415-648-1299
2480 Mission Street, Ste. 107B, San Francisco, CA 94110
www.Sollega.com

NOTES

PROJECT INFO.	
Location	
Installer	
Main Contact	
Email	
Phone	

DRAWING INFO.	
Date & Time	
Prepared/Approved by	
Sheet Name	

w_building	159
l_building	117
pressure_units	psf
w_panel	6.43
l_panel	3.28
s_row	4.09
nw height	39.5
nw parapet	1
nw major	FALSE
nw minor	FALSE
nw q_value	23.88
ne height	39.5
ne parapet	1
ne major	TRUE
ne minor	TRUE
ne q_value	23.88
sw height	39.5
sw parapet	1
sw major	FALSE
sw minor	FALSE
sw q_value	23.88
se height	39.5
se parapet	1
se major	TRUE
se minor	TRUE
se q_value	23.88
zone_de q_value_north	23.88
zone_de q_value_east	23.88
zone_de q_value_west	23.88
zone_de q_value_south	23.88

13.3	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	14.49	16.78	18.97	20.79	22.95
7.26	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.9	8.61	10.33	13.12	15.94	18.3	20.54
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.1	7.77	8.4	10.72	13.21	15.58	17.42	19.1
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.25	7.75	9.09	11.3	13.57	15.61	17.06	18.37
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.27	7.71	9.64	11.71	13.75	15.49	16.62	17.62
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.18	8.22	10.07	11.99	13.8	15.27	16.11	16.88
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7	8.63	10.39	12.15	13.75	14.96	15.57	16.14
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.39	8.96	10.61	12.21	13.6	14.6	15.02	15.42
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.71	9.21	10.74	12.19	13.39	14.19	14.45	14.72
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.97	9.39	10.81	12.1	13.13	13.76	13.88	14.04
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	8.17	9.51	10.8	11.95	12.83	13.31	13.32	13.39
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.17	7.38	7.5	7.48	8.32	9.57	10.75	11.76	12.49	12.85	12.76	12.77
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.24	7.64	7.99	8.27	8.43	8.42	9.58	10.64	11.53	12.14	12.39	12.22	12.17
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.45	7.96	8.45	8.89	9.25	9.48	9.54	10.5	11.27	11.77	11.93	11.7	11.6
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.51	8.11	8.72	9.32	9.88	10.35	10.66	10.71	10.99	11.39	11.47	11.18	11.05
7.11	6.95	6.95	6.95	6.95	6.95	6.95	6.95	7.41	8.07	8.78	9.5	10.23	10.93	11.55	11.98	12.1	11.66	11.01	10.69	10.52
7.26	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.55	8.29	9.09	9.95	10.86	11.79	12.72	13.58	14.24	14.48	13.7	10.85	10.47
9.01	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	9.56	10.55	11.63	12.79	14.03	15.3	16.55	17.61	17.6	15.66	15.24

Ballast Configuration	Project ID:		Project Status:	**For Construction**

General Project Information

Customer
Building Owner
Installation Location

SAMPLE

Site & Building Information

The following values are provided to Sollega by the Customer. It remains the responsibility of the Customer to verify with the Engineer of Record and with the Building Official that these values are appropriate for this project, and to notify Sollega immediately if these parameters require adjustment.

ASCE Perimeters	Unit	Equation	Value
Wind Speed ASCE 7-10 (3s gust)	mph	V	110
Ground Snow Load	psf		0
Exposure Category			B
Site Topographic Effects			None
Building Risk Category			II
Building Roof Height	ft	z	40

All pressure coefficients determined by CERMAK PETERKA PETERSEN / CPP Windlab based on results of Boundary Layer Wind Tunnel testing of the FastRack510 Mounting System.

Basic Velocity Pressures	Unit	Equation	Values	Notes
Velocity Pressure Exp. Coefficient		K_Z	0.765	ASCE Table 30.3-1
Topographic Factor		K_{ZT}	1.00	ASCE Fig. 26.8-1
Directionality Factor		K_D	0.85	ASCE Table 26.6-1
Basic Velocity Pressure	psf	q_Z	20.14	ASCE 30.3.2 equation 30.3-1

Array Configuration & Weights	Unit	Equation	Value	Notes
Number of Sub-arrays			1	Distinctly disconnected systems
Module Manufacturer			LG	Per Customer
Module Wattage			340	
Module Dimensions	in		77.17x39.37x1.81	L x W x D
Module Weight	lbs		44.75	
Module Tilt Angle	deg		10	
Row Spacing	in		51.74	Distance from the edge of one module to the edge of the module in the next row
Number of Modules	#		378	
Number of FastRacks	#		418	
Ratio of FastRacks to Modules			1.11	The number of FastRacks divided by the number of Modules
Array Platform Area	sq ft		10,809	Area covered by Array
Total Roof Area	sq ft		120,338	Area of the entire roof

ITEM	Units	Equation	Per Module	Total	Notes
Module Area	sq ft	A_A	21.10	7,975	Per Manufacturer & Model above
Module Weight	lb		44.75	16,916	Per Manufacturer & Model above
FastRack Weight	lb		5.00	2,090	
Racking System Weight	lb	D	50.28	19,006	
Ballast Weight	lb	B_T	84.84	32,070	
Total Weight	lb	W_T	135.12	51,076	

ITEM	Units	Equation	Value	Notes
Ballast Block Weight	lb	W_{CMU}	30.0	Ballast used should be 16" x 8" x 4" nominal blocks (CMUs)
Are Roof Anchors Used?			Y	
ASD (Allowable) Anchor Strength Uplift	lb	S_R	400	Installer's engineer must verify that anchor connections used meet or exceed the assumed capacity.
ASD (Allowable) Anchor Strength Lateral	lb	S_L	400	Installer's engineer must verify that anchor connections used meet or exceed the assumed capacity.

Wind Load Factors from ASCE 7-10

All pressure coefficients determined by CERMAK PETERKA PETERSEN / CPP Windlab based on results of Boundary Layer Wind Tunnel testing of the FastRack510 Mounting System.

ITEM	Units	Equation	Sub-Array												Total	Notes
Sub Array			**A**													
Min. Coefficient of Friction (Static)		COF														*+
Modules	#		378												**378**	
Array Area	sq ft	A_A	10,809												**10,809**	
Racking System Weight	lb	D_{Sys}	19,006												**19,006**	**
Module Area	sq ft	A_M	7,975												**7,975**	
FastRack Count	#		418												**418**	
Total Lift (After Load Combination)	lb	F_L	-42,251												**-42,251**	ASCE 7-10 Basic Load Combination 2.4.1
Total Net Lift	lb	$F_{LN} = F_L - (0.6 * D_{Sys})$	-30,848												**-30,848**	
Total Drag	lb	F_D	-8,026												**-8,026**	ASCE 7-10 Basic Load Combination 2.4.1
Roof Anchor Count	#	$RA_T = \Sigma RA$	57												**57**	
Total Roof Anchor Strength (Uplift)	lb	$S_{RT} = RA_T * S_R$	22,960												**22,960**	
Total Roof Anchor Strength (Lateral)	lb	$S_{LT} = RA_T * S_L$	22,960												**22,960**	
Total Net Lift After Anchors ++	lb	$F_{NA} = F_{LN} - RA_{ML} * RA_T$	-11,277													
Total Net Drag After Anchors	lb	$F_{ND} = F_D + RA_{MD} * RA_T$	0													States 0 for 0 or greater
Ballast Required	lb	$B_L = (F_{NA} + F_{ND}/COF) / .6$	18,796													
CMUs on FastRacks	#	CMU	1,069												**1,069**	CMU weight is 30 lbs
Designed Ballast Weight	lb	$B_T = \Sigma CMU * W_{CMU}$	32,070												**32,070**	
Avg Anchor Load (Lift)	lb	$RA_{ML} = (F_{LN} + (0.6 * B_T)) / RA_T$	202													++
Avg Anchor Load (Drag)	lb	$RA_{MD} = F_D / RA_T$	140													
Uplift Resistance?	Y / N	$-F_{LN} < (0.6 * B_T) + S_{RT}$	Y													
Drag Resistance?	Y / N	$-F_D < S_{LT}$ OR $B_T > B_L$	Y													
Total Weight	lb	$W_T = B_T + D$	51,076												**51,076**	
Distributed Weight ***	psf	$W_{SA} = W_T / A_A$	4.73												**4.73**	
AVG global load on Roof	psf	$W_{GA} = W_T / A_A$													**0.42**	

Notes

* Customer to notify Sollega if different COF should be used. COF increases with larger arrays.
** Racking System Weight includes all components excluding ballast
*** Total distributed weight over the Array Area only.
\+ A blank coefficient of friction indicates that all lateral loads are resisted through anchorage.
++ Anchors are only effective for modules directly local to the attachment so design load is analyzed on a per module basis. This implies that anchors are not necesarrily loaded to total allowable strength .Value listed is a sum of remaining lift after

Seismic Calculations	Project ID:	Project Status:	**For Construction**

General Project Information

Customer	0
Building Owner	0
Installation Location	0

Seismic Configuration: **Anchored Design Without Friction**

Seismic Design Category		D	Class D "Stiff Soil" is default
Component Amplification Factor	a_p	1	component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
Spectral Acceleration Short Period *	S_{DS}	0.721	spectral acceleration, short period, as determined from Section 11.4.4
Component Response Modification Factor	R_P	1.5	component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)
Importance Factor	I_P	1	component importance factor that varies from 1.00 to 1.50 (see Section 13.1.3)
Total System Weight	W_P	51,076	Total Deadload
Height of full structure	z	40.00	height in structure of point of attachment of component with respect to the base. For items at or below the base, z shall be taken as 0. The value of z/h need not exceed
Building Height	h	40.00	average roof height of structure with respect to the base
Roof Anchor Lateral Strength	lbs	400	Lateral Eccentric Moment strength. See Anchor Products testing Report.
Seismic Load	F_P	**29,460**	ASCE Equation 13.3-1, A
Applied Seismic Load	$F_{Applied}$	**20,622**	.7 of F_P as Prescribed by Basic Load Combinations in ASCE 2.4.1
Max Seismic Load	F_{pmax}	58,921	MAX
Min Seismic Load	F_{pmin}	11,048	MIN

13.3 SEISMIC DEMANDS ON NONSTRUCTURAL COMPONENTS

13.3.1 Seismic Design Force. The horizontal seismic design force (F_p) shall be applied at the component's center of gravity and distributed relative to the component's mass distribution and shall be determined in accordance with Eq. 13.3-1:

$$F_p = \frac{0.4a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}\left(1 + 2\frac{z}{h}\right) \quad (13.3\text{-}1)$$

F_p is not required to be taken as greater than

$$F_p = 1.6 S_{DS} I_p W_p \quad (13.3\text{-}2)$$

and F_p shall not be taken as less than

$$F_p = 0.3 S_{DS} I_p W_p \quad (13.3\text{-}3)$$

where

F_p = seismic design force
S_{DS} = spectral acceleration, short period, as determined from Section 11.4.4
a_p = component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
I_p = component importance factor that varies from 1.00 to 1.50 (see Section 13.1.3)
W_p = component operating weight
R_p = component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)

			Sub Array											
			A											
Total Ballasted Weight	lbs.	51,076	51,076	0	0	0	0	0	0	0	0	0	0	0
Applied Seismic load per Array	$F_{Applied}$	20,622	20,622	0	0	0	0	0	0	0	0	0	0	0
Roof Anchors Needed	#	**52**	**52**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Seismic Configuration: **Anchored Design WITH Friction****

Roofing Material type		TPO / PVC / EPDM	Non-Manufacturer Specific	Contribution of Friction (SEAOC PV1 - 2012)
Coefficient of Friction (Kinetic)	μ_K	0.59		$(0.9\text{-}0.2S_{DS})(0.7\mu)W_{pf}$

			Sub Array											
			A											
Total Ballasted Weight, W_{pf}	lbs.	51,076	51,076	0	0	0	0	0	0	0	0	0	0	0
Applied Seismic load per Array	lbs.	20,622	20,622	0	0	0	0	0	0	0	0	0	0	0
Allowable Frictional Resistence	lbs.	15,943	15,943	0	0	0	0	0	0	0	0	0	0	0
Remaining Seismic Load	lbs.	4,679	4,679	0	0	0	0	0	0	0	0	0	0	0
25% of Applied Seismic Load	lbs.	5,156	5,156	0	0	0	0	0	0	0	0	0	0	0
Roof Anchors Needed^	#	**13**	**13**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Seismic Configuration: **Un-Anchored Using Prescriptive Design Displacement****

Prescriptive Design Seismic Displacement***	SEAOC PV1-2012, Displacement (in)	
Distance Between Arrays	$0.5*(I_p)*\Delta_{MPV}$	3.1
Distance Between Arrays and Roof Objects	$(I_p)*\Delta_{MPV}$	6.2
Distance Between Arrays and Roof Edge With Parapet	$(I_e)*\Delta_{MPV}$	3.1
Distance Between Araays and Roof Edge Without Parapet	$1.5*(I_e)*\Delta_{MPV}$	9.3

Seismic Design Category	Δ_{MPV} **(in)**
A,B,C	**6**
D,E,F	$[(S_{DS} - .4)^2]*60$

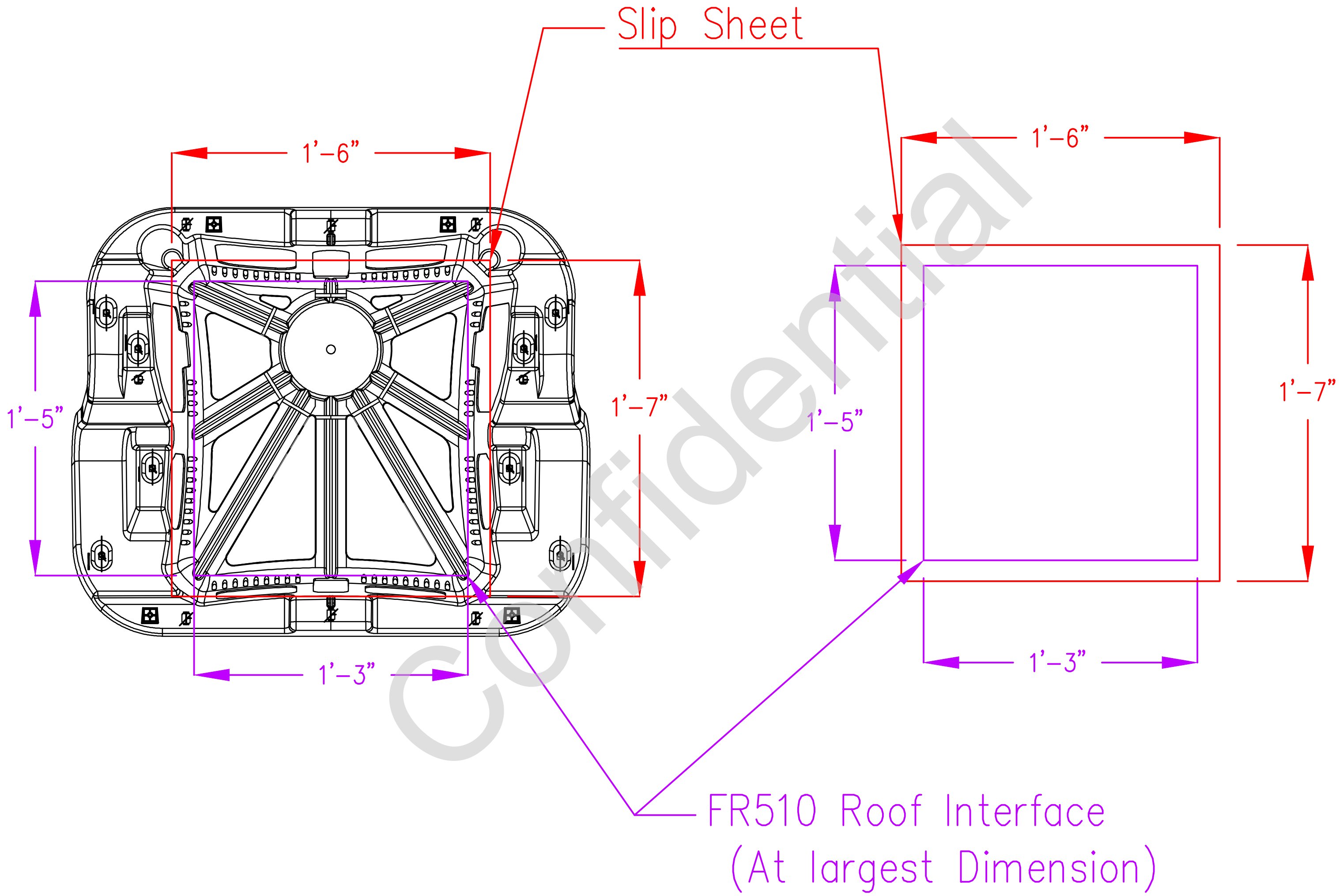
Notes

For designs using prescriptive displacement (no anchors) or anchored with consideration for friction, displacement values must be listed on plan set documents. Each separate array shall be interconnected as an integral unit such that for any vetical section throught the array, the members and connections shall have design strength to resist a total horizontal force across the section, in both tension and compression, equal to the larger of $0.133*S_{DS}*W_1$ and $0.1*W_1$. Where, W_1 = the weight of the portion of the array, including ballast, on the side of the section that has smaller weight.

http://geohazards.usgs.gov/designmaps/us/

^ Design anchor strength used, is the greater of 25% of the applied seismic load and the remaining seismic load after consideration for allowable friction.
* S_{DS} is determined by the U.S. Seismic Design Maps Web Application. See link here: http://geohazards.usgs.gov/designmaps/us/
** See Sollega Friction Report for Specific Roof Material
*** See SEAOC PV1 STRUCTURAL AND SEISMIC REQUIREMENTS AND COMMENTARY FOR ROOFTOP SOLAR PHOTOVOLTAIC ARRAYS FINAL REPORT 2012

Sollega FastRack 510 Complies with the SEAOC PV2 requirements for both attached and un-attached system design. All friction values were determined by NRTL testing in compliance with the SEAOC recommendations as well as ASTMG115.



Sollega East: 855-725-7225
32 Court St, Suite 904, Brooklyn NY 11201
Sollega West: 415-648-1299
2588 Mission St, Ste 210, San Francisco, CA 94110
www.Sollega.com

NOTES

PROJECT INFO.

Location	Location
Installer	Installer
Main Contact	Main Contact
Email	Email
Phone	Phone

DRAWING INFO.

Date & Time	Sep 09, 2014 (17:06)	
Prepared/Approved by	xx	xx
Sheet Name	PVD1	

Wind Tunnel Test Review of the Report
"Wind Loads on the Solar Ballasted Roof Mount System
'FastRack 510' of Sollega, Inc."

by

Joseph C. Klewicki

Department of Mechanical Engineering
University of Melbourne
Melbourne, VIC 3010 Australia
March 26, 2018

Executive Summary

A review was conducted of the Institut fur Industrieaerodynamik (IFI) report SOF01-1 regarding the sliding and uplift wind loads associated with the FastRack 510, ballasted roof mounting systems for photovoltaic panel arrays. This report applies to panel array systems having module tilt angles of 10 degrees and in a landscape configuration. This review examined the IFI tests relative to the relevant sections of the ASCE/SEI 49-12, ASCE/SEI 7-10 standards. The IFI tests studied 1:50 scale experiments of 7.5m and 12.5m low-rise buildings, and for the shorter building considered parapets that are 10% and 20% of the building height. The wind tunnel tests used simple rectangular buildings, but the report provides a number of extending analyses for building complexities (such as rooftop obstructions, L-shaped and multi-level buildings and taller neighboring structures), as well as PV array configuration variations (panel arrays having a 5 degree tilt angle, and effects of panel length).

The IFI is well-established in the wind engineering community, and has conducted numerous tests of wind loading associated with the installation of photovoltaic panel arrays. The present IFI study applies to flat roof, low rise, installations (less than plus or minus 7 degrees), and formally are appropriate for the open

country (ASCE 49-12 type C) wind exposures. The test conditions are, however, also likely to be applicable to suburban and flat terrain (types B and D). These wind tunnel tests are deemed to be of a quality sufficient to make the desired wind loading calculations. In accord with the ASCE/SEI standards, the wind load calculations used an extreme value analysis that is referenced to 3 second wind gusts. For completeness of documentation, one clarification regarding the effect of the array offset from the building edge is requested at the end of this Executive Summary.

All of the seven criteria listed in section 31.2 of the ASCE/SEI 7-10 standard are deemed to be satisfied. It is noted that while a 1m setback is used in the present tests, the current SEAOC PV2-2017 report recommends an absolute minimum setback of 1.2m (4 ft). The IFI report also cites a number of provisos that must be considered before the results of these wind tunnel tests can be reliably translated actual field installations. These include:

- an adherence to the setback used in the test or greater setback,
- a verification of the rigidity of connected array modules such that the load sharing assumption is well-justified,
- corrections for variations in the panel geometry (section 4.8),
- implementing the appropriate corrections (section 4.6) when the installation involves nearby taller buildings, and
- adherence to the minimum array size criteria (section 4.9).

The care and attention to detail taken in the IFI tests is apparent, and overall, the report is very thorough. This reviewer knows that IFI has considered this issue previously, but for completeness of documentation, it is prudent that the IFI provide some further commentary regarding the effect of the 1m offset of the present study relative to the ASCE/SEI 7-10 standard of 1.2m. Here it would also be useful to provide additional guidance to the customer regarding any potential deviations from the conditions of the tests. Commentary is made herein relative to the SEAOC PV2-2017, which replaces the older SEAOC PV2-2012 report that was relevant at the time of the IFI wind tunnel tests. Accordingly, since Figure 4.12 from the SOF01-1 report uses the array edge factor criteria from the newer SEAOC PV2-2017 report (Figure 4 in SEAOC PV2-2017), it is requested that IFI verify that this calculation remains compatible with the ASCE/SEI 7-10 standard under which the experiments were conducted. Regarding the wind tunnel test procedure, it is similarly requested that the IFI comment on the effect of the tube length on the net frequency response of their pressure measurements.

1. Introduction

The purpose of this document is to aid evaluations pertaining to the suitability of the ballasted photovoltaic panel mounting systems manufactured by Sollega Inc. of San Francisco, CA, for low-rise flat roof installations. Per ASCE/SEI standards, wind tunnel tests were conducted by the Aachen University of Applied Sciences' *Institut fur Industrieaerodynamik* (Institute for Industrial Aerodynamics, hereafter IFI) for Sollega in order to estimate the aerodynamic loads experienced by their FastRack 510 PV panel mounting systems under a landscape orientation. Elements of the wind tunnel procedure included the capacity of the tests to appropriately model the features of the atmospheric surface layer (ASL) wind profile relevant to the given terrain classification(s), the capacity of the experimental procedure and instrumentation to produce the data needed to evaluate the wind loading, and whether the post-processing of the wind tunnel results were in accord with the applicable American Society of Civil Engineers (ASCE/SEI 7-10 and ASCE/SEI 49-12) standards.

Given these considerations, the present report contains:

1) A brief commentary on the reputation of the IFI and their technical suitability with regard to conducting the present wind tunnel tests,
2) An assessment of whether the wind tunnel studies adhered to the relevant requirements described in ASCE/SEI 7-10 and ASCE/SEI 49-12,
3) Commentary on whether the wind load calculations by IFI adhered to the standards indicated in ASCE/SEI, SEAOC PV2-2017 and DSA IR 16-8 standards.

2. Reputation and Capabilities of the IFI

The IFI has affiliation with Aachen University of Applied Sciences. Of those universities specializing in engineering and other applied technical areas, Aachen is one of Germany's largest and most well-regarded. The IFI is extensively contracted for producing and characterizing engineering data for the purposes of design and construction. The capabilities of the IFI include acoustics and aero-acoustics of civil structures, industrial aerodynamics, fire research (including fire spread and smoke control), wind engineering (including the wind loading of structures), as well as a number of testing and certification services. Of particular relevance to the present application, the IFI has been conducting tests of wind induced uplift on roofing systems for over 40 years. According to their website, the IFI has conducted well over 50 investigations relating to the wind loads on photovoltaic panels. Many of these have been for US based customers, and thus the IFI engineers are well-versed in the ASCE/SEI 7-10, ASCE 49-12 and SEAOC PV2-2017 standards.

Facilities at the IFI suitable for the study of PV mounting systems include both small and large boundary layer facilities. The present tests were conducted in their large boundary layer wind tunnel. The IFI wind tunnels are comparable to other well-regarded facilities used for wind engineering applications, such as those at CPP Wind Engineering in Fort Collins, Colorado, and those at the Wind Engineering, Energy and Environment Research Institute at the University of Western Ontario. Furthermore, although based in Germany, the IFI researchers are very familiar with the relevant US codes mentioned above, and are amongst the test laboratories explicitly listed in the SEAOC PV2-2017 standard. Overall, it is concluded that the IFI is a well-established and reputable applied research organization that has capabilities and expertise suitable for the evaluation of wind loads associated with photovoltaic panel mounting systems, such as those manufactured by Sollega Inc.

3. IFI Study Under Review

The wind tunnel study is described by the report: *Wind loads on the solar ballasted roof mount system FastRack 510 of* Sollega*, Inc., Design wind loads for uplift and sliding according to the American standard ASCE/SEI 7-10,* (report no. SOF01-1). As noted here and throughout, the IFI report clearly states the assumptions employed and limitations of the tests performed. The tests apply to the Sollega system installations on flat roofs. According to the ASCE/SEI standards, this corresponds to roofs with a slope of 7 degrees or less. Also in accord with the ASCE/SEI 7-10 standard, the tests described in SOF01-1 are generally valid for low rise buildings, having heights less than 18.3m, but can be used for buildings taller than 18.3m if they are deemed rigid according to the ASCE/SEI 7-10 standard. The wind tunnel tests were conducted on building models having sharp eaves, and for those with a parapet that is between 10% and 20% of the building height. The models in the wind tunnel tests were at a scale of 1:50 relative to an actual building. Annex C of the report provides an extensive documentation of the wind tunnel models and the associated test configurations.

The upstream roughness elements in the wind tunnel were configured to produce a boundary layer profile that approximated the open country exposure C profile of the ASCE/SEI 7-10 standard. The exposure class effectively specifies the rates of change in the wind speed and turbulence intensity with distance from the surface. Because the exposure C conditions tested are more stringent than for smooth surfaces, these tests also automatically satisfy the requirements for smooth terrain. Thus, as noted in SOF01-1, relative to the ASCE/SEI 7-10 standard these tests are also likely applicable for terrain categories B and D, provided that the other requirements of the standard are met. Exposures B, C and D respectively pertain to urban/suburban, open terrain with scattered obstructions and flat unobstructed areas.

The baseline tests were conducted for buildings without a parapet. These included scaled building heights of 7.5m and 12.5m. These were then followed by wind tunnel tests examining the scaled Sollega system installations on 7.5m buildings with parapet. The parapets examined had heights that were 10% and 20% of the building height. The PV array installation always employed a scaled 1.0m setback from the edge of the roof. This is slightly less than the 4ft (1.2m) recommendation given in SEAOC PV2-2017. Regardless, the results from these tests are only applicable for configurations employing a setback of at least 1.0m. The tests apply only to sharp-edged roofs, and other configurations would require additional studies. The wind loads were estimated from measured pressure coefficients at regular angles (15 degree increments from 0 to 90 degrees and from 90 to 180 degrees) from the case in which the photovoltaic array was mounted perpendicular to the mean wind direction. In the calculations of wind loading, IFI neglected the effects of the panel mounting system height on the overall wind displacement. This assumption is believed to be warranted since the height of the photovoltaic panel array is negligible relative to the height of the building.

4. Wind Tunnel Study Conformance to ASCE 7-10 Standards

The ASCE standards relevant to the wind tunnel tests are those articulated in ASCE/SEI 7-10, section 6.6.2, and in ASCE/SEI 49-12. These standards primarily pertain to the capacity of the wind tunnel tests to appropriately model the atmospheric surface layer (ASL) flow, and to produce the measurements needed to accurately estimate the uplift and sliding forces associated with the PV mounting systems. In the ASCE/SEI standard, seven conditions are required. These are:

1. The natural atmospheric boundary layer has been modeled to account for variation of wind speed with height.
2. The relevant macro- (integral) length and micro- length scales of the longitudinal component of the atmospheric turbulence are modeled to approximately the same scale as that used to model the building or structure.
3. The modeled building or other structure and surrounding structures and are geometrically similar to their full-scale counterparts, except that, for low-rise buildings meeting the requirements of Section 28.1.2, tests shall be permitted for the modelled building in a single exposure site as defined in Section 26.7.3.
4. The projected area of the modelled building or other structure and surroundings is less than 5 percent of the test section cross-sectional area unless correction is made for blockage.
5. The longitudinal pressure gradient in the wind tunnel test section is accounted for.
6. Reynolds number effects on pressures and forces are minimized.
7. Response characteristics of the wind tunnel instrumentation are consistent with the required measurements.

In what follows, reference is made to these seven conditions.

The tests were conducted in the IFI Large Boundary Layer Wind Tunnel. The cross-section of the test section in this wind tunnel is 2.7m wide by 1.6m high. The tests were conducted at a position that was about 10m downstream of the contraction that preceded the roughness elements. The maximum wind speed in the profile of Figure A.2 is about 12 m/s. The wind speeds in the portion of the profile encountered by the building models were, however, less than this. In accord with ASCE/SEI 49-12 and 7-10 specifications (also see Cermak et al.1999), an artificially thickened boundary layer intending to mimic the near-surface neutrally stratified atmospheric surface layer (ASL) profile is produced by using a series of vertical spires located well-upstream of the test section (Counihan 1969). Downstream of the spires, different sized roughness elements are used to generate near-surface mean wind profiles and turbulence intensity profiles at the model that mimic aspects of the conditions found in the ASL.

The specification of the downstream roughness is chosen (from previous studies, see Cermak et al. 1999) to produce the desired power-law variation of the normalized mean velocity, with a power-law exponent equal to $1/\alpha$. According to the ASCE 49-12 specifications, the value of α corresponding to open country is about 0.154. In the wind tunnel tests associated with SOF01-1, the mean profile data adhered to an average exponent of about 0.14. **This value is deemed to nominally match the ASCE open country classification, and thus satisfies condition 1.** The associated distribution of longitudinal turbulence intensity shows good agreement with the ASCE specifications out to about 350 mm from the surface and then drops-off significantly. For the purposes of estimating the wind loads on the model this is felt to be satisfactory since the model heights ranged between 150mm and 250mm.

The frequency content of the turbulence in the boundary layer is significant since it provides an indication of the scales causing the most energetic wind gusts that also produce that highest wind loads. Streamwise velocity spectra in the approach flow boundary layers are presented in Figure A.4 and A.5 of the SOF01-1 report. These data indicate that within their spectral range the wind tunnel spectra are consistently above the models for the inertial sub-range portion of the ASL streamwise velocity fluctuation spectrum. As expected (and noted in the report), they fail to non-dimensionally capture the low frequencies reflective of the much higher Reynolds numbers of the ASL than in the wind tunnel. For the purposes of accurately modelling the peak pressures experienced on the building model, however, the mid-range of frequencies near the low end of the inertial sub-range are of significant interest, as these are the frequencies associated with wind gusts having wavenumbers near the scale of the building. In SOF01-1, however, they further note that lower frequency gusts, i.e., those contributing to the portion of the spectrum where the wind tunnel data are well below the ASL model, are unlikely to be significant relative to wind loads. They convincingly explain (backed by literature citations) the basis for this assertion in section A.1 of SOF01-1. Overall, the inability to capture the low frequencies of the ASL in a wind tunnel is intrinsic to the flow physics, and thus is universally observed. In the present IFI tests, the fact that the amplitudes of the wind tunnel spectra (within their spectral range) consistently exceed those of the scaled ASL spectral models errs on the conservative side, i.e., toward over-estimating the load. **Thus, condition 2 is deemed to be satisfied.**

As indicated in section 3 above, the IFI wind tunnel tests modeled ASCE/SEI 7-10 terrain category C, with likely applicability to categories B and D as well. The IFI studies are broadly relevant to regular shaped low rise buildings situated in these terrain categories (see ASCE/SEI 7-10). **This generically satisfies condition 3. Note, however, that for a given installation, specific or unusual features may require assessment. For suburban installations, this includes adjacency to much taller buildings.**

An important distinction between wind tunnel tests and those in the ASL is that the streamlines in the wind tunnel are confined by the tunnel walls. Owing to simple conservation of mass considerations, it is known that this confinement can cause discrepancies from the actual flow behaviors of interest that come in the form of flow acceleration effects. The ASCE 7-10 (ASCE 49-12) standard cites a maximum acceptable flow blockage of 5%. (Note that the ASCE/SEI 7-05 standard indicates a value of 8%.) This quantity is effectively the percentage of the wind tunnel cross sectional area that is blocked by the model itself. For most of the present studies the blockage ranged between 5% and 8%, and in this regard, the discussion in Annex A of the IFI report provides a technically convincing reasoning for why this level of deviation from the standard is acceptable. On the other hand, a few of the tests had blockage conditions of nearly 10% (9.8%), or almost double that indicated in current standard. In this regard, the IFI report justifies this level of blockage via the citations of the studies of Hunt and Tieleman (references 16 and 5 in SOF01-1). These studies validated that open (or partially open, i.e., slotted) test sections can be used to mitigate blockage effects. Namely, a slotted test section produces mean streamline curvature effects caused by the body that adhere closely to the actual ASL case. In their tests, the IFI used a partially open test section that had a slotted upper wall, and, according to the reputable studies they cite, this is sufficient to mitigate the effects in the 9.8% blockage tests. ***Given this, condition 4 is believed to be satisfied.***

In their studies, the overall pressure gradient in the wind tunnel test section is set to zero by adjusting the slotted ceiling of the test section. Given that there is no mechanism to generate a longitudinal pressure gradient other than flow blockage, **condition 5 is believed to be satisfied.**

The Reynolds number is the primary non-dimensional parameter governing the flow around objects embedded in the neutrally stratified ASL. Owing to the 1:50 scale of the IFI experiments, direct matching of the Reynolds number is impossible. For the given structures, however, this should not present a significant issue. This is because the body (building shape) has sharp edges. As such the surrounding flow exhibits essentially Reynolds number invariant properties in relation to the flow separation phenomena from the building edges, and also in relation to the underlying drag mechanisms. This rather directly relates to the streamline displacement caused by the presence of the body, and the associated streamline curvature underlies the dominant (pressure based) source of the wind loading. The sharp edges effectively fix the positions of flow separation starting at Reynolds numbers well below those of the present study. **This satisfies condition 6.**

Factors associated with the experimental technique include the proper installation and accurate use of the relevant instrumentation, the data density of the measurements (in this case surface pressures, see Figure A.8 as well as the extensive documentation of the wind tunnel models in Annex C of SOF01-1), the sampling frequencies, and the sampling durations. All of these were performed in accord with sound experimental practice. The frequency response of the sensors is an important factor relative to accurately quantifying the unsteady wind loads. Thus, specific attention was devoted to attaining a sufficient frequency response of the pressure sensors. In accord with the physics of the boundary layer, for the IFI tests no appreciable pressure induced wind loads were expected in their tests (at about 12 m/s) for frequencies greater than about 100 Hz. In all of their tests, the response of the pressure sensors was about 200 Hz, while the data were sampled at 650Hz. **Collectively, condition 7 is deemed satisfied.**

In summary, almost of the ASCE/SEI criteria are formally satisfied. In the case in which it was not formally satisfied, i.e., for the flow blockage of 9.8%, it is the opinion of this reviewer that the slotted design of the wind tunnel test section renders the results acceptable. Another potentially relevant element of Method 3 (Wind Tunnel Procedure) of the ASCE/SEI 7-10 standard (section

31.2) pertains to variations of the wind speed with direction. The IFI study accounts for the maximum wind speed from all directions, and thus subsumes any concern in this regard. The other elements pertain to dynamic excitation of the structure and wind-borne debris regions. Such factors were not investigated in the IFI tests**.**

5. Conformance to the IR 16-8 and SEAOC PV2-2017 Requirements

From the above, it is concluded that, except for the 9.8% blockage issue just described, the wind tunnel tests and associated procedures are directly in accord with the ASCE/SEI 7-10 standard. For California-based installations, the SEAOC PV2-2017 standard applies, and the California Division of State Architect (DSA) sets forth some additional requirements in its IR 16-8 document. Here it is relevant to note that while developed in California, the SEAOC PV2-2017 report provides guidelines that are widely adopted. The subsections of IR 16-8 relevant to the present PV panel test conditions are in section 2.1.4, and these relate to low profile tilted systems on flat roofs. These are now discussed.

Consistent with section 2.1.4.1 of IR 16-8, the IFI wind tunnel tests are also deemed to satisfy the ASCE/SEI 7-10 and ASCE/SEI 49-12 specifications for wind tunnel tests. (Once again, the 9.8% blockage is deemed to be well-accounted for through the use of a slotted test section.) These are also the specifications noted in SEAOC PV2-2012. In this regard, it is relevant to note that the SEAOC PV2-2017 report references the wind tunnel requirements from the more recent ASCE/SEI 7-16 document, while the IFI tests were conducted in accord with the ASCE/SEI 7-10 standard. The ASCE/SEI 7-16 specifications for wind tunnel tests are reproduced in section 7.1 of the SEAOC PV2-2017 report. With regard to these newer specifications, it seems apparent that IFI was aware of the SEAOC PV2-2017 standards and recommendations. Specifically, the aforementioned thoroughness of the IFI documentation addresses the added levels of detail requested by the ASCE/SEI 7-16 standard (noted in SEAOC PV2-2017), as well as the additional bulleted list of recommendations pertaining to wind tunnel test reports given in section 7.2.6 of SEAOC PV2-2017. ***Regarding this bulleted list, the IFI is requested to provide a comment on the effect of the tubing length they used relative to the frequency response of the associated pressure measurements.***

Under the modelling component requirements in IR 16-8, it is noted that the wind tunnel tests do not require exactly scaled replicas of the specific buildings, but rather generic models may be employed as long they capture the wind flow behaviors over different roof zones. As described above, and as detailed in SOF01-1 (Section 3, Section 4.2, Annex A and Annex C), the wind tunnel tests measured the pressure distributions on the buildings in accord with ASCE/SEI 7-10 standards. Additionally, Sections 4.3 - 4.8 and 4.13 of SOF01-1 describe the load calculation procedures respectively associated with rooftop obstructions, multi-level roofs, L-shaped buildings, taller neighboring structures, array interruptions, panel aspect ratio variations, and building shape effects. The procedure that they describe here are all in accord with ASCE/SEI 7-10. As described in section 6 below, the wind tunnel data were used to determine the area averaged wind loads in a manner consistent with the ASCE/SEI 7-10 standard. Furthermore, as previously noted, the IFI report(s) were clear in articulating the scope and limitations of their tests. This includes low rise buildings having a flat roof with sharp eaves in exposure categories C (with likely applicability to categories B and D), with a 1.0m setback from the edge of the roof, and parapets of 10% and 20% of the building height. **These are in accord with the DSA IR 16-8 requirements.**

IR 16-8 also indicates that the ASCE/SEI 7-10 wind tunnel procedure for low profile tilted PV systems should be supplemented to incorporate the additional specifications described in SEAOC PV2-2012 (and SEAOC PV2-2017). For the present review, the specifications and requirements cited in section 31.6.3 of SEAOC PV2-2017 are relevant. These include the qualifications and experiences of the peer reviewer, the scope of the peer review, the status of the wind tunnel study, recommendations, and an assessment by the reviewer regarding whether the wind loads from the wind tunnel study are in conformance with ASCE 7-10 standards.

The author of this review has no affiliation with the IFI laboratory and has no conflict of interest relative to the present review. Furthermore, he has been conducting experimental studies of boundary layer turbulence and the flow around objects immersed in boundary layers for about 30 years. This includes a large number of studies within laboratory wind tunnel and water channel facilities, and over a decade of field studies in the atmospheric surface layer, including the participation in major field trials in urban areas where the flow patterns are dominated by the presence of buildings. Lastly, the present reviewer is familiar with the relevant ASCE and California specific codes, and has previously conducted assessments of wind tunnel studies for PV installations in California and elsewhere.

The scope of the present peer-review is to:

i) verify that the experimental procedures satisfied the relevant ASCE/SEI (7-5/7-10 and 49-12), SEAOC (PV2-2017) and DSA (IR16-8) requirements and standards,

ii) form and draw a judgment on whether the pressure coefficients presented in the SOF01-1 report were derived in accord with the relevant standards,

iii) when appropriate, offer a fluid dynamics based opinion regarding whether aspects of the methodology were conservative or not, and

iv) in accord with Section 31.6.3 of SEAOC PV2-2017, provide a set of recommendations or requests for clarification pertaining to specific aspects of the IFI report.

The IFI wind tunnel tests were completed in January 2017, with the associated report completed in Feburary 2017. Thus, its status is one of a completed investigation. From the IFI report, I am of the opinion that, apart from the points of clarification requested in the executive summary, the relevant ASCE/SEI standards (ASCE/SEI 7-10, Section 31.2, ASCE 7-05, Chapter 6.6.2) were met.

6. Summary of Wind Load Calculations

As described in Annex A of the IFI report (see Figure A.8), pressure distributions were experimentally measured on the top and bottom surfaces of the model PV panels in accord with ASCE/SEI 7-10 standards. These measurements were then used to calculate the relevant wind loads. As described in Sections 3.2-3.4 of the IFI report, pressure coefficients were calculated using an extreme value analysis that is consistent with the ASCE/SEI 7-10 standard. In this analysis, the ASCE 7-10 basic wind speed is based upon a 3-second gust at 10m height for 50 year return, and for wind exposure category C. From the data, pressure coefficients were calculated for loaded areas corresponding to 1, 2, 4, 9, 16, 25, 36, 56, 112 and 224 module units. The details pertaining to the calculation of the pressure coefficients (including parapet factors) are given in Annex D. An extensive reporting of the resulting pressure coefficients and parapet factors is also provided in Annex D. The calculations for both the uplift and sliding forces use force coefficients that are derived from the pressure measurements. The process used for obtaining these force coefficients is also described in Sections 3.2-3.4, with a detailed accounting of the extreme value analysis that IFI employed given in Annex B. As documented in these and other sections of the IFI report, the wind load calculations are in accord with the ASCE/SEI 7-10 standards. Other load considerations include the effect of the static coefficient of friction with the roof surface, the gravitationally induced sliding component associated with a slanted roof surface, rooftop obstructions, panel geometry effects, and the effects of building shape. These are described in the later subsections of Section 4 of the IFI report, and are verified to be in accord with the ASCE/SEI 7-10 standards. A noted difference from the previous SEAOC PV2-2012 report is the criteria employed in Section 4.7 that describes array interruptions in the east-west direction, i.e., perpendicular to the long edge of the array panels. The recommendation is to use the conservative calculations associated with the 1st to 4th module, and this is in accord with both the previous and present standard. The question/clarification pertains to the use of the linearly varying pressure coefficient prescription over 6 system heights as reflected in Figure 4.12, which comes for SEAOC PV2-2017. ***It is thus requested that the IFI provide a verification that the criteria from the newer SEAOC PV2-2017 report is still compatible with the ASCE/SEI 7-10 standard.***

In a manner consistent with ASCE 7-10, the module pressure coefficients are determined by employing a zonal approach that makes distinctions between outer and interior roof-zones, as well as groups that distinguish between being nearer to the leading or trailing edge of the building, see Figures 4.1-4.8 of the IFI report. This nominally determines whether the row group will be experiencing a suction pressure associated with the leading edge boundary layer separation characteristic of low-rise, flat roofed structures. The pressure coefficient calculations for the zonal areas are described in Section 4.2 of the IFI report. Regarding the load estimates it is important to reiterate that each module is assigned a single zone, even though in general any given module may occupy more than one load zone. The assignment is made such that the highest load zone occupied by the individual module is employed. The net result of this is to provide a conservative estimate for the required ballast.

Calculations of the loads allow for a specification for groups of individual PV panels, distinguished between leading edge (north) rows, trailing edge (south) rows and the number of modules per row. This applies to both the uplift and sliding forces, and these were determined as a function of flow direction. Here we note that as the wind direction changes the critical sliding and uplift forces and the row/module combinations upon which they act also changes. The manner in which the load data is computed has implications regarding installation, as large area estimates assume that the sub-components (rows and modules) are interconnected to form a larger structure. This provides for load sharing, which leverages the low likelihood of extreme pressures acting over large portions of the overall PV array during any given time duration. For this reason, the IFI report specifies the previously noted minimum array size requirements (two inter-connected rows with at least two module units per row), as well as explicitly notes the assumption of load sharing, see Section 4.9 of SOF01-1.

The equivalent full-scale setback employed in the IFI study is 1.0m, while the SEAOC PV2-2017 specification is 4ft (1.22m). While these are close, the effects of the corner vortices are likely to be more intense than if the SEAOC PV2-2017 specification were followed. Regarding installation, in the absence of additional justification/analysis it is thus recommended that setbacks less than 1m not be employed without further tests. As a standard feature of IFI load calculations, in the case where a PV module straddles more than one zone, the load calculation conservatively assigns the more critical (larger) load values to that module. Another conservative feature relates to the IFI specification that edge zone load values be used for modules along array interruptions, e.g., as produced by roof features such as skylights (see Section 4.3 of SOF01-1). In this case, while it is true that the loads on such modules are likely be larger than those on acting interior modules, they are also likely to be less than experienced by edge modules. The IFI report also specifies that edge load criteria be used in the region adjacent to the obstruction (region P of Figure 4.9), since the acceleration around the base of the roof-mounted object can be significant. In accord with the ASCE/SEI 7-10 standard, the tests described in SOF01-1 are generally valid for low-rise buildings, having heights less than 18.3m, but can be used for buildings taller than 18.3m if they are deemed rigid according to the ASCE/SEI 7-10 standard. As noted in the Section 3.2.3.4 commentary of SEAOC PV2-2017, the net pressure coefficient calculation tends to be conservative, and increasingly so for shorter buildings. Thus, as long as the calculated pressures and ballast are adequate for the low rise designation, the IFI estimates should satisfy the SEAOC PV2-2017 standard. The SOF01-1 report specifically notes that their load estimates assume that the array modules are rigidly connected, and thus leverage the benefits of load sharing. Section 4.9 specifies the minimum requirements regarding the interconnectedness of the PV arrays. **These must be adhered to, and in an installation, the structural interconnectivity should be verified.** Smaller arrays will require additional testing, and probably additional ballast. Annex D of SOF01-1 describes how the pressure coefficients are calculated. Different from the SEAOC PV2-2017 specification, the calculation of the normalized loaded area uses an exponent, γ, that can range from 0 to 1, while the SEAOC PV2-2017 calculation uses a direct scaling with building height ($\gamma = 1$). This deviation leads to a more conservative estimate, and thus is acceptable.

7. References

ASCE/SEI 7-05, American Society of Civil Engineers standard for "Minimum Design Loads for Buildings and Other Structures," Chapter 6. 2006.

ASCE/SEI 7-10, American Society of Civil Engineers standard for "Minimum Design Loads for Buildings and Other Structures," Section 31.2. 2010.

ASCE/SEI 49-12 American Society of Civil Engineers standard for "Wind Tunnel Testing for Buildings and Other Structures," 2012.

J.E. Cermak et al., ASCE Manuals and Reports on Engineering Practice No. 67, "Wind Tunnel Studies of Buildings and Structures" (1999).

J. Counihan, "An Improved Method of Simulating an Atmospheric Boundary Layer in a Wind Tunnel," *Atmos. Environ.* **3**, 197-214.

IR 16-8, Division of the State Architect, California Department of General Services, Interpretation of Regulations Document 16-8: "Solar Photovoltaic and Thermal Systems Review and Approval Requirements," revision 10/16/2012.

SEAOC-PV2-2012, Structural Engineers Association of California, "Wind Design for Low-Profile Solar Photovoltaic Arrays on Flat Roofs, August, 2012.

SEAOC PV2-2017, Structural Engineers Association of California, "Wind Design for Solar Arrays," July, 2017.

Hochschule Aachen

I.F.I. Institut
für Industrieaerodynamik GmbH
Institute at Aachen University of
Applied Sciences

Welkenrather Straße 120
52074 Aachen, Germany

Phone: +49 (0) 241/879708-0
Fax: +49 (0) 241/879708-10
Email: info@ifi-aachen.de

Client: Sollega, Inc., San Francisco, CA 94110, USA

Report No.: SOF01-1

Date: 02/28/2017

Wind loads on the solar ballasted roof mount system „FastRack 510" of Sollega, Inc.

Design wind loads for uplift and sliding according to the American standard ASCE/SEI 7-10

Reviewed by:

Dr.-Ing. Th. Kray

(Head of department of PV wind loading)

Prepared by:

Dipl.-Ing. (FH) J. Paul

(Consultant for wind loading)

Management:
Dipl.-Ing. B. Konrath, Dr.-Ing. R.-D. Lieb

Scientific Advisory Board:
Prof. Dr.-Ing. R. Grundmann, Prof. Dr.-Ing. H. Funke, Prof. Dr.-Ing. Th. Heynen

Founded by:
Prof. Dr.-Ing. H.J. Gerhardt, Prof. Dr.-Ing. C. Kramer

Sparkasse Aachen
IBAN: DE26 3905 0000 0047 4400 03
BIC: AACSDE33

Amtsgericht Aachen
HRB 4518

VAT No.: DE121682741

Accredited Test and Certification Body; European Notified Product Certification Body 1368 according to CPR

Certified according to ISO 9001

LADBS approved laboratory for wind tunnel testing of buildings and structures, Testing Agency License Number TA 24830

Contents

Caution:

The given equations for the calculation of the ballast apply to flat roofs with sharp eaves and parapets. If the PV system is deployed on a roof with curved or mansard eaves or on a roof with a slope greater than 7°, ballast calculation must be carried out individually.

The present design loads for wind actions apply without restriction to solar arrays deployed on low-rise buildings as defined in section 26.2 of ASCE 7-10. The wind tunnel testing also applies to buildings higher than 18.3m (60ft) which are considered rigid. A building may always be assumed as rigid if it is at least as wide as it is high. Whether a building is considered rigid or flexible depends on the building's properties such as natural frequency for along-wind response and structural damping at the natural frequency. With these two properties the gust effect factor may be calculated which is a measure for the building's stiffness or flexibility. According to section 26.2 of ASCE 7-10 this check may be further simplified by checking the natural frequency only. If the natural frequency is greater than 1 Hz, the building is permitted to be considered rigid.

Details of the study

Project No.:	SOF01
Project description:	Determination of the pressure distributions on the solar ballasted roof mount system “FastRack 510” with a module tilt angle of 10deg of Sollega, Inc.. The wind tunnel measurements were conducted with scaled models in the large boundary layer wind tunnel of I.F.I.. Measurements and analysis are in accordance with the American Standards ASCE 7-10 [1] and ASCE 49-12 [2].
Test set-up design:	December 2016
Testing:	January 2017
Test equipment:	The test equipment used by I.F.I. for wind tunnel measurement of pressures is calibration-free. The pressure measurement system consists of the PSI DTC Initium Main Frame, the PSI 9IFC NetScanner System Interface and 8 PSI DTC ESP-32HD Scanners. Additionally, a Pitot-static tube is used for measurement of the incident dynamic pressure. The measuring chain consists of pressure taps, brass tubes, flexible tubes, restrictors and pressure scanners.

1 Introduction

Sollega, Inc., San Francisco, CA 94110, USA develop and manufacture mounting systems for photovoltaic panels on flat roofs. In this context, flat roofs are defined as roofs having a slope of less than ± 7° (cf. ASCE/SEI 7-10 [1]) so that with view to the wind flow over them it can be assumed that the flow separates on the roof edge or parapet. Typical for the flow over flat roofs is the forming of vortices with high rotational speeds due to cornering flow. These vortices, also called "delta wing vortices", create correspondingly high suction effects on the roof, especially in the corner and edge zones.

The installation of PV systems leads to the problem of their securement, as these systems are mainly installed onto existing roofs and shall not or cannot be secured against sliding or uplift by the use of penetrating fasteners through the roof membrane. In the past, in order to protect the roof membranes and to increase friction, it was generally chosen to lay the PV elements on granular-rubber mats in combination with additional weights. However, as many flat roofs have only limited load bearing capabilities, people involved in the PV industry are trying to find systems which need as little ballast as possible or are secured by their dead load alone in situations of normal exposure. Today, these systems, described as "ballast-free" or more correctly "low ballast", are subject to controversial discussions in technical literature, as according to ASCE/SEI 7-10 there are no values for the pressure compensation mechanisms used in these cases.

Therefore, models of the solar ballasted roof mount system “FastRack 510” with a module tilt angle of 10deg in landscape orientation of Sollega, Inc. were submitted to wind tunnel tests in compliance with the guidelines of the ASCE/SEI 7-10, Chapter 31. The aim of these tests was to correctly determine the wind loads which can be realistically expected and to calculate any resulting ballast requirements in accordance with the wind exposure of the site. I.F.I. Institut für Industrieaerodynamik GmbH, Institute at the Aachen University of Applied Sciences (in the following I.F.I. for short) was commissioned by Sollega, Inc. to carry out these tests.

1.1 Description of the solar ballasted roof mount system “FastRack 510”

The modules of the solar ballasted roof mount system “FastRack 510” with a module tilt angle of 10deg in landscape orientation are installed on a substructure. The system consists of solar PV panels which are tilted south. The modules are 1960mm x 991 mm x 33 mm in size. Due to the gap between adjacent modules of 10 mm the spacing of the columns is 1970 mm. The row spacing (distance from ridge to ridge of two consecutive rows) is 1304 mm. The system has a height of 341 mm for the given module dimensions.

The representative 8x9 PV arrays for 10deg landscape configuration studied in the wind tunnel test were placed at offset distances of 1.0 m from the roof edges. The studied building configurations are given in Table 1.1 in full scale dimensions. The model scale was 1:50.

Figure 1.1 shows the most important geometric dimensions of the array assembly for the 10deg system in landscape orientation. Where geometric distortions such as solar panel thickness were necessary, priority was placed on matching venting gap sizing around the base and edges of the panels of the wind tunnel models.

Table 1.1: Building configurations studied in wind tunnel testing

Configuration	roof height *h* [m]	building width *W* [m]	building depth *L* [m]	parapet height *hp* [m]
1	7.5	60	60	0
2	12.5	60	60	0
3	7.5	60	60	0.75
4	7.5	60	60	1.5

Figure 1.2 shows the array assembly of the solar ballasted roof mount system “FastRack 510” 10deg in landscape orientation.

In the wind tunnel scale model PV panels in 10deg landscape configuration were arranged on a flat roof in a configuration of eight module units per row and nine rows behind one another. Seven rows were fitted with pressure taps. Two rows were designed as dummies without any pressure taps.

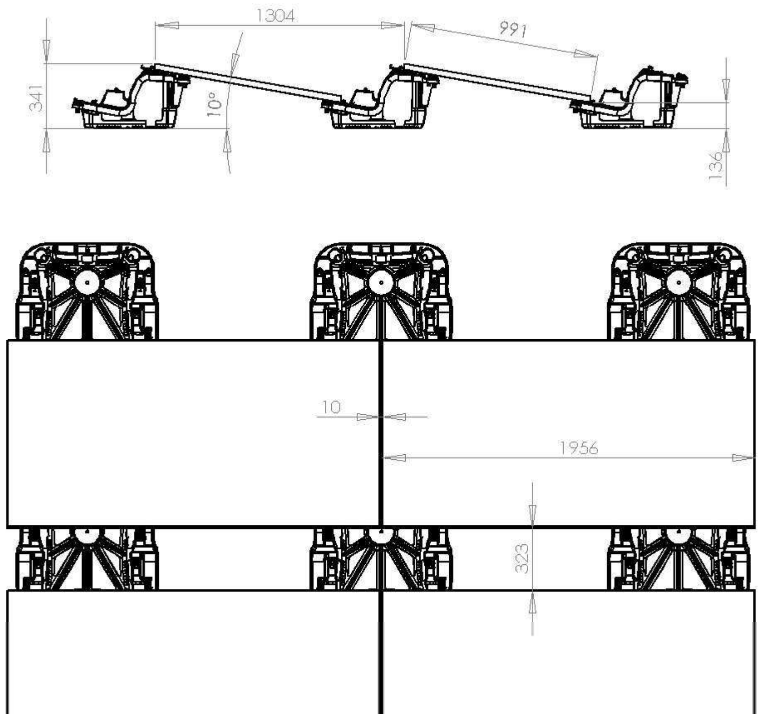


Figure 1.1: Geometric dimensions of the array assembly of the solar ballasted roof mount system "FastRack 510" 10deg in landscape orientation

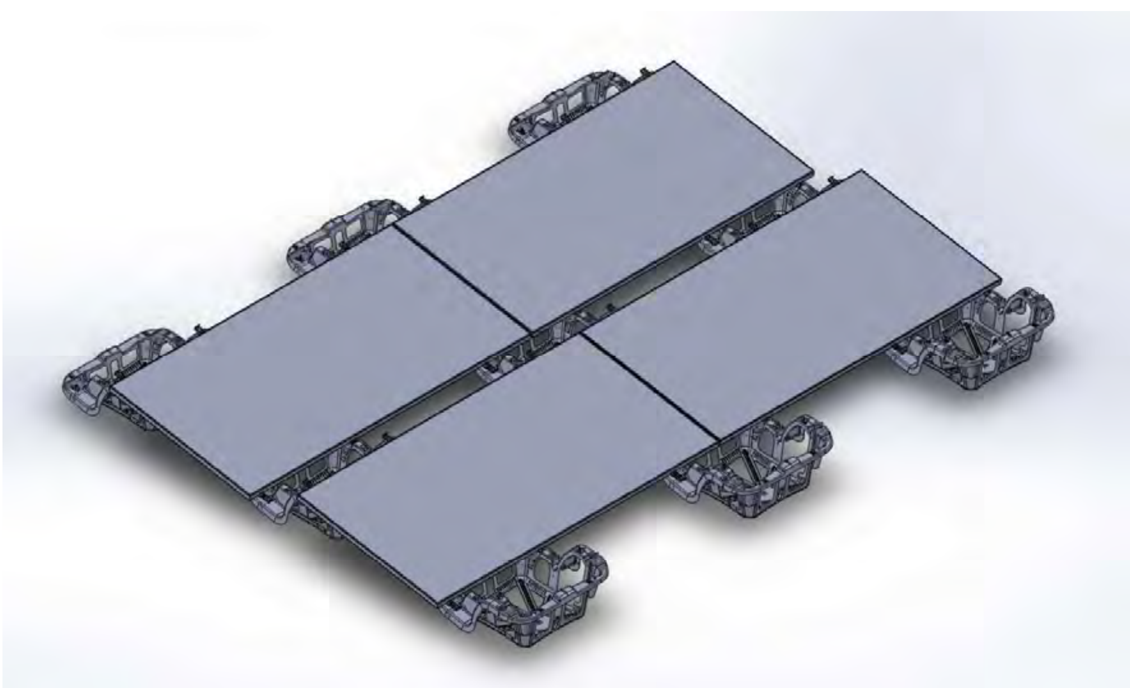


Figure 1.2: Array assembly of the solar ballasted roof mount system "FastRack 510" 10deg in landscape orientation

Situations were modelled where the PV arrays were set in 7 different positions on the roofs, see Annex C.1 for further details. Wind tunnel testing was conducted at 15° intervals for seven wind directions per wind sector from 0° to 90° and 90° to 180°, respectively. In this way, the effects of corner vortices and reattached flow were accounted for. The positions of instrumented rows were interchanged with dummy row positions in the testing. The corresponding wind tunnel models are shown in Annex C.2. The upwind exposure category that can be seen in the fetch of the large boundary layer wind tunnel corresponded to open country exposure (Exp. C).

2 Summary

The present report contains the design loads for wind actions on the solar ballasted roof mount system “FastRack 510” with a module tilt angle of 10deg in landscape orientation. The results are given as dimensionless pressure coefficients for normalized wind areas of various sizes and shall be applied using the peak velocity pressure in accordance with ASCE/SEI 7-10 [1]. The module tilt angle, gap dimensions and row spacing may vary slightly as a function of varying module sizes.

The test results are likely to be appropriate for upwind Exposures B, C and D on flat-roofed buildings, assuming use in compliance with ASCE/SEI 7-10, Chapter 30.1.3. Pressure coefficients are given separately for different array and roof zones and for four wind sectors. These results are only to be used for arrays with a minimum setback of 1.0 m from the roof edges on flat roofs with a maximum roof angle of 7°.

The necessary ballast for the securement of the solar ballasted roof mount system depends on the stiffness of connecting members. Stiff members exploit the lack of the non-simultaneous action of building- or array-induced gusts on large effective wind areas. If wind forces on highly loaded zones of arrays can be largely redistributed by the interconnected substructure, the benefits of load sharing are applicable.

Another element affecting the formation of edge vortices in the edge zones of the roof is the presence or rather the height (in relation to the building height) of a parapet. This is explained by lifting of the vortices higher above the roof surface. As a result the wind-induced loads tend to increase in some roof positions, but decrease in others.

3 Fundamentals

3.1 General

The wind loads on solar roof mount systems are dependent upon the wind direction and the wind displacement due to the volume of the building. Wind speeds above flat roofs vary considerably with position on the roof. Modules installed close to the roof corners are subjected to higher wind loads than other roof locations due to the flow acceleration caused by the delta wing vortices. Conversely, solar arrays with a greater offset from the roof edges than tested in the wind tunnel study generally see lower wind loads.

3.2 Method of analysis

The wind tunnel model of the solar roof mount system was reproduced on a scale of 1:50. In order to calculate the design wind loads, the pressure distributions on the bottom and top surfaces of the panels were measured in a wind tunnel test in compliance with the guidelines of the ASCE 7-10 [1], Chapter 31 and ASCE 49-12 [2]. The upwind exposure category in the wind tunnel corresponded to Exposure C.

The test data were processed under consideration of the spatio-temporal correlation in such a way that the pressure coefficients are in a form compatible with the ASCE/SEI 7-10. Descriptions of the boundary layer wind tunnel, of the model set-up and of the test methods can be found in Annex A of this report.

The literature presents different methods for the determination of wind loads on buildings and structures (including the supporting structure and panels). One of the most common methods is the analysis of extreme values. This method is described in detail in Annex B of this report.

3.3 Design velocity pressure

In order to determine the wind loads, the pressure coefficients c_p have to be multiplied with the peak velocity pressure q_z. The following equation (1) gives the local peak velocity pressure:

$$q_z = 0.613 * K_z * K_{zt} * K_d * v^2 \quad (1)$$

where

- q_z is the local peak velocity pressure at roof height, z, of the industrial building according to ASCE/SEI 7-10
- K_z velocity pressure exposure coefficient defined in ASCE/SEI 7-10, section 30.3.1
- K_{zt} topographic factor (ASCE/SEI 7-10, section 26.8)
- K_d wind directionality factor, see ASCE/SEI 7-10, section 26.6
- v basic wind speed [m/s] from ASCE/SEI 7-10, figure 26.5

The ASCE/SEI 7-10 basic wind speed is based on 3-second gust at 10 m height, 50-year return and Exposure C. The reference height chosen for determining the design velocity pressure is the roof height, *z*.

3.4 Pressure coefficients

Non-dimensional pressure coefficients c_p were calculated by means of extreme value analysis with a subsequent conversion into the pseudo-steady format. The analysis was carried out in such a way that the pressure coefficients were calculated for effective wind areas corresponding to single module units, 2, 4, 9, 16, 25, 36, 56, 112 and 224 module units.

3.4.1 Area-averaging of pressure coefficients as a function of time

At every pressure tap a time series of pressures was recorded for each wind direction. The recorded pressure is the difference between the pressure at the pressure tap, $p_{tap}(t)$, and the static pressure in the wind tunnel, $p_{st}(t)$. By dividing the recorded pressure, $p_{recorded}(t)$, with the velocity pressure $\bar{q}_{WT}$ which is averaged over the sampling time of 1 min in full scale, see also Annex B, the pressure coefficient, $C_p(t)$, is calculated.

$$C_p(t) = \frac{p_{tap}(t) - p_{st}(t)}{\bar{q}_{WT}} = \frac{p_{recorded}(t)}{\bar{q}_{WT}} \quad (2)$$

These local pressure coefficients are averaged over the tributary areas assigned to the taps on the upper and lower module and deflector surfaces to calculate the net pressure coefficients, $\Delta C_p(t)$.

$$\Delta C_p(t) = \frac{\Delta p_{recorded}(t)}{\bar{q}_{WT}} = \left(\sum_{i \in upper\ surface\ taps} C_{p_i}(t) \cdot \frac{A_i}{A_{total}} \right) - \left(\sum_{j \in lower\ surface\ taps} C_{p_j}(t) \cdot \frac{A_j}{A_{total}} \right) \quad (3)$$

with

- A_i as the tributary areas of the upper surfaces associated with the taps i
- A_j as the tributary areas of the lower surfaces associated with the taps j

and

$$\sum_{i \in upper\ surface\ taps} A_i = A_{total}$$
$$\sum_{j \in lower\ surface\ taps} A_j = A_{total} \quad (4)$$

By these calculations several time series are combined to one time series for which peak values may be determined according to the method outlined in Annex B.

3.5 Design wind forces and design ballast

Figure 3.1 shows the definition of the wind directions and of the coordinate system, which are the basis for the design wind forces. Wind direction 0° corresponds to wind blowing on the north façade of the flat-roofed building.

The wind forces as calculated from equations (5) to (7) include a load factor of 1.6. In opposition to earlier editions of the ASCE/SEI 7 the basic wind maps in ASCE/SEI 7-10 include the importance and load factor, thus the wind load calculated according to ASCE/SEI 7-10 is directly applicable for strength design.

$$F_x = q_z * (- c_{pM} * \sin \alpha * A_M) \quad (5)$$

$$F_y = q_z * c_F * A_M \quad (6)$$

$$F_z = q_z * (- c_{pM} * \cos \alpha * A_M) \quad (7)$$

where:

- F_x is the sliding force per module unit in x-direction

- F_y is the sliding force per module unit in y-direction
- F_z is the uplift force per module unit in z-direction
- q_z is the local peak velocity pressure at roof height, z, of the industrial building according to ASCE/SEI 7-10
- A_M is the module area per module unit
- c_F is the aerodynamic friction coefficient; $c_F = 0.001$
- c_{pM} is the module pressure coefficient
- α is the module tilt angle

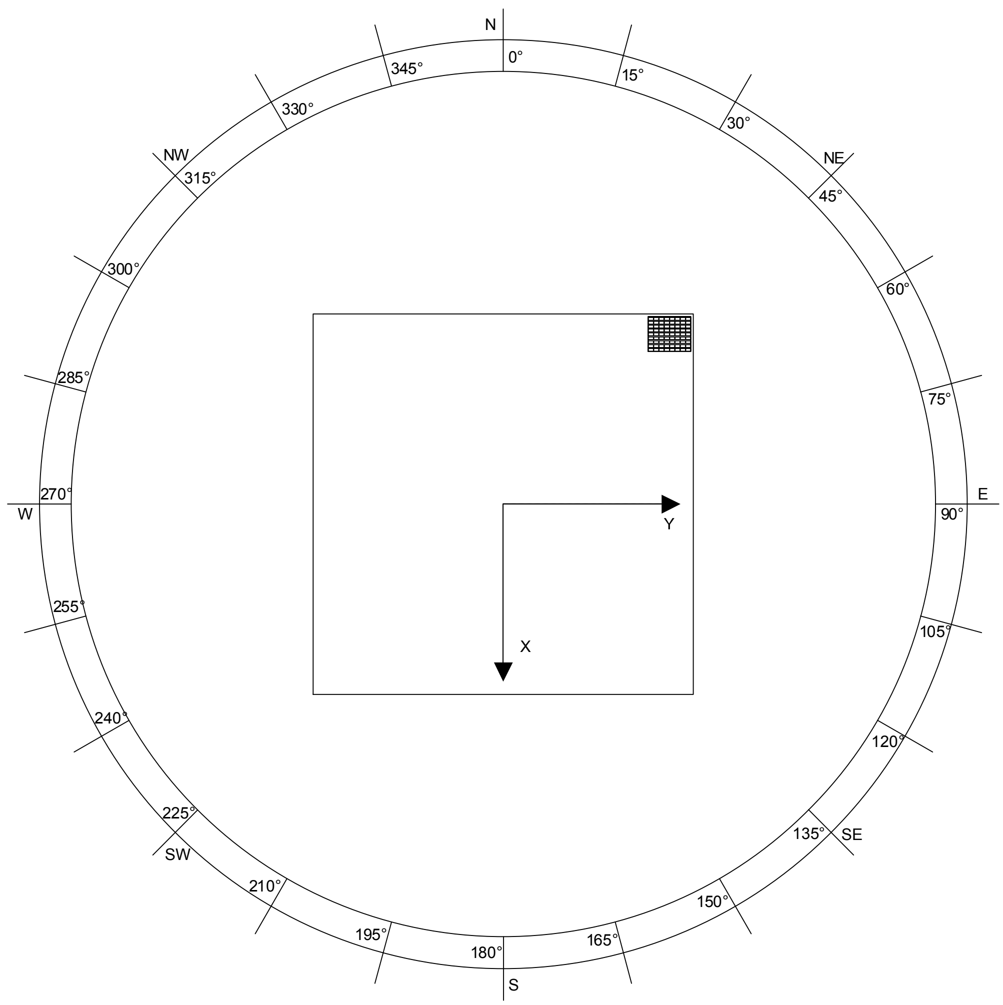


Figure 3.1: Definition of the wind directions and of the coordinate system for the studied solar ballasted roof mount system "FastRack 510"

The resulting wind forces in y-direction are negligibly small, but not zero. Whether F_y is included or suppressed in ballast calculations has negligible effect on the final result. To make sure the reader understands that a very small value was chosen for F_y. The following equations can be deduced from the friction:

$$F_R = (F_x^2 + F_y^2)^{½} = \mu_{R,0} * F_N \tag{8}$$

$$F_N = G_{DL} - F_z + G_B \tag{9}$$

where:

- F_R is the static friction force
- $\mu_{R,0}$ is the static friction coefficient
- F_N is the normal force
- G_{DL} is the dead load of the module unit with the mass m_{DL}
- G_B is the additional weight with the mass m_B ("design ballast")

Under consideration of a load factor for wind S_W = 1.0 and of the mass of a mounting unit m_{DL} combined with dead load factors S_{DI} and S_{DII}, the necessary additional mass m_B ("design ballast") is calculated as follows:

$$m_{B,sliding} = \frac{S_W \cdot \left[\frac{\sqrt{F_x^2 + F_y^2}}{\mu_{R,0}} + F_z\right]}{S_{DII} \cdot g} - \frac{S_{DI}}{S_{DII}} \cdot m_{DL} \tag{10}$$

$$m_{B,uplift} = \left[\frac{S_W \cdot F_z}{S_{DII} \cdot g} - \frac{S_{DI}}{S_{DII}} \cdot m_{DL}\right] \tag{11}$$

The value of the acceleration due to gravity g used in equations (10) and (11) is 9.81 m/s².

Designers using this report must be aware that the value F_z will be different for the uplift case than for the sliding case. F_z is a function of pressure coefficient, c_p, which is a function of effective wind area, A. Effective wind area is typically smaller for uplift cases than for sliding, and effective wind area for uplift typically varies depending on the structural properties at array corners, edges, and interior, so several cases must be checked. (In other words, it is easier to lift up the corner of an array than to lift the middle of the array.)

4 Results

4.1 Analysis of the aerodynamic properties of the array of panels

The aerodynamic forces on the panels are the result of the local deflection of the wind on the panels. The acceleration of the reattached flow over the panels creates suction (negative pressure). Cornering wind leads to the peak loads for most of the modules deployed in arrays. Because of the wind displacement due to the buildings on which the solar ballasted roof mount system was studied, the flow is not homogeneous over all the panels on the roof, meaning that the critical wind directions vary from panel to panel.

Conversely, this fact supports the effect of uplift securement in the array or its interconnected panels, as there are always some zones which are submitted to smaller loads for a certain wind direction and therefore the simultaneity of maximum wind loading decreases as the length and the number of rows increase.

As known from many wind tunnel studies, the wind loads on solar roof mount systems need not be applied simultaneously to the roof components and cladding wind loads from ASCE/SEI 7-10. As recommended in [3], these design checks should be carried out separately.

4.2 Design pressure coefficients for the solar ballasted roof mount system "FastRack 510"

The solar array tested in the wind tunnel is divided for the analysis into effective wind areas of varying size, the pressure coefficients of which are given in Annex D in Tables D.2 to D.15. The selected effective wind areas correspond to single module units, 2, 4, 9, 16, 25, 36, 56, 112 and 224 module units and are normalized by building area. In addition, seven roof zones were delimited to reproduce the progression of the wind loads over the roof, see Figure 4.1 to Figure 4.4. Roof zones are depicted separately for east winds from 0° to 90° and 90° to 180°, and for west winds from 180° to 270° and 270° to 360°.

Roof zoning needs to be performed separately according to Figure 4.1 to Figure 4.4 and assumes that panels are tilted towards the south edge of the building. The array setback "*a*" from the roof edges has to be equal to or greater than 1.0 m.

For winds from north, the length of roof zone 1, L_1, corresponds to 20 m or the building's length, whichever is smaller. L_2, the length of roof zone 2, corresponds to 20 m or the building's length minus 20 m, whichever is smaller, but not less than 0 m. L_3, the length of roof zone 3, corresponds to the building's length minus 40 m, but not less than 0 m.

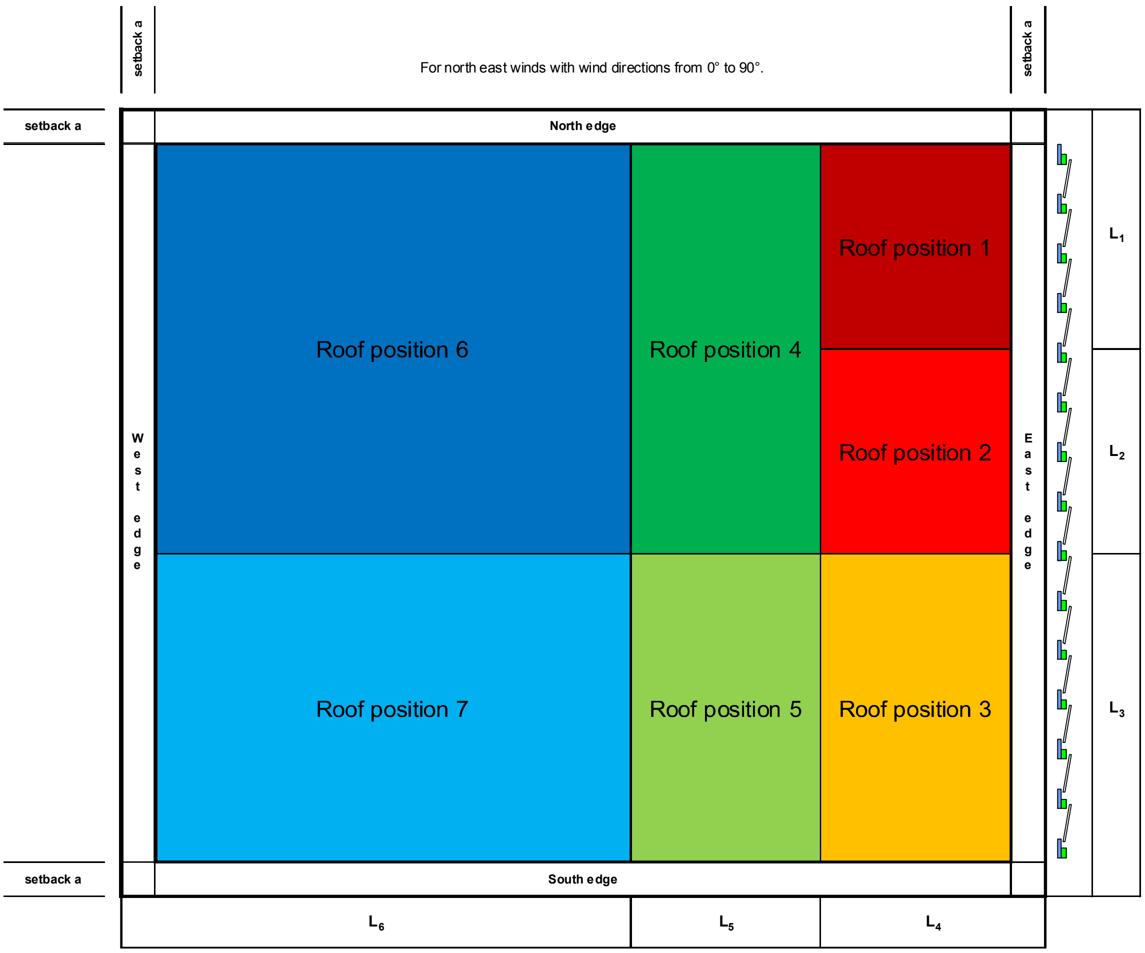


Figure 4.1: Definition of roof zones for the solar ballasted roof mount system "FastRack 510" with a minimum offset "*a*" from the roof edges equal to or greater than 1.0 m and for north east winds from 0° to 90°; valid for flat-roofed buildings with a maximum roof angle of 7°

For winds from south, the length of roof zone 3, L_7, corresponds to 20 m or the building's length, whichever is smaller. L_8, the length of roof zone 2, corresponds to 20 m or the building's length minus 20 m, whichever is smaller, but not less than 0 m. L_9, the length of roof zone 1, corresponds to the building's length minus 40 m, but not less than 0 m.

The width of roof zones 1, 2 and 3, L_4, corresponds to 20 m or the building's width, whichever is smaller. Accordingly, the dimension L_5, the width of roof zones 4 and 5, corresponds to 20 m or the building's width minus 20 m, whichever is smaller, but not less than 0 m. Accordingly, the dimension L_6, the width of roof zones 6 and 7, corresponds to the building's width minus 40 m, but not less than 0 m.

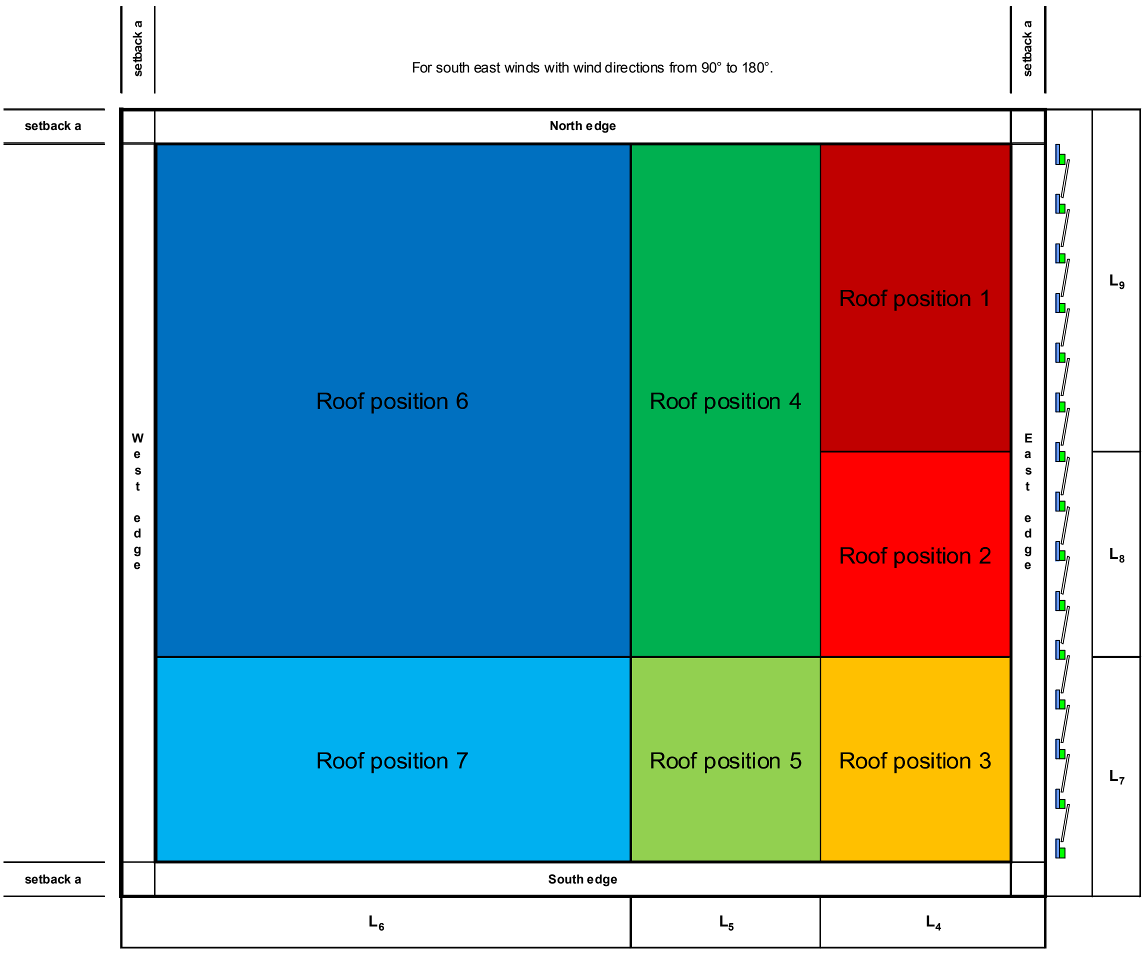


Figure 4.2: Definition of roof zones for the solar ballasted roof mount system "FastRack 510" with a minimum offset "*a*" from the roof edges equal to or greater than 1.0 m and for south east winds from 90° to 180°; valid for flat-roofed buildings with a maximum roof angle of 7°

Pressure coefficients were calculated separately for wind sectors from north (0°-90°) and south (90°-180°). For winds from north, pressure coefficients were calculated separately for north rows and inner rows. For winds from south, pressure coefficients were calculated separately for south rows and inner rows. Two load cases, 'sliding' and 'uplift', were distinguished. Pressure coefficients are given in Annex D.

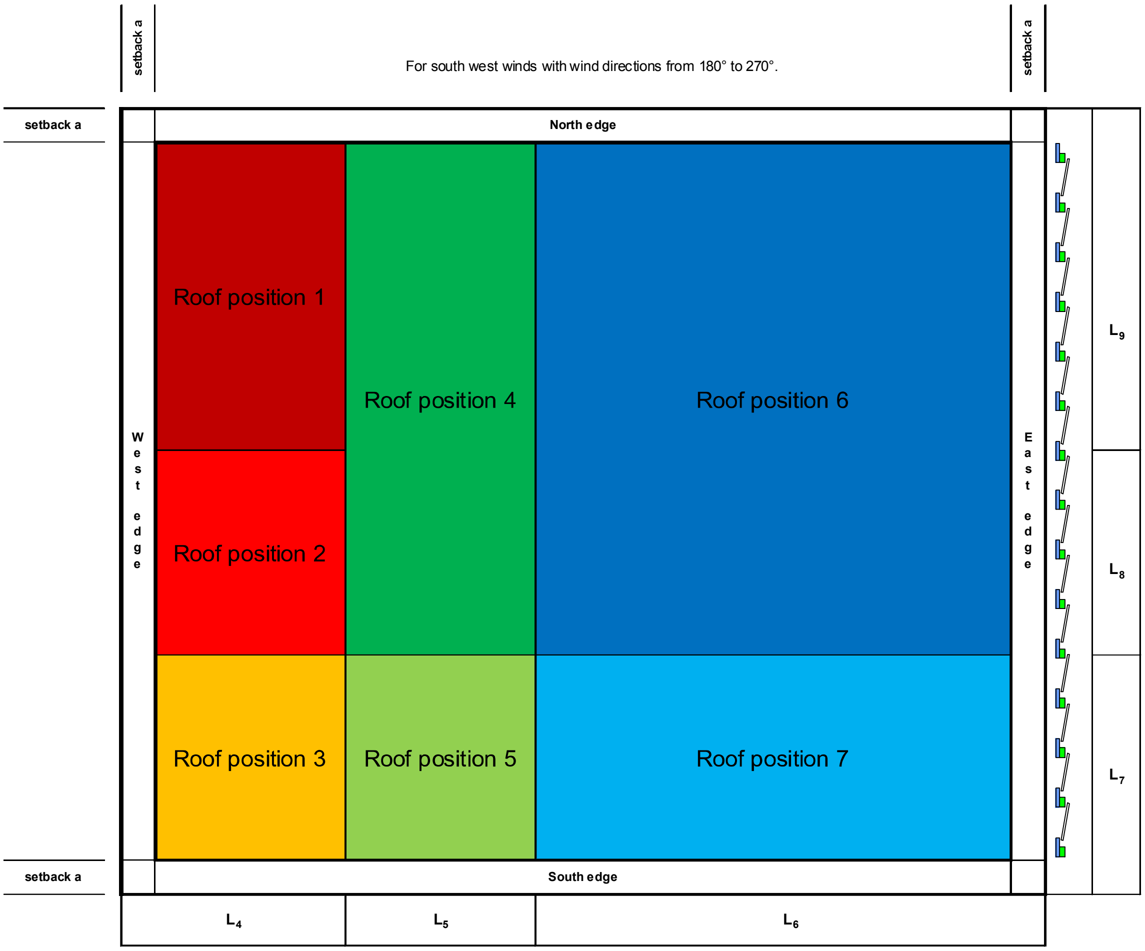


Figure 4.3: Definition of roof zones for the solar ballasted roof mount system "FastRack 510" with a minimum offset "*a*" from the roof edges equal to or greater than 1.0 m and for south west winds from 180° to 270°; valid for flat-roofed buildings with a maximum roof angle of 7°

The ratio of row spacing to system height is a very important parameter. If it is increased with respect to the tested spacing by more than 10%, downwind rows will be less sheltered from wind attack. For all rows whose ratio of row spacing to system height is greater than 110% of the tested one, it is recommended that the more conservative of north, inner or south row values may be used. The system height corresponds to the vertical distance from the roof to the system's ridge, h_S, see Figure 4.13. The wind directions were defined in such a way that the wind direction 0° corresponds to wind blowing on the north façade of the flat-roofed building. In this way, the defined zones adjust to the orientation of the rows to the edges of the building and may be applied to any geographical wind direction by means of rotation of the coordinate system. Design pressure coefficients were provided for array rows that are parallel to the building edges. However, they may be applied if the main axis of the array is not skewed more than 15° with the building edges.

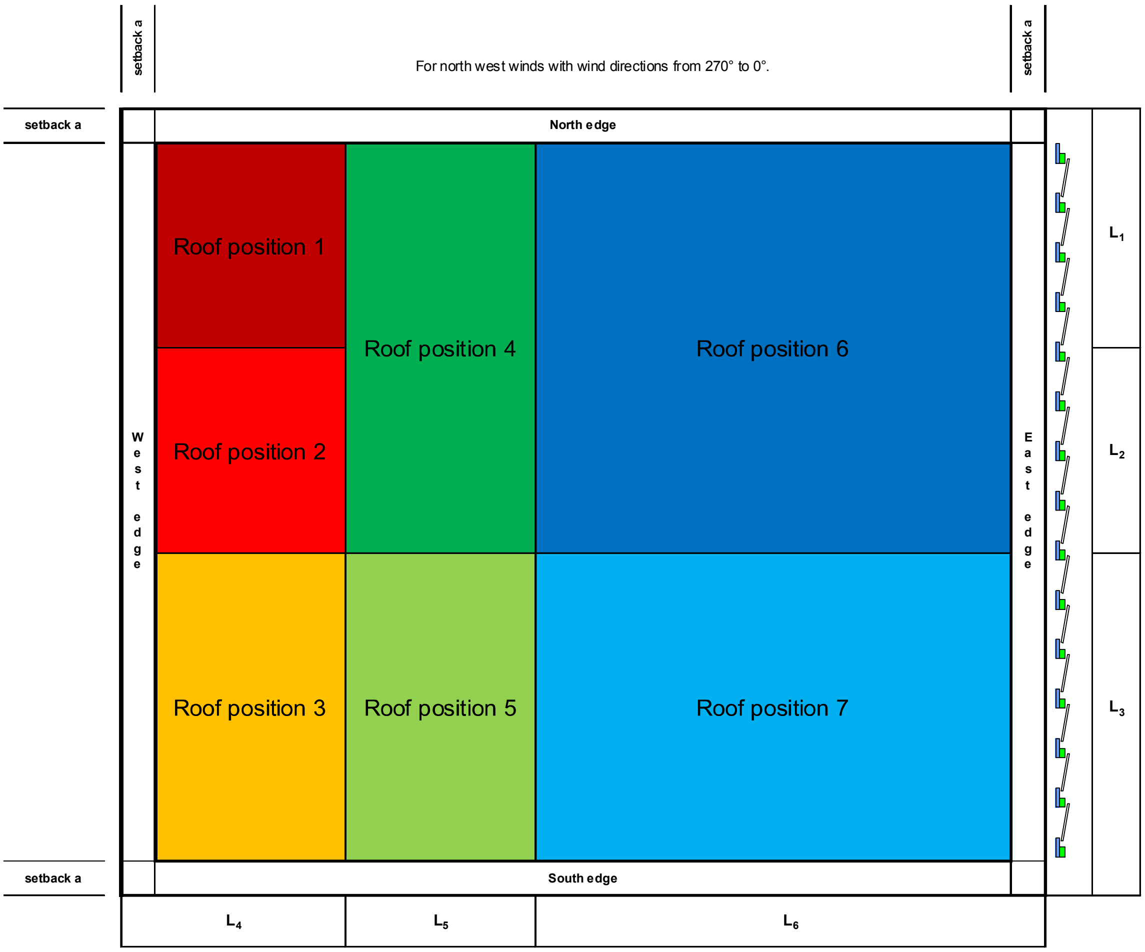


Figure 4.4: Definition of roof zones for the solar ballasted roof mount system "FastRack 510" with a minimum offset "*a*" from the roof edges equal to or greater than 1.0 m and for north west winds from 270° to 0°; valid for flat-roofed buildings with a maximum roof angle of 7°

Figure 4.5 to Figure 4.8 show the array zones for the "FastRack 510" system. Array zones are depicted separately for east winds from 0° to 90° and 90° to 180°, and for west winds from 180° to 270° and 270° to 360°, respectively. Array zoning needs to be performed separately according to Figure 4.5 through Figure 4.8. The highest ballast resulting from Figure 4.1 to Figure 4.4 is the design ballast for "FastRack 510". A PV panel is always assigned to a zone as a whole. If a panel is situated in two or more zones, the most critical one has to be taken into account for wind load calculation.

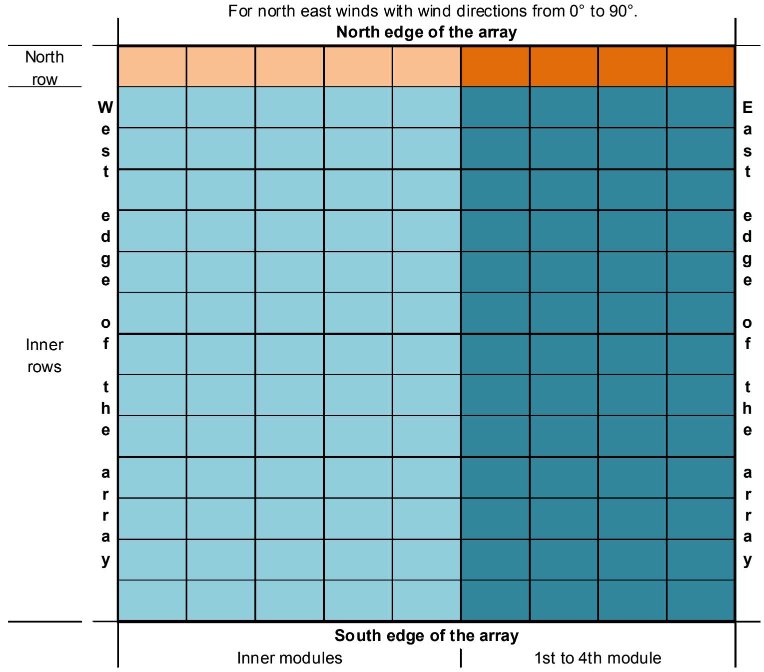


Figure 4.5: Definition of array zones for the solar ballasted roof mount system "FastRack 510" with a minimum offset "*a*" from the roof edges equal to or greater than 1.0 m and for north east winds from 0° to 90°; valid for flat-roofed buildings with a maximum roof angle of 7°

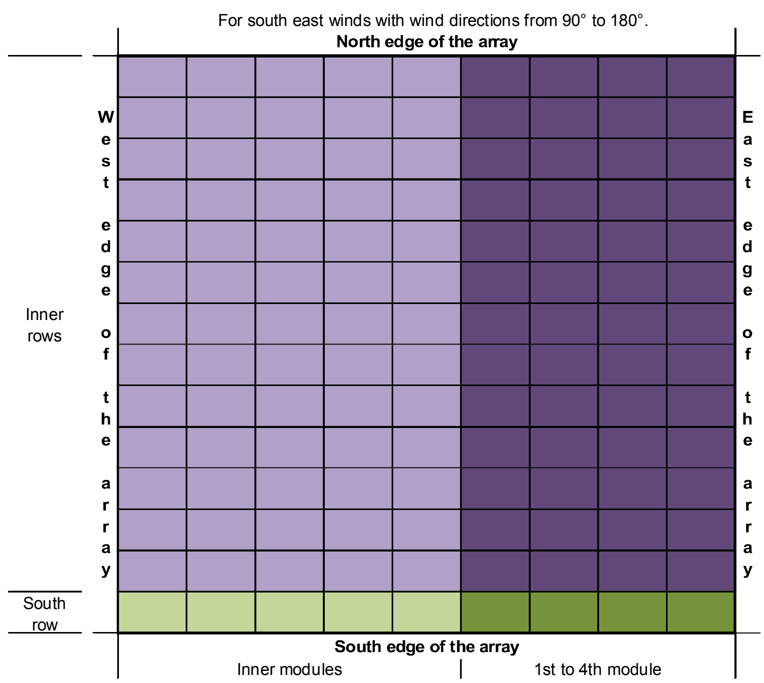


Figure 4.6: Definition of array zones for the solar ballasted roof mount system "FastRack 510" with a minimum offset "*a*" from the roof edges equal to or greater than 1.0 m and for south east winds from 90° to 180°; valid for flat-roofed buildings with a maximum roof angle of 7°

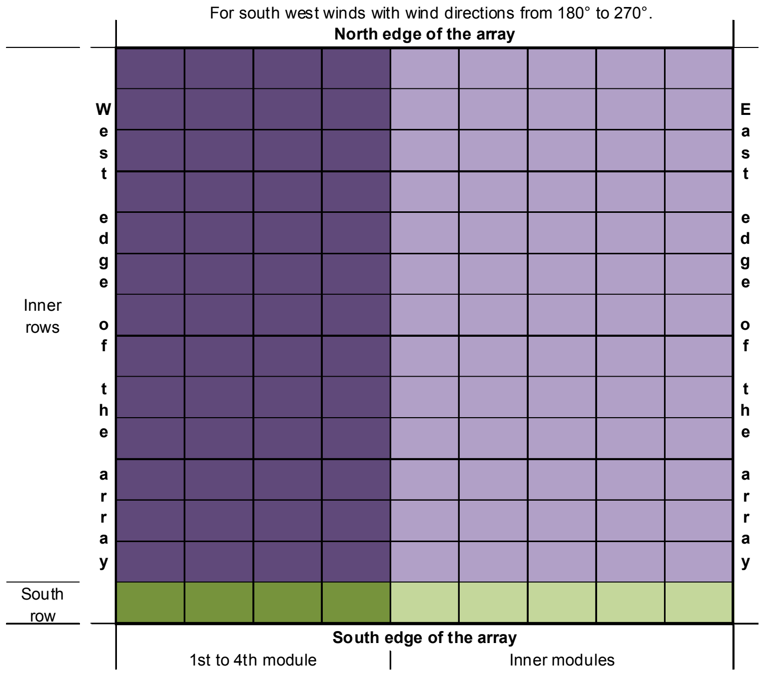


Figure 4.7: Definition of array zones for the solar ballasted roof mount system “FastRack 510” with a minimum offset “*a*” from the roof edges equal to or greater than 1.0 m and for south west winds from 180° to 270°; valid for flat-roofed buildings with a maximum roof angle of 7°

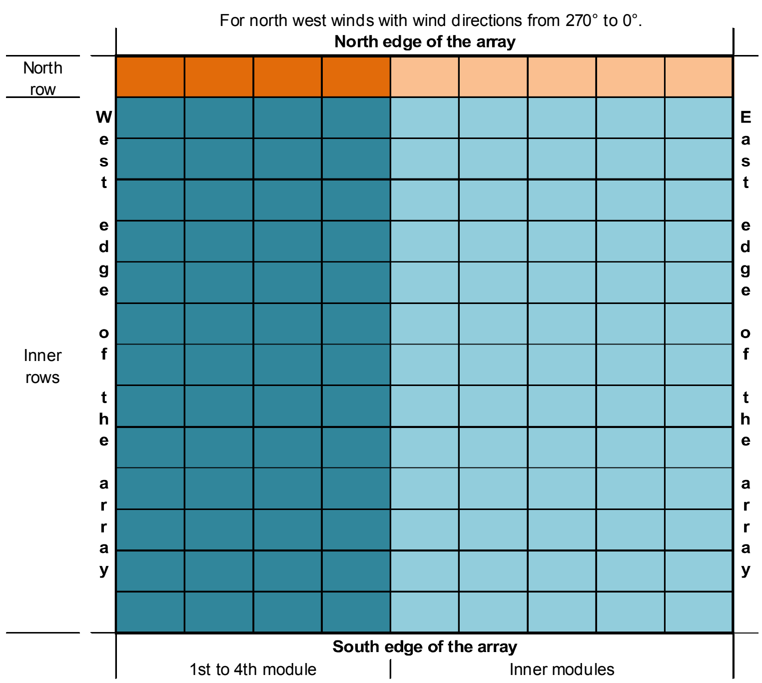


Figure 4.8: Definition of array zones for the solar ballasted roof mount system “FastRack 510” with a minimum offset “*a*” from the roof edges equal to or greater than 1.0 m and for north west winds from 270° to 0°; valid for flat-roofed buildings with a maximum roof angle of 7°

4.3 Rooftop obstructions

Rooftop obstructions, such as HVAC units, elevator overruns, penthouses, and other roof objects protruding above the roof see accelerated flow at their perimeter zone P, see Figure 4.9.

The zone of accelerated flow may be limited to a distance a_s of

$$a_s = \min\left(\frac{1}{2}\cdot\left(l_1^{\,2}+l_2^{\,2}\right)^{\frac{1}{2}};h_v\right) \tag{12}$$

from the obstruction where l_1, l_2 and h_v correspond to width, length and height of the rooftop obstruction, respectively.

In the absence of additional testing, it is recommended that 1st to 4th module unit values for "FastRack 510" be used for PV modules placed within zone P. For rooftop obstructions not exceeding a_s = 3m, design pressure coefficients and ballast should be selected based on zoning according to Figure 4.1 through Figure 4.4.

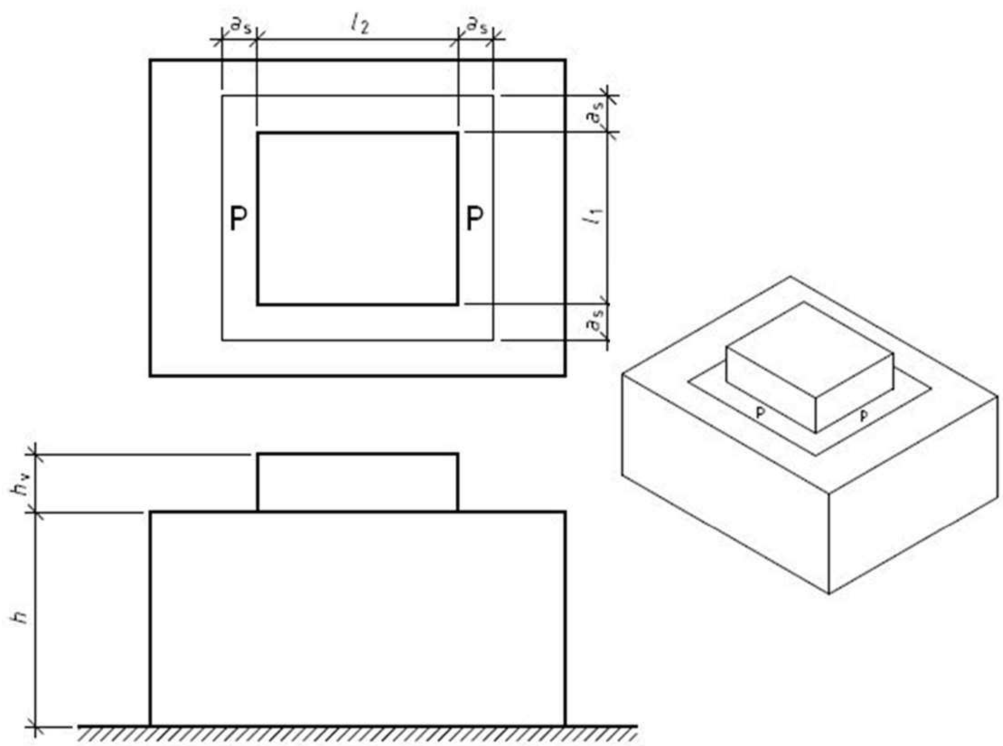


Figure 4.9: Zone of accelerated flow P; Legend: h roof height, h_v height of rooftop obstruction, l_1 width of rooftop obstruction, l_2 length of rooftop obstruction, a_s width of zone P [4]

For large penthouses or other rooftop objects exceeding a_s = 3m, this will be unconservative, as flow acceleration around the base on the object can be significant. Therefore, placement of panels in the zone of accelerated flow around such objects is only permitted if roof position 2 values are applied.

4.4 Stepped (multi-level) roofs

For stepped (multi-level) flat roofs which are set back at least one lower-level roof height, h, from the roof edges, the flow will be reattached on the lower-level roof. Correspondingly, the height of the upper level above the lower-level roof, h_v, as well as l_1 and l_2 have to be used for roof zoning and calculation of A_N on the upper-level roof.

Any upper-level roof which is set back less than one lower-level roof height from the roof edges may be considered isolated, i.e. the lower-level roof is not present.

4.5 L-shaped and other non-rectangular buildings

L-shaped roofs and other non-rectangular buildings, e.g. T-shaped or U-shaped buildings, deviate from the simple rectangular building shape on which testing and zoning are based. Figure 4.10 shows an L-shaped building with corresponding dimensions and the application of roof zones to it. For each roof east and west edge, the largest dimensions that extend from that edge are used to define equivalent enveloping rectangles. As demonstrated in Figure 4.10, for the sample L-shaped building five equivalent rectangles result which enclose outward or protruded corners. Hence, zoning is performed as defined in Figure 4.1 through Figure 4.4.

The dimensions of the equivalent rectangles are permitted to be used to determine W_L and W_S as defined in Annex D. The highest ballast calculated for the five equivalent enveloping rectangles shall be taken for design where rectangles overlap.

The strongest conical vortices are produced by square corners and cause the peak loads on roof mounted solar arrays. In some situations, such as for chamfered corners with angles larger than 135° or rounded corners, vortices are expected to be weakened or even not to form depending on the size of the chamfer. However, in the absence of any testing, it is recommended to use good engineering judgement for any zoning along building edges. One possible approach involves approximation of a chamfered corner by a staircase with infinitively small steps. In other words, these steps will resemble an array of L-shapes for which the method given in Figure 4.10 is applicable.

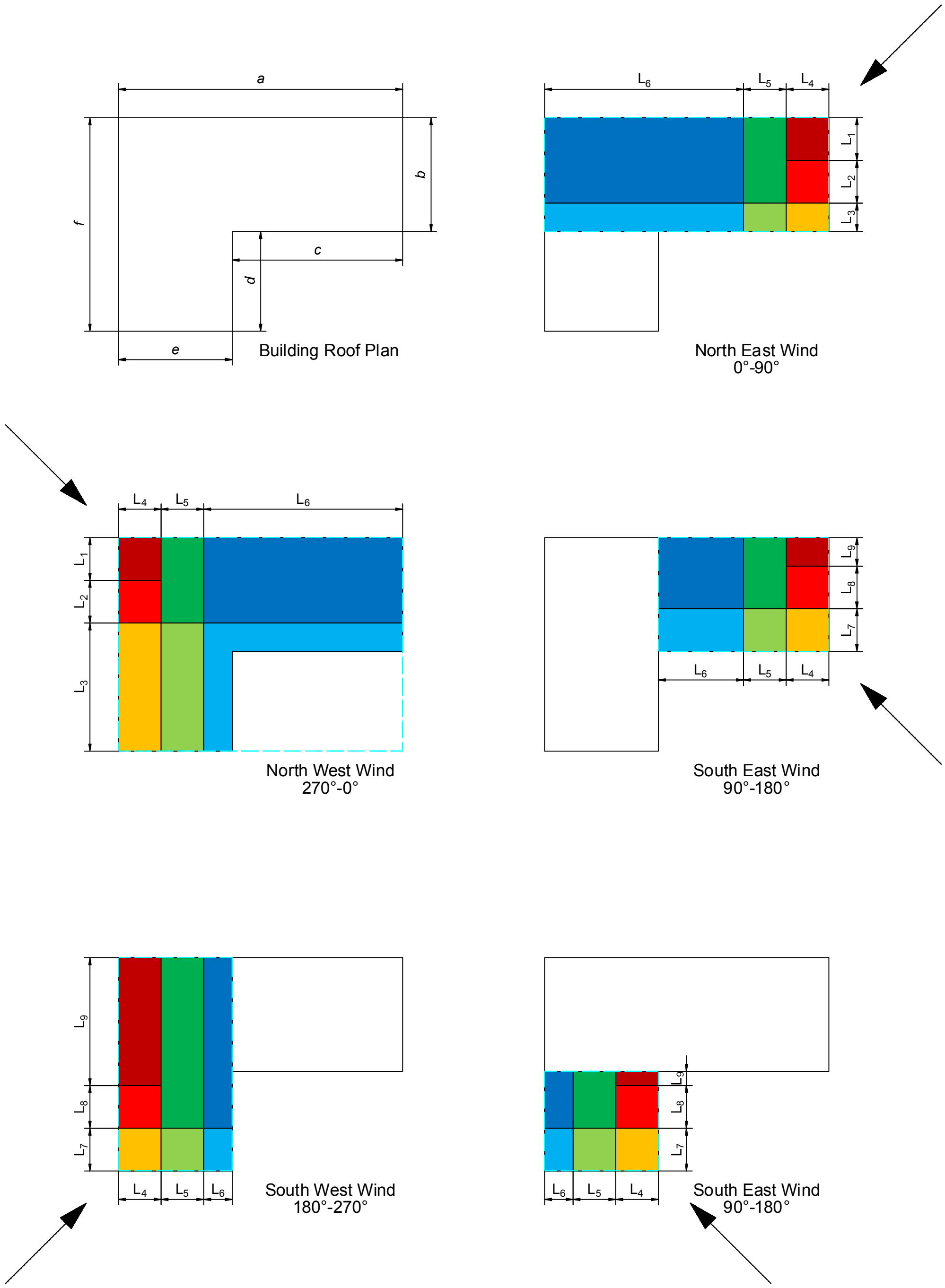


Figure 4.10: Application of roof zones to an L-shaped roof based on equivalent enveloping rectangles

Rounded side walls may be approximated by polygons having corner angles up to 180 degrees. The boundary layer separation at the roof edges with subsequent flow reattachment in the roof interior causes loads which do not scale with building dimensions. Accordingly, round buildings such as water towers may conservatively be assumed to require dark blue zone (roof position 6) wind loads. The diameter of the round building shall be used to calculate the normalized wind area, A_n. For buildings with more than 4 sides it may be increasingly complex to perform zoning. Therefore, a more simple approach involves selecting the dimensions of the enveloping rectangle for zoning and normalized wind area calculation. Good engineering judgement should be employed when applying these values to the complex building shape.

4.6 Taller neighboring structures

In the relevant literature a lot of case studies are available which describe the wind effects of neighboring structures on a nearby structure, but codes and standards give only little guidance on how to handle such situations.

However, to the best knowledge of the authors the method given in the European Standard EN 1991-1-4:2005 [5] is the only approach which gives general recommendation on how taller neighboring structures will affect the wind loads on a nearby structure. The method proposed by EN 1991-1-4 is given in Annex A.4 and is based on the assumption that the flow displacement caused by a tall neighboring structure will translate into flow acceleration which may be accounted for by increasing the peak velocity pressure. Annex A.4 states that if a building is more than twice as high as the average height h_{ave} of the neighboring structures then, as a first approximation, the design of any of those nearby structures may be based on the peak velocity pressure at height z_n above ground, see Figure 4.11.

$x \leq r \qquad z_n = \frac{1}{2} r$

$r < x < 2r \qquad z_n = \frac{1}{2}\left(r - \left(1 - \frac{2h_{low}}{r}\right) \cdot (x - r)\right)$

$x \geq 2r \qquad z_n = h_{low}$

in which the radius r is:

$r = h_{high} \quad$ if $\quad h_{high} \leq 2d_{large}$

$r = 2d_{large} \quad$ if $\quad h_{high} > 2d_{large}$

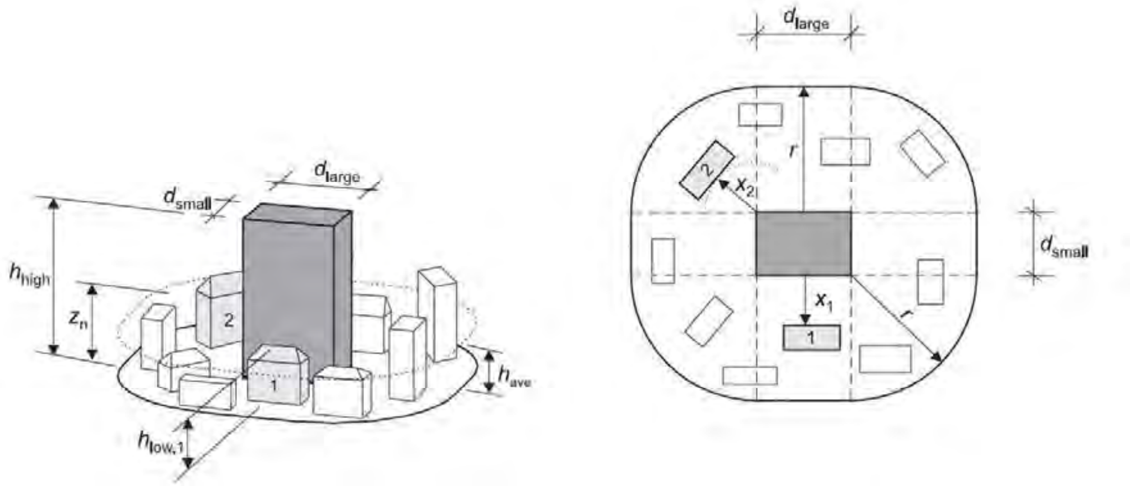


Figure 4.11: Influence of a high-rise building on two different nearby structures (1 and 2) [5]

The structural height, h_{low}, the radius r, the distance x and the dimensions d_{small} and d_{large} are illustrated in Figure 4.11. Increased wind velocities can be disregarded when h_{low} is more than half the height h_{high} of the high building, i.e. $z_n = h_{low}$.

4.7 Array interruptions in east-west-direction

In the absence of additional testing, it is recommended that 1st to 4th module unit pressure coefficients be used as well for module units whose distance to the module to the east or west, d, exceeds five system heights ($5h_S$). This may be the case if skylights are present or if there is a gap between a group of modules.

However, it is more accurate to assume that the pressure coefficients decrease linearly from 1st to 4th module unit pressure coefficients to interior module unit pressure coefficients over the distance d of eight system heights ($8h_S$) to two system heights ($2h_S$), as shown in Figure 4.12.

Figure 4.13 shows a sample array where the shaded modules have to be ballasted with the 1st to 4th module unit pressure coefficients or the interpolated pressure coefficients for $d/h_S > 2$. Array interruptions have to be considered separately for east and west winds.

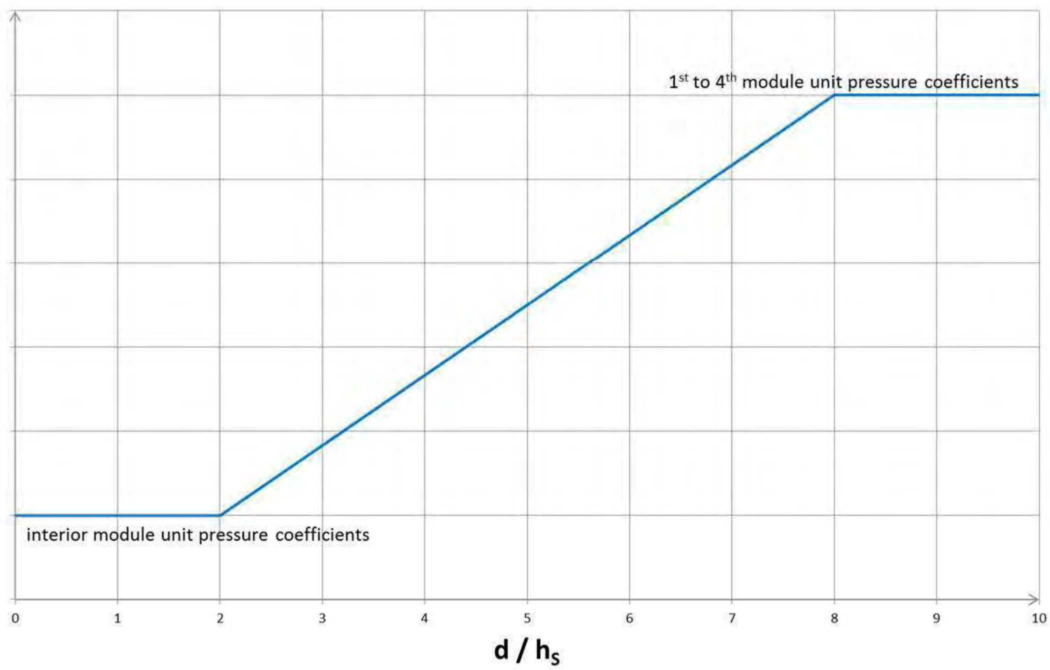


Figure 4.12: Gradual increase in pressure coefficients with normalized distance, d/h_S, from the closest (interrupted) array (does not apply to roof edge) for "FastRack 510"

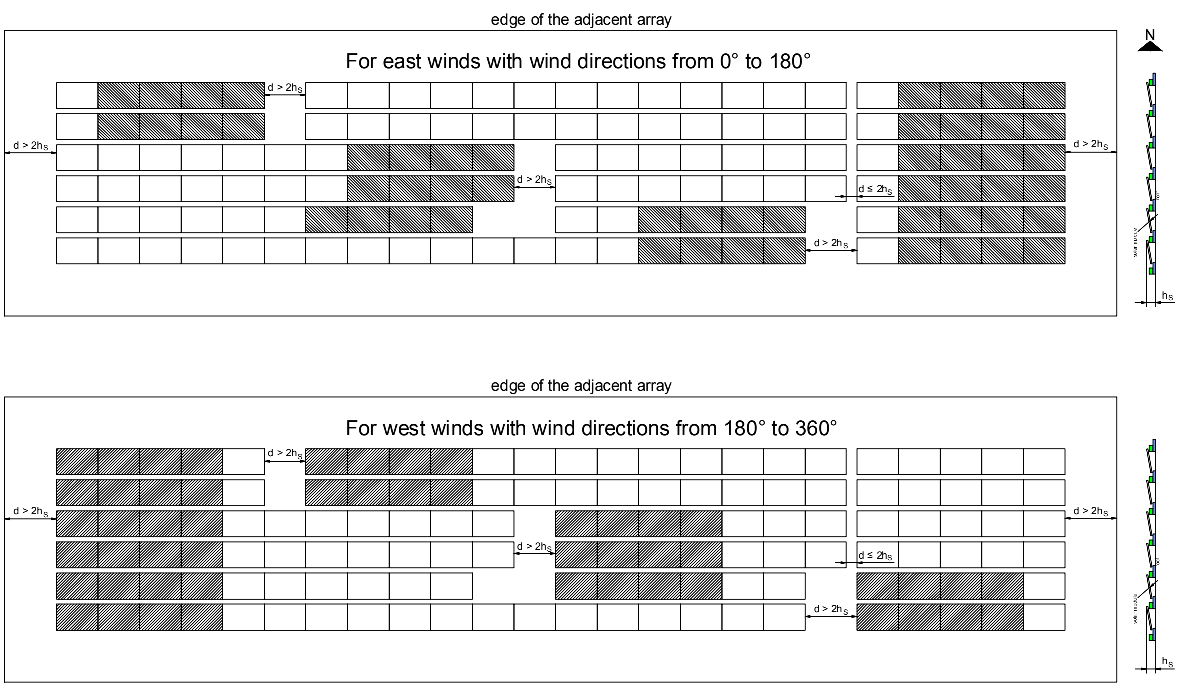


Figure 4.13: Sample array in landscape orientation; the shaded modules have to be ballasted with the 1st to 4th module unit pressure coefficients or the interpolated pressure coefficients; valid for "FastRack 510"

4.8 Effect of panel length, panel chord length and system height

The pressure coefficients given in Annex D apply to the "FastRack 510" system with modules in landscape orientation and chord length of l_c = 0.991 m, as tested. However, the test results may also be applied to panel chord lengths up to $l_{c,new}$ = 1.1 l_c without increase factor [3].

With respect to different panel length and system height compared with the tested dimensions of l_l = 1.960 m in landscape orientation and h_s = 0.341 m, the definitions of "1st to 4th module" and "interior modules" need adjustment. If the new panel dimensions are $l_{l,new}$ for panel length and $h_{s,new}$ for system height, the new "edge modules" are defined as having a length of

$$l_{edge,new} = l_{1^{st}\ to\ 4^{th}} \cdot \frac{h_{s,new}}{h_s} = \left(4 \cdot l_l + 3 \cdot w_g\right) \cdot \frac{h_{s,new}}{h_s} = \left(4 \cdot 1.960m + 3 \cdot 0.010m\right) \cdot \frac{h_{s,new}}{0.341m} \qquad (13)$$
$$= 23.08 \cdot h_{s,new}$$

where w_g is the gap width. Hence, if $h_{s,new} > h_s$, then $l_{edge,new} > l_{1^{st}\ to\ 4^{th}}$. Moreover, if $h_{s,new} = h_s$, but $l_{l,new} < l_l$, then more than 4 modules have to be classified as new "edge modules".

4.9 Requirements for the interconnected substructure

Applying the pressure coefficients from Annex D for normalized wind areas of varying size requires statically connected rows and columns which are capable of load sharing.

For the solar ballasted roof mount system the pressure coefficients given in Annex D depend on the normalized wind area.

The minimum array size has to be comprised of two interconnected rows with at least two module units per row. Smaller arrays may require additional ballast, as additional load cases may be relevant.

4.10 Effect of the static friction coefficient of the layers under the panels

For roofing materials such as bituminous roof membranes or plastic foils the static friction coefficient has to be determined according to the kind of material. In this context the effect of wet surfaces and protective layers which may be required by the manufacturer must also be taken into account, since accumulation of dirt combined with moisture as well as glass fibre may reduce friction considerably. The same applies for the imprint of a shape due to elements pressing into the roof depending on the resistance of the insulating materials.

4.11 Effect of the component of the weight which is parallel to the surface of a sloped roof

The results such as given in Section 4.2 also apply to flat-roof buildings with a slope of up to 7°. However, in this case the roof pitch angle α must be taken into account in the calculation of the necessary ballast, since the component of the weight which is parallel to the sloped roof has to be compensated for by the static friction force. The correction coefficient k_α for the necessary additional mass m_B against sliding can be conservatively calculated using equation (14):

$$k_\alpha = \mu_0 / [\mu_0 * \cos\alpha - \sin\alpha] \quad (14)$$

4.12 Effect of the module tilt angle

The module tilt angle is 10° for the south-facing system. It is expected that the results in this report will only be used for a 10° tilt. For loads on an equivalent product with a 5° tilt, see Figure 4.14, consistent with SEAOC PV-2 provisions [3], a reduction factor of 8% for up to n=4 modules sharing loads, 13% for up to n=25 modules sharing loads and 22% for up to n=112 modules sharing loads, respectively, may be applied to module pressure coefficients, c_{pM}, for the 10° tilt angle.

4.13 Effect of the building shape

The design pressure coefficients and their progression into loads apply to flat roofs of enclosed or partially enclosed buildings. Flat roofs in this context can be regarded as all roofs which do not have more than a 7° slope and, therefore, with view to the wind flow over them, have a uniform boundary layer separation zone on the windward roof edge.

In opposition to sharp-edged roofs, the use of the pressure coefficients for the studied PV roofing system on a roof with curved or mansard eaves requires an individual statement.

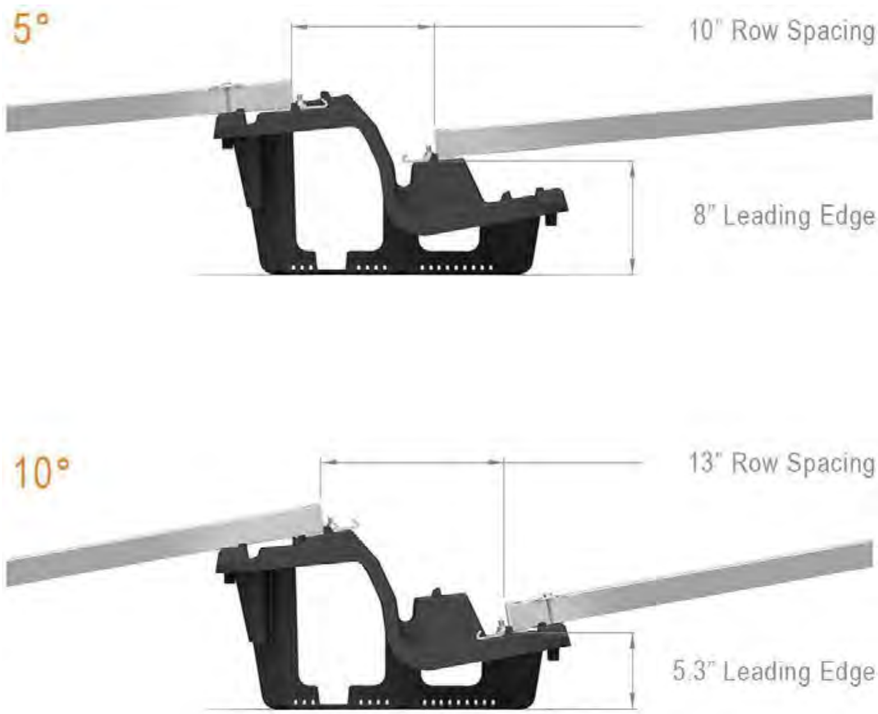


Figure 4.14: Comparison of 5deg and 10deg array assemblies of the solar ballasted roof mount system "FastRack 510" in landscape orientation

As shown in Annex D, due to the presence of a parapet the resulting wind loads tend to increase in some roof positions, but decrease in others. The parapet factor, k_p, depends on the array position on the roof and on the parapet height, h_p, and may be interpolated linearly for values between h_p =0 m and h_p = 1.5 m. For values of h_p > 1.5 m, k_p at h_p = 1.5 m may be applied. Therefore, the necessary additional mass m_B is calculated with the parapet factor from Annex D as follows:

$$m_{B\ sliding} = \frac{S_W \cdot \left[\frac{\sqrt{F_x^2 + F_y^2}}{\mu_{R,0}} + F_z \right]}{S_{DII} \cdot g} \cdot k_\alpha \cdot k_p - \frac{S_{DI}}{S_{DII}} \cdot m_{DL} \tag{15}$$

$$m_{B\ uplift} = \left[\frac{S_W \cdot F_z}{S_{DII} \cdot \cos\alpha \cdot g} \cdot k_p - \frac{S_{DI}}{S_{DII}} \cdot m_{DL} \right] \tag{16}$$

4.14 Equilibrium of moments

The calculated ballast weights are based on equations of static equilibrium considering uplift and sliding forces. They do not consider equilibrium of moments. Uplift forces are considered to act concentrically with the centroid of dead loads, which is not necessarily the case in a solar array, depending on the ballast layout.

For example, for a module on the edge of an array it may be necessary to provide more of the module's ballast toward the outer edge of the module, depending on the assumptions of load-sharing with adjacent modules.

Good engineering judgement should be employed when determining the distribution of ballast within an array.

5 Literature

[1] American Society of Civil Engineers, Minimum design loads for buildings and other structures, ASCE 7-10, 2010

[2] American Society of Civil Engineers, Wind tunnel testing for buildings and other structures, ASCE 49-12, 2012

[3] Structural Engineers Association of California (SEAOC), Wind design for low-profile solar photovoltaic arrays on flat roofs, Report SEAOC PV2-2012, SEAOC Solar Photovoltaic Systems Committee, Sacramento, CA, August 2012

[4] NEN, NEN 7250:2014, Zonne-energiesystemen - Integratie in daken en gevels - Bouwkundige aspecten, Delft, The Netherlands, 2014

[5] CEN, EN 1991-1-4:2005: Eurocode1: Actions on structures – Part 1-4: General actions – Wind actions, 2005

Annex A

To report No. SOF01-1

Wind loads on the solar ballasted roof mount system „FastRack 510” of Sollega, Inc.

– Test methods –

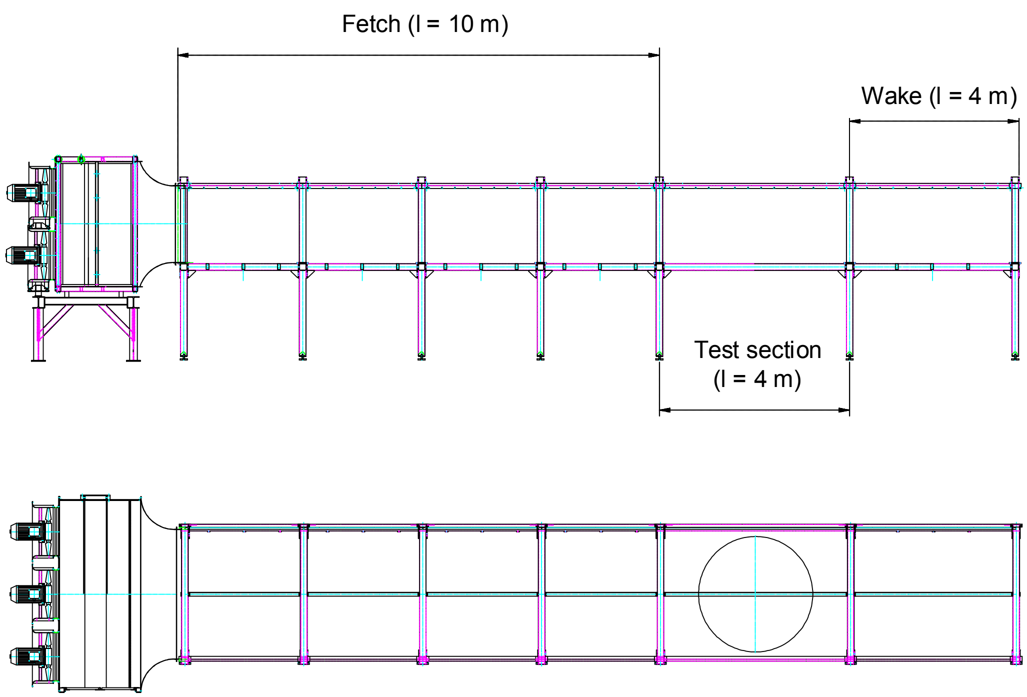
A Test methods

A.1 Boundary layer wind tunnel and model

The wind pressure distributions on the surfaces of the solar ballasted roof mount system “FastRack 510” with a module tilt angle of 10deg of Sollega, Inc. were experimentally determined in the large boundary layer wind tunnel of I.F.I.. Figure A.1 shows a diagram of the wind tunnel. The test section is 2.7 m wide, 1.6 m high and 4.0 m long. Upstream of the test section, the fetch is equipped with a flow straightener, turbulence screens and Counihan-turbulence generators. The wind tunnel floor is set up with a barrier wall and rough materials for simulation of upwind terrain corresponding to Exposure (Exp.) C as defined in ASCE/SEI 7-10. Figure A.2 shows the velocity profile for the power law exponent of 0.14. Figure A.3 shows the profile of the longitudinal velocity fluctuations (i.e. turbulence intensity).

Wind tunnel studies conducted in boundary-layer flows require proper scaling of the prototype boundary layer approaching the study site. At the 1:50 geometrical scale used during the present study, full scaling of the prototype boundary layer was not possible. Gerhardt and Kramer (1992) [1] as well as Kind (1988) [2] indicated that the flow pattern over the upwind corner of the building rooftop is mainly dependent on the velocity of the approaching wind at rooftop level, with other parameters such as the Jensen number being of lesser importance. Since the boundary layer depth was not fully scaled in the study, the wind-tunnel flow lacked low frequency, large scale, gusts. This lack of large-scale, low frequency gusts was not expected to influence the aerodynamics of the small PV panels.

Figure A.4 and Figure A.5 show the streamwise wind spectra measured at different heights with a hot-film probe in the wind tunnel incident flow, along with spectra specified in the relevant literature. The agreement between the measured and target spectra is reasonable, given the large geometrical scale. As pointed out by Tieleman in a series of papers ([3]-[8]), flow modelling criteria at large geometrical scales of around 1:50 can be relaxed if one is interested in peak pressure coefficients. Wind tunnel simulation of the atmospheric surface-layer flow lacks the capability of duplicating the large- and small-scale eddies at the same dimensionless frequencies. Therefore, concentrating on the duplication of the horizontal turbulence intensities and the small-scale turbulence parameter at those heights where the wind loads are being measured on the model can attain the best wind tunnel simulation of the peak pressures. Furthermore, exaggeration of the small-scale turbulence tends to give better agreement with full-scale measurements, especially in high suction areas on flat roofs under the influence of the corner (delta wing) vortices [6]. This may be partly attributed to the fact that at large geometrical scales a better match of the Reynolds number is achieved [9].



Drive:	Axial fans with 6x22 kW electric motors	
	Flow velocity u = 1 m/s ... 20 m/s	
Fetch:	Flow straightener, screens, turbulence generators, barrier wall, roughness elements	
Test section:	Test section length	4.00 m
	Test section width	2.70 m
	Test section height	1.60 m

Figure A.1: Set-up and technical data of the large I.F.I.-boundary layer wind tunnel

The models were mounted on a turntable. In order to test the different wind directions, the model plate was rotated into the respective flow directions. Basis for the model design were the CAD-drawings provided by Sollega, Inc.

Figure A.6 shows one model in the wind tunnel of the “FastRack 510” 10deg landscape system without wind deflector. Figure A.7 shows a close-up of the modelled 8x9 array.

Seven rows with eight modules each were fitted with 224 pressure taps on the upper and lower surfaces of the modules, see Figure A.8.

The remaining rows were designed as dummies without any pressure taps. The pressure tapped rows were moved across the roof and the arrays.

Using tubes the pressure taps were connected to PSI DTC-Initium pressure scanners. The distribution of the pressure taps is depicted in Figure A.8. The pressure distributions were measured for two wind sectors at 15° intervals, 0°-90° and 90°-180°.

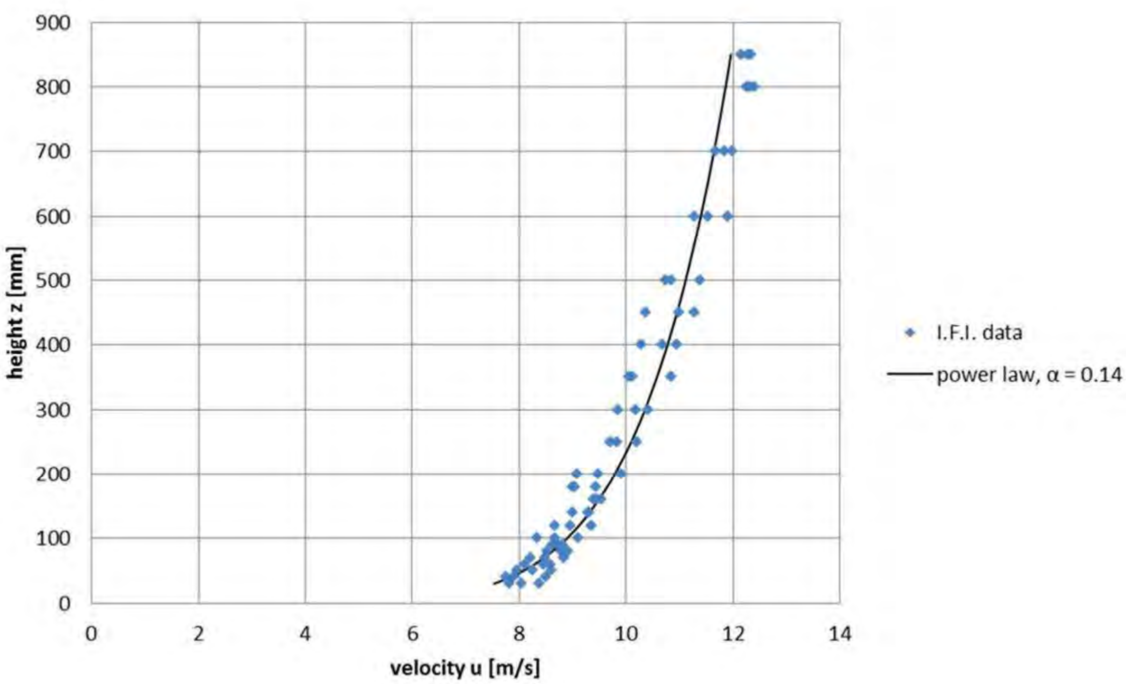


Figure A.2: Velocity distribution in the large boundary layer wind tunnel for a power law exponent of α = 0.14

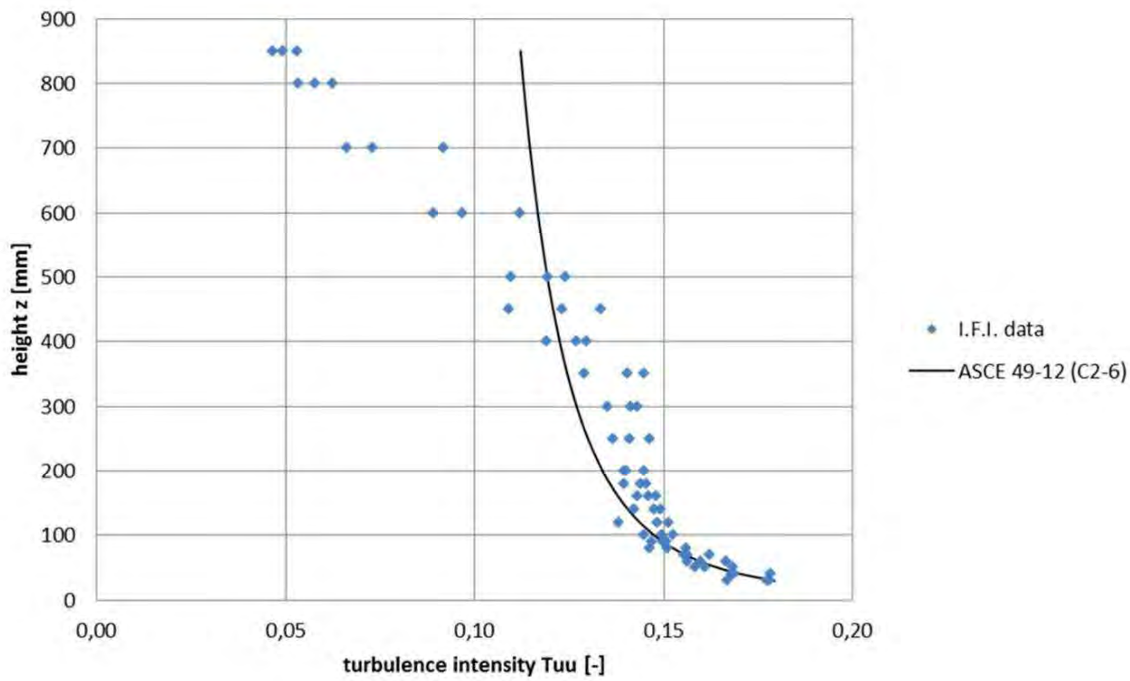


Figure A.3: Distribution of the longitudinal turbulence intensity in the large boundary layer wind tunnel for a power law exponent of α = 0.14

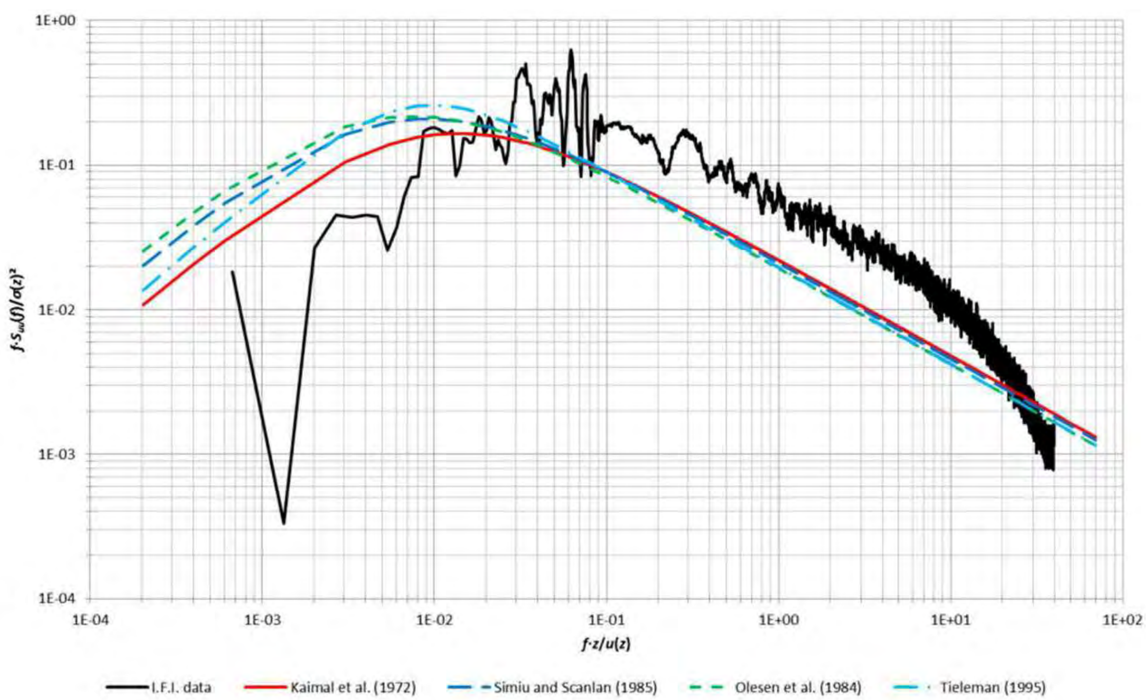


Figure A.4: Spectrum of the streamwise velocitiy fluctuations at z = 150 mm (model scale) in Exposure category C for a power law exponent of α = 0.14 compared with data from references [10]-[13]; relevant for testing of the solar ballasted roof mount system “FastRack 510” on a geometrical scale of 1:50

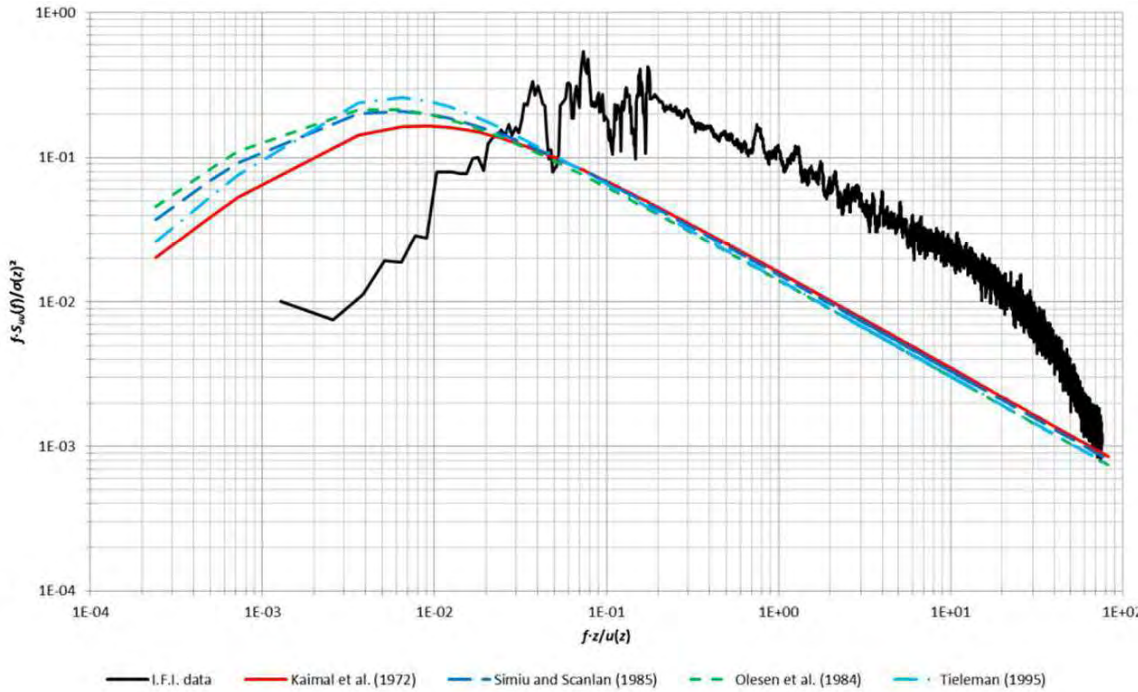


Figure A.5: Spectrum of the streamwise velocitiy fluctuations at z = 250 mm (model scale) in Exposure category C for a power law exponent of α = 0.14 compared with data from references [10]-[13]; relevant for testing of the solar ballasted roof mount system "FastRack 510" on a geometrical scale of 1:50

Figure A.6: Wind tunnel model of the flat-roofed building and roof position 2 with the solar ballasted roof mount system "FastRack 510" with a module tilt angle of 10deg mounted on the turntable including view of the fetch in the large I.F.I. boundary layer wind tunnel; 8x9 array in the east roof portion, wind direction 0°

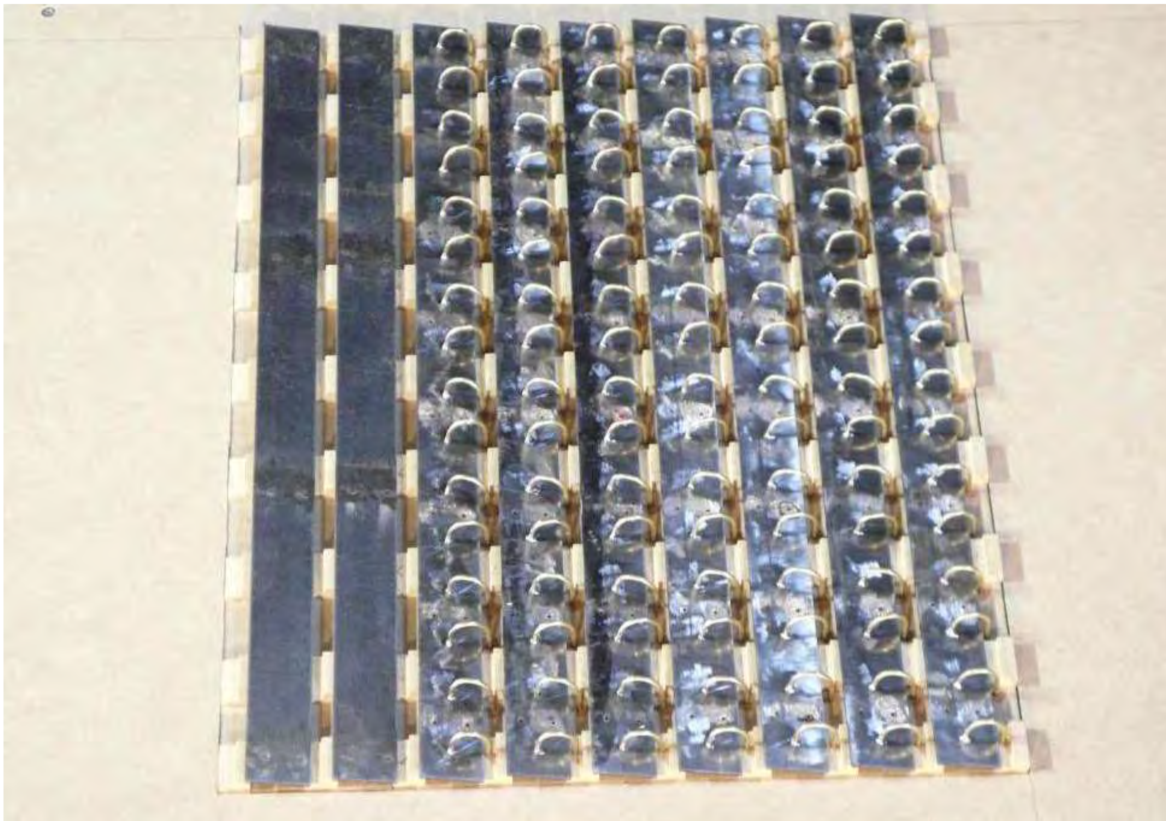


Figure A.7: Close-up of the 8x9 array of the solar ballasted roof mount system "FastRack 510" with a module tilt angle of 10deg

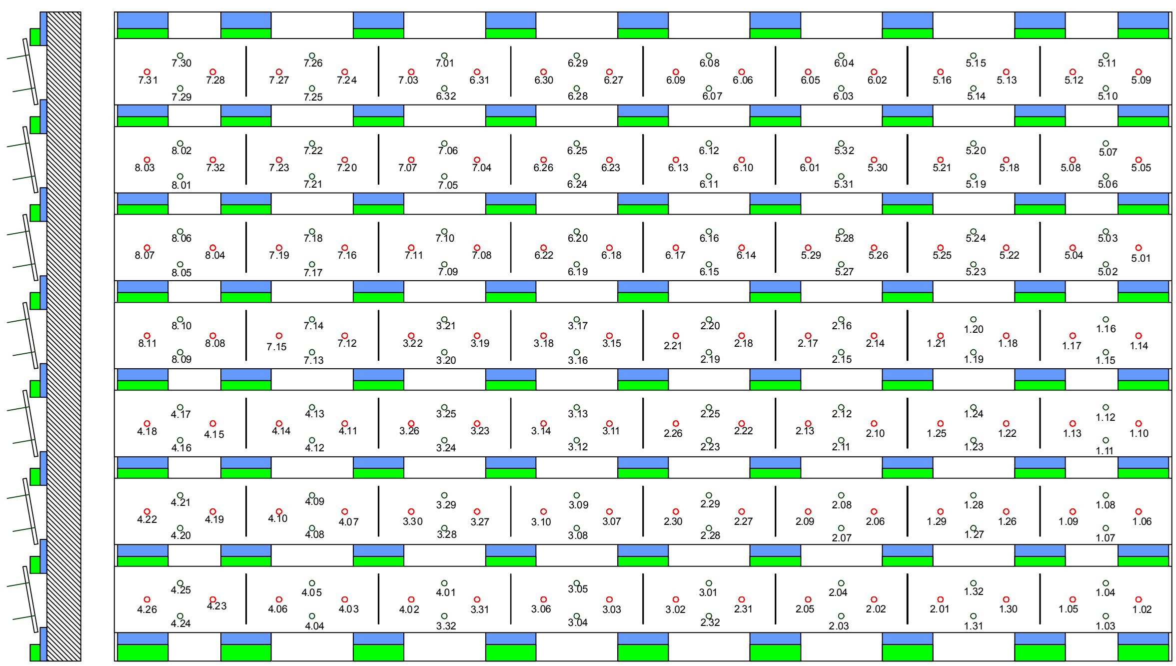


Figure A.8: Pressure taps on the solar ballasted roof mount system "FastRack 510" with a module tilt angle of 10deg

A.2 Reynolds' Similarity

The transferability of wind load assumptions, which are based on model tests in a wind tunnel, onto the full scale is given if it is guaranteed that the flow fields in the model and in nature are similar. The similarity of the flow fields in the case of flow around obstacles is given when on the one hand the incident flow and on the other hand the displacement of the flow are similar in the model and in nature. The similarity of the incident flow is met with tests in boundary layer wind tunnels, see Section A.1.

The Reynolds number is the primary non-dimensional parameter governing the flow around objects embedded in the neutrally stratified atmospheric surface layer. Owing to the 1:50 scale of the wind tunnel simulation, direct matching of the Reynolds number is impossible. Sharp-edged buildings, however, exhibit essentially Reynolds number invariant properties relative to the overall drag and thus the flow displacement that underlies the wind loading. These sharp edges effectively fix the positions of flow separation starting at very low Reynolds numbers of approx. $4x10^4$ ([5], [8]).

A.3 Blockage effects

The most extensive study of blockage effects was conducted by the automotive industry. The results are given in [14]. According to [14] blockage ratios of approx. 15% are uncritical in open or partially open test sections which is also reflected in the German VDI (Association of German Engineers) Guideline 3783 [18] for wind tunnel testing.

Effects of blockage on measurements made in a turbulent boundary layer flow occur due to flow momentum conserved through the continuity equation and due to energy conservation through the Bernoulli equation. As pointed out in [15] a large variety of blockage correction methods exist of which only few are applicable to mean pressures. The probably best solution is to use a partially open working section with e.g. slatted walls, about half solid and half open, to give characteristic midway between an open-jet and a conventional closed wind tunnel, a method 'tolerant' to blockage ratios up to about 25% [15]. Hunt [16] adopted this strategy with the moveable wind tunnel roof and concluded from changing between normal blockage (flat roof) and an isobaric roof (overcorrection) that the upper bound for acceptable blockage can be extended to 10% in the case of squat models (cubes), as no appreciable difference in the mean pressure between both configurations occurred. A similar result was presented by Tieleman [5] who could not discern any appreciable trends in either the mean or peak base-pressure coefficients for either the reattached or non-reattached flow cases on prisms.

The present measurements were conducted in a partially open test section (open roof) with blockage ratios of less than or about 7.1% for the 7.5 m high roof. Although blockage has been recently limited to 5% [20], the maximum blockage of 8% as given in ASCE/SEI 7-10 [19] appears to be a more reasonable value which was met in the present tests. For the 12.5 m high roof blockage was about 9.8% which is below the acceptable blockage limit found by Hunt [16] and Tieleman [5].

A.4 Data acquisition

The measuring chain – pressure tap, brass tube, flexible tube, pressure scanner – is a vibratory system. To avoid artificial amplification or damping of pressure signals the method of Holmes and Lewis (1986) [17] was applied. By inserting restrictors a flat frequency response was achieved up to at least 200 Hz.

The pressure taps were scanned computer-controlled via the PSI DTC-Initium system. This multi-channel pressure scanning system consists of a control unit and pressure scanners. The pressure transducers are piezo-resistive differential sensors with a full scale pressure range of ±1000 Pa. Each individual pressure scanner is equipped with 32 pressure ports. In this study, eight pressure transducers scanning simultaneously were used.

At the 1:50 scale, the sampling rate of 650 Hz with 78,000 sampling values per data series resulted in a sampling time of approximately 120 s. With the velocity ratio of 0.24, the measured model roof height mean wind velocity is representative of a 24 minute sampling in full scale.

The measured pressures were consistently referred to the wind velocity pressure averaged over each of the 24 1-minute intervals. The wind velocity pressure was measured by means of a Pitot-static tube at the roof height.

The variation of mean wind velocity, with the height above the ground (referred to as the boundary layer), is represented by the power law equation:

$$\bar{u}(z)/\bar{u}_{ref} = \left(z/z_{ref}\right)^{\alpha}; \qquad \text{(A1)}$$

where

$\bar{u}(z) =$ mean wind velocity at height z,

$\bar{u}_{ref}$ = mean wind velocity at reference height z_{ref} ,

z_{ref} =reference height,

α = power law exponent.

A power law exponent of $\alpha = 0.14$ is an appropriate value for all wind directions approaching a typical site in open country (Exposure C). Its target value was 0.153 according to ASCE 7-10 [19] and 0.14 according to ASCE 49-12 [20].

Figure A.9 shows the PSI DTC-Initium pressure scanning system.

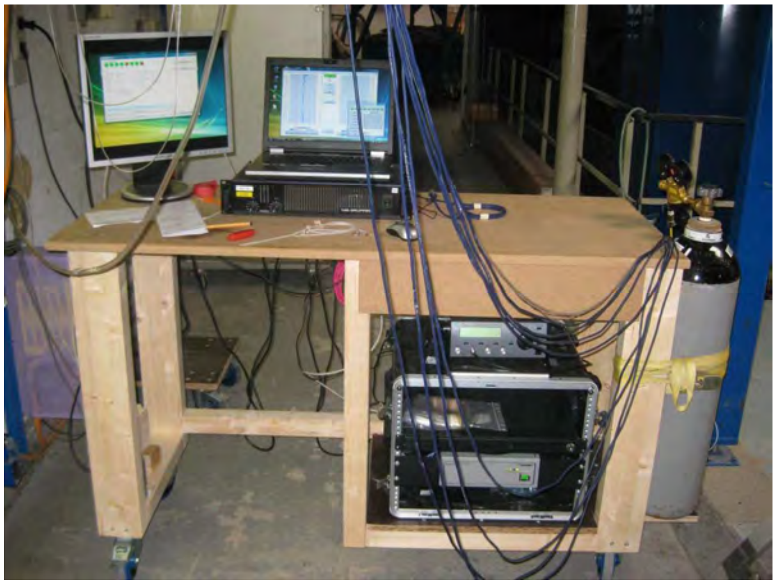


Figure A.9: PSI DTC-Initium pressure scanning system

A.5 Literature

[1] Gerhardt, H. J., Kramer, C., Effect of building geometry on roof wind loading, Journal of Industrial Aerodynamics, 43, 1765-1773, 1992

[2] Kind, R. J., Worst suctions near edges of flat rooftops with parapets, Journal of Wind Engineering and Industrial Aerodynamics, 31, 251-264, 1988

[3] Tieleman, H. W., Wind tunnel simulation of the turbulence in the surface layer, Journal of Wind Engineering and Industrial Aerodynamics, 36, 1309-1318, 1990

[4] Lin, J. X., Surry, D., Tieleman, H. W., The distribution of pressure near roof corners of flat roof buildings, Journal of Wind Engineering and Industrial Aerodynamics, 56, 235-265, 1995

[5] Tieleman, H., Akins, R., The effect of incident turbulence on the surface pressures of surface-mounted prisms, Journal of Fluids and Structures, 10, 367-393, 1996

[6] Tieleman, H.W., Surry, D., Mehta, K.C., Full/ model scale comparison of surface pressures on the Texas Tech experimental building, Journal of Wind Engineering and Industrial Aerodynamics, 61, 1-23, 1996

[7] Tieleman, H.W., Reinhold, T.A., Hajj, M.R., Importance of turbulence for the prediction of surface pressures on low-rise structures, Journal of Wind Engineering and Industrial Aerodynamics, 69 (71), 519-528, 1997

[8] Tieleman, H. W., Wind tunnel simulation of wind loading on low-rise structures: a review, Journal of Wind Engineering and Industrial Aerodynamics, 91, 1627-1649, 2003

[9] Cheung, J.C., Holmes, J.D., Melbourne, W.H., Lakshmanan, N., Bowditch, P., Pressures on a 1/10 scale model of the Texas Tech building, Journal of Wind Engineering and Industrial Aerodynamics, 69 (71), 529-538, 1997

[10] Kaimal, J. C., Wyngaard, J. C., Izumi, Y., Coté, O.R., Spectral characteristics of surface-Layer turbulence, Quarterly Journal of Royal Meteorological Society, 98, 563-589, 1972

[11] Simiu, F, Scanlan, R. H., Wind Effects on Structures: An Introduction to Wind Engineering, John Wiley & Sons, New York, 458 pp., 1985

[12] Olesen, H. R., Larsen, S. E., Hojstrup, J., Modelling velocity spectra in the lower part of the planetary boundary layer, Boundary-Layer Meteorology, 29, 285-312, 1984

[13] Tieleman, H. W., Universality of velocity spectra, Journal of Wind Engineering and Industrial Aerodynamics, 56, 55-69, 1995

[14] Mercker, E., Wiedemann, J., On the correction of interference effects in open wind tunnels, SAE-960671, Society of Automotive Engineers, 1996

[15] Cook, N. J.; The designer's guide to wind loading of building structures, Part 2 – static structures, Butterworths, 1990

[16] Hunt, A., Wind-tunnel measurements of surface pressures on cubic building models at several scales, Journal of Wind Engineering and Industrial Aerodynamics, 10, 137-163, 1982

[17] Holmes, J. D., Lewis, R. E., Optimization of dynamic-pressure-measurement systems. I. Single point measurements, Journal of Wind Engineering and Industrial Aerodynamics, 25, 249-273, 1987

[18] VDI Richtlinie 3783, Umweltmeteorologie – Physikalische Modellierung von Strömungs- und Ausbreitungsvorgängen in der atmosphärischen Grenzschicht – Windkanalanwendungen, Verein Deutscher Ingenieure, 2000

[19] American Society of Civil Engineers: Minimum design loads for buildings and other structures, ASCE 7-10, 2010

[20] ASCE/SEI 49-12, American Society of Civil Engineers standard for “Wind Tunnel Testing for Buildings and Other Structures”, 2012.

Annex B

To report No. SOF01-1

Wind loads on the solar ballasted roof mount system „FastRack 510" of Sollega, Inc.

– Equivalent static wind loads –

B Extreme value analysis by the method of Cook and Mayne

B.1 General

The method of Cook and Mayne for analysis of extreme values was published in a series of papers in the late seventies and early eighties ([5], [6], [7], [8]) and summarized in [4]. Many studies on common building shapes are documented in [4] and were analysed using the method of Cook and Mayne. Design pressure coefficients calculated by this method were largely incorporated into the Eurocode, EN 1991-1-4:2005 [9], and into the ISO 4354:2009 standard [10].

The method of Cook and Mayne is frequently used in wind engineering including the calculation of peak pressure coefficients acting on solar roof mount systems, see e.g. ([11], [12]). In 2014, Geurts and van Bentum introduced a novel guideline for wind loads on solar energy systems [13], NEN 7250:2014 [14]. This Dutch standard contains net pressure coefficients for the design of roof-parallel or tilted solar collectors on flat and pitched roofs. The extreme value analysis was carried out using the method of Cook [8].

The outcome of a comparison of methods to estimate peak wind loads on buildings was that the method of Cook and Mayne, which is also referred to as the Gumbel method, is the most robust and reliable for short record peak pressure coefficient estimation [15].

B.2 Detailed method

The method of Cook and Mayne is largely based on references [4] to [8] with refinement as suggested by the Dutch wind tunnel guideline [16] and by Peng et al. [15].

The Gumbel distribution is often used to fit the distribution of peak wind pressure coefficients

$$\hat{C}_p(t) = U_{\hat{C}p(t)} + \frac{y}{a_{\hat{C}p(t)}} \qquad \text{(B1)}$$

where $a_{\hat{C}p(t)}$ is the dispersion and $U_{\hat{C}p(t)}$ is the mode determined from a series of observed peaks, $\hat{C}_p(t)$ is the pressure coefficient, and t is the duration in which a single peak is observed (reference duration). Equation (B1) corresponds to a 37% probability of non-exceedance as expressed by the reduced variate if it is set to $y = 0$. $a_{\hat{C}p(t)}$ and $U_{\hat{C}p(t)}$ are determined based upon N observed peaks using the Lieblein BLUE formulation [17], as listed in the schematic in Figure B.1. Research by Vega-Avila (2008) [18] and Vega and Letchford (2009) [19] revealed that the ASCE 7 Standard possess loading coefficients on the 37th percentile (or FT1 mode) or smaller. Most loading coefficients in ASCE7 are even below the 15th percentile [18].

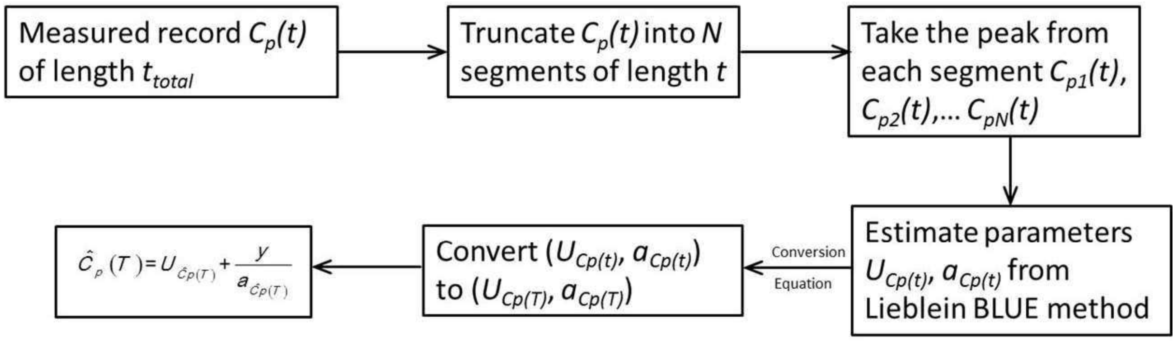


Figure B.1: Observed peak method (Gumbel method)

This method requires a total record duration of $t_{total} = N \cdot t$. The resultant cumulative distribution function corresponds to the reference duration of t. For example, $\hat{C}_p$ representing a 37% probability of non-exceedance within a one minute reference duration could be estimated by dividing a 24 min record into 24 1-minute segments, observing the largest peak in each segment, estimating the Gumbel parameters using these peaks, and identifying the 37% probability of non-exceedance from the Gumbel cumulative distribution function.

Subsequently, a procedure has to be applied which converts the Gumbel parameters between different reference durations. This allows the estimation of $a_{\hat{C}p(t)}$ and $U_{\hat{C}p(t)}$ using a sufficient N within a relatively short data record, followed by a conversion to the desired longer reference duration T. For the two reference duration values (t, T, $t \leq T$), the conversion is

$$a_{\hat{C}p(T)} = a_{\hat{C}p(t)} \quad \text{(B2)}$$

$$U_{\hat{C}p(T)} = U_{\hat{C}p(t)} + 1/a_{\hat{C}p(t)} \cdot \ln(T/t) \quad \text{(B3)}$$

$\hat{C}_p(T)$ is then identified by combining equations (B1), (B2) and (B3)

$$\hat{C}_p(T) = U_{\hat{C}p(t)} + 1/a_{\hat{C}p(t)} \cdot \left[\ln(T/t) + y\right] \quad \text{(B4)}$$

$$\hat{C}_p(T) = U_{\hat{C}p(T)} + \frac{y}{a_{\hat{C}p(T)}}$$

B.3 Sample calculation

Table B.1 shows a peak pressure coefficient distribution fitted with a Gumbel distribution as described in section B.2. The measured record with a measuring time of 24 min in full scale is divided in 24 1-minute segments. For each segment, the peak and mean pressure coefficients are identified. All pressure coefficients refer to a velocity pressure $\bar{q}_{WT}$ which is averaged over the sampling time of 1 min in full scale of the respective segment.

Table B.1: Peak pressure coefficient distribution with corresponding mean pressure coefficients for 24 segments of a one minute duration; all pressure coefficients refer to a velocity pressure $\bar{q}_{WT}$ averaged over 1 min in full scale of the respective segment

N	y	$C_{pN}\ (t = 1\text{min})$	$\bar{C}_{pN}\ (t = 1\text{min})$
1	-1.3	-1.036	-0.470
2	-1.0	-1.126	-0.479
3	-0.8	-1.147	-0.481
4	-0.6	-1.169	-0.505
5	-0.5	-1.210	-0.511
6	-0.4	-1.216	-0.516
7	-0.3	-1.257	-0.519
8	-0.1	-1.277	-0.526
9	0.0	-1.285	-0.528
10	0.1	-1.292	-0.539
11	0.2	-1.293	-0.542
12	0.3	-1.296	-0.547
13	0.4	-1.337	-0.547
14	0.6	-1.338	-0.557
15	0.7	-1.378	-0.558
16	0.8	-1.379	-0.559
17	1.0	-1.417	-0.565
18	1.1	-1.436	-0.580
19	1.3	-1.452	-0.581
20	1.6	-1.470	-0.585
21	1.8	-1.489	-0.588
22	2.2	-1.579	-0.591
23	2.7	-1.649	-0.606
24	3.8	-1.721	-0.633

The Gumbel parameters are determined via a numerical approach by use of the Lieblein method [17]:

$$U_{\hat{C}p(t=1\min)} = \sum_{N=1}^{24} C_{pN}\left(t = 1\min\right) \cdot A_N \tag{B5}$$

$$1/a_{\hat{C}p(t=1\min)} = \sum_{N=1}^{24} C_{pN}\left(t = 1\min\right) \cdot B_N \tag{B6}$$

A and *B* are specific estimators corresponding to each segment given by [17]. In this case the resulting Gumbel parameters are as follows:

$U_{\hat{C}p(t=1\min)}$ = -1.262

$1/a_{\hat{C}p(t=1\min)}$ = -0.143

In the next step, the peak pressure coefficient which refers to a duration of t = 1 min is calculated using equation (B1):

$\hat{C}_p\left(t = 1\min\right)$ = (-1.262) + 0 · (-0.143) = -1.262

As the two reference duration values, t and T, both correspond to 1 min, equation (B4) for reference duration conversion gives the same result:

$\hat{C}_p\left(T = 1\min\right)$ = (-1.262) + (-0.143) · [ln(1min/1min) + 0
= (-1.262) + (-0.143) · 0 = -1.262

In ASCE 7-10 [1] the design velocity pressure corresponds to the 3-second-gust. Therefore, the pressure coefficient needs to be converted into a pseudo-steady pressure coefficient referring to a 3-second gust by use of the Durst curve, see Figure C26.5-1 of the ASCE 7-10 standard [1], as follows:

$$\tilde{C}_p\left(\tau = 3\mathrm{s}\right) = \hat{C}_p\left(\tau = 1\min\right) \cdot \frac{\overline{\mathrm{q}}\left(\tau = 1\min\right)}{\overline{\mathrm{q}}\left(\tau = 3\mathrm{s}\right)} = \hat{C}_p\left(\tau = 1\min\right) \cdot 0.675 \tag{B7}$$

The resulting peak pressure coefficient related to a 3-second wind gust is calculated using the 0.675 factor of equation (B7):

$\tilde{C}_p\left(\tau = 3\mathrm{s}\right)$ = -1.262 · 0.675 = -0.852

B.4 References

[1] American Society of Civil Engineers, Minimum design loads for buildings and other structures, ASCE 7-10, 2010

[2] American Society of Civil Engineers, Wind tunnel testing for buildings and other structures, ASCE 49-12, 2012

[3] Structural Engineers Association of California (SEAOC), Wind design for low-profile solar photovoltaic arrays on flat roofs, Report SEAOC PV2-2012, SEAOC Solar Photovoltaic Systems Committee, Sacramento, CA, August 2012

[4] Cook, N. J.; The designer's guide to wind loading of building structures, Part 2 – static structures, Butterworths, 1990

[5] Cook, N. J., Mayne, J. R., A novel working approach to the assessment of wind loads for equivalent static design, Journal of Wind Engineering and Industrial Aerodynamics 4, pp. 149-164, 1979

[6] Cook, N. J., Towards better estimation of extreme winds, Journal of Wind Engineering and Industrial Aerodynamics 9, pp. 295-326, 1982

[7] Cook, N.J., Calibration of the quasi-static and peak-factor approaches to the assessment of wind loads against the method of Cook and Mayne, Journal of Wind Engineering and Industrial Aerodynamics 10, 315-341, 1982

[8] Cook, N. J., Mayne, J. R., A refined working approach to the assessment of wind loads for equivalent static design, Journal of Wind Engineering and Industrial Aerodynamics 6, 125-137, 1980

[9] CEN, EN 1991-1-4:2005, Eurocode 1: Actions on Structures – Part 1-4: General Actions – Wind Actions, Brussels, Belgium, 2005.

[10] International Organization for Standardization, ISO 4354:2009 - Wind actions on structures, 2009

[11] Cao, J., Yoshida, A., Saha, P. K., Tamura, Y., Wind loading characteristics of solar arrays mounted on flat roofs, Journal of Wind Engineering and Industrial Aerodynamics, 123, Part A, 214-225, 2013

[12] Geurts, C., Blackmore, P., Wind loads on stand-off photovoltaic systems on pitched roofs, Journal of Wind Engineering and Industrial Aerodynamics, 123, Part A, 239-249, 2013

[13] Geurts, C.P.W.; van Bentum, C.A., A novel guideline for wind loads on solar energy systems, ICBEST 2014, June 9-12, Aachen, Germany, 2014

[14] NEN, NEN 7250:2014, Zonne-energiesystemen - Integratie in daken en gevels - Bouwkundige aspecten, Delft, The Netherlands, 2014

[15] Peng, X., Yang, L., Gavanski, E., Gurley, K., Prevatt, D., A comparison of methods to estimate peak wind loads on buildings, Journal of Wind Engineering and Industrial Aerodynamics 126, 11-23, 2014

[16] Civiel Centrum Uitvoering Research en Regelgeving, CUR guideline 103: Wind tunnel research. The determination of design wind loads at (highrise) buildings and parts of buildings (in Dutch), CUR NET, Gouda, 2005

[17] Lieblein, J., Efficient methods of extreme-value methodology, National Bureau of Standards, Report No. NBSIR 74-602, Washington, 1974

[18] Vega-Avila, R. E., Wind directionality: A reliability-based approach, Ph.D. thesis, Texas Tech University, August 2008

[19] Vega, R. E., Letchford, C. W., Probabilistic analysis of the ASCE 7 wind directionality factor, 11th Americas Conference on Wind Engineering, San Juan, Puerto Rico, June 22-26, 2009

Annex C

To report No. SOF01-1

Wind loads on the solar ballasted roof mount system „FastRack 510" of Sollega, Inc.

– Wind tunnel models –

C Wind tunnel models

C.1 Tested array positions on the roofs

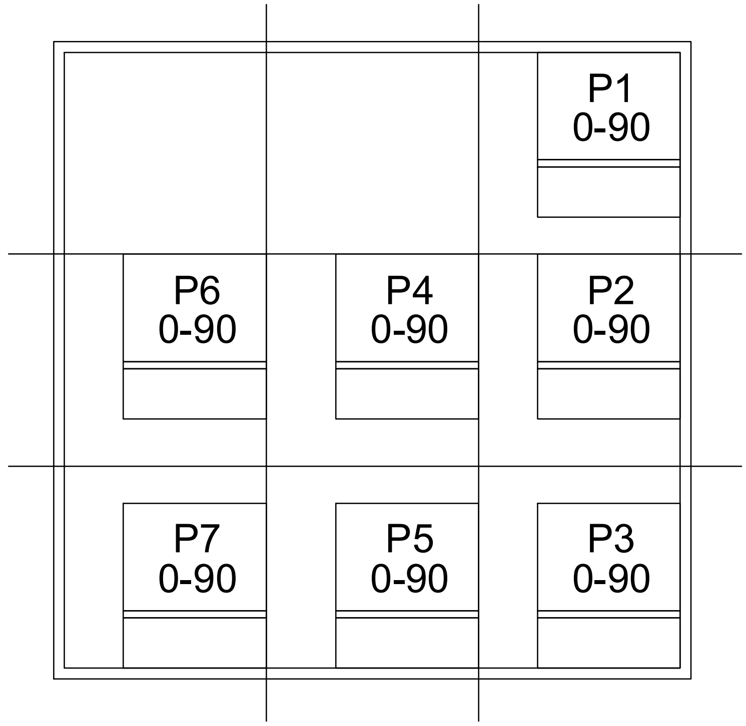


Figure C.1: Array positions for the wind sector 0°-90° for the „FastRack 510" system

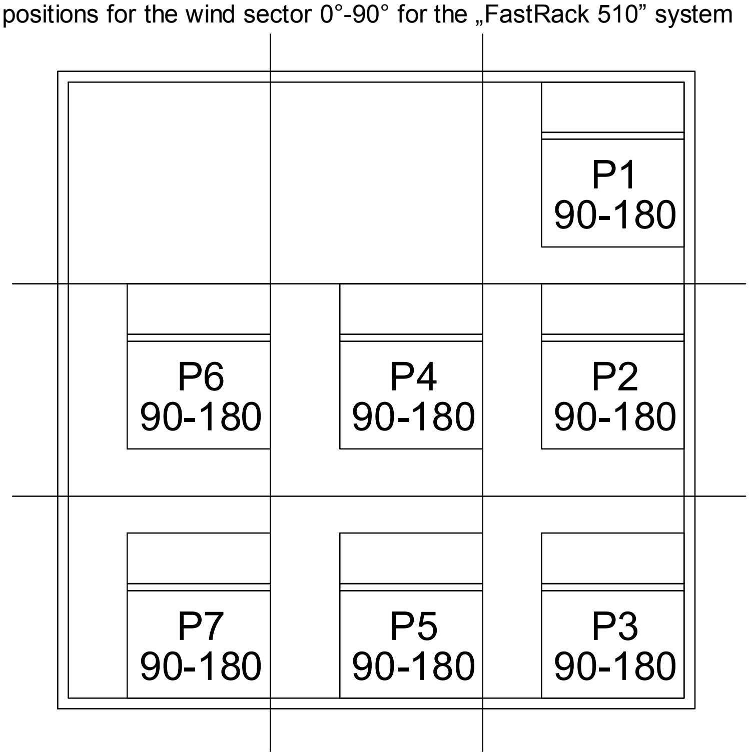


Figure C.2: Array positions for the wind sector 90°-180° for the „FastRack 510" system

C.2 Tested array positions in the wind tunnel

Figure C.3: Roof height 7.5 m, roof position 1, no parapet, wind sector 0°-90°

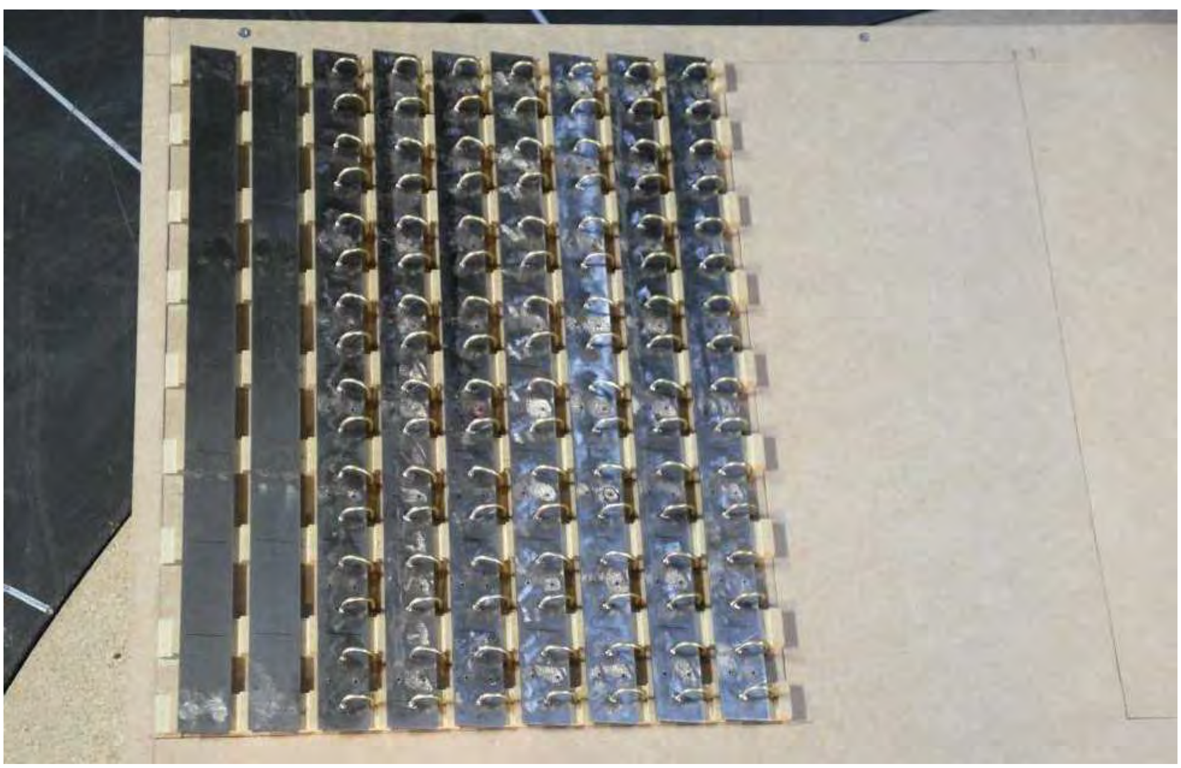


Figure C.4: Roof height 7.5 m, roof position 1, no parapet, wind sector 90°-180°

Figure C.5: Roof height 7.5 m, roof position 2, no parapet, wind sector 0°-90°

Figure C.6: Roof height 7.5 m, roof position 2, no parapet, wind sector 90°-180°

Figure C.7: Roof height 7.5 m, roof position 3, no parapet, wind sector 0°-90°

Figure C.8: Roof height 7.5 m, roof position 3, no parapet, wind sector 90°-180°

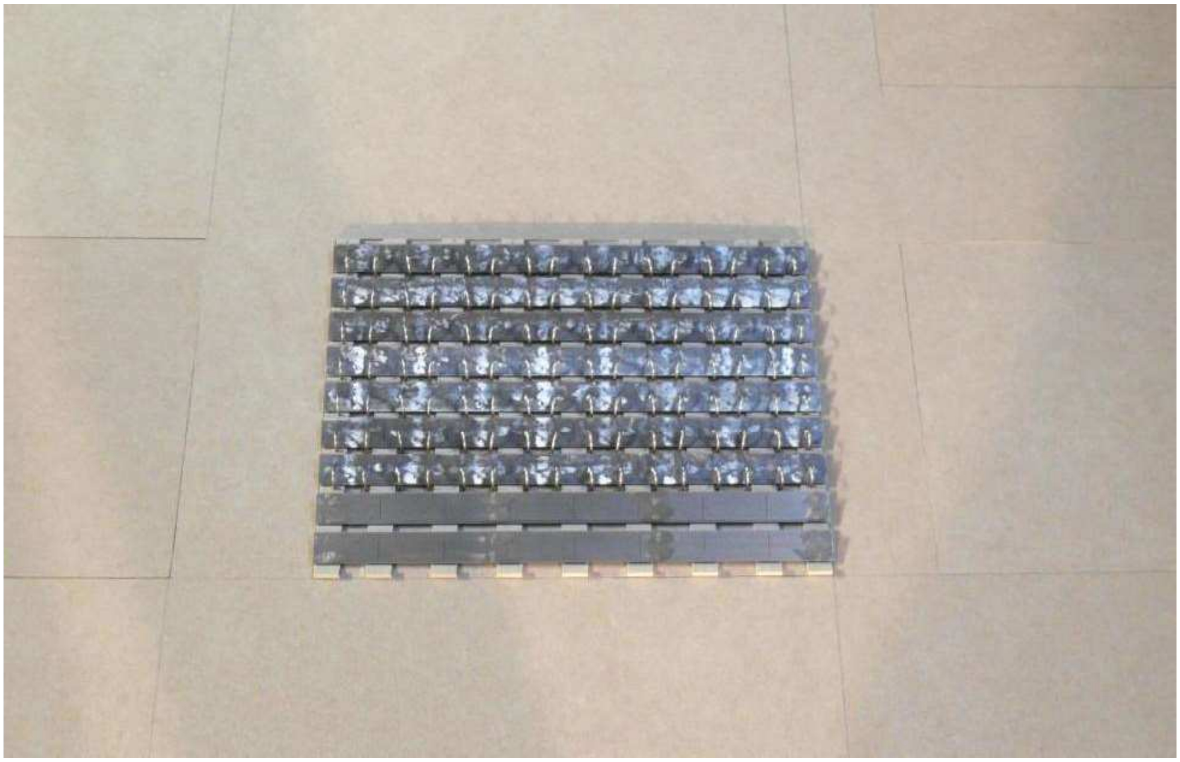


Figure C.9: Roof height 7.5 m, roof position 4, no parapet, wind sector 0°-90°

Figure C.10: Roof height 7.5 m, roof position 4, no parapet, wind sector 90°-180°

Figure C.11: Roof height 7.5 m, roof position 5, no parapet, wind sector 0°-90°

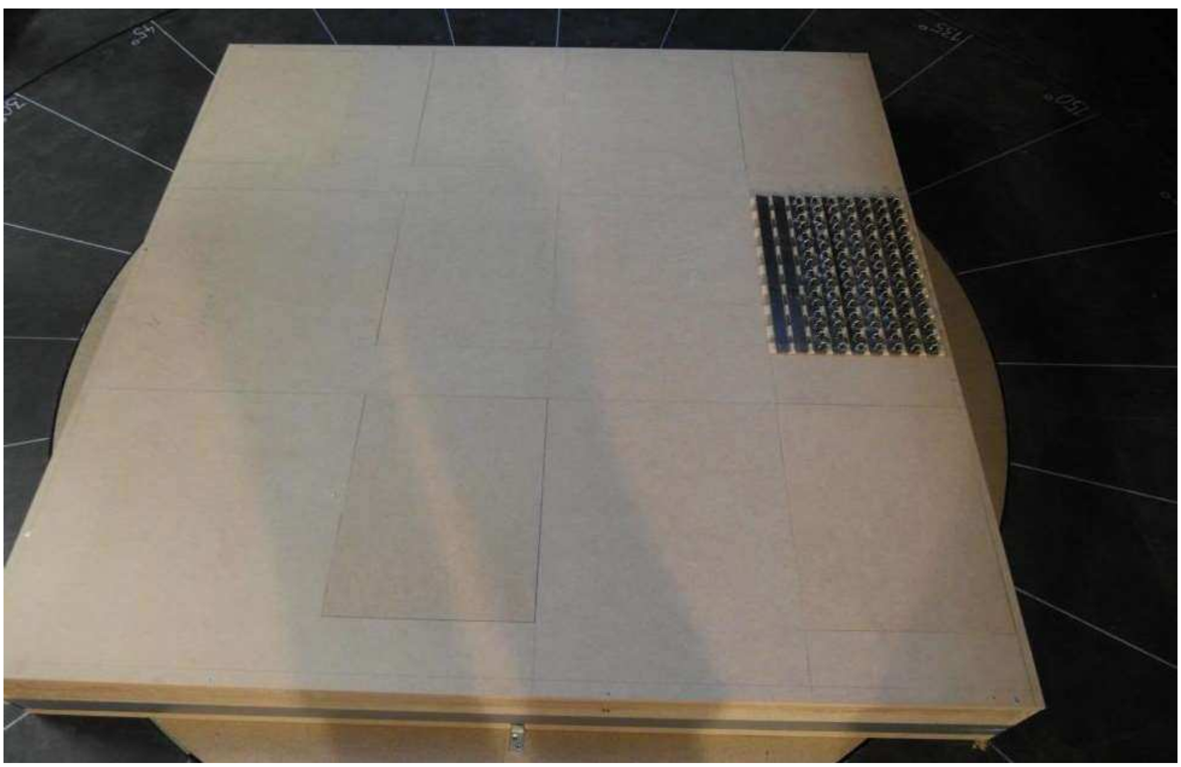


Figure C.12: Roof height 7.5 m, roof position 5, no parapet, wind sector 90°-180°

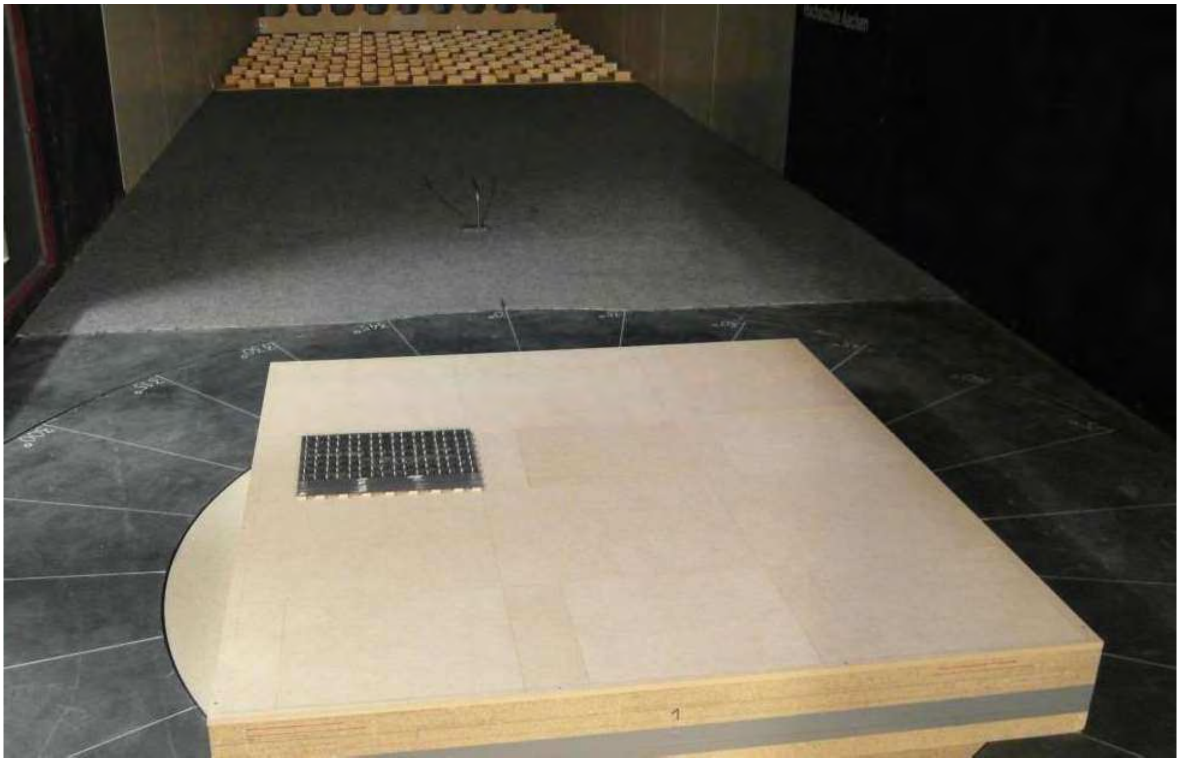


Figure C.13: Roof height 7.5 m, roof position 6, no parapet, wind sector 0°-90°

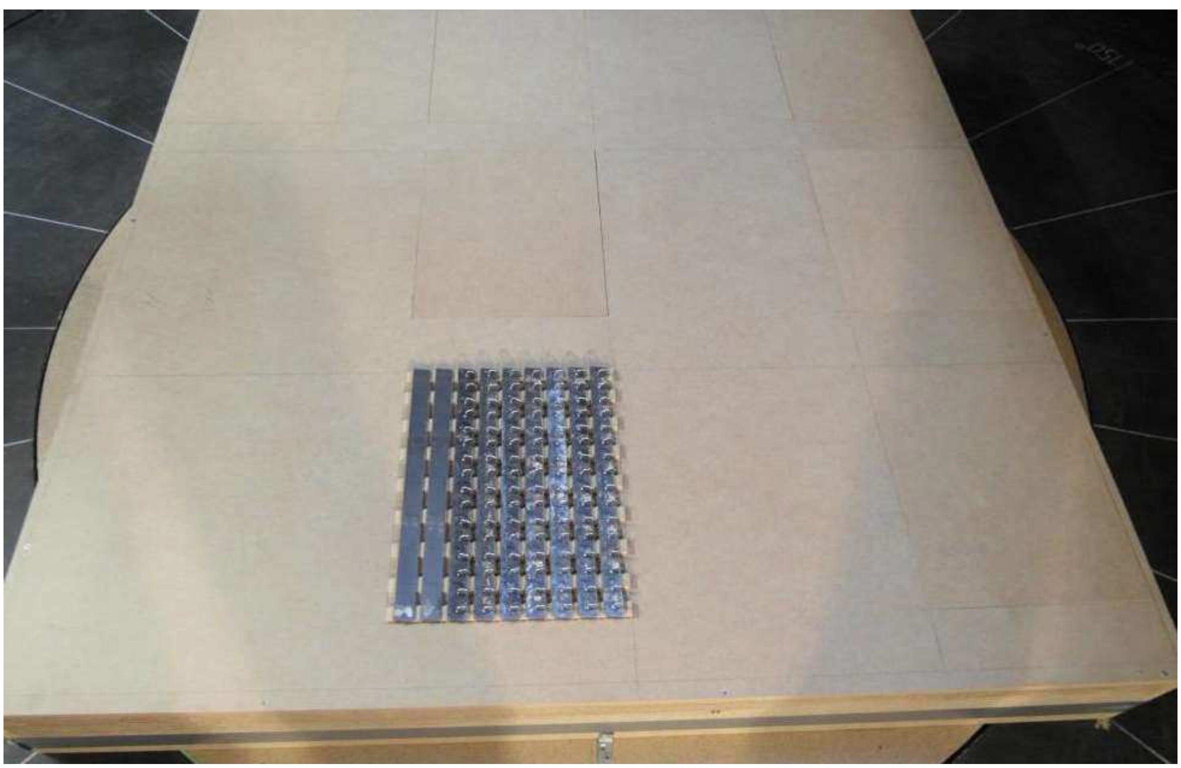


Figure C.14: Roof height 7.5 m, roof position 6, no parapet, wind sector 90°-180°

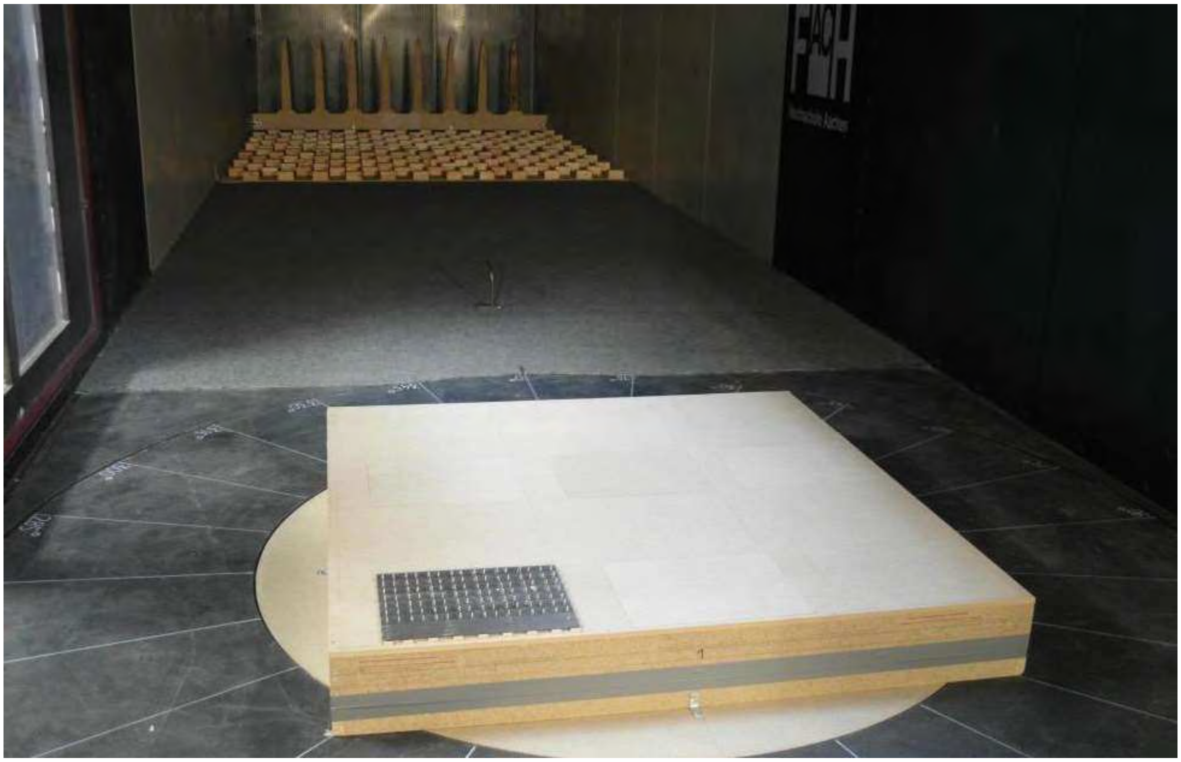


Figure C.15: Roof height 7.5 m, roof position 7, no parapet, wind sector 0°-90°

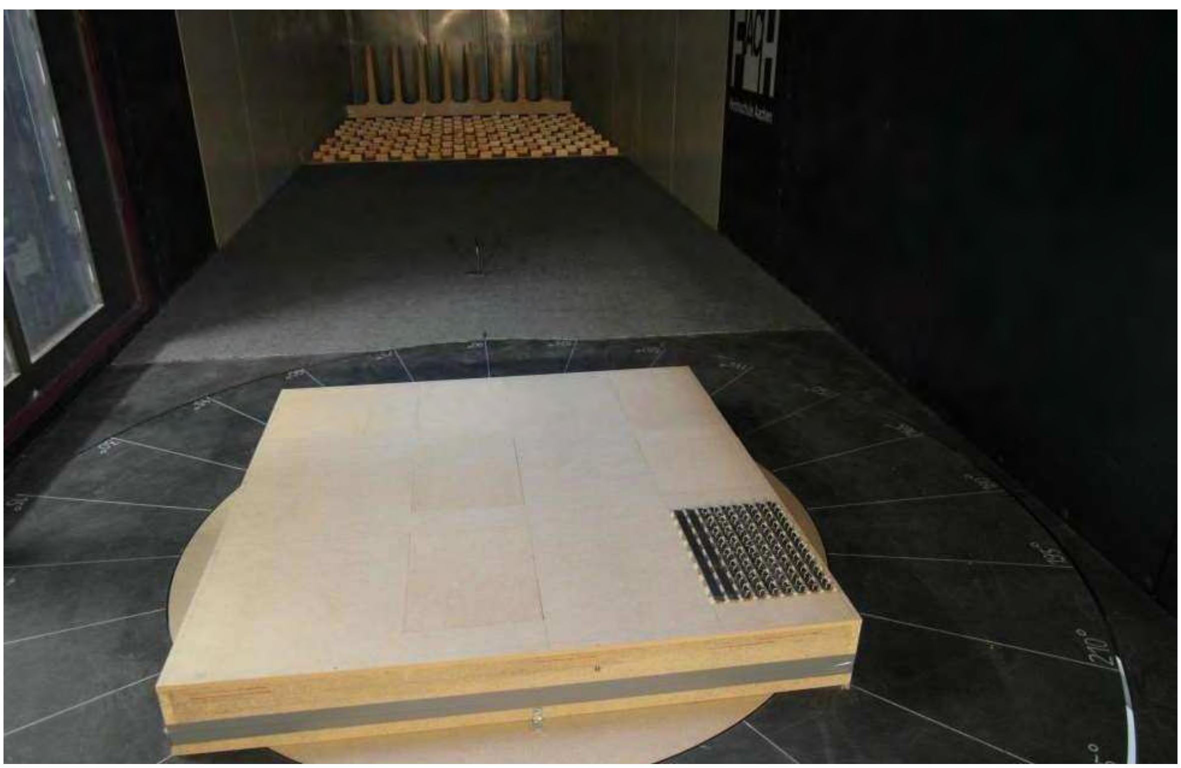


Figure C.16: Roof height 7.5 m, roof position 7, no parapet, wind sector 90°-180°

Figure C.17: Roof height 7.5 m, roof position 1, parapet with h_p = 0.75 m, wind sector 0°-90°

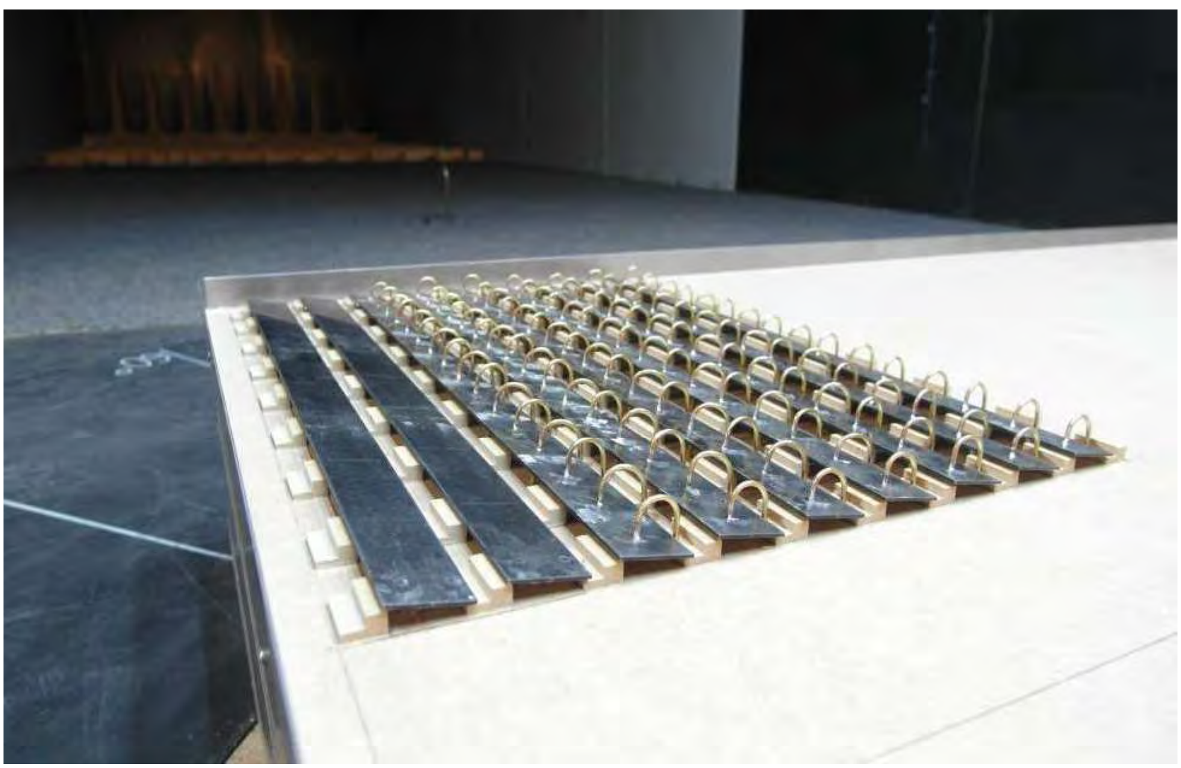


Figure C.18: Roof height 7.5 m, roof position 1, parapet with h_p = 0.75 m, wind sector 90°-180°

Figure C.19: Roof height 7.5 m, roof position 2, parapet with h_p = 0.75 m, wind sector 0°-90°

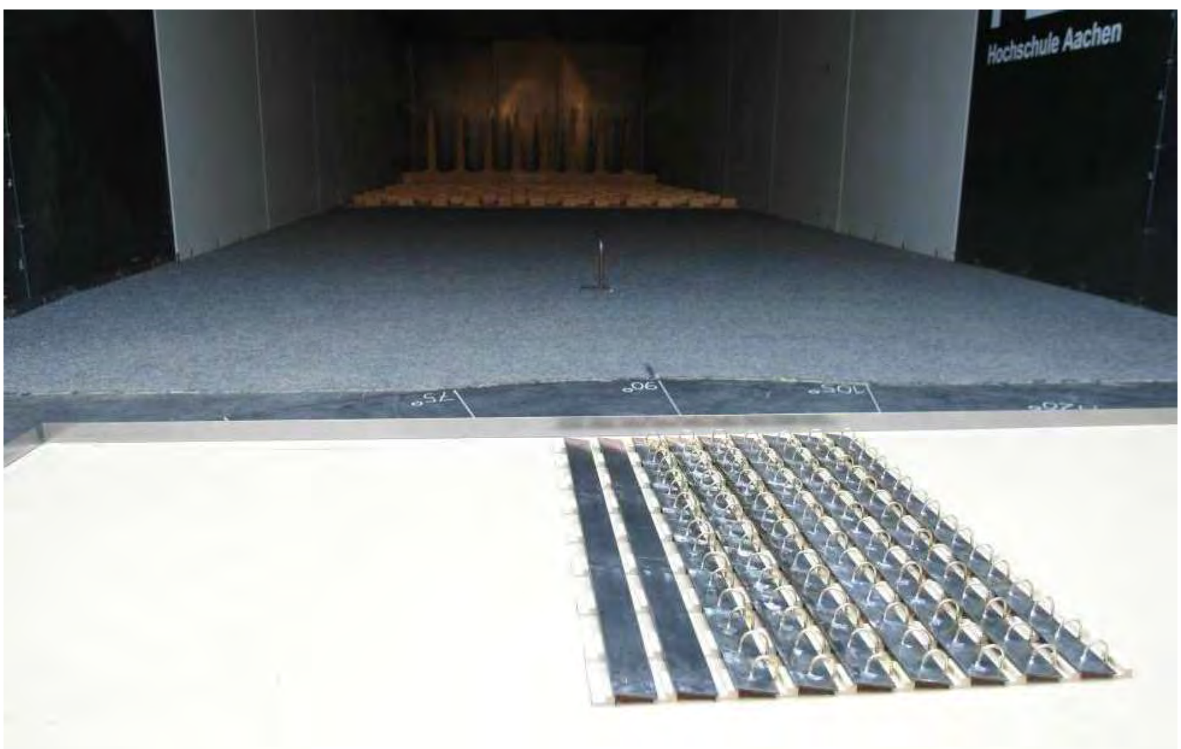


Figure C.20: Roof height 7.5 m, roof position 2, parapet with h_p = 0.75 m, wind sector 90°-180°

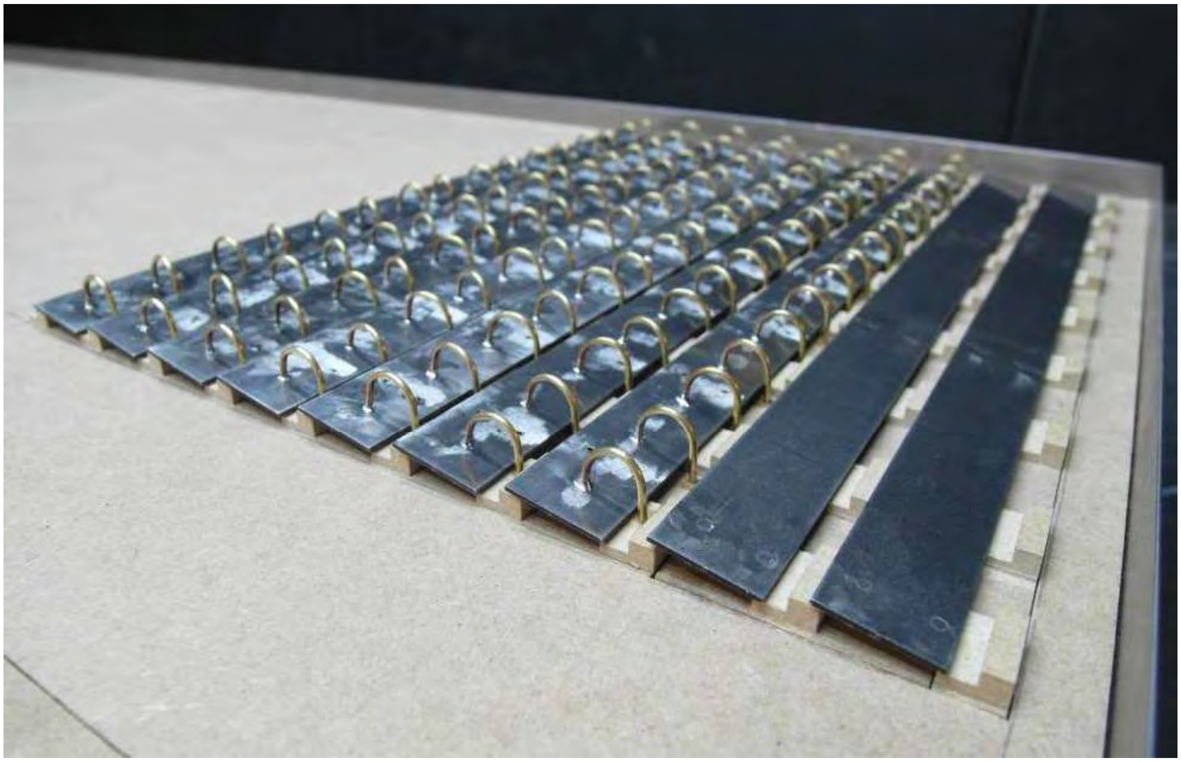


Figure C.21: Roof height 7.5 m, roof position 3, parapet with h_p = 0.75 m, wind sector 0°-90°

Figure C.22: Roof height 7.5 m, roof position 3, parapet with h_p = 0.75 m, wind sector 90°-180°

Figure C.23: Roof height 7.5 m, roof position 4, parapet with h_p = 0.75 m, wind sector 0°-90°

Figure C.24: Roof height 7.5 m, roof position 4, parapet with h_p = 0.75 m, wind sector 90°-180°

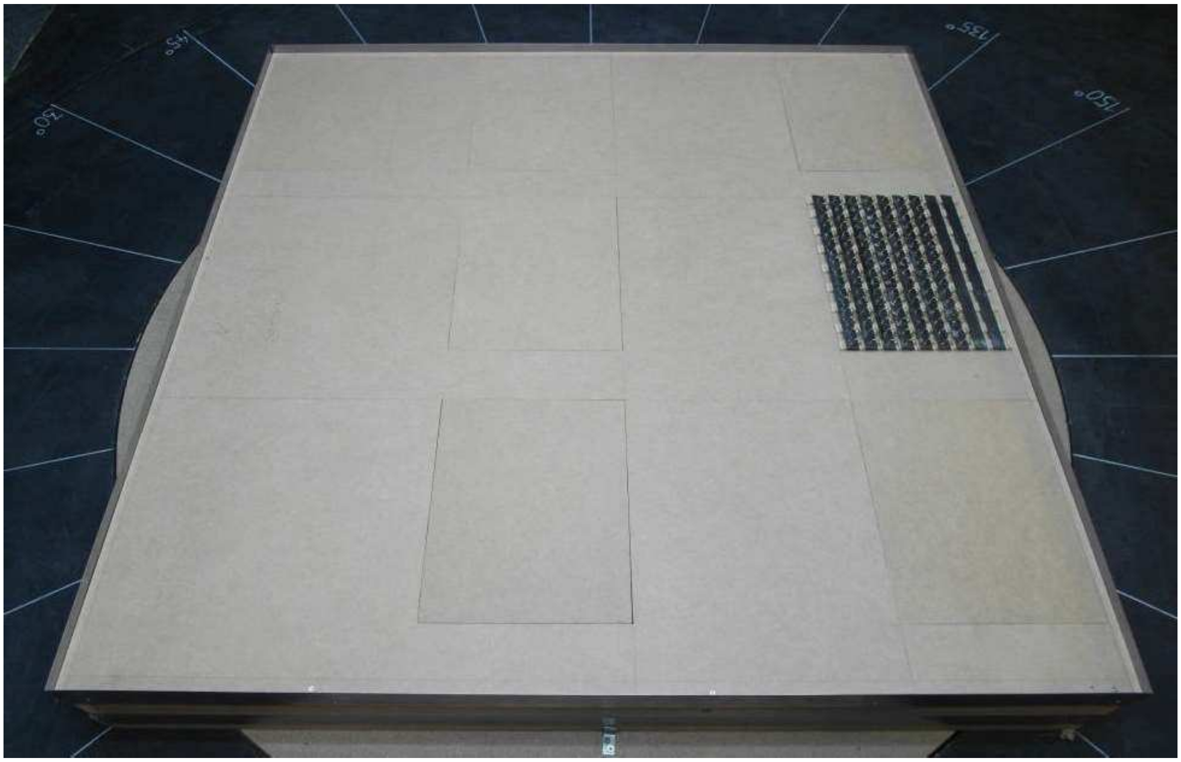


Figure C.25: Roof height 7.5 m, roof position 5, parapet with h_p = 0.75 m, wind sector 0°-90°

Figure C.26: Roof height 7.5 m, roof position 5, parapet with h_p = 0.75 m, wind sector 90°-180°

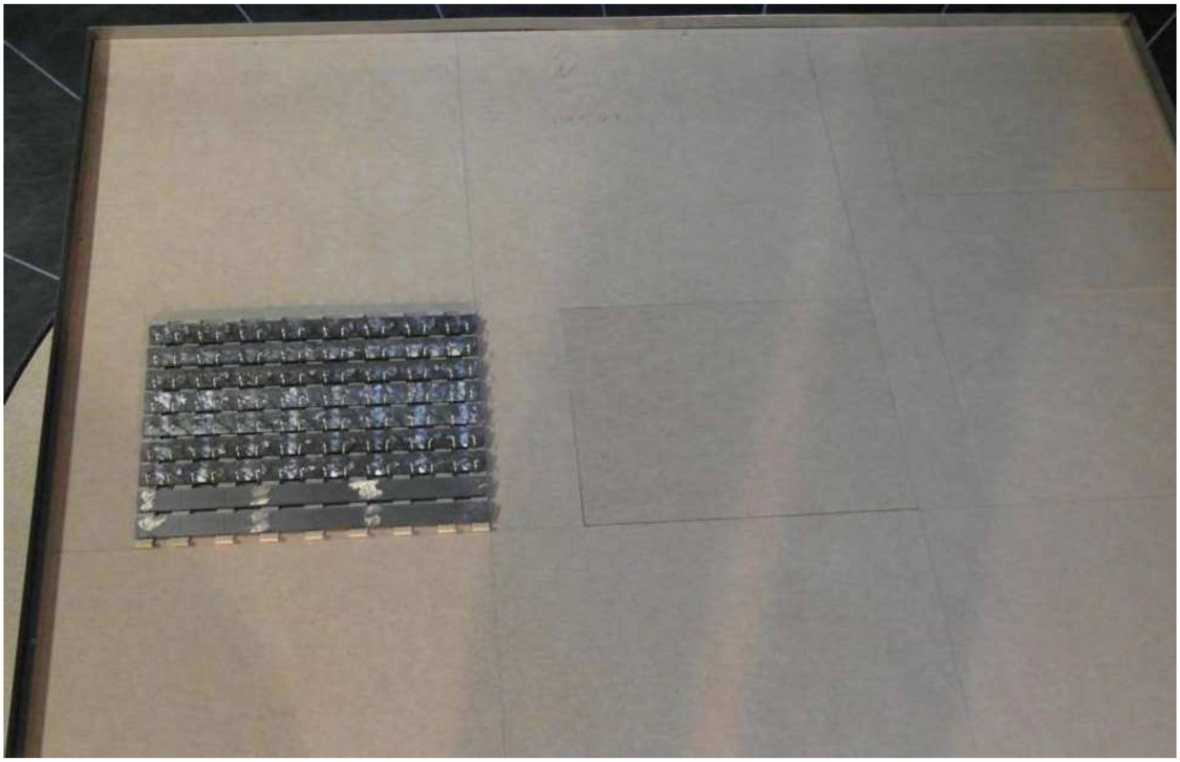


Figure C.27: Roof height 7.5 m, roof position 6, parapet with h_p = 0.75 m, wind sector 0°-90°

Figure C.28: Roof height 7.5 m, roof position 6, parapet with h_p = 0.75 m, wind sector 90°-180°

Figure C.29: Roof height 7.5 m, roof position 7, parapet with h_p = 0.75 m, wind sector 0°-90°

Figure C.30: Roof height 7.5 m, roof position 7, parapet with h_p = 0.75 m, wind sector 90°-180°

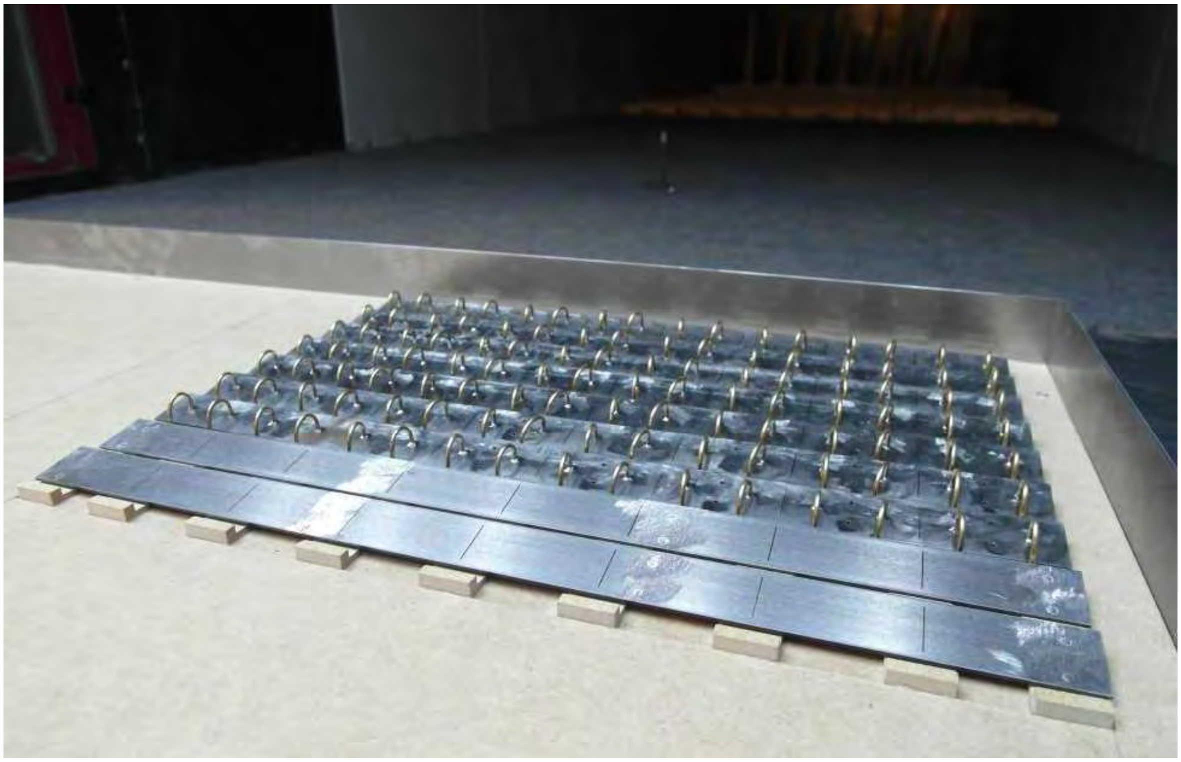


Figure C.31: Roof height 7.5 m, roof position 1, parapet with h_p = 1.50 m, wind sector 0°-90°

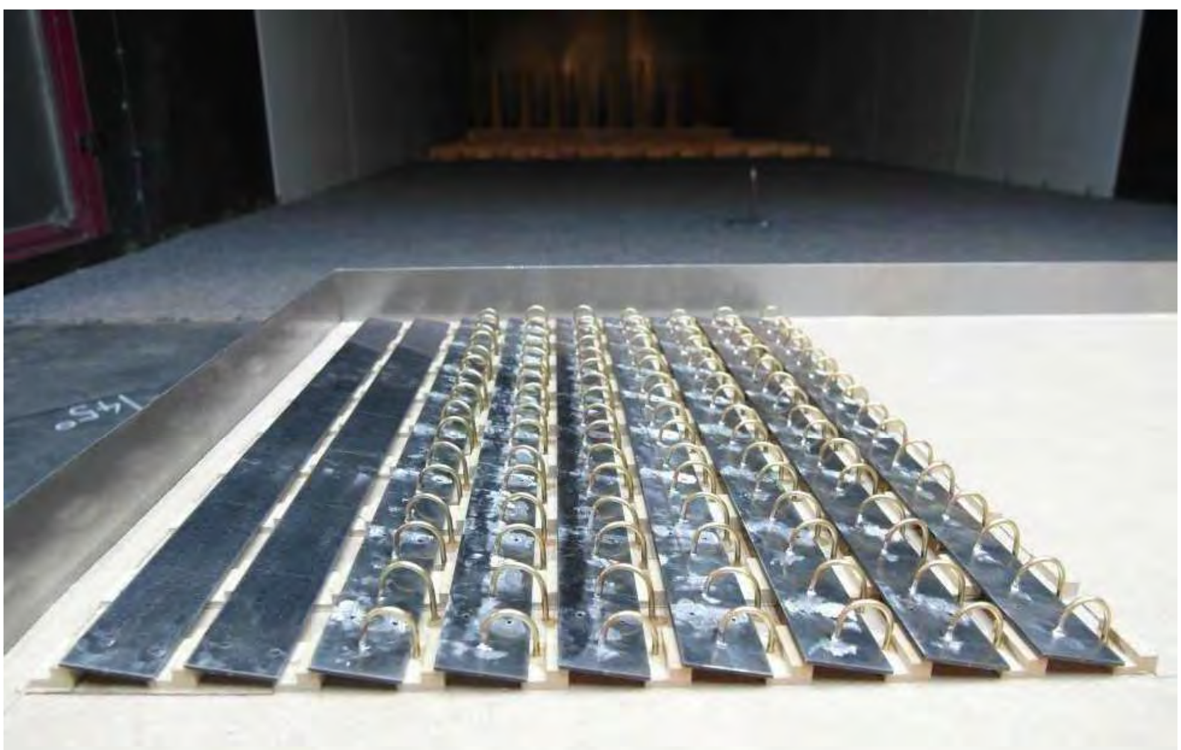


Figure C.32: Roof height 7.5 m, roof position 1, parapet with h_p = 1.50 m, wind sector 90°-180°

Figure C.33: Roof height 7.5 m, roof position 2, parapet with h_p = 1.50 m, wind sector 0°-90°

Figure C.34: Roof height 7.5 m, roof position 2, parapet with h_p = 1.50 m, wind sector 90°-180°

Figure C.35: Roof height 7.5 m, roof position 3, parapet with h_p = 1.50 m, wind sector 0°-90°

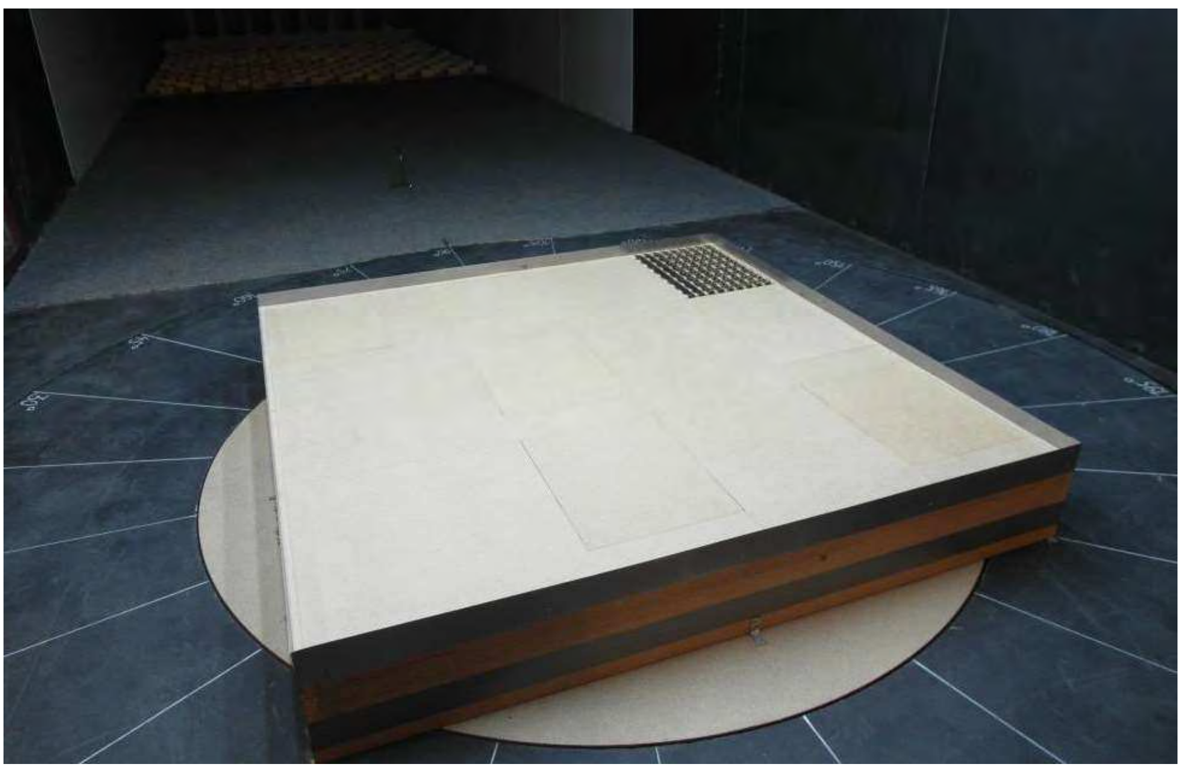


Figure C.36: Roof height 7.5 m, roof position 3, parapet with h_p = 1.50 m, wind sector 90°-180°

Figure C.37: Roof height 7.5 m, roof position 4, parapet with h_p = 1.50 m, wind sector 0°-90°

Figure C.38: Roof height 7.5 m, roof position 4, parapet with h_p = 1.50 m, wind sector 90°-180°

Figure C.39: Roof height 7.5 m, roof position 5, parapet with h_p = 1.50 m, wind sector 0°-90°

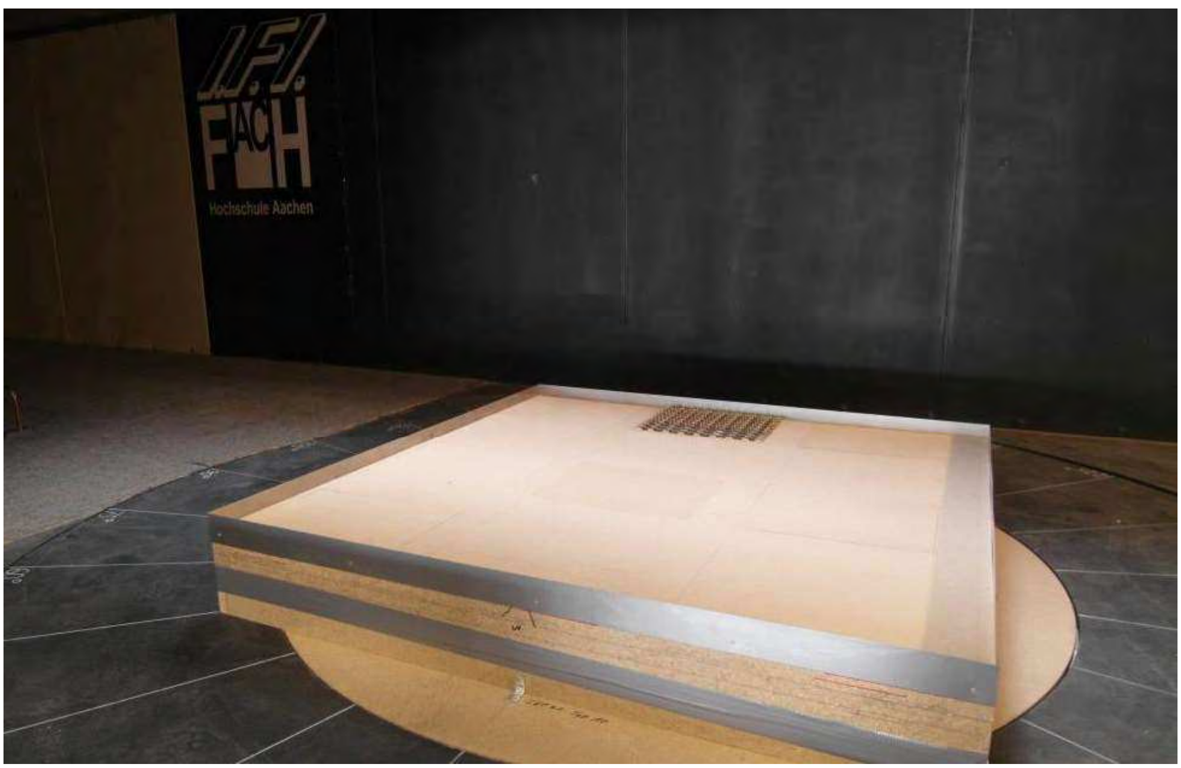


Figure C.40: Roof height 7.5 m, roof position 5, parapet with h_p = 1.50 m, wind sector 90°-180°

Figure C.41: Roof height 7.5 m, roof position 6, parapet with h_p = 1.50 m, wind sector 0°-90°

Figure C.42: Roof height 7.5 m, roof position 6, parapet with h_p = 1.50 m, wind sector 90°-180°

Figure C.43: Roof height 7.5 m, roof position 7, parapet with h_p = 1.50 m, wind sector 0°-90°

Figure C.44: Roof height 7.5 m, roof position 7, parapet with h_p = 1.50 m, wind sector 90°-180°

Figure C.45: Roof height 12.5 m, roof position 1, no parapet, wind sector 0°-90°

Figure C.46: Roof height 12.5 m, roof position 1, no parapet, wind sector 90°-180°

Figure C.47: Roof height 12.5 m, roof position 2, no parapet, wind sector 0°-90°

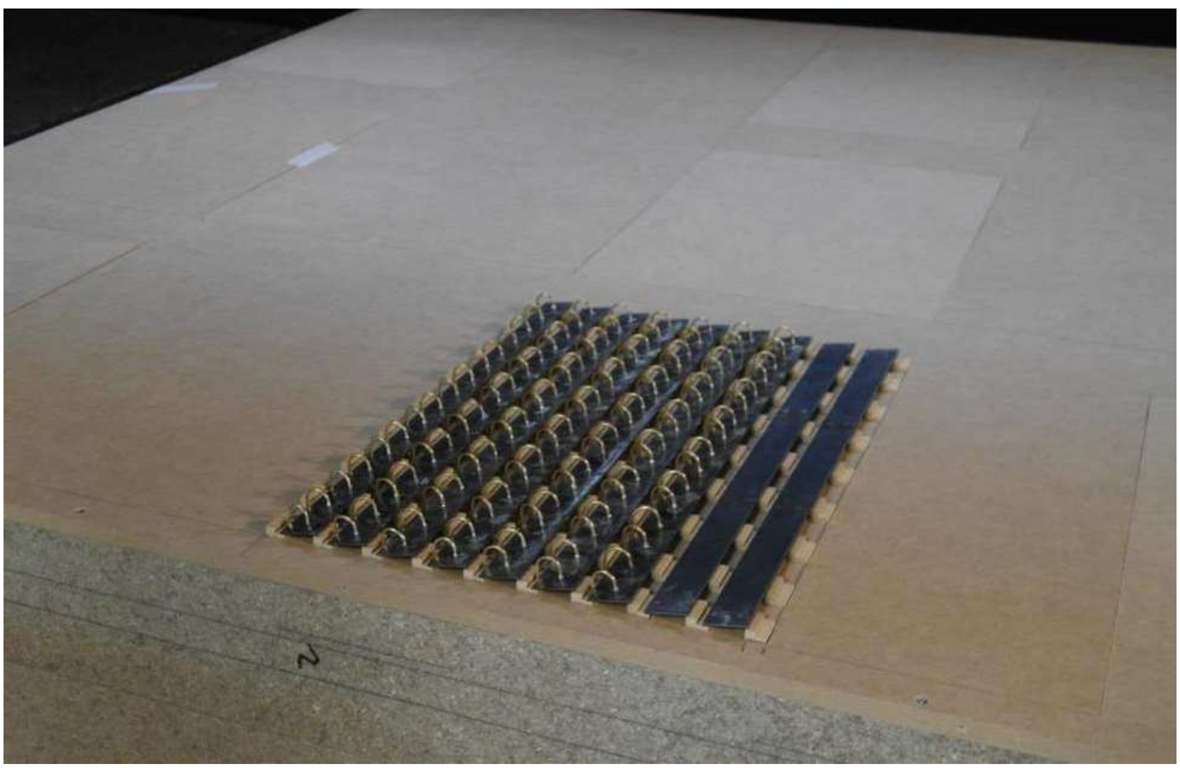


Figure C.48: Roof height 12.5 m, roof position 2, no parapet, wind sector 90°-180°

Figure C.49: Roof height 12.5 m, roof position 3, no parapet, wind sector 0°-90°

Figure C.50: Roof height 12.5 m, roof position 3, no parapet, wind sector 90°-180°

Figure C.51: Roof height 12.5 m, roof position 4, no parapet, wind sector 0°-90°

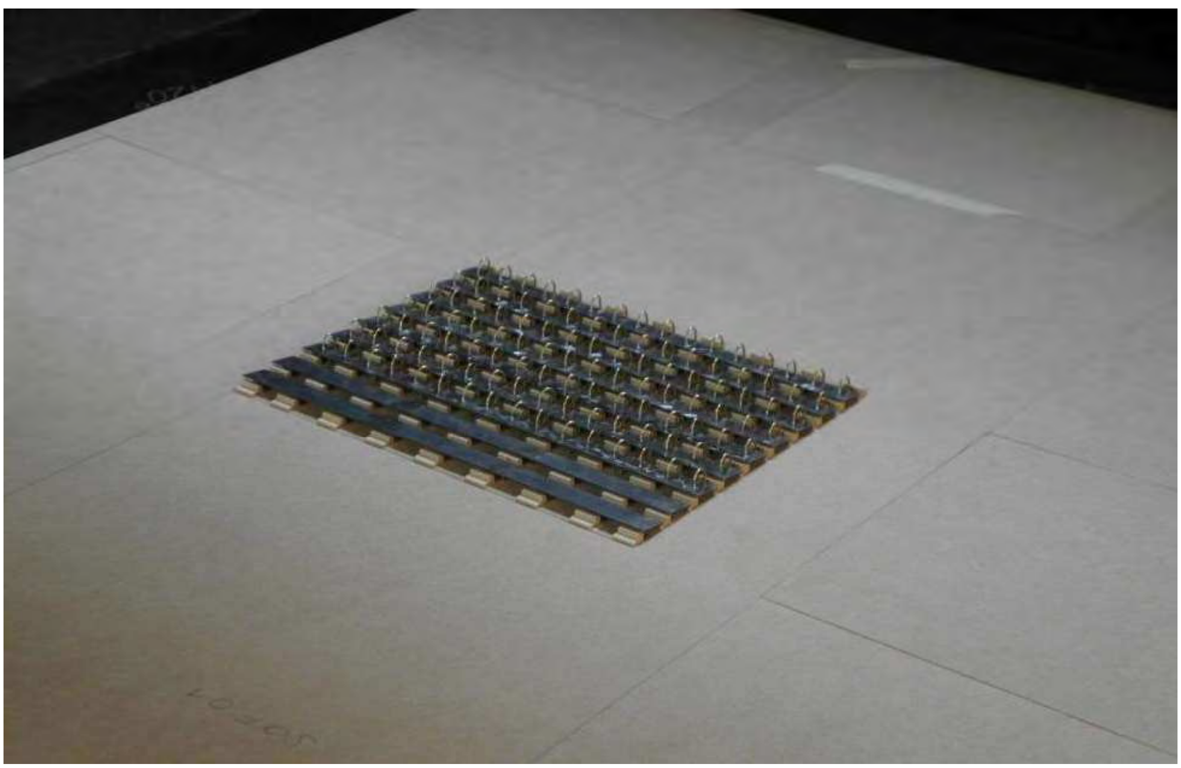


Figure C.52: Roof height 12.5 m, roof position 4, no parapet, wind sector 90°-180°

Figure C.53: Roof height 12.5 m, roof position 5, no parapet, wind sector 0°-90°

Figure C.54: Roof height 12.5 m, roof position 5, no parapet, wind sector 90°-180°

Figure C.55: Roof height 12.5 m, roof position 6, no parapet, wind sector 0°-90°

Figure C.56: Roof height 12.5 m, roof position 6, no parapet, wind sector 90°-180°

Figure C.57: Roof height 12.5 m, roof position 7, no parapet, wind sector 0°-90°

Figure C.58: Roof height 12.5 m, roof position 7, no parapet, wind sector 90°-180°

Annex D

To report No. SOF01-1

Wind loads on the solar ballasted roof mount system „FastRack 510” of Sollega, Inc.

– Pressure coefficients and parapet factors –

D Pressure coefficients and parapet factors

D.1 Pressure coefficients

Pressure coefficients are given as a function of normalized wind area, A_n. Depending on roof position of an array the definition of normalized wind area, A_n, varies as expressed by equations (D1) and (D2).

Equation (D1) expresses a dependence of pressure coefficients on building area. For buildings wider or longer than 4h no further increase of pressure coefficients is found. However, normalization of effective wind area works better if an additional dependence on normalized building height scaled by a power law exponent, $\left(\max\left(6.12\text{m};h\right)/12.5\text{m}\right)^{\gamma}$, is introduced. This behavior is observed from the data in most roof positions, see Table D.1.

Note that this is consistent with the SEAOC PV-2 approach which suggests scaling of roof zones with building height. However, the present approach is slightly different by introducing the scaling with $\left(h/12.5m\right)^{\gamma}$ into the equation for A_n.

Pressure coefficients in north rows of roof position 6 are partially observed not to scale with building dimensions at all, see equation (D2). In this case, the value of the power law exponent, γ, is -2. This is likely to occur as the peak minimum loads are caused by wind approaching normal to the wall rather than by corner vortices due to oblique wind directions.

In summary, the following definitions of normalized wind area, A_n, are used in the present report:

$$A_{n\,1} = \frac{1000 \cdot A}{\max\left[150;\min\left(h \cdot W_L; 4 \cdot h^2; 4 \cdot W_s^2\right)\right] \cdot \left(\frac{\max\left(6.12\text{m};h\right)}{12.5\text{m}}\right)^{\gamma}}$$,valid for $\gamma > -2$ (D1)

$$A_{n\,2} = \frac{1000 \cdot A}{625}$$,valid for $\gamma = -2$ (D2)

where:

- A is the effective wind area ($A = n \cdot A_M$)
- n is the number of modules which share loads (number of modules that comprise the effective wind area A for a given load case)
- A_M is the module area per module unit
- h is the roof height

- W_L is the width of a building on its longest side
- W_S is the width of a building on its shortest side
- γ is a power law exponent in a range of -2 to 0

Table D.1: Values for the power law exponent, γ, depending on roof position and row category

		Roof position 1	Roof position 2	Roof position 3	Roof position 4	Roof position 5	Roof position 6	Roof position 7
		γ [-]	γ [-]	γ [-]	γ [-]	γ [-]	γ [-]	γ [-]
North row, wind from north, 0°-90°	1st-4th module	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
	Interior modules	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
Inner rows, wind from north, 0°-90°	1st-4th module	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
	Interior modules	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
Inner rows, wind from south, 90°-180°	1st-4th module	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00
	Interior modules	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00
South row, wind from south, 90°-180°	1st-4th module	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00
	Interior modules	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00

Linear interpolation shall be permitted for module pressure coefficients and represantative ballast according to equations (D11) and (D12) as a function of normalized wind area, A_n:

$$c_{pM,ab}(A_n) = c_{pM,a} + \frac{c_{pM,b} - c_{pM,a}}{\log(A_{n,b}) - \log(A_{n,a})} \cdot \left[\log(A_n) - \log(A_{n,a})\right]$$

$$\text{for } A_{n,a} \le A_n \le A_{n,b} \qquad \text{(D3)}$$

$$m_{ab}(A_n) = m_a + \frac{m_b - m_a}{\log(A_{n,b}) - \log(A_{n,a})} \cdot \left[\log(A_n) - \log(A_{n,a})\right]$$

$$\text{for } A_{n,a} \le A_n \le A_{n,b} \qquad \text{(D4)}$$

$$c_{pM,bc}(A_n) = c_{pM,b} + \frac{c_{pM,c} - c_{pM,b}}{\log(A_{n,c}) - \log(A_{n,b})} \cdot \left[\log(A_n) - \log(A_{n,b})\right]$$

$$\text{for } A_{n,b} \le A_n \le A_{n,c} \qquad \text{(D5)}$$

$$m_{bc}(A_n) = m_b + \frac{m_c - m_b}{\log(A_{n,c}) - \log(A_{n,b})} \cdot \left[\log(A_n) - \log(A_{n,b})\right]$$

for $A_{n,b} \leq A_n \leq A_{n,c}$ (D6)

$$c_{pM,cd}(A_n) = c_{pM,c} + \frac{c_{pM,d} - c_{pM,c}}{\log(A_{n,d}) - \log(A_{n,c})} \cdot \left[\log(A_n) - \log(A_{n,c})\right]$$

for $A_{n,c} \leq A_n \leq A_{n,d}$ (D7)

$$m_{cd}(A_n) = m_c + \frac{m_d - m_c}{\log(A_{n,d}) - \log(A_{n,c})} \cdot \left[\log(A_n) - \log(A_{n,c})\right]$$

for $A_{n,c} \leq A_n \leq A_{n,d}$ (D8)

$$c_{pM,de}(A_n) = c_{pM,d} + \frac{c_{pM,e} - c_{pM,d}}{\log(A_{n,e}) - \log(A_{n,d})} \cdot \left[\log(A_n) - \log(A_{n,d})\right]$$

for $A_{n,d} \leq A_n \leq A_{n,e}$ (D9)

$$m_{de}(A_n) = m_d + \frac{m_e - m_d}{\log(A_{n,e}) - \log(A_{n,d})} \cdot \left[\log(A_n) - \log(A_{n,d})\right]$$

for $A_{n,d} \leq A_n \leq A_{n,e}$ (D10)

In equations (D3) to (D10) the indices *a*, *b, c, d* and *e* refer to the lower and upper bound of segments within curves which envelope the module pressure coefficients, c_{pM} and the represantative ballast, *m*, according to equations (D11) and (D12). The lower and upper bounds which define the segments of A_n are given in section D.3.

Note that the following values were set in calculating the representative ballast according to equations (D11) and (D12):

- S_{DI} load factor for dead load I = 1.0
- S_{DII} load factor for dead load II = 1.0
- S_W load factor for wind = 1.5
- $\mu_{R,0}$ static friction coefficient = 0.5
- q_z peak velocity pressure at roof height = 1 kN/m^2
- A_M module area per module unit ≈ 1.94 m^2
- α module tilt angle = 10deg
- m_{DL} dead load of one module unit = 20kg

$$m_{B,uplift} = S_W \cdot \frac{F_z}{g} - m_{DL} \tag{D11}$$

$$m_{B,sliding} = \frac{S_W}{g} \cdot \left[\frac{\sqrt{F_x^2}}{\mu_{R,0}} + F_z \right] - m_{DL} \tag{D12}$$

Using equations (D11), (D12), (5) and (7) the following equations result:

$$m_{B,uplift} = \frac{S_W}{g} \cdot F_z - m_{DL} = \frac{S_W}{g} \cdot q_z \cdot \left(-c_{pM} \cdot \cos(\alpha) \cdot A_M \right) - m_{DL} \tag{D13}$$

$$m_{B,sliding} = \frac{S_W}{g} \cdot \left[\frac{\sqrt{\left[q_z \cdot \left(-c_{pM} \cdot \sin(\alpha) \cdot A_M \right) \right]^2}}{\mu_{R,0}} + \left[q_z \cdot \left(-c_{pM} \cdot \cos(\alpha) \cdot A_M \right) \right] \right] - m_{DL} \tag{D14}$$

The representative ballast is calculated for the information of the reader only.

D.2 Parapet factors

Parapets with heights of 0.75 m and 1.50 m were included in the test matrix for the 7.5 m building height only. Therefore, parapet factors were calculated as a function of effective wind area, *A*.

Linear interpolation shall be permitted for parapet factors as a function of effective wind area, *A*:

$$k_{p,ab}(A) = k_{p,a} + \frac{k_{p,b} - k_{p,a}}{\log(A_b) - \log(A_a)} \cdot \left[\log(A) - \log(A_a) \right]$$

$$\text{for } A_a \le A \le A_b \tag{D15}$$

$$k_{p,bc}(A) = k_{p,b} + \frac{k_{p,c} - k_{p,b}}{\log(A_c) - \log(A_b)} \cdot \left[\log(A) - \log(A_b) \right]$$

$$\text{for } A_b \le A \le A_c \tag{D16}$$

$$k_{p,cd}(A) = k_{p,c} + \frac{k_{p,d} - k_{p,c}}{\log(A_d) - \log(A_c)} \cdot \left[\log(A) - \log(A_c) \right]$$

$$\text{for } A_c \le A \le A_d \tag{D17}$$

In equations (D15) to (D17) the indices *a*, *b*, *c* and *d* refer to the lower and upper bound of segments within curves which reasonably approximate the parapet factors, k_p. The lower and upper bounds which define the segments of *A* are given in section D.4.

Annex E

To report No. SOF01-1

Wind loads on the solar ballasted roof mount system „FastRack 510” of Sollega, Inc.

– Sample calculation –

E Sample calculation

In this annex the calculation of design ballast for a sample roof and array zone for the solar ballasted roof mount system „FastRack 510" is demonstrated.

E.1 Input data

To demonstrate the sequence of steps for this sample calculation, the project specific building dimensions are set as follows:

- h is the roof height; h = 10 m
- h_p is the parapet height; h_p = 0.75 m
- W_L is the width of a building on its longest side; W_L = 60 m
- W_S is the width of a building on its shortest side; W_S = 40 m
- α_{roof} is the roof pitch angle; α_{roof} = 0.5°

According to ASCE 7-10, the peak velocity pressure at the site is determined with the following parameters:

- Exposure C terrain category
- basic wind speed V_b = 40 m/s
- no relevant topographic influence; K_{zt} = 1.0
- wind directionality factor k_d = 1.0

These input data result in a peak velocity pressure q_z = 0.982 kN/m².

ASCE 7-10 gives the following load factors for strength design:

- S_{DI} is the load factor for dead load I = 0.9
- S_{DII} is the load factor for dead load II = 0.9
- S_W is the load factor for wind = 1.0

In the following, it is assumed that the "FastRack 510" 10deg system in landscape orientation is used. A dead weight m_{DL} = 20 kg is assumed. Further system specific values are given below:

- α module tilt angle = 10deg
- A_M module area per module unit ≈ 1.94 m^2
- $\mu_{R,0}$ static friction coefficient = 0.5

- n_{uplift} is the number of modules which share loads (number of modules that comprise the effective wind area A for the load case “uplift”) = 9
- $n_{sliding}$ is the number of modules which share loads (number of modules that comprise the effective wind area A for the load case “sliding”) = 20

Roof position 3, north row, wind from north, 0°-90°,1st to 4th module values are assumed.

E.2 Pitch angle correction factor

The pitch angle correction factor takes the effect of the component of the weight which is parallel to the surface of a sloped roof into account, see section 4.11.

$$k_\alpha = \mu_0 / [\mu_0 \cdot \cos \alpha_{roof} - \sin \alpha_{roof}] = 0.5 / [0.5 \cdot \cos(0.5°) - \sin(0.5°)] = 1.018 \qquad (E1)$$

E.3 Parapet factor

Parapet factors are a function of the effective wind area *A*. As the effective wind areas for the two load cases may be different, separate parapet factors have to be calculated.

The parapet factors for roof position 3, north row, wind from north, 0°-90°, 1st to 4th module are given in Annex D, Table D.20. In the present case, the parapet has a height of 0.75 m. In the following, parapet factors are determined by interpolation of values as a function of *A*.

$$A_{uplift} = n_{uplift} \cdot A_M = 9 \cdot 1.94 m^2 = 17.5 m^2 \qquad (E2)$$

$$A_{sliding} = n_{sliding} \cdot A_M = 20 \cdot 1.94 m^2 = 38.8 m^2 \qquad (E3)$$

$$k_{p\ uplift\ bc}\left(A_{uplift}\right) = k_{p\ b} + \frac{k_{p\ c\ uplift} - k_{p\ b\ uplift}}{\log\left(A_{c\ uplift}\right) - \log\left(A_{b\ uplift}\right)} \cdot \left[\log\left(A_{uplift}\right) - \log\left(A_{b\ uplift}\right)\right]$$

$$k_{p\ uplift\ bc}\left(A_{uplift} = 17.5 m^2\right) = 0.59 + \frac{0.88 - 0.59}{\log\left(30 m^2\right) - \log\left(1 m^2\right)} \cdot \left[\log\left(17.5 m^2\right) - \log\left(1 m^2\right)\right]$$

$$k_{p\ uplift\ bc}\left(A_{uplift} = 17.5 m^2\right) = 0.83$$

$$\text{for } A_b = 1 m^2 \le A_{uplift} \le A_c = 30 m^2 \qquad (E4)$$

$$k_{p,sliding,cd}\left(A_{sliding}\right)=k_{p,c,sliding}+\frac{k_{p,d,sliding}-k_{p,c,sliding}}{\log\left(A_{d,sliding}\right)-\log\left(A_{c,sliding}\right)}\cdot\left[\log\left(A_{sliding}\right)-\log\left(A_{c,sliding}\right)\right]$$

$$k_{p,sliding,cd}\left(A_{sliding}=38.8m^2\right)=0.89+\frac{0.89-0.89}{\log\left(10{,}000m^2\right)-\log\left(30m^2\right)}\cdot\left[\log\left(38.8m^2\right)-\log\left(30m^2\right)\right]$$

$$k_{p,sliding,cd}\left(A_{sliding}=38.8m^2\right)=0.89$$

$$\text{for } A_c=30m^2\le A_{sliding}\le A_d=10{,}000m^2 \qquad \text{(E5)}$$

E.4 Normalized wind area

For calculation of pressure coefficients, the normalized wind area, A_n, for the subzone in question (roof position 3, north row, wind from north, 0°-90°, 1st to 4th module) needs to be determined. Two load cases have to be differentiated.

The power law exponent for this subzone is given in Table D.1 with γ = -1.5. For exponents γ > -2 equation (D1) has to be applied.

$$A_{n,uplift}=\frac{1000\cdot A_{uplift}}{\max\left[150;\min\left(h\cdot W_L;4\cdot h^2;4\cdot W_s^2\right)\right]\cdot\left(\frac{\max\left(6.12\text{m};h\right)}{12.5\text{m}}\right)^{\gamma}}$$

$$A_{n,uplift}=\frac{1000\cdot 17.5m^2}{\max\left[150;\min\left(10m\cdot 60m;4\cdot\left(10m\right)^2;4\cdot\left(40m\right)^2\right)\right]\cdot\left(\frac{\max\left(6.12\text{m};10m\right)}{12.5\text{m}}\right)^{-1.5}}$$

$$A_{n,uplift}=31.24$$

(E6)

$$A_{n,sliding}=\frac{1000\cdot A_{sliding}}{\max\left[150;\min\left(h\cdot W_L;4\cdot h^2;4\cdot W_s^2\right)\right]\cdot\left(\frac{\max\left(6.12\text{m};h\right)}{12.5\text{m}}\right)^{\gamma}}$$

$$A_{n,sliding}=\frac{1000\cdot 38.8m^2}{\max\left[150;\min\left(10m\cdot 60m;4\cdot\left(10m\right)^2;4\cdot\left(40m\right)^2\right)\right]\cdot\left(\frac{\max\left(6.12\text{m};10m\right)}{12.5\text{m}}\right)^{-1.5}}$$

$$A_{n,sliding}=69.42$$

(E7)

E.5 Module pressure coefficients

Using the values from Table D.6 for the load cases “sliding” and “uplift”, the module pressure coefficients according to Annex D can be interpolated.

Interpolations for the “uplift” load case:

$$c_{pM,bc,uplift}(A_n) = c_{pM,b,uplift} + \frac{c_{pM,c,uplift} - c_{pM,b,uplift}}{\log(A_{n,c,uplift}) - \log(A_{n,b,uplift})} \cdot \left[\log(A_{n,uplift}) - \log(A_{n,b,uplift})\right]$$

$$c_{pM,bc,uplift}(A_n) = -1.06 + \frac{-0.38 - (-1.06)}{\log(45) - \log(6)} \cdot \left[\log(31.24) - \log(6)\right]$$

$$c_{pM,bc,uplift}(A_n) = -0.50$$

(E8)

Interpolations for the “sliding” load case:

$$c_{pM,cd,sliding}(A_n) = c_{pM,c,sliding} + \frac{c_{pM,d,sliding} - c_{pM,c,sliding}}{\log(A_{n,d,sliding}) - \log(A_{n,c,sliding})} \cdot \left[\log(A_{n,sliding}) - \log(A_{n,c,sliding})\right]$$

$$c_{pM,cd,sliding}(A_n) = -0.38 + \frac{-0.18 - (-0.38)}{\log(450) - \log(45)} \cdot \left[\log(69.42) - \log(45)\right]$$

$$c_{pM,cd,sliding}(A_n) = -0.34$$

(E9)

The below-given summary of module pressure coefficients is used for calculation of project specific design ballast, see section E.6.

$$c_{pM,bc,uplift}(A_n = 31.24) = -0.50 \qquad \text{(E10)}$$

$$c_{pM,cd,sliding}(A_n = 69.42) = -0.34 \qquad \text{(E11)}$$

E.6 Design ballast for the specific project

Using the module pressure coefficient from equation (E10), the design ballast for the “uplift” load case is determined as follows:

$$m_{B\,uplift} = \left[\frac{S_W \cdot F_z}{S_{DII} \cdot \cos\alpha_{roof} \cdot g} \cdot k_p - \frac{S_{DI}}{S_{DII}} \cdot m_{DL}\right]$$

$$m_{B\,uplift} = \left[\frac{S_W \cdot q_z \cdot (-c_{pM} \cdot \cos\alpha \cdot A_M)}{S_{DII} \cdot \cos\alpha_{roof} \cdot g} \cdot k_p - \frac{S_{DI}}{S_{DII}} \cdot m_{DL}\right] \qquad \text{(E14)}$$

$$m_{B\,uplift} = \left[\frac{1.0 \cdot 982\frac{N}{m^2} \cdot (-(-0.50) \cdot \cos(10°) \cdot 1.94m^2)}{0.9 \cdot \cos(0.5°) \cdot 9.81\frac{m}{s^2}} \cdot 0.83 - \frac{0.9}{0.9} \cdot 20kg\right]$$

$$m_{B\,uplift} = 69.2kg$$

Using the module pressure coefficient from equation (E11)), the design ballast for the "sliding" load case is determined as follows:

$$m_{B,sliding} = \frac{S_W \cdot \left[\frac{\sqrt{F_x^2 + F_y^2}}{\mu_{R,0}} + F_z\right]}{S_{DII} \cdot g} \cdot k_\alpha \cdot k_p - \frac{S_{DI}}{S_{DII}} \cdot m_{DL}$$

$$m_{B,sliding} = \frac{S_W \cdot q_z \cdot \left[\frac{\sqrt{\left(-c_{pM} \cdot \sin\alpha \cdot A_M\right)^2 + \left(c_F \cdot A_M\right)^2}}{\mu_{R,0}} + \left(-c_{pM} \cdot \cos\alpha \cdot A_M\right)\right]}{S_{DII} \cdot g} \cdot k_\alpha \cdot k_p - \frac{S_{DI}}{S_{DII}} \cdot m_{DL}$$

$$m_{B,sliding} = \frac{1.0 \cdot 982 \frac{N}{m^2} \cdot \left[\frac{\sqrt{\left(-(-0.34) \cdot \sin(10°) \cdot 1.94 m^2\right)^2 + 0.002 m^4}}{1000} + \left(-(-0.34) \cdot \cos(10°) \cdot 1.94 m^2\right)\right]}{0.9 \cdot 9.81 \frac{m}{s^2}} \cdot 1.018 \cdot 0.89 - \frac{0.9}{0.9} \cdot 20 kg \quad \text{(E15)}$$

$$m_{B,sliding} = 69.1 kg$$

Intertek

8431 Murphy Drive
Middleton, WI 53562 USA

Telephone: 608.836.4400
Facsimile: 608.831.9279
www.intertek.com

Test Verification of Conformity

In the basis of the tests undertaken, the sample(s) of the below product have been found to comply with the requirements of the referenced specifications at the time the tests were carried out.

Applicant Name & Address:	Sollega, Inc 2480 Mission St, Ste 107B San Francisco, CA 94110 USA
Product Description:	FastRack 510 ballast mounting system.
Ratings & Principle Characteristics:	<u>Fire Class Resistance Rating:</u> -Tilt Mount (Asymmetrical). Class A Fire Rated for Low Slope applications with Type1 listed photovoltaic modules. Angle of tilt allowed by the systems is any greater than or equal to 5^{o} and specified in the installation instructions. Minimum of one block in 3 of 4 feet around panel. No perimeter guarding is required.
Models:	FR510
Brand Name:	Sollega FastRack 510
Relevant Standards:	UL 2703 (Section 15.2 and 15.3) Standard for Safety Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels, First Edition dated Jan. 28, 2015 **Referencing** UL1703 Third Edition dated Nov. 18, 2014, (Section 31.2) Standard for Safety for Flat-Plate Photovoltaic Modules and Panels.
Verification Issuing Office:	Intertek Testing Services NA, Inc. 8431 Murphy Drive Middleton, WI 53562
Date of Tests:	04/29/2015 to 04/30/2015
Test Report Number(s):	102077497MID-001

This verification is part of the full test report(s) and should be read in conjunction with them. This report does not automatically imply product certification.

Completed by:	Chris Zimbrich	**Reviewed by:**	Gregory Allen
Title:	Technician III, Fire Resistance	**Title:**	Engineering Team Lead, Fire Resistance
Signature:	Christopher Zimbrich	**Signature:**	Gregory Allen
Date:	04/30/2015	**Date:**	04/30/2015

Intertek

REPORT NUMBER: 102077497MID-001
ORIGINAL ISSUE DATE: April 30, 2015

TEST REPORT

EVALUATION CENTER
Intertek Testing Services NA Inc.
8431 Murphy Drive
Middleton, WI 53562

RENDERED TO

Sollega, Inc
2588 Mission St, Ste 210
San Francisco, CA 94110

CONTACT NAME:
Elie Rothschild
elie@sollega.com

PRODUCT EVALUATED:

FastRack 510
5º/10º Tilt Ballast Mounting System

EVALUATION PROPERTY:
Class 'A' System Fire Class Rating of Panel with Mounting Systems in Combination with Roof Coverings, For Low Slope Applications

Report of Testing the photovoltaic module roof mount system by Sollega, Inc for evaluation with the applicable requirements of: UL 1703 (2014) Section 31.2 and UL 2703 (2015) Sections 15.2 and 15.3.

1 Table of Contents

2 Introduction

Intertek Testing Services NA (Intertek) Fire Testing Laboratory in Middleton, Wisconsin conducted an investigation of the external fire resistance characteristics of a photovoltaic module roof mount system supplied by Sollega, Inc for a class 'A' application. Samples were submitted to Intertek, Middleton and received in April 24, 2015 in good condition.

The tests were conducted in accordance with the fire resistance criteria of UL 1703 (2014) Section 31.2 and UL 2703 (2015) Sections 15.2 and 15.3 referencing UL 790 (2004) *"Standard Test Methods for Fire Tests of Roof Coverings"*. Testing was conducted with Type 1 panels, for a low slope application. The testing was conducted per the requirements of Table 31.2 in UL 1703 (2014).

3 Test Samples

The test decks were constructed by Intertek personnel.

1. The test samples were submitted by the client.
2. The test materials were applied by Intertek personnel at Middleton location.

The samples are described in more detail in the table below.

Deck#	Deck Type	System
1	Spread of Flames Class 'A' Flame from South	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.
2	Spread of Flames Class 'A' Flame from South	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.
3	Spread of Flames Class 'A' Flame from North	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.
4	Spread of Flames Class 'A' Flame from North	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets).. Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.

5	Spread of Flames Class 'A' Flame from East	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets).. Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.
6	Spread of Flames Class 'A' Flame from East	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets).. Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.
7	Spread of Flames Class 'A' Flame from South	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 10º Tilt, 5.25" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets).. Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.
8	Spread of Flames Class 'A' Flame from North	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 10º Tilt, 5.25" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets).. Photovoltaic Module: SolarWorld, SW270 Mono, Type 1.

Description of Sollega FastRack 510 Mounting System.
The following components were represented in the evaluation of the ballast mount system.

- FastRack 510 Injection Molded 10º Base
- Pull Clamp
- End Clamp
- 4" x 8" x 16" concrete blocks

The FastRack 510 system has can be used with multiple tilt angles. Per UL 1703 (2014) Section 31.2.1.6 the lowest inclination specified in the installation instructions is tested, with greater inclinations granted. The change in tilt from 5º to 10º causes the leading edge gap to alter significantly; therefore two additional tests were conducted as confirmation tests at 10°.

System installed per the Assembly Instructions, FR510 Install Manual 5 Degree23.

4 Testing and Evaluation Methods

The tests were conducted in accordance with the fire resistance criteria of UL 1703 (2014) Section 31.2 and UL 2703 (2015) referencing UL 790 (2004) *"Standard Test Methods for Fire Tests of Roof Coverings".*

The following test equipment was used to conduct the test.

Roofing Lab Equipment	Inventory Number	Measurement Uncertainty	Calibration Date
ASTM E108 Test Apparatus (Shop)	204	NA	Daily
Davis Anemometer (A/2-4 BB)	221	±2% of max reading	1/21/15
Accusplit Timer	611	±0.001% (over 3hr. period)	9/8/14

5 Tests Results

5.1. Results and Observations

Calibration

Test Conditions (Class ‘A’)

Test Date	4/29/15
Air Velocity	1046.6 average fpm
Slope of Cal. Deck	5:12
Average flame temp	1412
Ambient air temp.	69ºF

Test Conditions (Class ‘A’)

Test Date	4/30/15
Air Velocity	1045 average fpm
Slope of Cal. Deck	5:12
Average flame temp	1405
Ambient air temp.	63ºF

Spread of Flames Tests

Test Observations Deck 1

Test Date	4/29/15
Slope of Test Deck	½:12
Ambient Temperature	68°F
Panel/Rack Set-Back	3’8”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:39		Surface ignition of roof materials.
01:18	1’	
02:31	2’	
05:16	3’	
08:41	4’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 4’6”.

Test Observations Deck 2

Test Date	4/29/15
Slope of Test Deck	½:12
Ambient Temperature	67°F
Panel/Rack Set-Back	3’8”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:36		Surface ignition of roof materials.
01:15	1’	
02:44	2’	
04:22	3’	
07:35	4’	
09:43	5’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 5’0”.

Test Observations Deck 3

Test Date	4/29/15
Slope of Test Deck	½:12
Ambient Temperature	68°F
Panel/Rack Set-Back	3’8”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:37		Surface ignition of roof materials.
01:18	1’	
02:47	2’	
04:39	3’	
07:43	4’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 4’11”.

Test Observations Deck 4

Test Date	4/29/15
Slope of Test Deck	½:12
Ambient Temperature	68°F
Panel/Rack Set-Back	3’8”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:38		Surface ignition of roof materials.
01:11	1’	
02:58	2’	
04:53	3’	
09:56	4’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 4’0”.

Test Observations Deck 5

Test Date	4/30/15
Slope of Test Deck	½:12
Ambient Temperature	67°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:36		Surface ignition of roof materials.
01:13	1'	
02:56	2'	
05:36	3'	
07:45	4'	
09:42	5'	
10:00		Test stop.

Results: Class "A". Maximum spread of flames is 5'1".

Test Observations Deck 6

Test Date	4/30/15
Slope of Test Deck	½:12
Ambient Temperature	68°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:38		Surface ignition of roof materials.
01:07	1'	
02:52	2'	
05:37	3'	
08:56		
10:00		Test stop.

Results: Class "A". Maximum spread of flames is 4'10".

Test Observations Deck 7

Test Date	4/30/15
Slope of Test Deck	½:12
Ambient Temperature	73°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:37		Surface ignition of roof materials.
01:09	1'	
02:33	2'	
05:51	3'	
10:00		Test stop.

Results: Class "A". Maximum spread of flames is 3'7".

Test Observations Deck 8

Test Date	4/30/15
Slope of Test Deck	½:12
Ambient Temperature	76°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:39		Surface ignition of roof materials.
01:11	1'	
03:21	2'	
05:31	3'	
08:52		
10:00		Test stop.

Results: Class "A". Maximum spread of flames is 4'3".

6 Conclusion

The results of the Class ‘A’ System Fire Class Rating of Photovoltaic Panels with Mounting Systems in Combination with Roof Coverings, For Low Slope Applications is stated in the following table. The Sollega FastRack 510 mounting system was provided by Sollega, Inc and testing included the use of Type 1 photovoltaic panels. Testing was conducted per UL 1703 (2014) Section 31.2 and UL 2703 (2015) Sections 15.2 and 15.3 referencing UL 790 (2004) *“Standard Test Methods for Fire Tests of Roof Coverings”.*

Sample	Surface Material	Test	Rating
1	Sollega FastRack 510 (5º) with Type 1 panel, South Exposure.	Spread of Flame	Pass
2	Sollega FastRack 510 (5º) with Type 1 panel, South Exposure.	Spread of Flame	Pass
3	Sollega FastRack 510 (5º) with Type 1 panel, North Exposure.	Spread of Flame	Pass
4	Sollega FastRack 510 (5º) with Type 1 panel, North Exposure.	Spread of Flame	Pass
5	Sollega FastRack 510 (5º) with Type 1 panel, East Exposure.	Spread of Flame	Pass
6	Sollega FastRack 510 (5º) with Type 1 panel, East Exposure.	Spread of Flame	Pass
7	Sollega FastRack 510 (10º) with Type 1 panel, South Exposure.	Spread of Flame	Pass
8	Sollega FastRack 510 (10º) with Type 1 panel, North Exposure.	Spread of Flame	Pass

The Sollega FastRack 510 (5º&10°) mounting system with Type 1 photovoltaic panel met the requirements for a Class A fire application in accordance with UL 1703 (2014) Section 31.2 and UL 2703 (2015) in compliance with UL 790 (2004) *“Standard Test Methods for Fire Tests of Roof Covering”* at for low slope applications. Per Section 31.2.1.6 of UL 1703 (2014) the rating obtained for a 5º inclination can be used for any greater inclinations stated in the mounting instructions. .

This report does not automatically imply product certification. Products must be under a certification program and bear the Warnock Hersey registered certification mark to demonstrate compliance.

INTERTEK TESTING SERVICES NA

Reported by: Chris Zimbrich
Technician III,
Fire Resistance
Intertek, Building Products

Reviewed by: Gregory Allen
Engineering Team Leader,
Openings
Intertek, Building Products

Photographs

Test #1

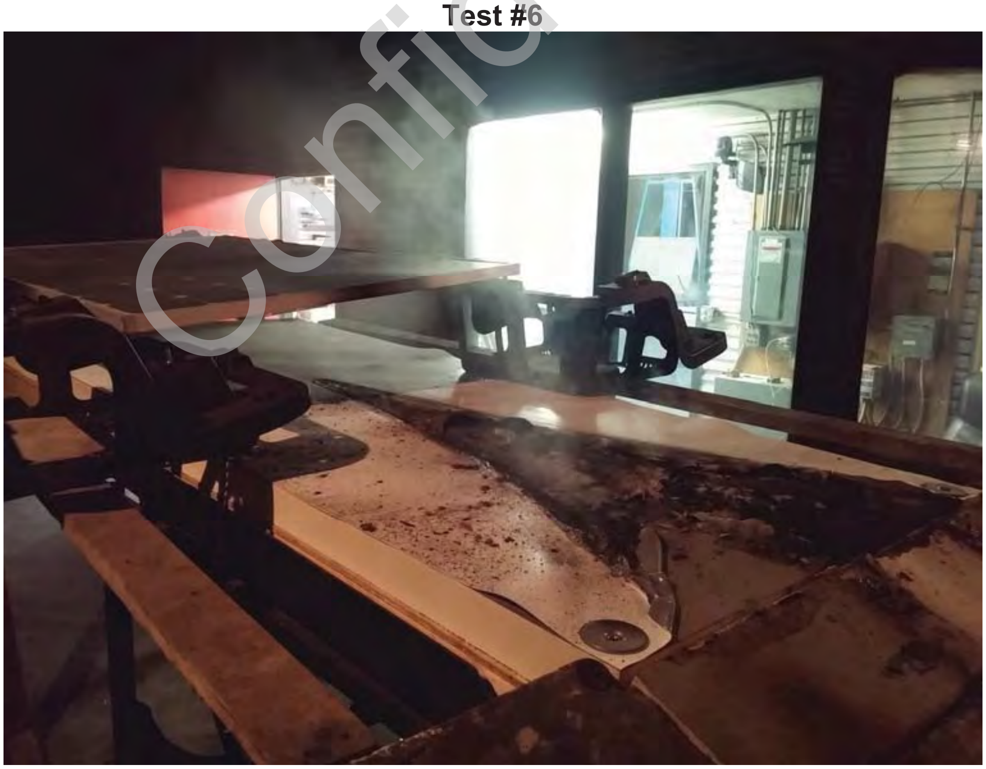
Test #2

Test #3

Test #4

Test #5

Test #6



Test #7

Test #8

REVISION SUMMARY

DATE	SUMMARY
April 30, 2015	Initial report

8431 Murphy Drive
Middleton, WI 53562 USA

Telephone: 608.836.4400
Facsimile: 608.831.9279
www.intertek.com

Test Verification of Conformity

In the basis of the tests undertaken, the sample(s) of the below product have been found to comply with the requirements of the referenced specifications at the time the tests were carried out.

Applicant Name & Address:	Sollega, Inc 2480 Mission St, Ste 107B San Francisco, CA 94110 USA
Product Description:	FastRack 510 ballast mounting system.
Ratings & Principle Characteristics:	<u>Fire Class Resistance Rating:</u> -Tilt Mount (Asymmetrical) Class A for Low Slope Applications when using Type 2, Listed Photovoltaic Modules. Angle of tilt allowed by the systems is any greater than or equal to 5^{o} and specified in the installation instructions. Minimum of one block in 3 of 4 feet around panel. No perimeter guarding is required.
Models:	FR510
Brand Name:	Sollega FastRack 510
Relevant Standards:	UL 2703 (Section 15.2 and 15.3) Standard for Safety Mounting Systems, Mounting Devices, Clamping/Retention Devices with Flat-Plate Photovoltaic Modules and Panels, First Edition dated Jan. 28, 2015 **Referencing** UL1703 Third Edition revision date Jun, 2016, (Section 31.2) Standard for Safety for Flat-Plate Photovoltaic Modules and Panels.
Verification Issuing Office:	Intertek Testing Services NA, Inc. 8431 Murphy Drive Middleton, WI 53562
Date of Tests:	07/08/2016 to 07/13/2016
Test Report Number(s):	102630255MID-001

This verification is part of the full test report(s) and should be read in conjunction with them. This report does not automatically imply product certification.

Completed by:	Chris Zimbrich	**Reviewed by:**	Kent Kelsey
Title:	Technician II, Fire Resistance	**Title:**	Lead Engineer, Fire Resistance
Signature:	Christopher Zimbrich	**Signature:**	Kent Kelsey
Date:	07/19/2016	**Date:**	07/19/2016

TEST REPORT

REPORT NUMBER: 102630255MID-001
ORIGINAL ISSUE DATE: July 19, 2016

EVALUATION CENTER
Intertek Testing Services NA Inc.
8431 Murphy Drive
Middleton, WI 53562

RENDERED TO

Sollega, Inc
2480 Mission Street, Suite 107B
San Francisco, CA 94110

CONTACT NAME:
Elie Rothschild
elie@sollega.com

PRODUCT EVALUATED:

FastRack 510
5º/10º Tilt Ballast Mounting System

EVALUATION PROPERTY:
Class 'A' System Fire Class Rating of Panel with Mounting Systems in Combination with Roof Coverings, For Low Slope Applications

Report of Testing the photovoltaic module roof mount systems by Sollega, Inc. for evaluation with the applicable requirements of: UL 1703, 2002 edition (rev. Jul 2016) Section 31.2 and UL 2703, 2015 edition, Sections 15.2 and 15.3.

1 Table of Contents

2 Introduction

Intertek Testing Services NA (Intertek) Fire Testing Laboratory in Middleton, Wisconsin conducted an investigation of the external fire resistance characteristics of a photovoltaic module roof mount system supplied by Sollega, Inc for a class 'A' application. Samples were submitted to Intertek, Middleton and received in June 2016 in good condition.

The tests were conducted in accordance with the fire resistance criteria of UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3. *"Standard Test Methods for Fire Tests of Roof Coverings".* Testing was conducted with Type 2 panels, for a low slope application. The testing was conducted per the requirements of Table 31.2 in UL 1703 (2016).

3 Test Samples

The test decks were constructed by Intertek personnel.

1. The test samples were submitted by the client.
2. The lumber used to construct the test decks was tested and verified to have a moisture content between 8% and 12%.
3. The test materials were applied by Intertek personnel at Middleton location.

The samples are described in more detail in the table below.

Deck#	Deck Type	System
1	Spread of Flames Class 'A' Flame from South	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: Suniva, 285-C01-SW, Type 2 Serial Number: SSUSG00021606140061 Sample ID: MID1606231050-001 .
2	Spread of Flames Class 'A' Flame from South	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: Suniva, 285-C01-SW, Type 2 Serial Number: SSUSG00021606140097 Sample ID: MID1606231050-002 .

3	Spread of Flames Class 'A' Flame from North	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: Suniva, 285-C01-SW, Type 2 Serial Number: SSUSG00021606140098 Sample ID: MID1606231050-003 .
4	Spread of Flames Class 'A' Flame from North	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: Suniva, 285-C01-SW, Type 2 Serial Number: SSUSG00021606140104 Sample ID: MID1606231050-004 .
5	Spread of Flames Class 'A' Flame from East	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: Suniva, 285-C01-SW, Type 2 Serial Number: SSUSG00021606140042 Sample ID: MID1606231050-005 .
6	Spread of Flames Class 'A' Flame from East	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510, 5º Tilt, 8" between deck and leading edge, 1 block per basket used as ballast (in 3 of 4 baskets). Photovoltaic Module: Suniva, 285-C01-SW, Type 2 Serial Number: SSUSG00021606130199 Sample ID: MID1606231050-006 .

Description of Sollega FastRack 510 Mounting System.
The following components were represented in the evaluation of the ballast mount system.

FastRack 510 Injection Molded 10º Base

Pull Clamp
End Clamp
4" x 8" x 16" concrete blocks

The FastRack 510 system has can be used with multiple tilt angles. Per UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2.1.6 the lowest inclination specified in the installation instructions is tested, with greater inclinations granted. The change in tilt from 5º to 10º causes the leading edge gap to alter significantly; prior testing of the FR510 system with Type 1 modules (Report 102077497MID-001r1) ran 2 confirmation tests. The effect the leading edge gap change had was negligible, therefore it was deemed unnecessary to run confirmation tests with Type 2.

System installed per the Assembly Instructions, FR510 Install Manual 5 Degree23.

4 Testing and Evaluation Methods

The tests were conducted in accordance with the fire resistance criteria of UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3. *"Standard Test Methods for Fire Tests of Roof Coverings".*

The following test equipment was used to conduct the test.

Roofing Lab Equipment	Inventory Number	Measurement Uncertainty	Calibration Due Date
ASTM E108 Test Apparatus (Shop)	204	N/A	Daily
Davis Anemometer (A/2-4 BB)	221	±2% of max reading	03/11/2017
Accusplit Timer	1313	±0.001% (over 3hr. period)	12/08/2016
Moisture Meter	1110	N/A	Daily
Moisture Meter Calibration Block	1380	±0.134%	09/28/2016
Thermocouple Probe	1317	±3.96°F	12/08/2016
K-Meter	1355	±1.0°F	01/11/2017

5 Tests Results

5.1. Results and Observations

Calibration

Test Conditions (Class ‘A’)

Test Date	07/08/16
Air Velocity	1066 average fpm
Slope of Cal. Deck	5:12
Average flame temp	1387
Ambient air temp.	79ºF

Test Conditions (Class ‘A’)

Test Date	07/13/16
Air Velocity	1057 average fpm
Slope of Cal. Deck	5:12
Average flame temp	1385
Ambient air temp.	80ºF

Spread of Flames Tests

Test Observations Deck 1

Test Date	07/08/16
Slope of Test Deck	½:12
Ambient Temperature	80°F
Panel/Rack Set-Back	3’11”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
01:07		Surface ignition of roof materials.
01:48	1’	
06:10	2’	
09:48	3’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 3’2”.

Test Observations Deck 2

Test Date	07/13/16
Slope of Test Deck	½:12
Ambient Temperature	82°F
Panel/Rack Set-Back	3’11”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:43		Surface ignition of roof materials.
01:06	1’	
02:49	2’	
04:38	3’	
07:30	4’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 4’8”.

Test Observations Deck 3

Test Date	07/13/16
Slope of Test Deck	½:12
Ambient Temperature	82°F
Panel/Rack Set-Back	3’11”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:45		Surface ignition of roof materials.
01:18	1’	
03:05	2’	
04:31	3’	
06:40	4’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 4’11”.

Test Observations Deck 4

Test Date	07/13/16
Slope of Test Deck	½:12
Ambient Temperature	86°F
Panel/Rack Set-Back	3’11”

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:56		Surface ignition of roof materials.
01:38	1’	
09:26	2’	
10:00		Test stop.

Results: Class “A”. Maximum spread of flames is 2’1”.

Test Observations Deck 5

Test Date	07/13/16
Slope of Test Deck	½:12
Ambient Temperature	86°F
Panel/Rack Set-Back	3'11"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:59		Surface ignition of roof materials.
01:19	1'	
02:03	2'	
03:21	3'	
05:52	4'	
08:51	5'	
10:00		Test stop.

Results: Class "A". Maximum spread of flames is 5'3".

Test Observations Deck 6

Test Date	07/13/16
Slope of Test Deck	½:12
Ambient Temperature	88°F
Panel/Rack Set-Back	3'11"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
00:49		Surface ignition of roof materials.
00:58	1'	
01:51	2'	
03:30	3'	
05:16	4'	
09:17	5'	
10:00		Test stop.

Results: Class "A". Maximum spread of flames is 5'5".

6 Conclusion

The results of the Class ‘A’ System Fire Class Rating of Photovoltaic Panels with Mounting Systems in Combination with Roof Coverings, For Low Slope Applications is stated in the following table. The Sollega FastRack 510 mounting system was provided by Sollega, Inc and testing included the use of Type 2 photovoltaic panels. Testing was conducted per UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3. *“Standard Test Methods for Fire Tests of Roof Coverings”.*

Sample	Surface Material	Test	Rating
1	Sollega FastRack 510 (5º) with Type 2 panel, South Exposure.	Spread of Flame	Pass
2	Sollega FastRack 510 (5º) with Type 2 panel, South Exposure.	Spread of Flame	Pass
3	Sollega FastRack 510 (5º) with Type 2 panel, North Exposure.	Spread of Flame	Pass
4	Sollega FastRack 510 (5º) with Type 2 panel, North Exposure.	Spread of Flame	Pass
5	Sollega FastRack 510 (5º) with Type 2 panel, East Exposure.	Spread of Flame	Pass
6	Sollega FastRack 510 (5º) with Type 2 panel, East Exposure.	Spread of Flame	Pass

The Sollega FastRack 510 (5º&10°) mounting system with Type 2 photovoltaic panel met the requirements for Class A fire application in accordance with UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3. *“Standard Test Methods for Fire Tests of Roof Covering”* for low slope applications. Per Section 31.2.1.6 of UL 1703, 2002 Edition (rev. Jun 2016) the rating obtained for a 5º inclination can be used for any greater inclinations stated in the mounting instructions. .

This report does not automatically imply product certification. Products must be under a certification program and bear the Warnock Hersey registered certification mark to demonstrate compliance.

INTERTEK TESTING SERVICES NA

Reported by: Christopher Zimbrich

Chris Zimbrich
Technician II, Fire Resistance
Intertek, Building Products

Reviewed by: Kent Kelsey

Kent Kelsey
Lead Engineer, Fire Resistance
Intertek, Building Products

APPENDIX A
Photographs

Test #1

Test #2

Test #3

Test #4

Test #5

Test #6

REVISION SUMMARY

DATE	SUMMARY
July 19, 2016	Initial report

8431 Murphy Drive
Middleton, WI 53562 USA

Telephone: 608.836.4400
Facsimile: 608.831.9279
www.intertek.com

Test Verification of Conformity

In the basis of the tests undertaken, the sample(s) of the below product have been found to comply with the requirements of the referenced specifications at the time the tests were carried out.

Applicant Name & Address:	Sollega, Inc 2480 Mission St, Ste 107B San Francisco, CA 94110 USA
Product Description:	FastRack 510 ballast mounting system w/ rails.
Ratings & Principle Characteristics:	<u>Fire Class Resistance Rating:</u> -Tilt Mount (Asymmetrical) Class A for Low Slope Applications when using Type 3, Listed Photovoltaic Modules. Per Section 31.2.1.6 of UL 1703 (rev. Jun 2016) the rating obtained for a 5° inclination can be used for any greater inclinations stated in the mounting instructions. No perimeter guarding is required.
Models:	FR510
Brand Name:	Sollega
Relevant Standards:	UL 2703 (Section 15.2 and 15.3) Standard for Safety Mounting Systems, Mounting Devices, Clamping/Retention Devices with Flat-Plate Photovoltaic Modules and Panels, First Edition dated Jan. 28, 2015 **Referencing** UL1703 Third Edition revision date June, 2016, (Section 31.2) Standard for Safety for Flat-Plate Photovoltaic Modules and Panels.
Verification Issuing Office:	Intertek Testing Services NA, Inc. 8431 Murphy Drive Middleton, WI 53562
Date of Tests:	09/29/2017-10/02/2017
Test Report Number(s):	103246455MID-001

This verification is part of the full test report(s) and should be read in conjunction with them. This report does not automatically imply product certification.

Completed by:	Christopher Zimbrich	**Reviewed by:**	Chad Naggs
Title:	Technician I, Fire Resistance	**Title:**	Technical Team Lead, Fire Resistance
Signature:		**Signature:**	
Date:	10/02/2017	**Date:**	10/02/2017

Intertek

REPORT NUMBER: 103246455MID-001
ORIGINAL ISSUE DATE: October 2, 2017

TEST REPORT

EVALUATION CENTER
Intertek Testing Services NA Inc.
8431 Murphy Drive
Middleton, WI 53562

RENDERED TO

Sollega, Inc.
2588 Mission St
Ste 210
San Francisco, CA 94110

CONTACT NAME:
Elie Rothschild
elie@sollega.com

PRODUCT EVALUATED:
FastRack 501 5°/10° Tilt Ballast Mounting System
w/ Type 3 Modules

EVALUATION PROPERTY:
Class 'A' System Fire Class Rating of Panel
with Mounting Systems in Combination with
Roof Coverings, For Low Slope Applications

Report of Testing the photovoltaic module roof mount system by Sollega, Inc for evaluation with the applicable requirements of: UL 1703, 2002 edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 edition, Sections 15.2 and 15.3.

1 Table of Contents

2 Introduction

Intertek Testing Services NA (Intertek) Fire Testing Laboratory in Middleton, Wisconsin conducted an investigation of the external fire resistance characteristics of photovoltaic module roof mount systems supplied by Sollega, Inc for a class 'A' application. Samples were submitted to Intertek, Middleton and received on September 29th, 2017 in good condition.

The tests were conducted in accordance with the fire resistance criteria of UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3. *"Standard Test Methods for Fire Tests of Roof Coverings"*. Testing was conducted with Type 3 PV panels, for a Low slope application. The testing was conducted per the requirements of Table 31.2 in UL 1703 (2016).

3 Test Samples

The test decks were constructed by Intertek personnel.

1. The test samples were submitted by the client.
2. The lumber used to construct the test decks was tested and verified to have a moisture content between 8% and 12%.
3. The test materials were applied by Intertek personnel at the Middleton location.

The samples are described in more detail in the table below.

Deck#	Deck Type	System
1	Spread of Flames Class 'A' 5° tilt 13" btw deck and bottom of south edge of module Flame from South	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510 w/ rails, Module clamps used to mount module. Photovoltaic Module: Stion, Model STL-145A, Type 3. 2 modules used. Sample Number: MID1709291148-001.
2	Spread of Flames Class 'A' 5° tilt 13" btw deck and bottom of south edge of module Flame from South	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510 w/ rails, Module clamps used to mount module. Photovoltaic Module: Stion, Model STL-145A, Type 3. 2 modules used. Sample Number: MID1709291148-002.
3	Spread of Flames Class 'A' 5° tilt 13" btw deck and bottom of south edge of module Flame from North	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510 w/ rails, Module clamps used to mount module. Photovoltaic Module: Stion, Model STL-145A, Type 3. 2 modules used. Sample Number: MID1709291148-003.
4	Spread of Flames Class 'A' 5° tilt 13" btw deck and bottom of south edge of module Flame from North	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510 w/ rails, Acrylic core tape used to mount module. Photovoltaic Module: Stion, Model STL-145A, Type 3. 2 modules used. Sample Number: MID1709291148-004.
5	Spread of Flames Class 'A' 5° tilt 13" btw deck and bottom of south edge of module Flame from East	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510 w/ rails, Acrylic core tape used to mount module. Photovoltaic Module: Stion, Model STL-145A, Type 3. 2 modules used. Sample Number: MID1709291148-005.
6	Spread of Flames Class 'A' 5° tilt 13" btw deck and bottom of south edge of module Flame from East	Sheathing: 15/32" AC plywood. Insulation Board: 4" Poly ISO. Membrane: 60mm TPO. Rack: FastRack 510 w/ rails, Acrylic core tape used to mount module. Photovoltaic Module: Stion, Model STL-145A, Type 3. 2 modules used. Sample Number: MID1709291148-006.

4 Testing and Evaluation Methods

The tests were conducted in accordance with the fire resistance criteria of UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3. *"Standard Test Methods for Fire Tests of Roof Coverings".*

The following test equipment was used to conduct the test.

Roofing Lab Equipment	Inventory Number	Measurement Uncertainty	Calibration Due Date
ASTM E108 Test Apparatus (Shop)	204	N/A	Daily
Davis Anemometer (A/2-4 BB)	221	±2% of max reading	07/05/2018
Accusplit Stopwatch	1397	±0.001% (over 3hr. period)	04/10/2018
Moisture Meter	1110	N/A	Daily
Moisture Meter Calibration Block	1380	±0.134%	10/28/2017
Thermocouple Probe	1317	±3.96°F	10/10/2017
K-Meter	1354	±1.0°F	07/12/2018

5 Tests Results

5.1. Results and Observations

Calibration

Test Conditions (Class 'A')

Test Date	09/29/2017
Air Velocity	1046 average fpm.
Slope of Cal. Deck	5:12
Average flame temp	1401°F
Ambient air temp.	67°F

Test Conditions (Class 'A')

Test Date	10/02/2017
Air Velocity	1057 average fpm.
Slope of Cal. Deck	5:12
Average flame temp	1396°F
Ambient air temp.	69°F

Spread of Flames Tests

Test Observations Deck 1

Test Date	09/29/2017
Slope of Test Deck	½:12
Ambient Temperature	76°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
01:37		Ignition of surface materials.
02:41	1'	
04:38	2'	
08:59	3'	
10:00		Test stop.

Results: Pass. Maximum spread of flames is 3'2".

Test Observations Deck 2

Test Date	09/29/2017
Slope of Test Deck	½:12
Ambient Temperature	77°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
01:02		Ignition of surface materials.
01:18	1'	
02:11	2'	
04:13	3'	
07:28	4'	
10:00		Test stop.

Results: Pass. Maximum spread of flames is 4'8".

Test Observations Deck 3

Test Date	09/29/2017
Slope of Test Deck	½:12
Ambient Temperature	76°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
01:14		Ignition of surface materials.
01:24	1'	
03:41	2'	
04:52	3'	
06:37	4'	
08:55	5'	
10:00		Test stop.

Results: Pass. Maximum spread of flames is 5'2".

Test Observations Deck 4

Test Date	10/02/2017
Slope of Test Deck	½:12
Ambient Temperature	71°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
01:08		Ignition of surface materials.
01:38	1'	
02:48	2'	
04:37	3'	
06:41	4'	
08:56	5'	
10:00		Test stop.

Results: Pass. Maximum spread of flames is 5'0".

Test Observations Deck 5

Test Date	10/02/2017
Slope of Test Deck	½:12
Ambient Temperature	77°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
01:14		Ignition of surface materials.
01:37	1'	
03:52	2'	
06:04	3'	
08:49	4'	
10:00		Test stop.

Results: Pass. Maximum spread of flames is 4'7".

Test Observations Deck 6

Test Date	10/02/2017
Slope of Test Deck	½:12
Ambient Temperature	78°F
Panel/Rack Set-Back	3'8"

Time (min:sec)	Distance (feet-inches)	Observations/Comments
00:00		Burner ignited.
01:21		Ignition of surface materials.
01:41	1'	
03:51	2'	
06:14	3'	
09:31	4'	
10:00		Test stop.

Results: Pass. Maximum spread of flames is 4'2".

6 Conclusion

The results of the Class ‘A’ System Fire Class Rating of Photovoltaic Panels with Mounting Systems in Combination with Roof Coverings, For Low Slope Applications is stated in the following table. The FastRack 510 mounting system was provided by Sollega, Inc and testing included the use of Type 3 photovoltaic panels. Testing was conducted per UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3. *“Standard Test Methods for Fire Tests of Roof Coverings”.*

Sample	Surface Material	Test	Rating
1	Sollega FastRack 510 (5° tilt) with Type 3 panel and clamps, South exposure.	Spread of Flame	Pass
2	Sollega FastRack 510 (5° tilt) with Type 3 panel and clamps, South exposure.	Spread of Flame	Pass
3	Sollega FastRack 510 (5° tilt) with Type 3 panel and clamps, North exposure.	Spread of Flame	Pass
4	Sollega FastRack 510 (5° tilt) with Type 3 panel and tape, North exposure.	Spread of Flame	Pass
5	Sollega FastRack 510 (5° tilt) with Type 3 panel and tape, East exposure.	Spread of Flame	Pass
6	Sollega FastRack 510 (5° tilt) with Type 3 panel and tape, East exposure.	Spread of Flame	Pass

The Sollega FastRack 510 (5°&10°) mounting system with Type 3 photovoltaic panels met the requirement for a Class A fire application in accordance with UL 1703, 2002 Edition (rev. Jun 2016) Section 31.2 and UL 2703, 2015 Edition, Sections 15.2 and 15.3 *“Standard Test Methods for Fire Tests of Roof Covering”* for low slope applications.

Per Section 31.2.1.6 of UL 1703 (rev. Jun 2016) the rating obtained for a 5° inclination can be used for any greater inclinations stated in the mounting instructions.

The difference between module clamps and the acrylic tape was negligible in regards to fire performance.

This report does not automatically imply product certification. Products must be under a certification program and bear the Warnock Hersey registered certification mark to demonstrate compliance.

INTERTEK TESTING SERVICES NA

Reported by: ______________________
Christopher Zimbrich
Technician I, Fire Resistance
Intertek, Building Products

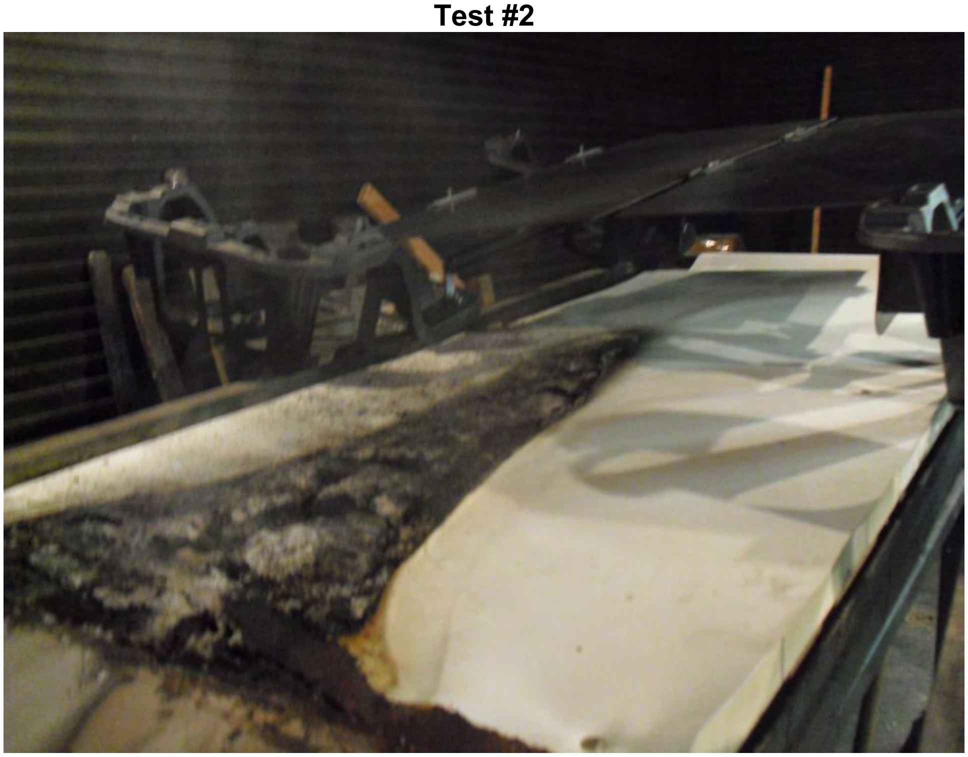
Reviewed by: ______________________
Chad Naggs
Technical Team Lead, Fire Resistance
Intertek, Building Products

7 Appendix A

PHOTOGRAPHS

Test #1

Test #2



Test #3

Test #4

Test #5

Test #6

REVISION SUMMARY

DATE	SUMMARY
October 2, 2017	Initial report

QAI LABORATORIES
CERTIFICATION TESTING INSPECTION

8385 White Oak Avenue
Rancho Cucamonga, CA 91730
909.483.0250 ph. | 909.483.0336 fx.

CLIENT: **Sollega**
2480 Mission Street, Suite 107B
San Francisco, CA 94110

Test Report No: RJ4603	**Date: April 1, 2016**

SAMPLE ID: The test samples are identified as: **FastRack FR 510** Tested over TPO or CAP Sheet Roof Assemblies.

SAMPLING DETAIL: Test samples were submitted to the laboratory directly by the client. No special sampling conditions or sample preparation were observed by QAI.

DATE OF RECEIPT: Roofing Substrate Samples were received at QAI on March 3rd and March 21st 2016 and **FastRack FR 510** on December 2nd 2015.

TESTING PERIOD: March 27th and 28th 2016

AUTHORIZATION: Testing authorized by Lee Rothschild on Signed Proposal Number JE-2016-031401-rev1.

TEST REQUESTED: **ASTM G115** *"Standard Guide for Measuring and Reporting Friction Coefficients."*

TEST PROCEDURE: Testing was conducted in accordance with **ASTM G115** for Static and Kinetic Coeffiecient Friction of a Ballasted Solar Racking System over a Cap Sheet and TPO Representative Roofing Assembly. One Roofing Assembly Measuring Four Feet wide By Eight Feet long was constructed for each Roofing Assembly which consisted of the roofing membrane adhered by an adhesive over 4" polyisocyanurate insulation Boards, cleaned with a towel and water, then conditioned in a 74 Degree F 50% Humid Environment until reaching constant weight. The Ballasted Racking System Measuring 4 lbs was loaded with 85 lbs of weight to simulate 60 lbs of ballast and four corners of a 25 lb module totaling an 89 lb assembly. This assembly was attached via cable through a pulley to a universal testing machine with measurement for both load and position recorded for each test. Three Replicate Tests were conducted in the dry condition and 3 tests were conducted in a wet condition per roofing assembly. For Each Test the 89 lb Ballasted Solar Racking System was placed on the representative roofing assembly in a new location and dragged for a minimum of 10 inches to record the peak load at which the system start moving and the average load for the system to continue moving after the peak load was achieved. Multiple Tests were conducted at different speeds from 2 to 20 Inches per minute to determine the best speed to load the specimen to avoid Stick-Slip Behavior. The tests were conducted at a constant rate of 18 inches per minute which exhibited the most stable kinetic friction. Tests were conducted in a draft free environment on a level surface.

TEST RESULTS: Results are on the subsequent pages of this report along with a picture of the test assembly.

Prepared By

Chris Taylor
Test Technician

Signed for and on behalf of
QAI Laboratories, Inc.

Drew Mersereau
Laboratory Supervisor

WWW.QAI.ORG
info@qai.org

intertek
Total Quality. Assured.

Listing Constructional Data Report (CDR)

1.0 Reference and Address				
Report Number	103282591LAX-001	Original Issued: 30-Jan-2020		Revised: 27-Feb-2020
Standard(s)	Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels [UL 2703:2015 Ed.1]			

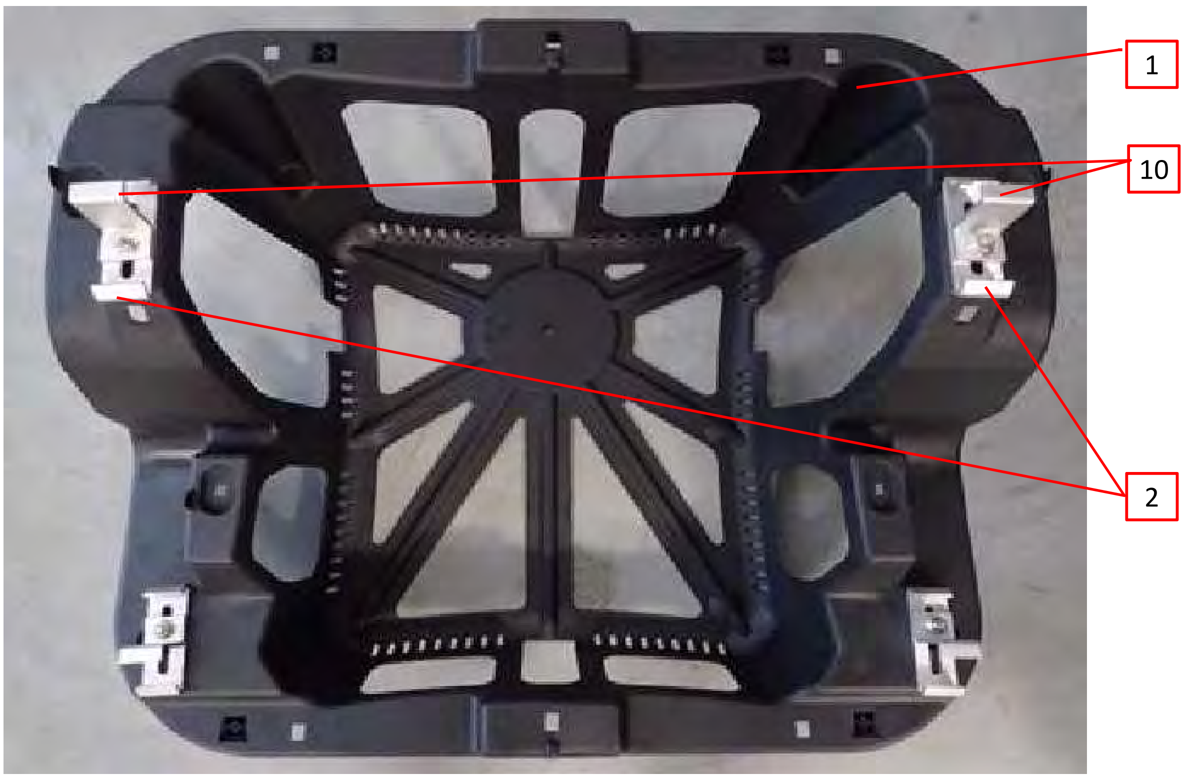
Applicant	Sollega Inc.	Manufacturer 1	**Universal Plastic Mold Inc.**
Address	2480 Mission St. Suite 107b San Francisco CA, 94110	Address	13245 Los Angeles St. Baldwin Park CA, 91706
Country	USA	Country	USA
Contact	Elie Rothschild Lee Rothschild	Contact	Mike Ashleigh
Phone	4155158710, 4158673562 4155785099, 7208397913	Phone	6262511057
FAX	NA	FAX	NA
Email	elie@sollega.com lee@sollega.com	Email	mashleigh@upminc.com

2.0 Product Description	
Product	Photovoltaic Racking System installed using FastRack 510 installation manual 10°version-Revision 1/1/2020
Brand name	Sollega
Description	The product covered by this report is the Ballast photovoltaic rack mounting system. It is designed to provide mounting, bonding, and grounding to photovoltaic modules. The main component of the Ballast product is a polymeric "basket" that is clamped to PV modules and ballasted to the roof top with concrete pavers. All other components are made of 300 series stainless steel or 6000 series aluminum. The other major components are the pull clamp and end clamp, which are sized to accommodate frame sizes (30 mm to 50 mm). The pull clamp and end clamp are not part of the ground path. Module to module bonding is achieved either through Bonding Jumper or the AKS midclamps. The overall grounding of the entire racking systems is to be designed and investigated to the edition of the National Electrical Code, NEC, to Article 690: Solar Photovoltaic Systems and Article 250: Grounding and Bonding in effect in the jurisdiction in which the project resides.
Models	FastRack 510
Model Similarity	NA
Ratings	**Fire Class Rating:** Class A for Low Slope Roof Applications when using Type 1,2 & 3 Listed Photovoltaic Module **Fuse Rating:** 30 A **Mechanical Load Testing:** Mechanical Load Rating: 10PSF Downward, 5PSF Upward, 5PSF Sloped Load Module Orientation: Landscape Maximum Size of PV Modules: 20.8ft^2 See illustartions 1a to 1b for list of approved modules.
Other Ratings	NA

3.0 Product Photographs

Photo 1 - FastRack FR510

Photo 2- FastRack FR510 Top View



3.0 Product Photographs

Photo 3- AK Grounding Mid-Clamp

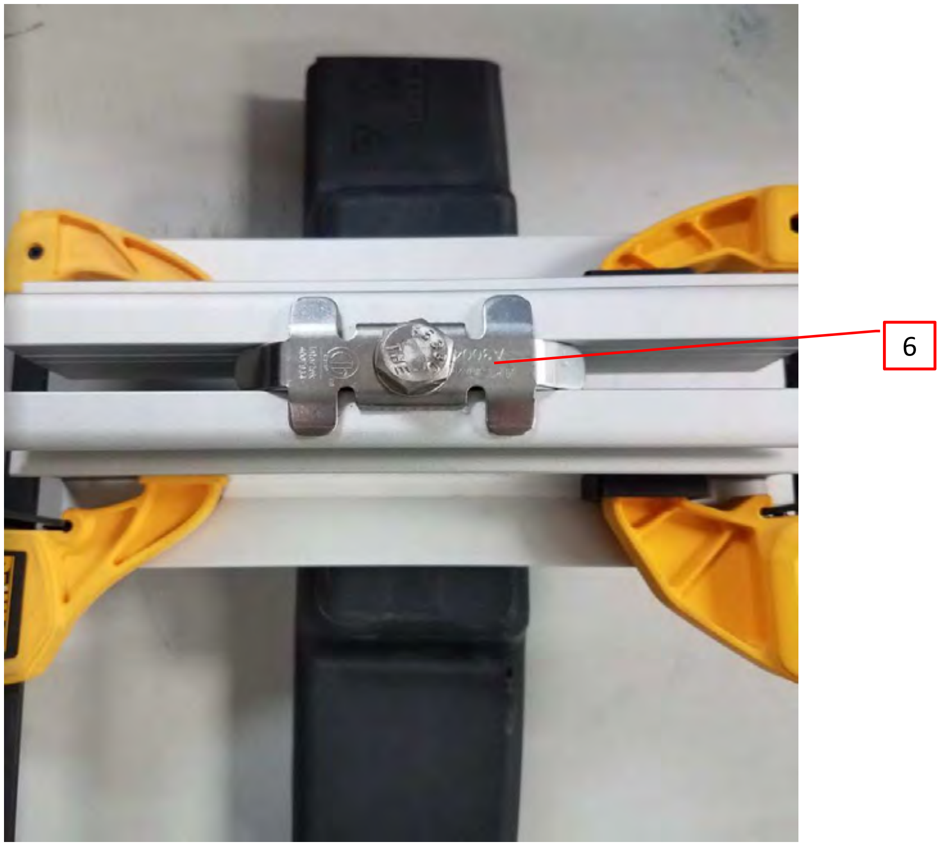
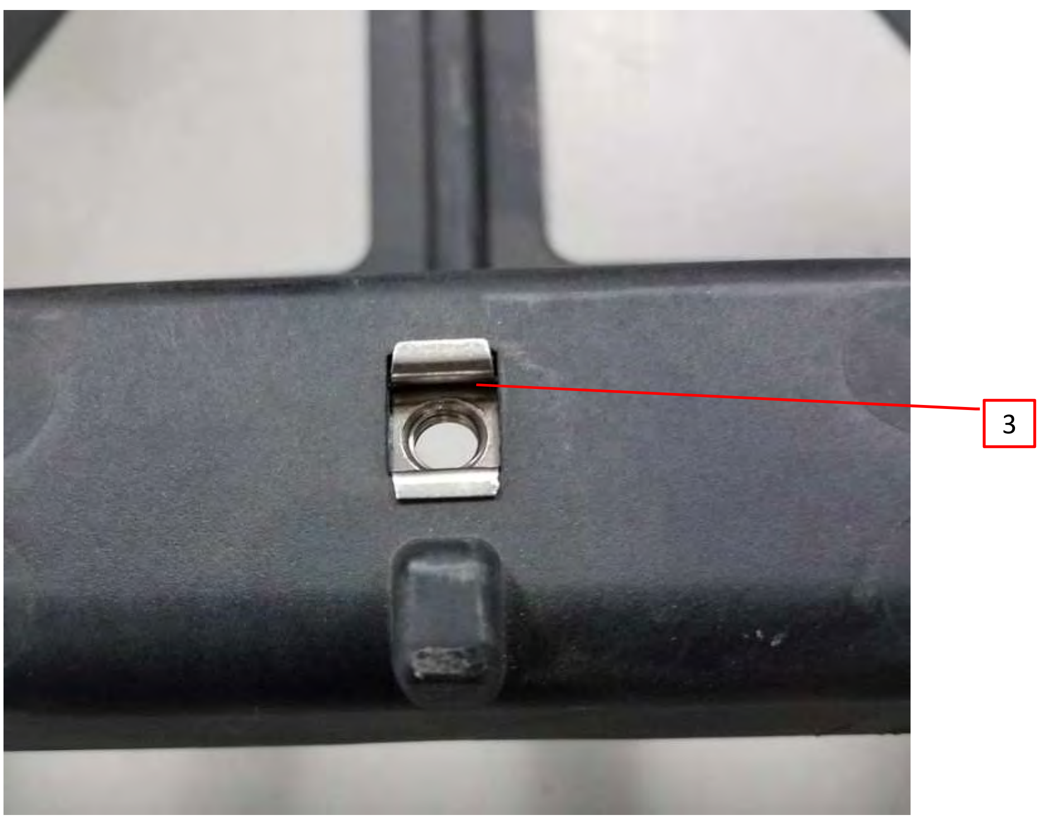


Photo 4- Stainless Steel Cage Nut



3.0 Product Photographs

Photo 5- Aluminum End Clamp

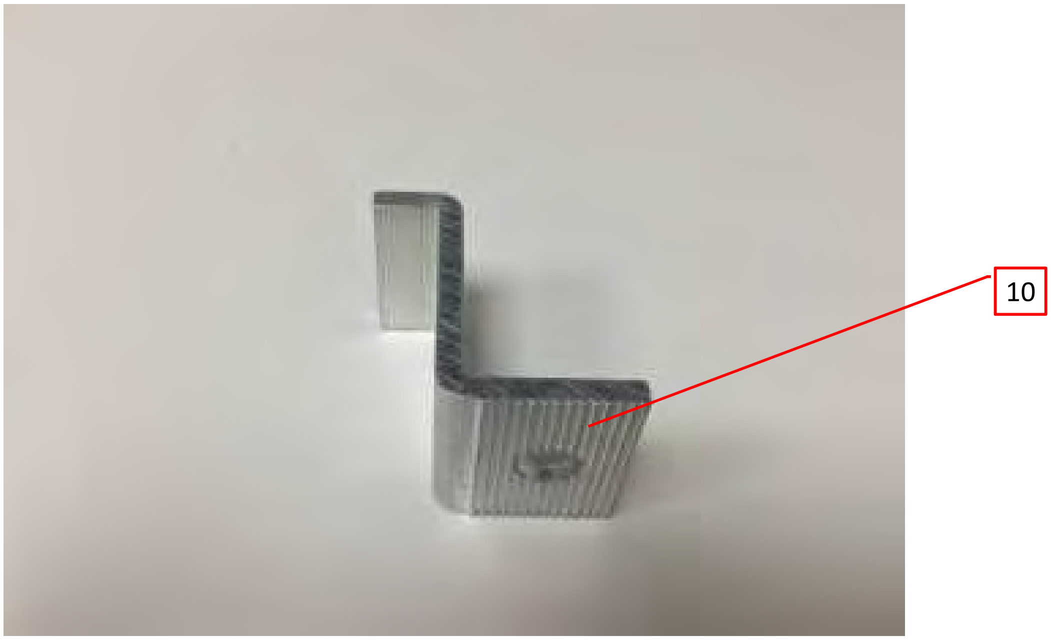
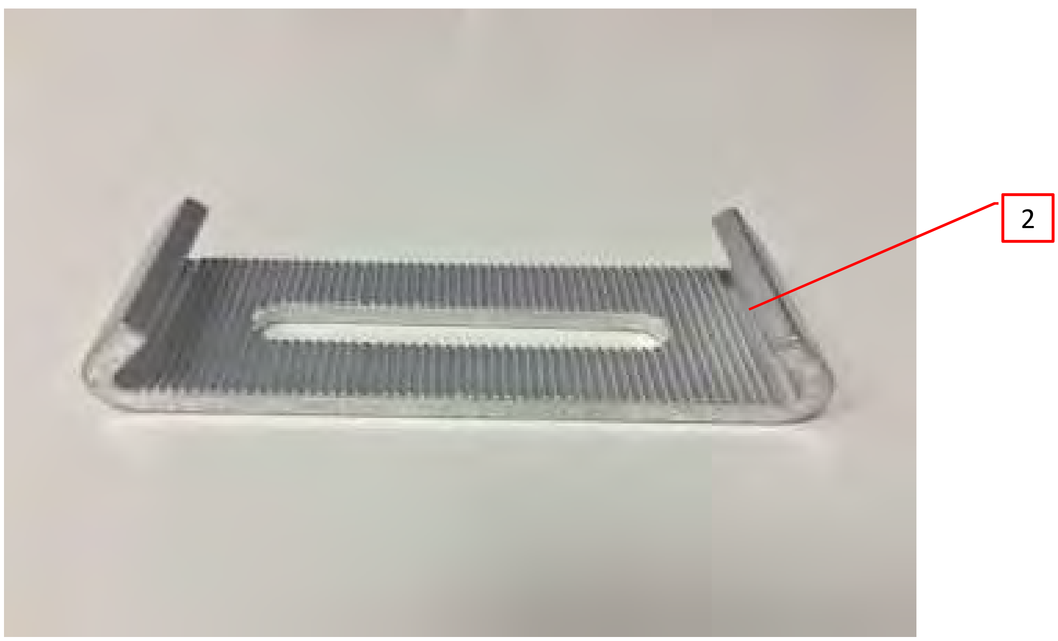


Photo 6- Aluminum Pull Clamp



3.0 Product Photographs

Photo 7- Sollega Slide on clamp

11

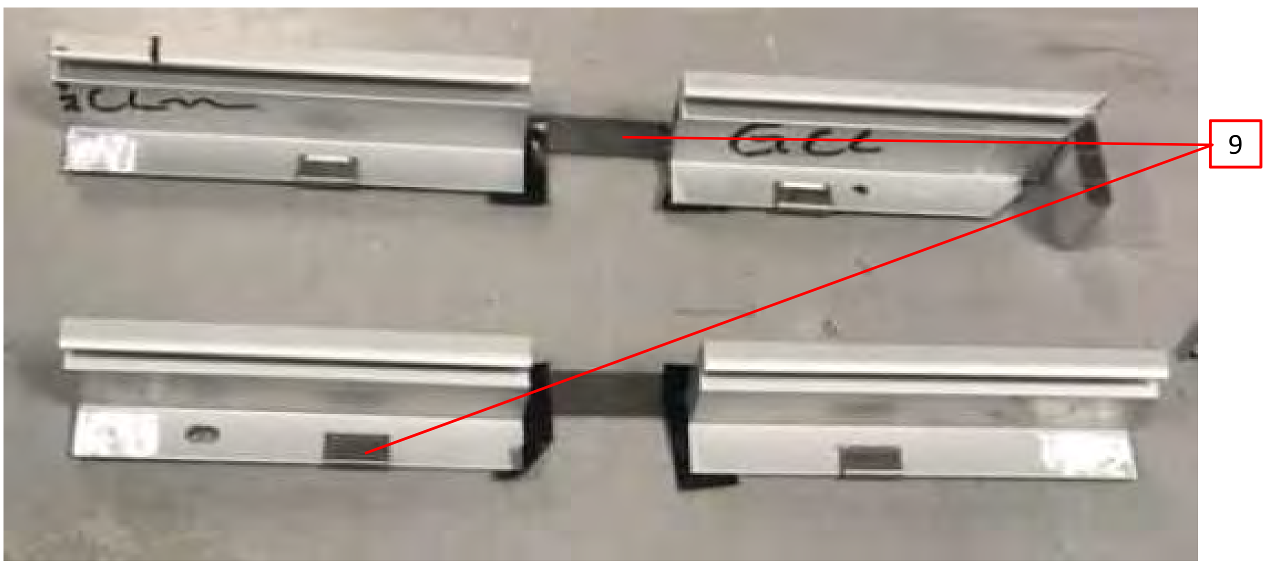
Photo 8- Sollega Slide on Clamp, Cont.

11

3.0 Product Photographs

Photo 9- Mechanical anchor Rail and U-Anchor 2600

Photo 10- Sollega Bonding Jumper Test Samples



3.0 Product Photographs

Photo 11- Grounding Lug

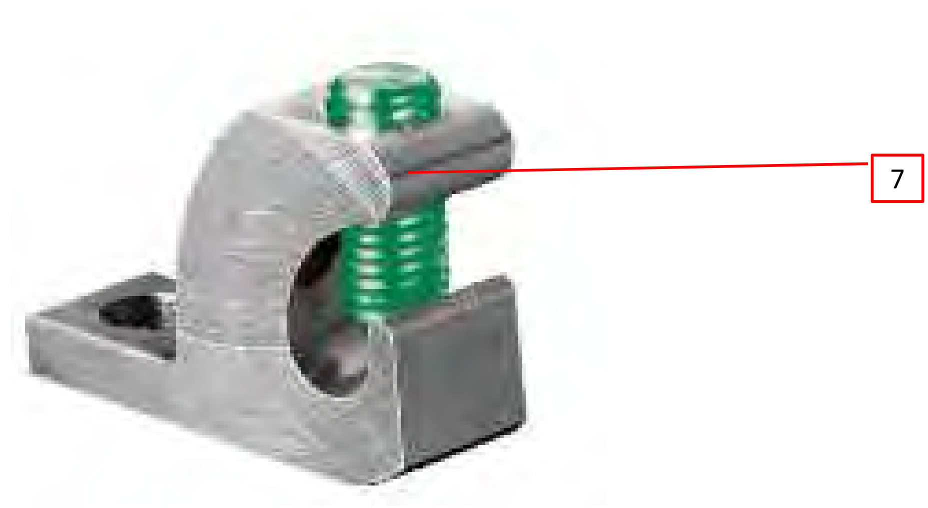
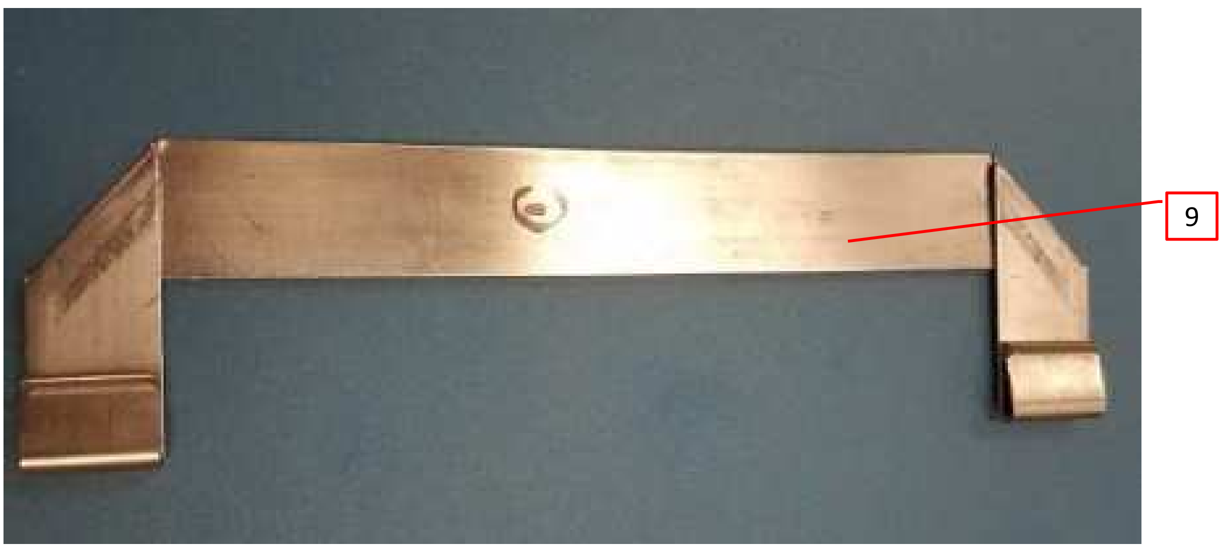


Photo 12- Stainless Steel Sollega Bonding Jumper



4.0 Critical Components						
Photo #	Item no.[1]	Name	Manufacturer/ trademark[2]	Type / model[2]	Technical data and securement means	Mark(s) of conformity [3]
1,2	1	FastRack510	UPM Plastics [E File: E36632]	FR- FastRack510	Material: BASF ULTRAMID 8233GHS as pellets. Glass Reinforced Nylon 6 The assembly consists of the FastRack Chassis, Square Washer, Carriage Bolt 5/16-18 TH, and Flange Nut 5/16-18 SST.See illustration 1c, 1d and 1e	UR
2,6	2	Pull Clamp	Sollega	FR-PC-A	Material: Extruded Aluminum Pull Clamp Secured onto the FastRack510 using the included 5/16-18 SST Flange Nut. used to secure module in conjunction with End Clamp. See illustration 2a and 2b	NR
4	3	Cage Nut	Sollega	FR-CN-S	Material: 300 Series Stainless Steel. 5/16” Threaded Cage used for securment of the grounding Mid Clamp to the FastRack See illustration 3	NR
9	4	L Foot	Sollega	L-Foot	Material: 6000 Series Aluminum Finish: Mill. Used for securment of FastRack. Attach and bond to the rail using T-Bolt/serrated flange nut hardware See illustrations 4	NR

4.0 Critical Components

Photo #	Item no.[1]	Name	Manufacturer/ trademark[2]	Type / model[2]	Technical data and securement means	Mark(s) of conformity[3]
9	5	Rail	Solar Warehouse	Alpha Rail	Material: 6000 Series Aluminum.Finish: Mill or Black for mechanical attachment of racking to the roof structure See illustration 5	NR
3	6	AK MidClamp	A K Stamping Co Inc. [E File: E356152]	AKS-MBC	Material: 300 Series Stainless Steel. Used to bond the module frames. The AKS midclamp was tested with GLC frame and can be used to pierce anodization coating thicknesses up to xxx microns. Max coating piercing leverge: 13.5mic See illustration 6	UR
11	7	Grounding Lug	Ilsco (E354420 and E34440)	GBL-4DBT	The grounding lug kit is secured onto the module mounting hole with stainless bolt/nut/star washer to ground the array. See illustration 7	UL
9	8	Anchor Product Uanchor (Not Shown)	Anchor Products	2000 2400 2600	Used as alternate component to Flat Roof Attachment in flat roof assembly to secure rail to roof via L-foot. See illustration 8	NR

4.0 Critical Components

Photo #	Item no.[1]	Name	Manufacturer/ trademark[2]	Type / model[2]	Technical data and securement means	Mark(s) of conformity[3]
10, 12	9	Slid on Bonding Jumper	Sollega	SPJ	Stainless steel. Used to bond module to module and row to row. Max coating piercing leverge: 28mic Length: 7" See illustration 9	NR
2,5	10	End Clamp	Sollega	EC	Material: Extruded Aluminum End Clamp Secured onto the FastRack510 using the included 5/16-18 SST Flange Nut. Size Range: 1.18" to 1.97" (30 to 50mm) See illustration 10 and 2a	NR
7,8	11	Slid on Pull Clamp	Sollega	SPC	Stainless Steel slide on module rentention clamp and attaches to the FastRack510 using Square Washer, Carriage Bolt 5/16-18 TH, and Flange Nut 5/16-18 SST See illustration 11	NR

NOTES:

1) Not all item numbers are indicated (called out) in the photos, as their location is obvious.

2) “Various“ means any type, from any manufacturer that complies with the "Technical data and securement means" and meets the "Mark(s) of conformity" can be used.

3) Indicates specific marks to be verified, which assures the agreed level of surveillance for the component. "NR" - indicates Unlisted and only visual examination is necessary. "See 5.0" indicates Unlisted components or assemblies to be evaluated periodically refer to section 5.0 for details.

5.0 Critical Unlisted CEC Components

No Unlisted CEC components are used in this report.

6.0 Critical Features

Recognized Component - A component part, which has been previously evaluated by an accredited certification body with restrictions and must be evaluated as part of the basic product considering the restrictions as specified by the Conditions of Acceptability.

Listed Component - A component part, which has been previously Listed or Certified by an accredited Certification Organization with no restrictions and is used in the intended application within its ratings.

Unlisted Component - A part that has not been previously evaluated to the appropriate designated component standard. It may also be a Listed or Recognized component that is being used outside of its evaluated Listing or component recognition.

Critical Features/Components - An essential part, material, subassembly, system, software, or accessory of a product that has a direct bearing on the product's conformance to applicable requirements of the product standard.

Construction Details - For specific construction details, reference should be made to the photographs and descriptions. All dimensions are approximate unless specified as exact or within a tolerance. In addition to the specific construction details described in this Report, the following general requirements also apply.

1. Mechanical Assembly - Components such as switches, fuseholders, connectors, wiring terminals and display lamps are mounted and prevented from shifting or rotating by the use of lockwashers, starwashers, or other mounting format that prevents turning of the component.
2. Corrosion Protection - All metal parts are made of 300 Series Stainless Steel or Aluminum and are corrosion resistant.
3. Grounding - Grounding of the Photovoltaic Modules is achieved through the Module Bonding Jumper and the AKS midclamp. Grounding Lug which is secured to the module frame, accepts the final equipment grounding conductor.
4. Markings - The product is Injection molded on the FastRack (Item 1). See illustration 12 for the example.

   1. Applicant's Name or Brand Name
   2. Model number
   3. Date of manufacturer
   4. Fire rating
   5. Load rating
5. Installation, Operating and Safety Instructions - Instructions for installation and use of this product are provided by the manufacturer. Refer to Sec 2, Product for specific version required to be included with the product.
   e) Maximum Series Fuse Rating of 30 Amps will be marked in the Installation Manual.
   f) Evaluated list of PV modules in section 7.0.

7.0 Illustrations

Illustration 1a - List of approved modules when bonding modules with AK Stamp

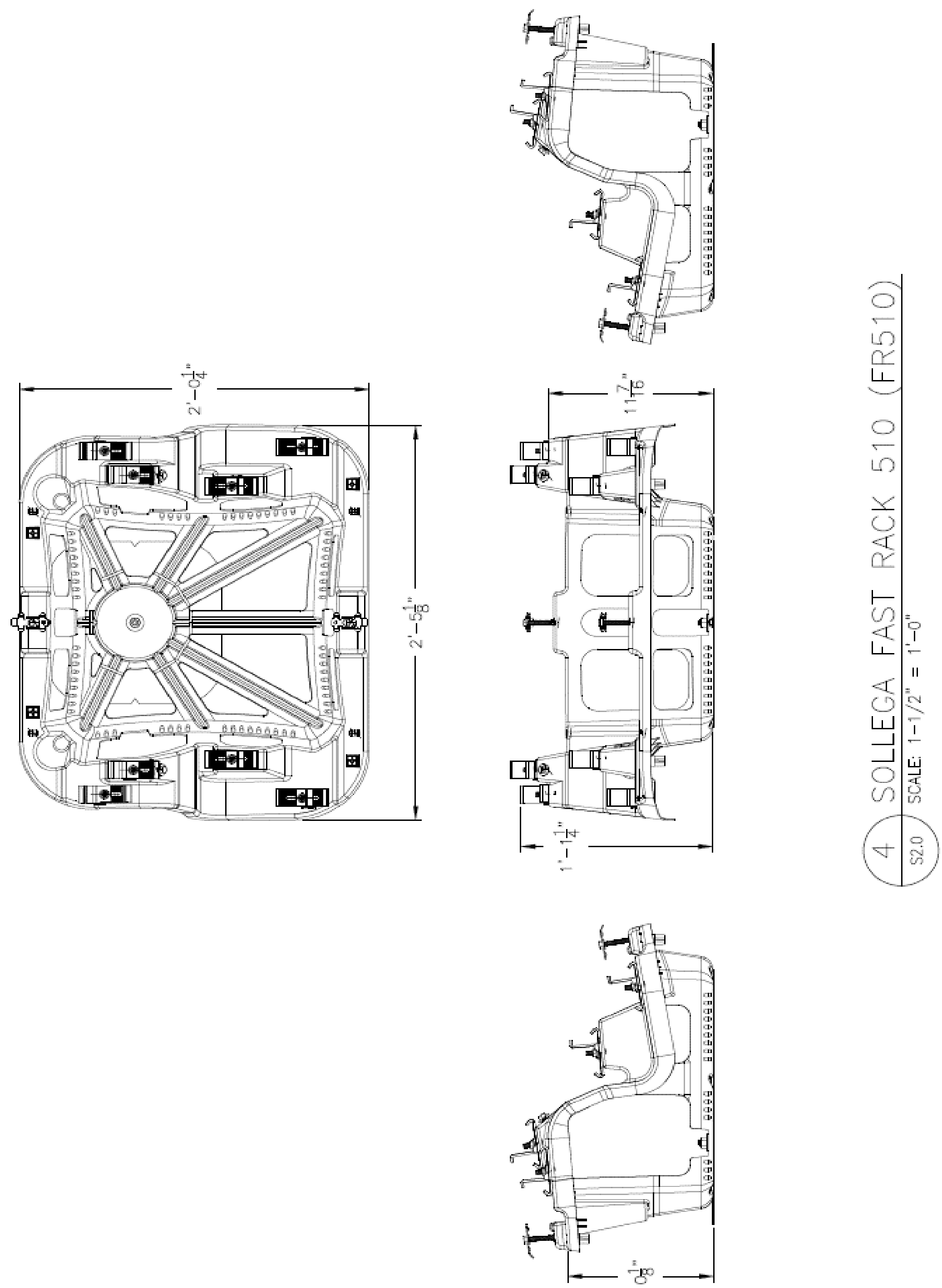
Manufacturer	Model
GCL	M6/72H

Illustration 1b - List of approved modules when bonding modules with Bonding Jumper

Manufacturer	Model
LG	LG335N1C-A5
Q-Cell	G4.4L

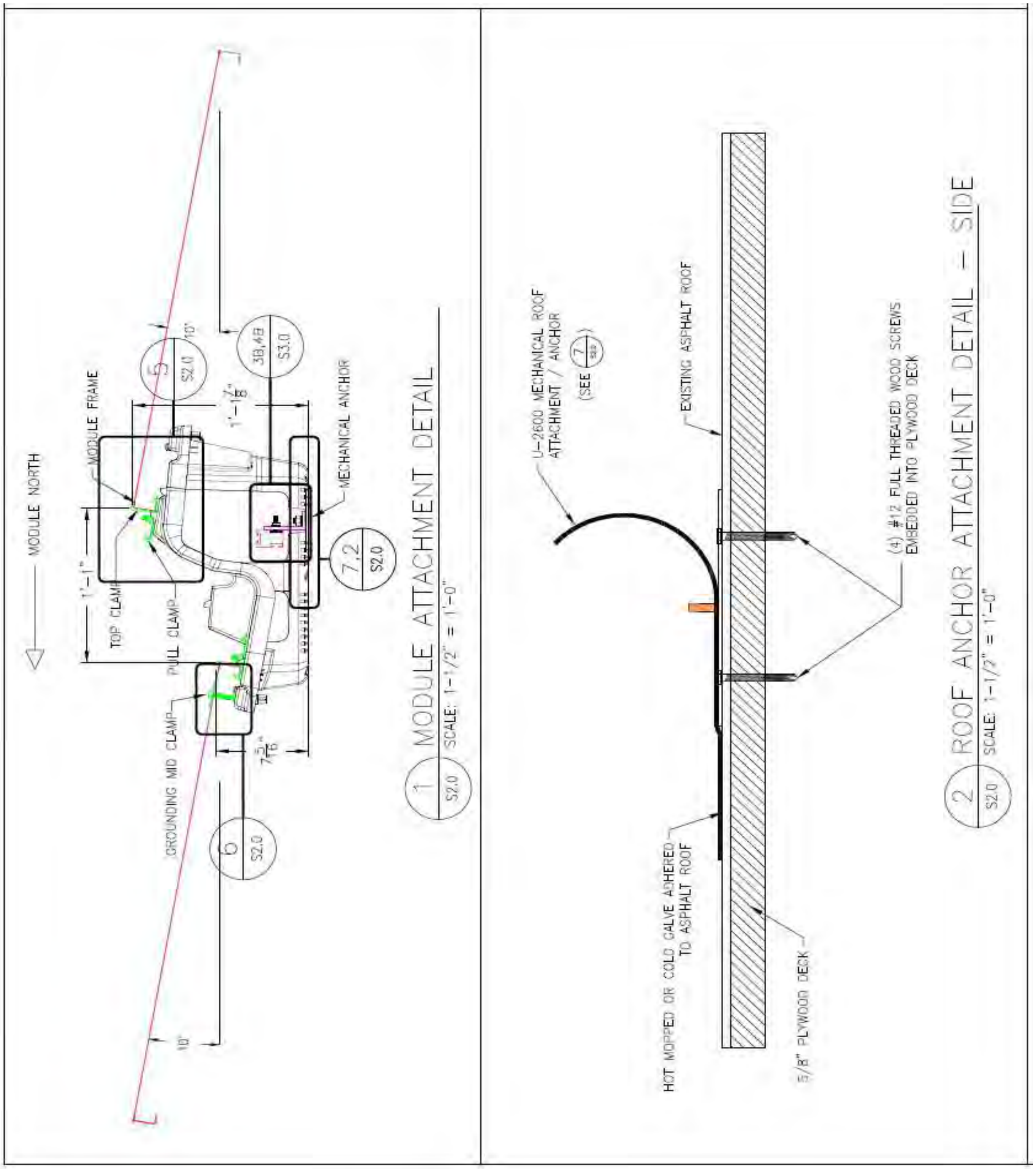
7.0 Illustrations

Illustration 1c- FastRack510



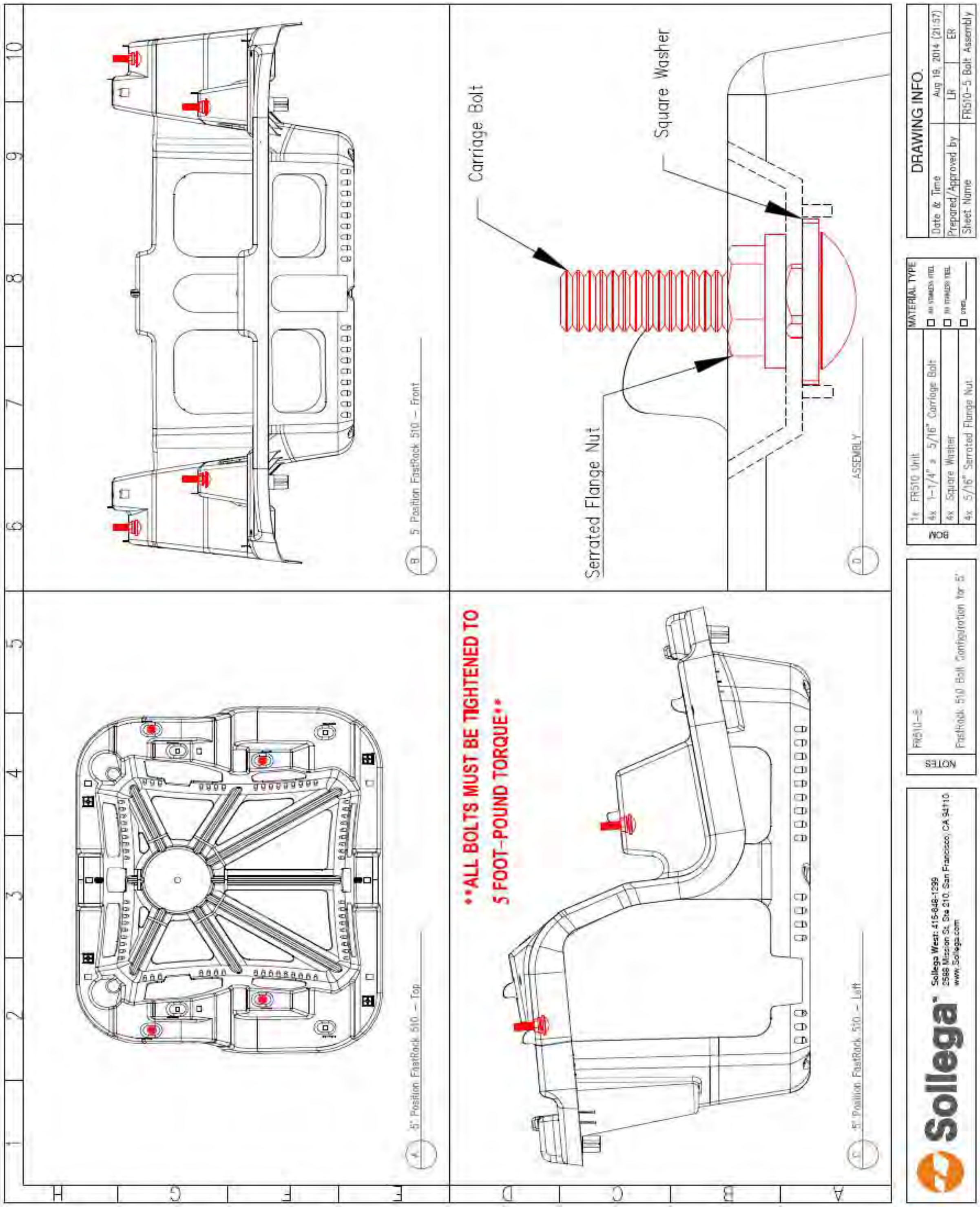
7.0 Illustrations

Illustration 1d- FastRack510, cont.



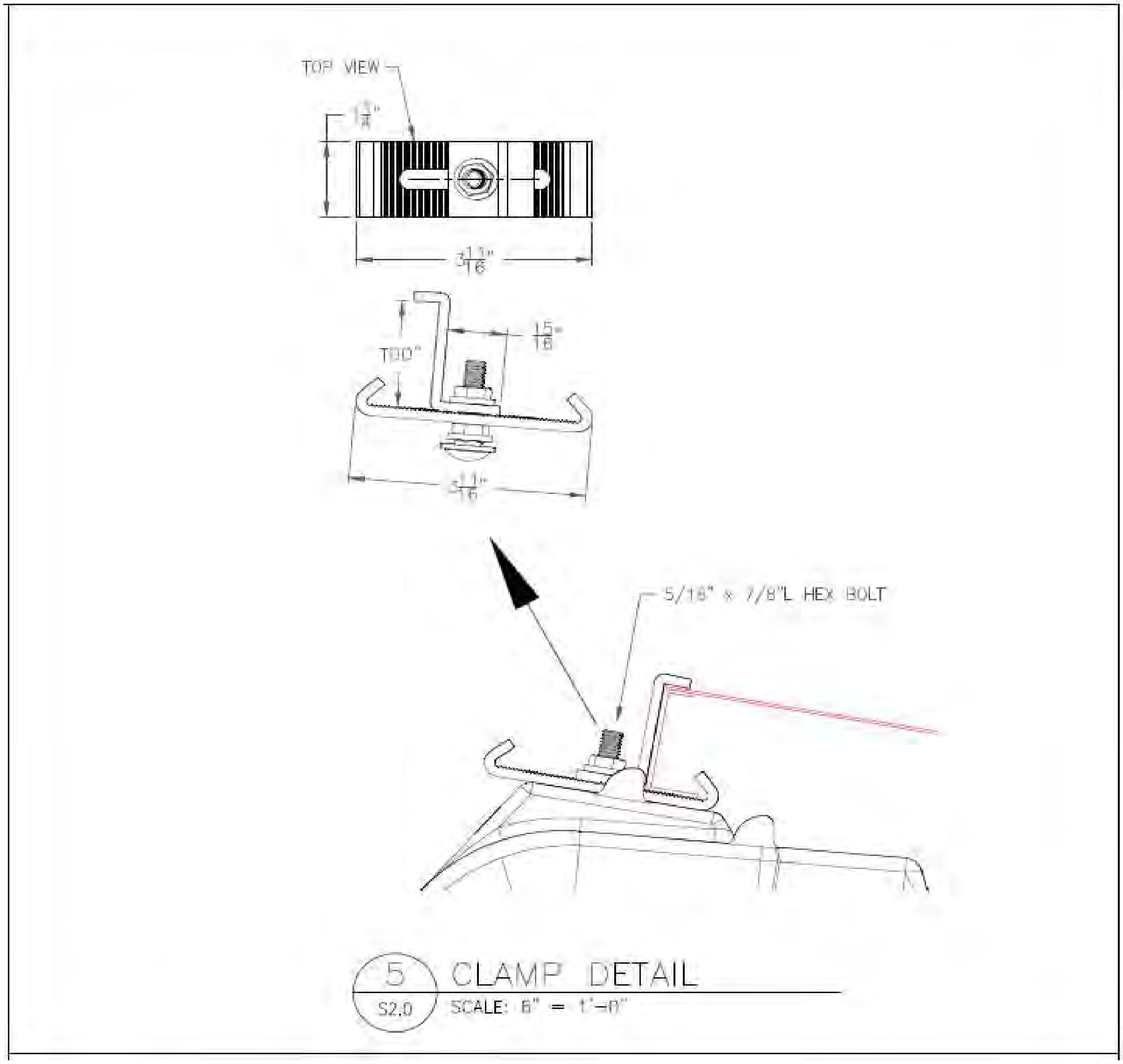
7.0 Illustrations

Illustration 1e- FastRack510, cont.



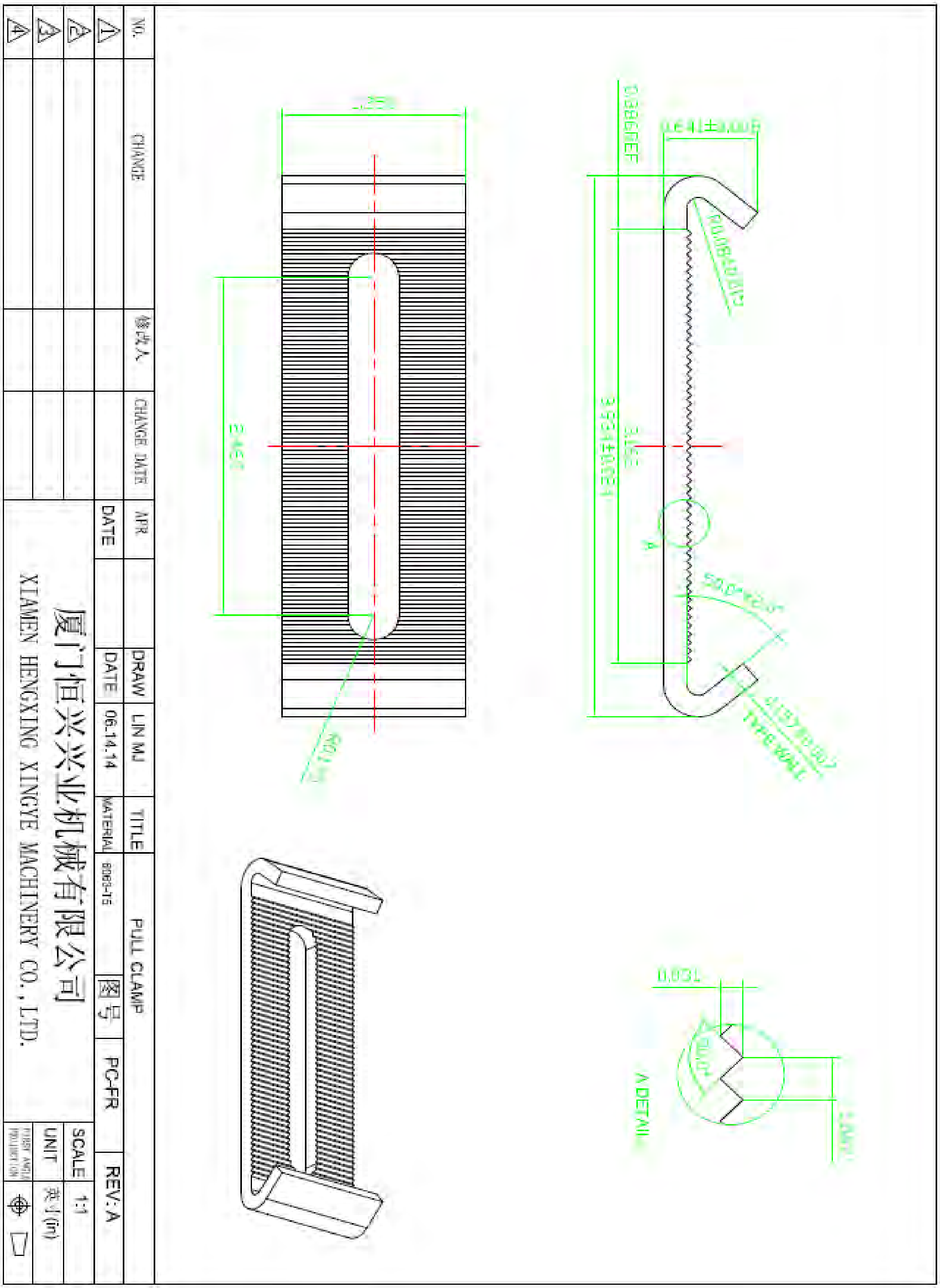
7.0 Illustrations

Illustration 2a- Pull Clamp and End Clamp Assembly



7.0 Illustrations

Illustration 2b- Pull Clamp



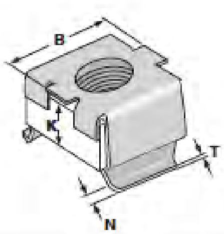
7.0 Illustrations

Illustration 3- Cage Nut

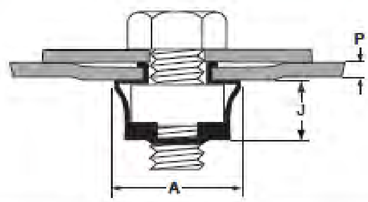
Steel / Spring Steel

Spring Nuts

Nuts



Profile of Typical Assembly



CAGE NUTS

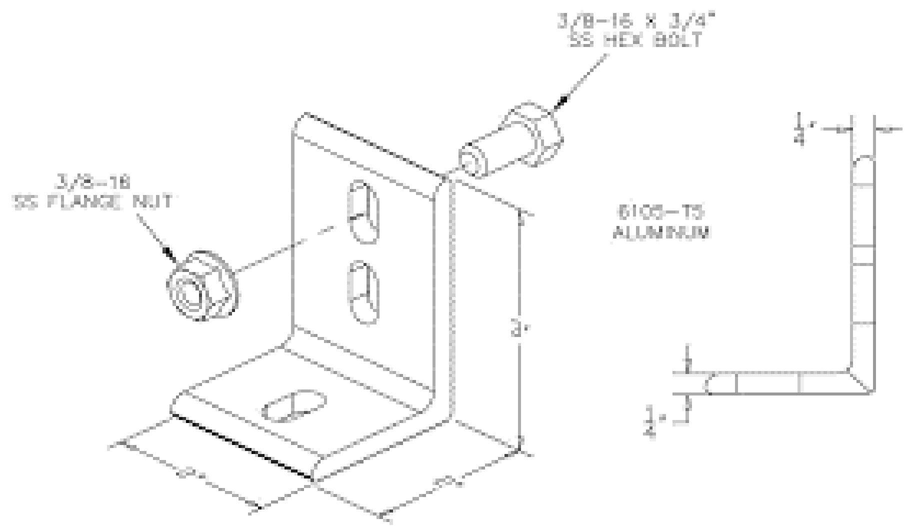
Tinnerman® Palnut

Screw Size	Part Numbers		B		A	J		N		T	K	P	
	Kanebridge	Tinnerman®	Cage Width (Static)		Cage Width (Assembled)	Cage Height		Foot Width		Material Thickness	Nut Thickness	Panel Range	
			Max	Min	Min	Max	Min	Max	Min	Ref	Ref	Max	Min
6-32	06NCAG 0608NCAG	7931-632	.530	.510	.540	.260	.240	.070	.050	.020	.156	.063	.025
8-32	08NCAG	7931-832	.530	.510	.531	.260	.240	.070	.050	.020	.156	.063	.025
10-24	10NCAG	7941-1024	.530	.510	.531	.260	.240	.070	.050	.020	.156	.105	.064
10-32	11NCAG	7931-1032	.530	.510	.531	.260	.240	.070	.050	.020	.156	.063	.025
12-24	12NCAG	7941-1224	.530	.510	.531	.260	.240	.070	.050	.020	.156	.105	.064
1/4-20	14NCAG	7988-1420	.530	.510	.531	.260	.240	.070	.050	.020	.187	.063	.025
5/16-18	31NCAG	7957-5618	.670	.650	.734	.310	.290	.110	.090	.025	.218	.126	.093
3/8-16	37NCAG	7937-3816	.670	.650	.734	.310	.290	.110	.090	.025	.218	.056	.028
3/8-16	37-.057NCAG	7953-3816	.670	.650	.700	.310	.290	.110	.090	.025	.218	.092	.057
3/8-16	37-.093NCAG	7957-3816	.670	.650	.700	.310	.290	.110	.090	.025	.218	.126	.093
1/2-13	50NCAG	7968-1213	.880	.860	.828	.420	.400	.120	.100	.025	.304	.092	.059

Description	A free floating square nut retained within a spring steel cage. The cage has two retaining legs on the same side of the nut, positioned 180° from each other, that hold the nut in place at panel edges or center panel locations.	
Applications/ Advantages	More economical and easier to install than other heavy duty nuts for blind side applications. Free floating nut will compensate for poorly aligned holes. The square cage design keeps the nut from rotating during tightening. Cage nuts are successfully used in heavy duty farm machinery, rail cars, home entetainment components and heating equipment among other applications.	
Material	*Cage*	*Nut*
	SAE 1050 - 1065 spring steel	*6-32 thru 1/4-20:* SAE 1108 or equivalent steel *5/16-18 & 3/8-16:* SAE 1018 or equivalent steel *1/2-13:* SAE 1108 or equivalent steel
Heat Treatment	Parts are quenched from the proper austentizing temperature directly into a salt bath at between 590°F and 710°F. Parts are held at this quench temperature for a recommended period. Parts are then removed from the salt quenched and air cooled to room temperature.	
Hardness	Rockwell C 44 - 51	
Plating	Cage nuts are typically supplied with a zinc plating.	

7.0 Illustrations

Illustration 4- L-Foot



7.0 Illustrations

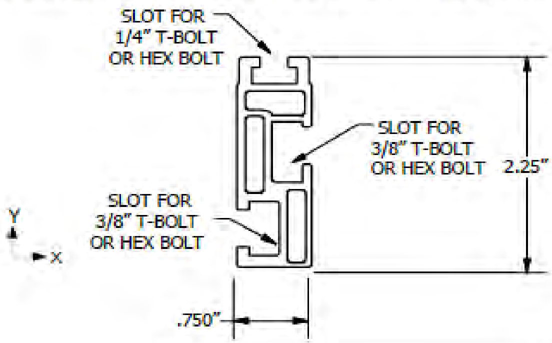
Illustration 5- Alpha Rail

SWH SOLAR WAREHOUSE

SWH Racking System Data Sheet Version 12.10.v2

SWH Solar Mount Rail

MFG-PN: MR-SW-SR-10.5, MR-SW-SR-12, MR-SW-SR-14, MR-SW-SR-14B, MR-SW-SR-17



- **Rail material:** 6063-T5 extruded aluminum alloy
- **Finish:** Clear or black anodized

Properties	Units	Solar Mount
Beam Height	in	2.250
Approximate Weight	plf	0.700
Total Cross Sectional Area	in²	0.588
Area Moment of Inertia X-Axis	in⁴	0.299[1]
Area Moment of Inertia Y-Axis	in⁴	0.038[1]
Tensile Strength	MPa	190.249[1]
Yield Stregth	MPa	165.732[1]
Elongation (G.L.=25mm)	%	17.2
Hardness (HR15T)		71

[1]updated 6/12/2012

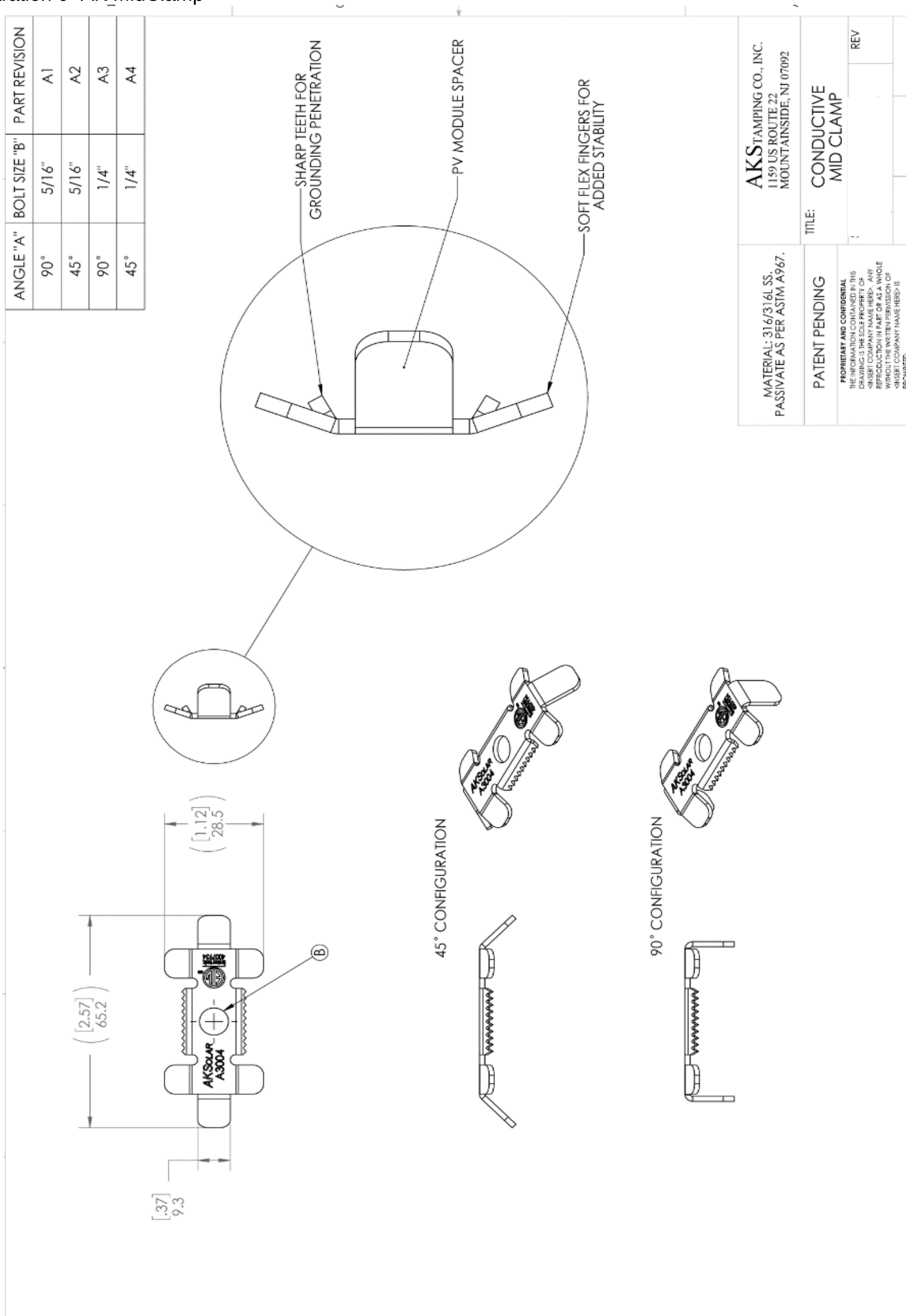
Typical Composition

Material	% Si	% Fe	% Cu	% Mn	% Mg	% Zn	% Ni	% Cr	% Pb	% Sn	% Ti	% Al
6063	0.3972	0.2679	0.0469	0.0666	0.4936	0.0436	0.0056	0.0205	0.0010	0.0044	0.0188	98.6

9628 Valley Blvd. Rosemead, CA 91770 | Phone 626-579-3288 | info@esolarwarehouse.com

7.0 Illustrations

Illustration 6- AK_MidClamp



7.0 Illustrations

Illustration 7- Grounding Lug

ILSCO connections matter

Copper Lay-In Ground Lug
Direct Burial

RoHS Compliant · UL LISTED 667P · SP LR-29801

TYPE
CGBL

Features
- Lay-in feature
- Manufactured from high strength copper
- Stainless steel hardware

Benefits
- Provides ease of installation of continuous loop grounding conductor
- Suitable for direct burial and for use with copper conductors
- Resists oxidation and corrosion in earth or concrete

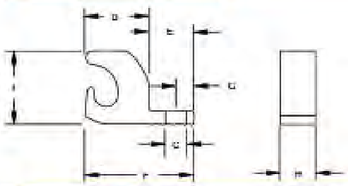


Fig. 1

Fig. 2

Catalog Number	Figure Number	Ground Wire Range	Bolt Size	Dimensions							Screw Type
				C	D	E	F	G	H	T	
GBL-4DB	1	4-14	10	.218	.680	.470	1.150	.190	.375	.825	Slot
GBL-4DB-14	1	4-14	1/4	.265	.680	.470	1.150	.210	.472	.825	Slot
*+ GBL-4DBT	1	4-14	10	.218	.680	.470	1.150	.190	.375	.825	Slot
* GBL-4DBT-14	1	4-14	1/4	.265	.680	.470	1.150	.210	.472	.825	Slot
*+ GBL-4DBTH	2	4-14	10	.218	.680	.470	1.150	.190	.375	.825	Hex
* GBL-4DBTH-14	2	4-14	1/4	.265	.680	.470	1.150	.210	.472	.825	Hex

All wire sizes, unless noted otherwise, are American Wire Gauge (AWG)
Tested to UL 467, UL File E34440
* T indicates tin plating
+ GBL-4DBT and GBL-4DBTH are UL2703 Listed UL E354420 Vol. 2
Optional MH Series mounting hardware kits available, consult ILSCO

G

4730 Madison Road, Cincinnati OH 45227-1426 | PH: 513.533.6200 | FAX: 513.871.4084 | www.ilsco.com
In Canada: 1050 Lakeshore Road East, Mississauga, Ontario, Canada L5E 1E4 | PH: 905.274.2341 | FAX: 905.274.8763

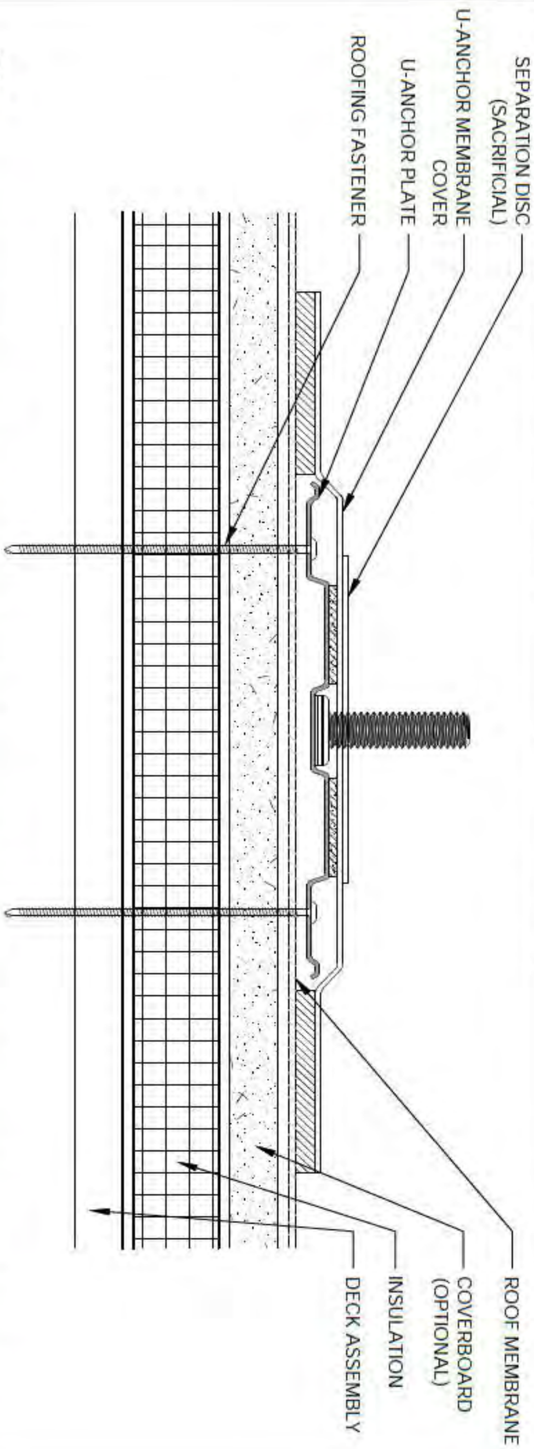
7.0 Illustrations

Illustration 8- Anchor Products

ANCHOR PRODUCTS™
PO Box 1551
Colleyville, TX 76034
www.anchorp.com
(888) 575-2131

Title: **U-Anchor U2600, Mechanically Attached, Modified Bitumen (APP, SBS, SBS Torch)**

DRAWN BY: ANCHOR PRODUCTS TECHNICAL SUPPORT	
REQUEST DATE:	CATEGORY: **Mod Bit**
REVISION DATE: 03/01/19	DRAWING NO.: **AP.2600.MB.MA.01a**
SCALE: NTS	

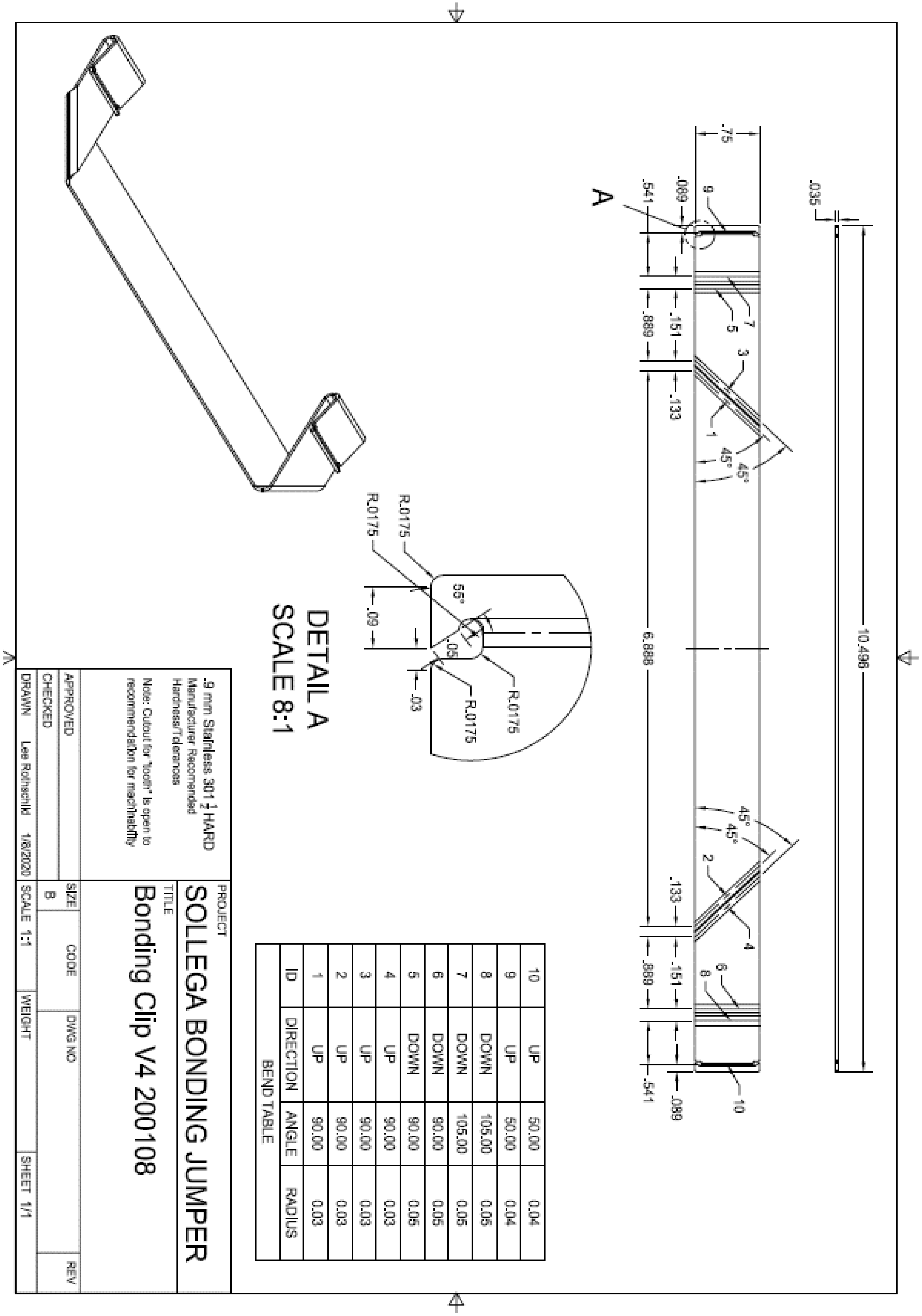


Notes:

1. ANCHOR PRODUCTS DETAIL DRAWINGS: REFER TO THE ROOFING AND FASTENER MANUFACTURERS AND OTHER RELATED PUBLISHED DOCUMENTATION, PRODUCT DATA SHEETS (PDS) AND SAFETY DATA SHEETS (SDS) FOR ADDITIONAL INFORMATION. ALL DETAIL DRAWINGS AND RELATED INSTALLATION GUIDELINES ARE PROVIDED BY ANCHOR PRODUCTS FOR THE SOLE PURPOSE OF CONVEYING ASSEMBLY STRUCTURE. ACCORDINGLY, THE DETAIL DRAWINGS ARE NOT OFFERED, AND SHOULD NOT BE CONSIDERED, AS A SUBSTITUTE FOR PROFESSIONAL DESIGN SERVICES.
2. TO ENSURE WARRANTIES CAN BE MAINTAINED, MOST ROOFING MANUFACTURERS REQUIRE THE FLASHING BE MADE OF THE SAME TYPE AND BRAND. MOST ROOFING MANUFACTURERS REQUIRE THAT THE INSTALLATION OF THE U-ANCHOR BE PERFORMED BY AN AUTHORIZED CONTRACTOR.
3. FASTENERS MUST BE INSTALLED PER THE FASTENER MANUFACTURER'S REQUIREMENTS FOR EACH SPECIFIC DECK TYPE FOR POSITIONING, DECK PENETRATION DEPTH, AND OTHER NECESSARY STANDARDS.
4. FOR PROPER INSTALLATION OF THE COVER MEMBRANE, FOLLOW THE ROOFING MANUFACTURER'S REQUIREMENTS FOR PROPER TORCH TECHNIQUES / COLD ADHESIVE APPLICATION RATES FOR PROPER BLEEDOUT. ADDITIONAL LAYERS MAY BE REQUIRED PER THE ROOFING MANUFACTURER. MAKE SURE TO FOLLOW THE SPECIFICATION FOR EACH BRAND TO MEET WARRANTY REQUIREMENTS.
5. AREA MUST BE PRIMED PER THE ROOFING MANUFACTURER'S REQUIREMENTS. MOST ROOFING MANUFACTURERS REQUIRE THEIR SPECIFIC BRAND OF PRIMER APPLIED AT THE SPECIFIED RATE.
6.

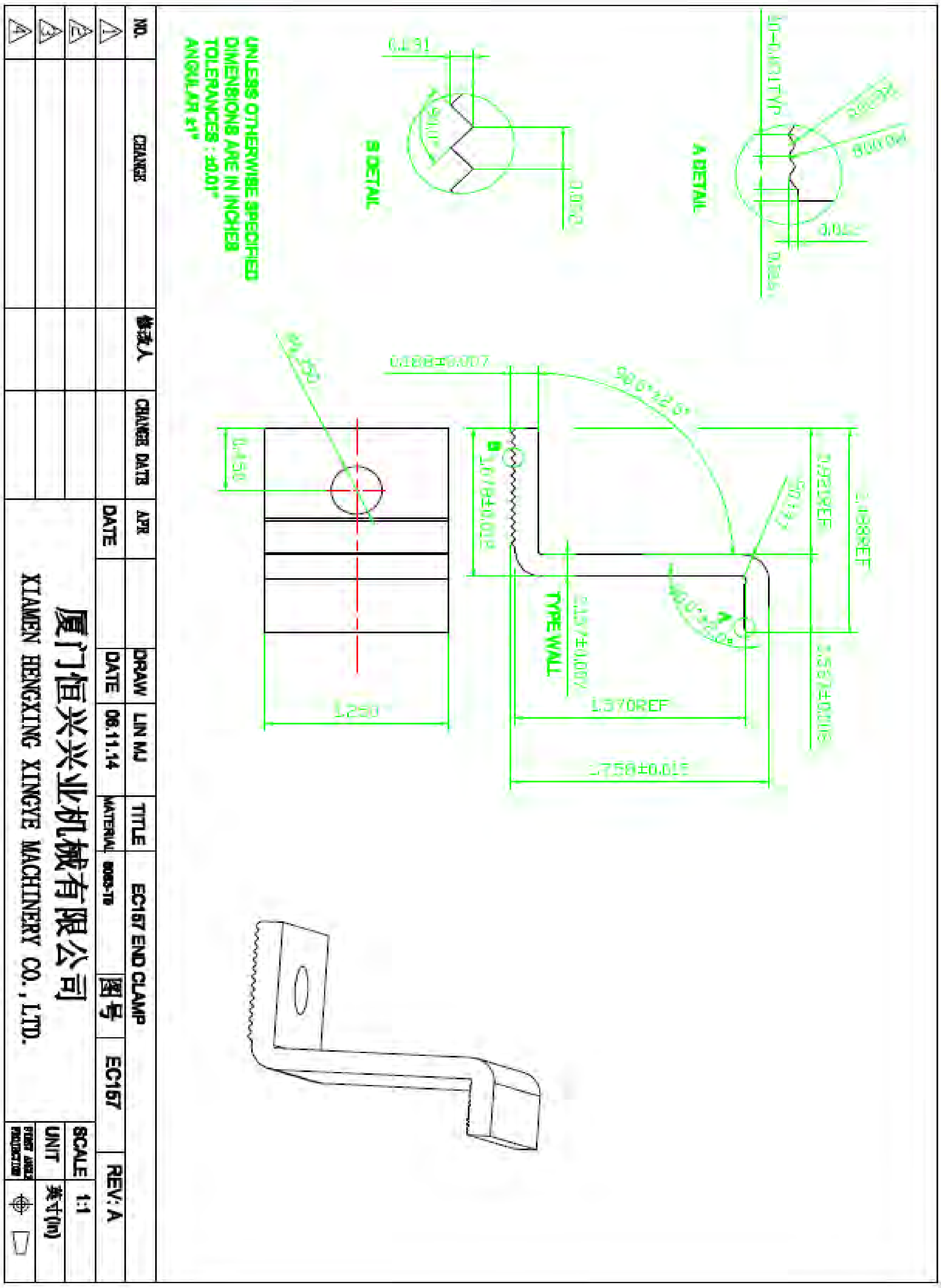
7.0 Illustrations

Illustration 9- Slid on Bonding Jumper



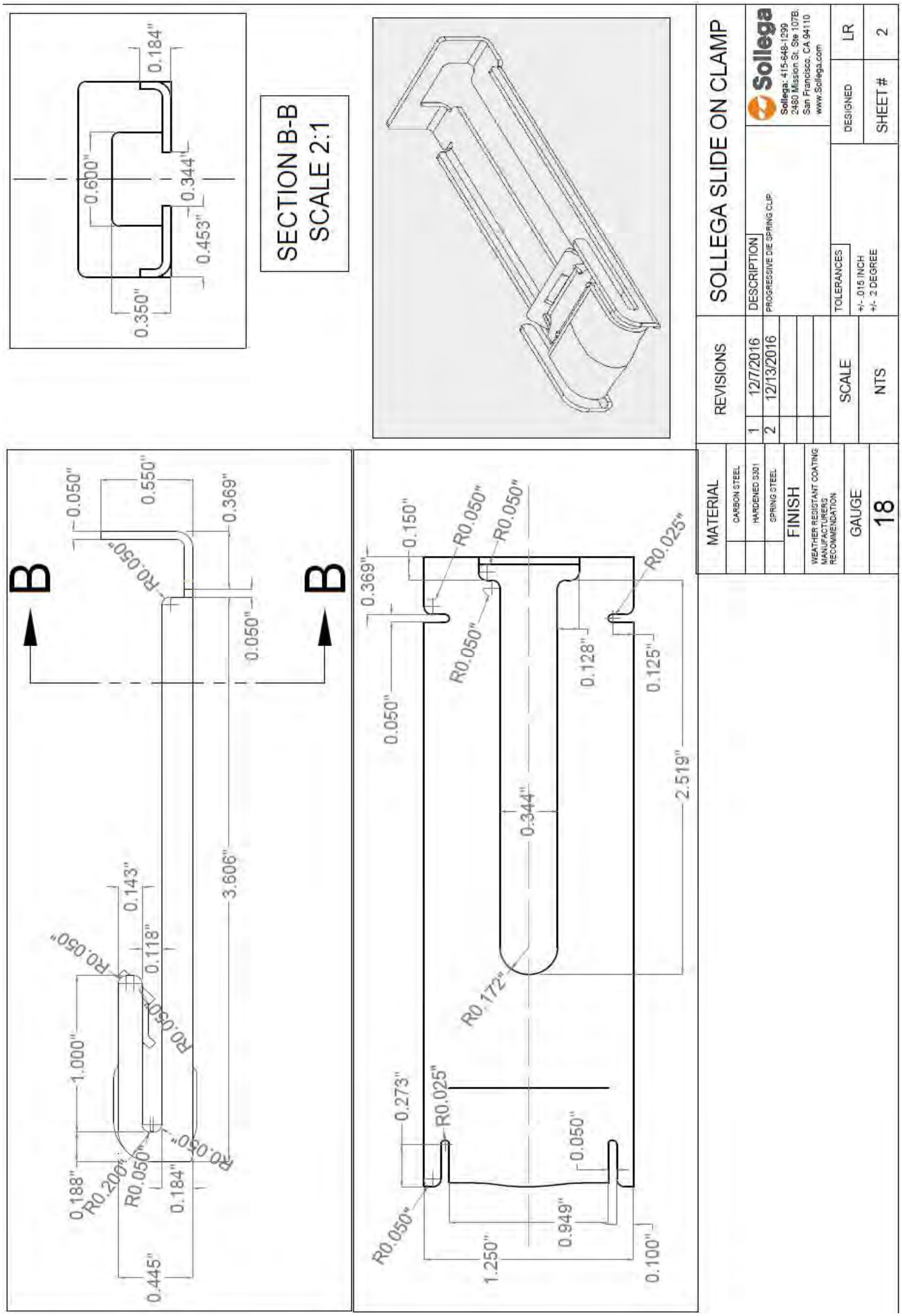
7.0 Illustrations

Illustration 10- End Clamp



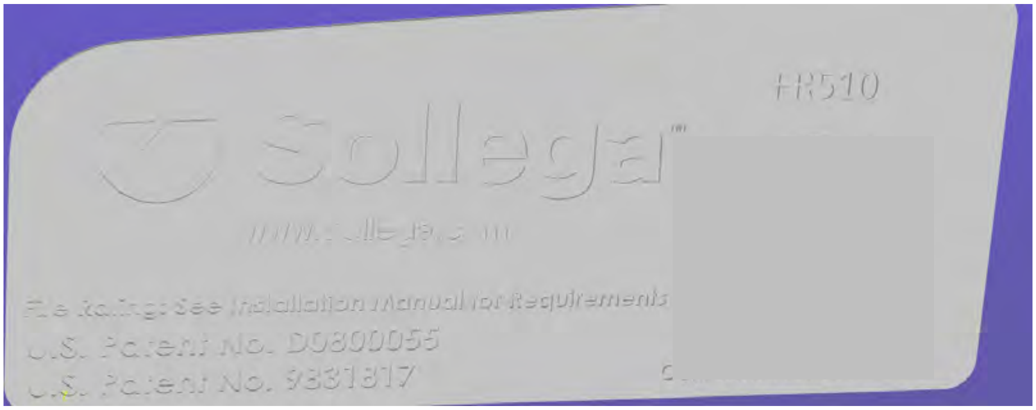
7.0 Illustrations

Illustration 11- Slid on Pull Clamp



7.0 Illustrations

Illustration 12- Label Example



8.0 Test Summary					
Evaluation Period	12-04-2017- 01-25-20			Project No.	G103282591
Sample Rec. Date	1-Dec-2017	Condition	Production	Sample ID.	LAN1712041518-001
Test Location	25791 Commercentre Drive, Lake Forest, CA 92630 USA				
Test Procedure	Testing Lab				

Determination of the result includes consideration of measurement uncertainty from the test equipment and methods. The product was tested as indicated below with results in conformance to the relevant test criteria.

The following tests were performed:

Test Description	UL 2703
Bonding Path Resistance	13
Temperature Cycling Test	17
Humidity Freeze Test	18
Mechanical Load Test	21
Bonding Conductor Test	22

Evaluation Period	10/2/2017			Project No.	G103246455
Sample Rec. Date	NA	Condition	Production	Sample ID.	NA
Test Location	8431 Murphy Drive, Middleton WI 53562				
Test Procedure	Testing Lab				

Determination of the result includes consideration of measurement uncertainty from the test equipment and methods. The product was tested as indicated below with results in conformance to the relevant test criteria.

The following tests were performed at Intertek Middleton, WI under report number 103246455MID-001 Class A for Low Slope Roof Applications when using Type 3, Listed Photovoltaic Module.

Test Description	UL2703	UL1703
Fire Testing	15	31

8.1 Signatures			
A representative sample of the product covered by this report has been evaluated and found to comply with the applicable requirements of the standards indicated in Section 1.0.			
Completed by:	Faraz Ebneali	Reviewed by:	Abhinav Prakash
Title:	Engineer	Title:	Reviewer
Signature:	*Signature on file*	Signature:	*Signature on file*

9.0 Correlation Page For Multiple Listings

The following products, which are identical to those identified in this report except for model number and Listee name, are authorized to bear the ETL label under provisions of the Intertek Multiple Listing Program.

BASIC LISTEE	Sollega Inc.
Address	2480 Mission St. Suite 107b San Francisco CA, 94110
Country	USA
Product	Photovoltaic Racking System installed using FastRack 510 installation manual 10° version- Revision 1/1/2020

MULTIPLE LISTEE 1	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	

MULTIPLE LISTEE 1 MODELS	BASIC LISTEE MODELS

MULTIPLE LISTEE 2	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	

MULTIPLE LISTEE 2 MODELS	BASIC LISTEE MODELS

MULTIPLE LISTEE 3	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	

MULTIPLE LISTEE 3 MODELS	BASIC LISTEE MODELS

10.0 General Information

The Applicant and Manufacturer have agreed to produce, test and label ETL Listed products in accordance with the requirements of this Report. The Manufacturer has also agreed to notify Intertek and to request authorization prior to using alternate parts, components or materials.

COMPONENTS
Components used shall be those itemized in this Intertek report covering the product, including any amendments and/or revisions.

LISTING MARK
The ETL Listing mark applied to the products shall either be separable in form, such as labels purchased from Intertek, or on a product nameplate or other media only as specifically authorized by Intertek. Use of the mark is subject to the control of Intertek.

The mark must include the following four items:

1) applicable country identifiers "US" and/or "C" or "US", "C" and "EU"
2) the word "Listed" or "Classified" or "Recognized Component" (whichever is appropriate)
3) a control number issue by Intertek
4) a product descriptor that identifies the standards used for certification. Example:

For US standards, the words, “Conforms to” shall appear with the standard number along with the word, “Standard” or “Std.” Example: “Conforms to ANSI/UL Std. XX.”

For Canadian standards, the words “Certified to CAN/CSA Standard CXX No. XX.” shall be used, or abbreviated, “Cert. to CAN/CSA Std. CXX No. XX.”

Can be used together when both standards are used.

Note: A facsimile must be submitted to Intertek, Attn: Follow-up Services for approval prior to use.
The facsimile need not have a control number. A control number will be issued **after signed Certification Agreements** have been received by the Follow-up Services office, approval of the facsimile of your proposed Listing Mark, satisfactory completion of the Listing Report, and scheduling of a factory assessment in your facility.

MANUFACTURING AND PRODUCTION TESTS
Manufacturing and Production Tests shall be performed as required in this Report.

FOLLOW-UP SERVICE
Periodic unannounced audits of the manufacturing facility (and any locations authorized to apply the mark) shall be scheduled by Intertek. An audit report shall be issued after each visit. Special attention will be given to the following:

1. Conformance of the manufactured product to the descriptions in this Report.
2. Conformance of the use of the ETL mark with the requirements of this Report and the Certification Agreement.
3. Manufacturing changes.
4. Performance of specified Manufacturing and Production Tests.

In the event that the Intertek representative identifies non-conformance(s) to any provision of this Report, the Applicant shall take one or more of the following actions:

1. Correct the non-conformance.
2. Remove the ETL Mark from non-conforming product.
3. Contact the issuing product safety evaluation center for instructions.

10.1 Evaluation of Unlisted Components

Because Unlisted Components are uncontrolled, and they do not fall under a third party follow up program, Intertek may require these components to be tested and/or evaluated at least once annually, more often for certain components, as part of the independent certification process. The Unlisted Components in Section 5.0 require testing and/or evaluation as indicated.

Note to Intertek Follow Up Inspector: The Component Evaluation Center, CEC, will notify you in writing when these components must be selected and sent to the CEC for re-evaluation

Ship the samples to:
Intertek Testing Services NA Inc.
ETL Component Evaluation Center
45000 Helm Street, Suite 150
Plymouth Twp., MI 48170 USA
Attn: Component Evaluation Center
Sample Disposition: Due to the destructive nature of the testing, all samples will be discarded at the conclusion of testing unless, the manufacturer specifically requests the return of the samples. The request for return must accompany the initial component shipment.

11.0 Manufacturing and Production Tests

The manufacturer agrees to conduct the following Manufacturing and Production Tests as specified:

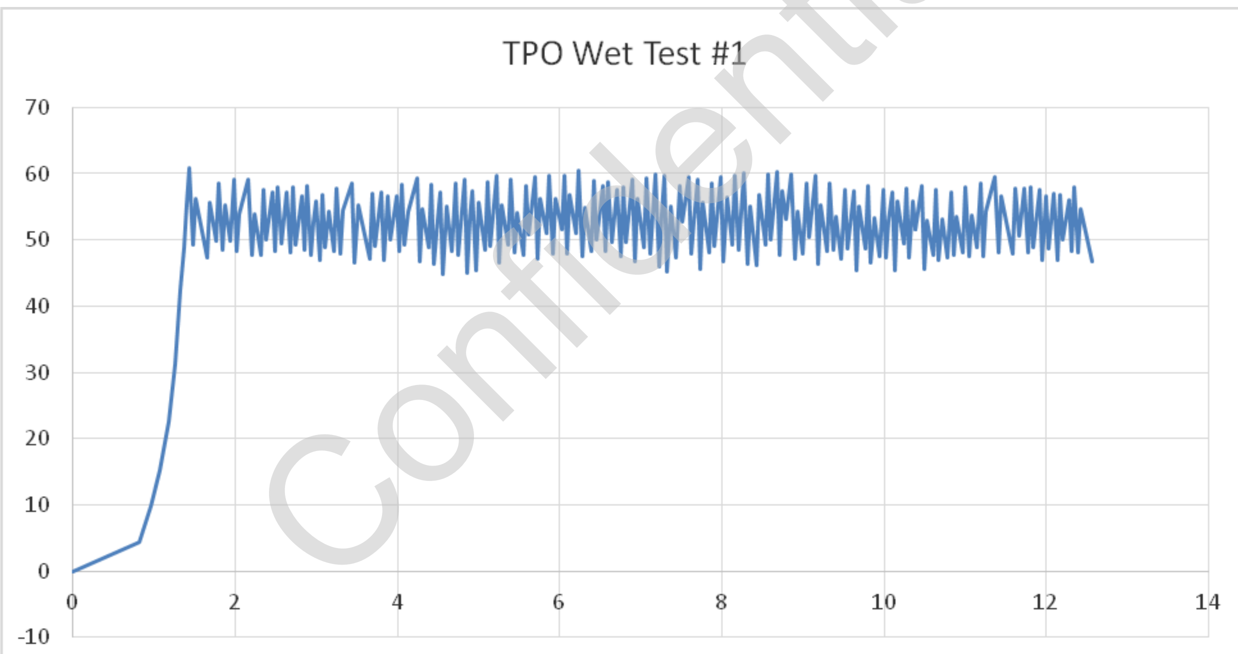
Required Tests

None.

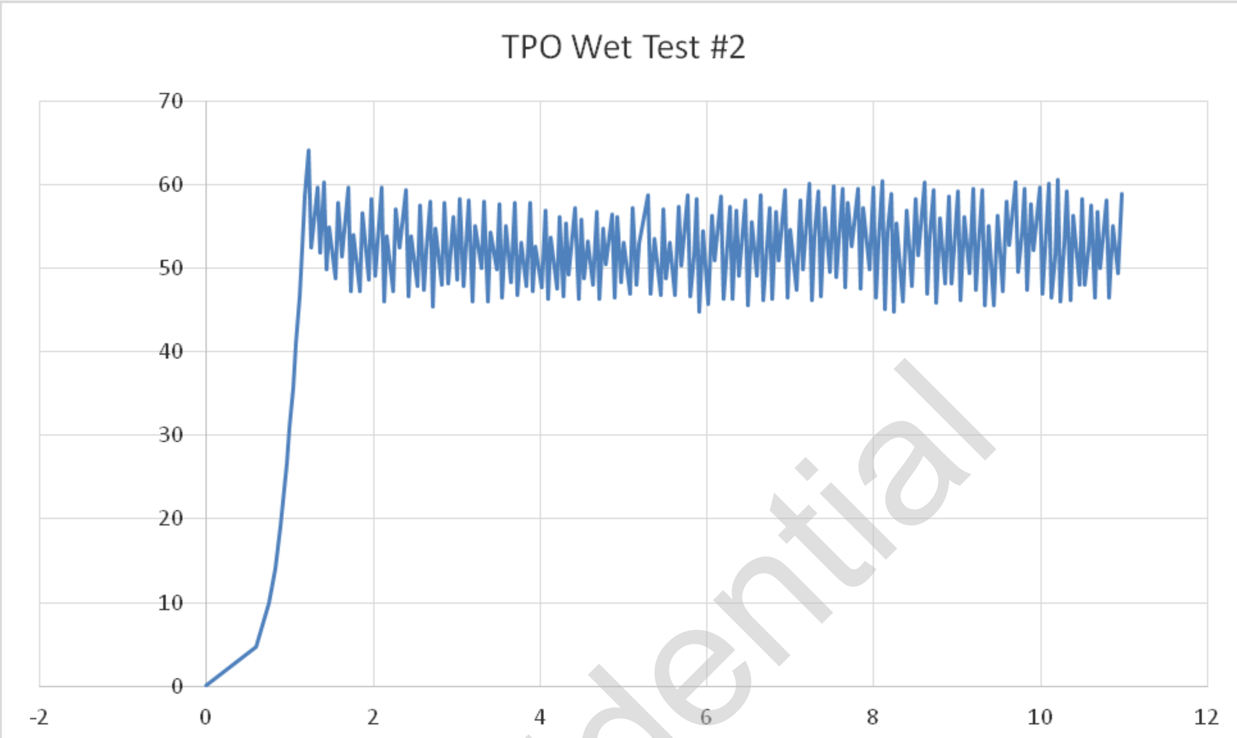
12.0 Revision Summary				
The following changes are in compliance with the declaration of Section 8.1:				
Date/ Proj # Site ID	Project Handler/ Reviewer	Section	Item	Description of Change
27-Feb-2020	V. Covarrubias	1	-	Corrected applicant address from: 2480 Mission St. Suite 107b CA, 94110 to: 2480 Mission St. Suite 107b San Francisco, CA 94110, USA.
G104263552SVN	D. Tesfaye			Updated manufacturer info **Name -** from: UPM Plastics to: Universal Plastic Mold Inc. **Address -** from: 13245 Los Angeles St. CA, 91706 to: 13245 Los Angeles St. Baldwin Park, CA 91706.

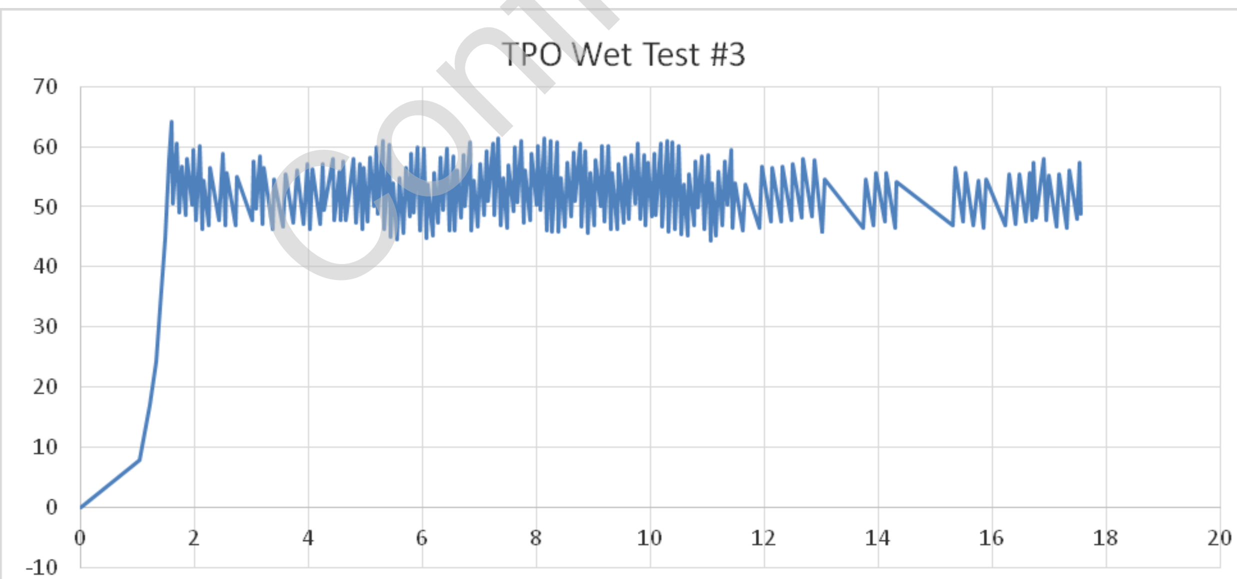
Test Results

TPO Wet				
Specimen	*Friction*	*Force (lbs)*	*Weight (lbs)*	*Cof*
TPO Wet Test #1	Static	60.9	89	0.68
TPO Wet Test #1	Kinetic	52.8	89	0.59
TPO Wet Test #2	Static	59.7	89	0.67
TPO Wet Test #2	Kinetic	52.5	89	0.59
TPO Wet Test #3	Static	64.2	89	0.72
TPO Wet Test #3	Kinetic	52.4	89	0.59
Average	**Static**	**61.6**	**89**	**0.69**
Average	**Kinetic**	**52.6**	**89**	**0.59**



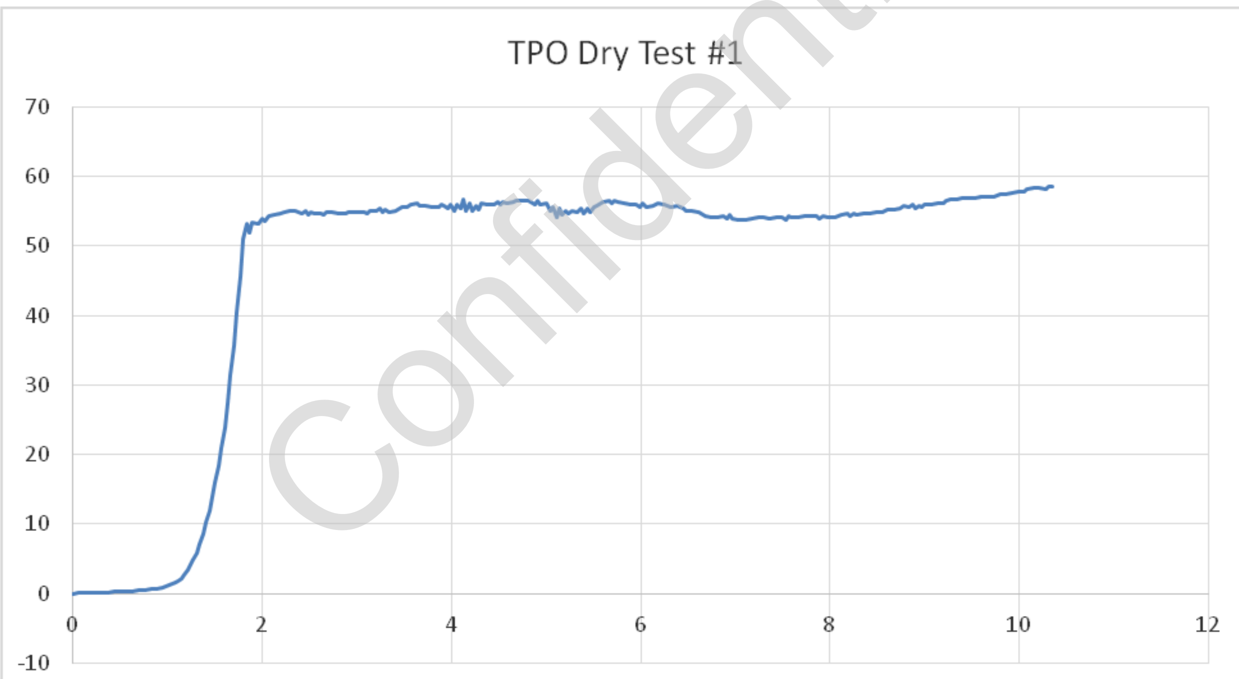
TPO Wet Testing Results (Continued)



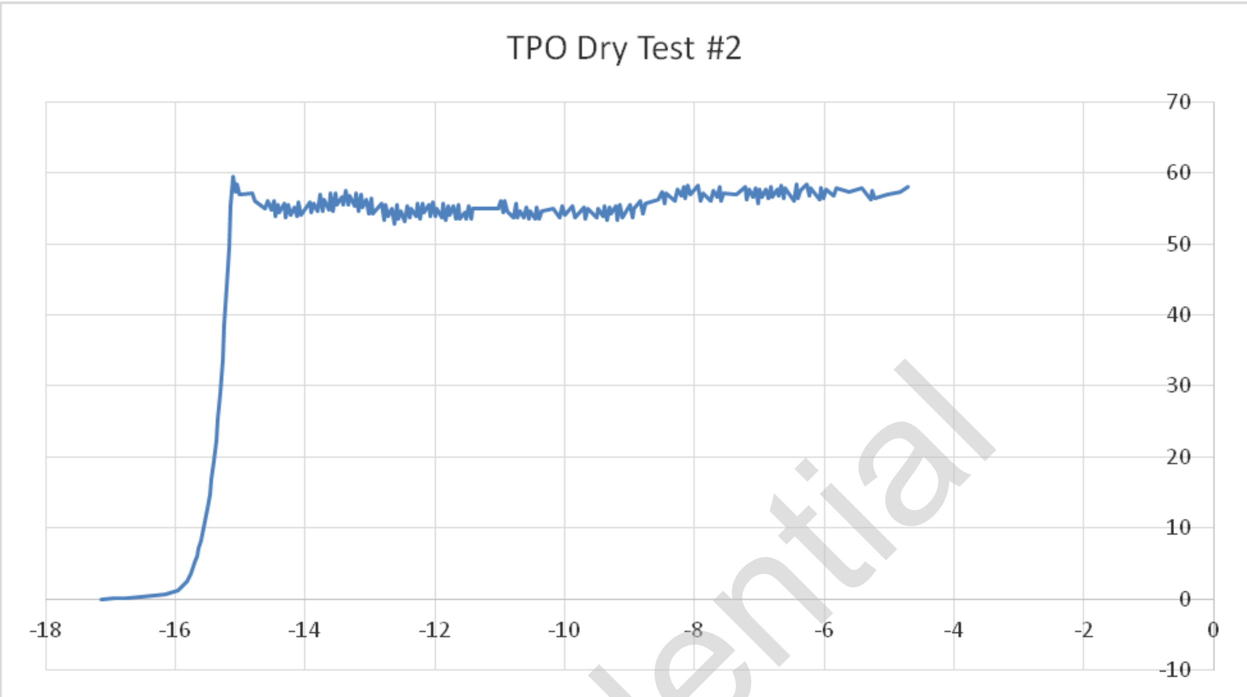


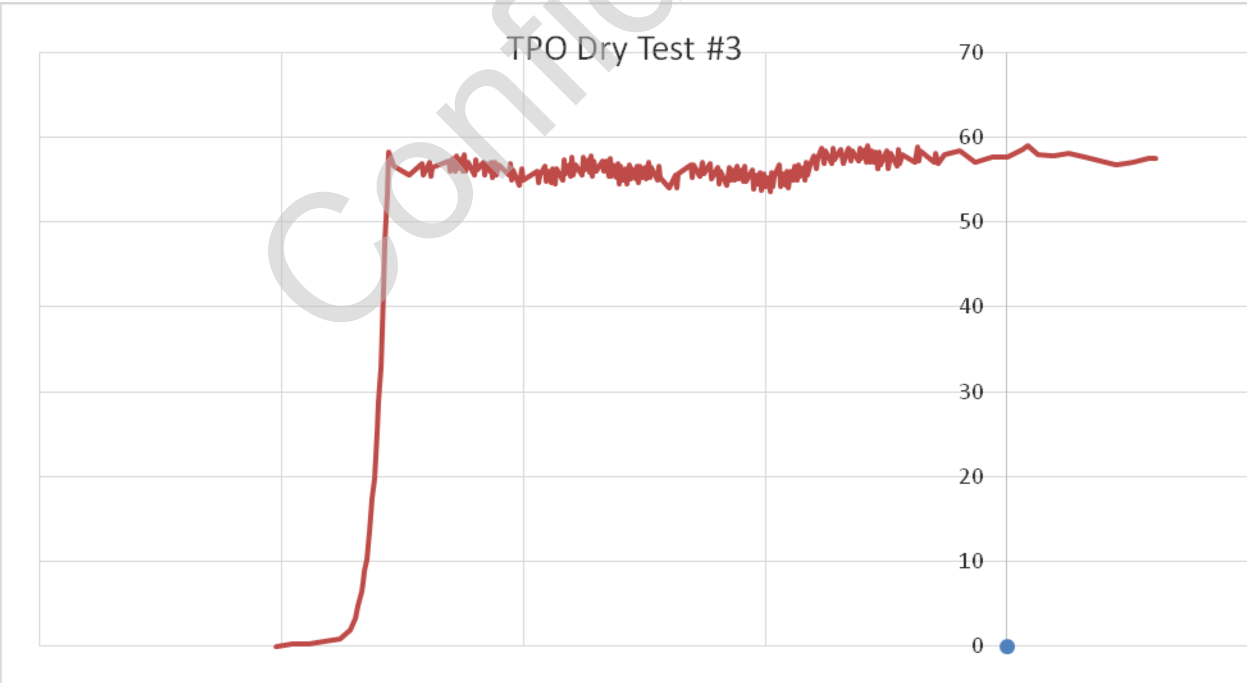
TPO Dry Testing Results

TPO Dry				
Specimen	*Friction*	*Force (lbs)*	*Weight (lbs)*	*Cof*
TPO Dry Test #1	Static	53.2	89	0.60
TPO Dry Test #1	Kinetic	55.5	89	0.62
TPO Dry Test #2	Static	59.6	89	0.67
TPO Dry Test #2	Kinetic	55.6	89	0.62
TPO Dry Test #3	Static	58.3	89	0.65
TPO Dry Test #3	Kinetic	56.4	89	0.63
Average	**Static**	**57.0**	**89**	**0.64**
Average	**Kinetic**	**55.8**	**89**	**0.63**



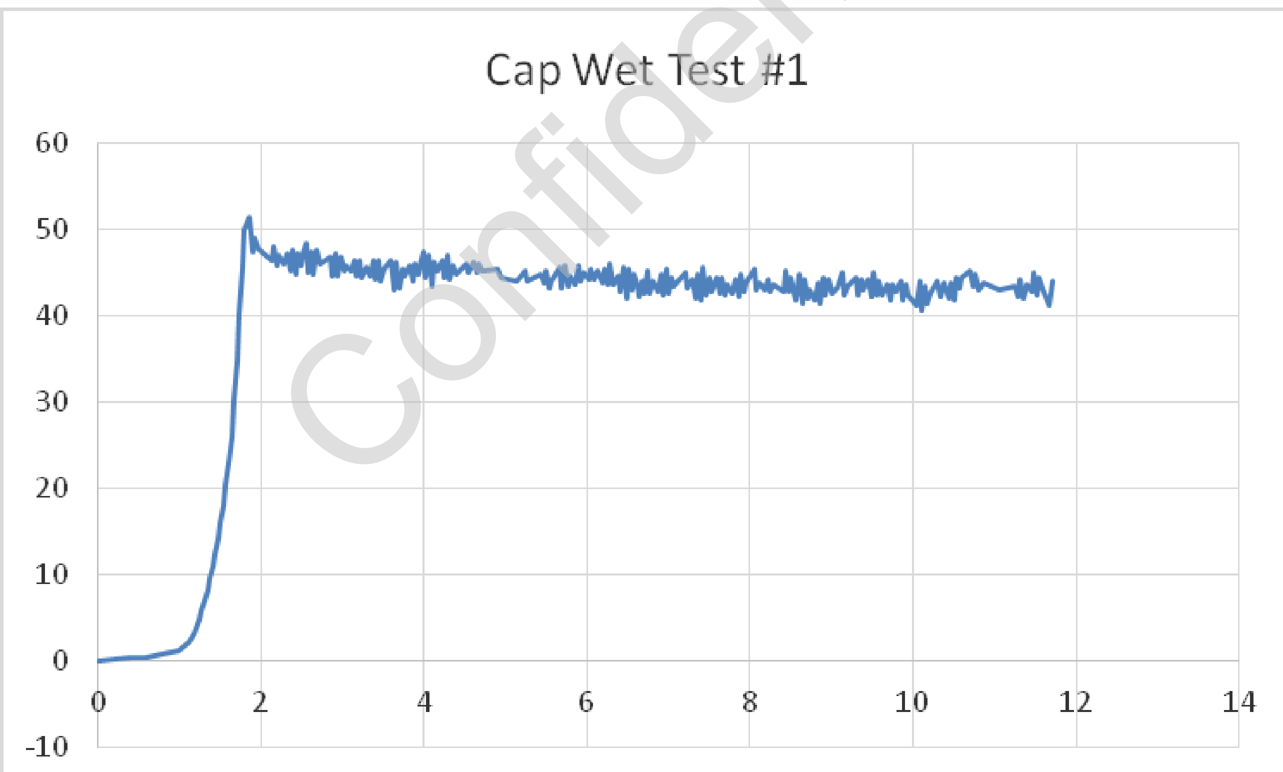
TPO Dry Testing Results (Continued)



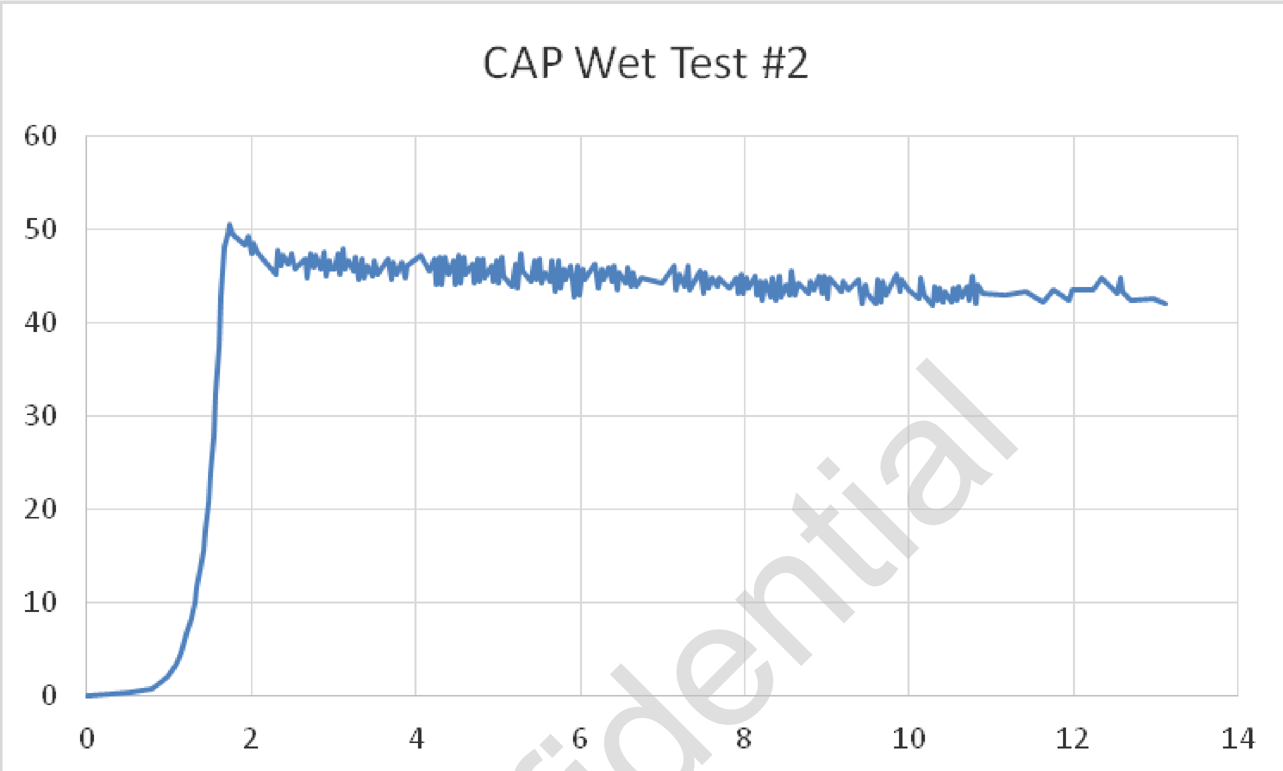


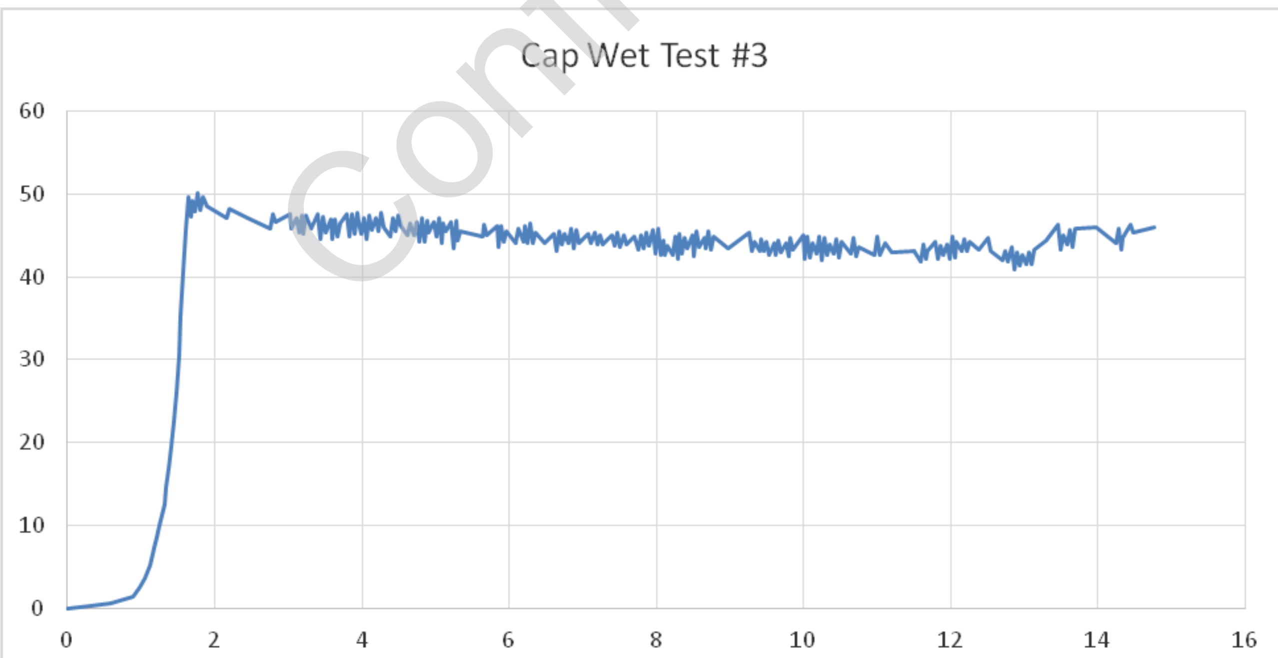
Cap Wet Testing Results

Cap Wet				
Specimen	*Friction*	*Force (lbs)*	*Weight (lbs)*	*Cof*
Cap Wet Test #1	Static	51.3	89	0.58
Cap Wet Test #1	Kinetic	43.9	89	0.49
Cap Wet Test #2	Static	50.6	89	0.57
Cap Wet Test #2	Kinetic	44.6	89	0.50
Cap Wet Test #3	Static	49.7	89	0.56
Cap Wet Test #3	Kinetic	44.4	89	0.50
Average	**Static**	**50.5**	**89**	**0.57**
Average	**Kinetic**	**44.3**	**89**	**0.50**



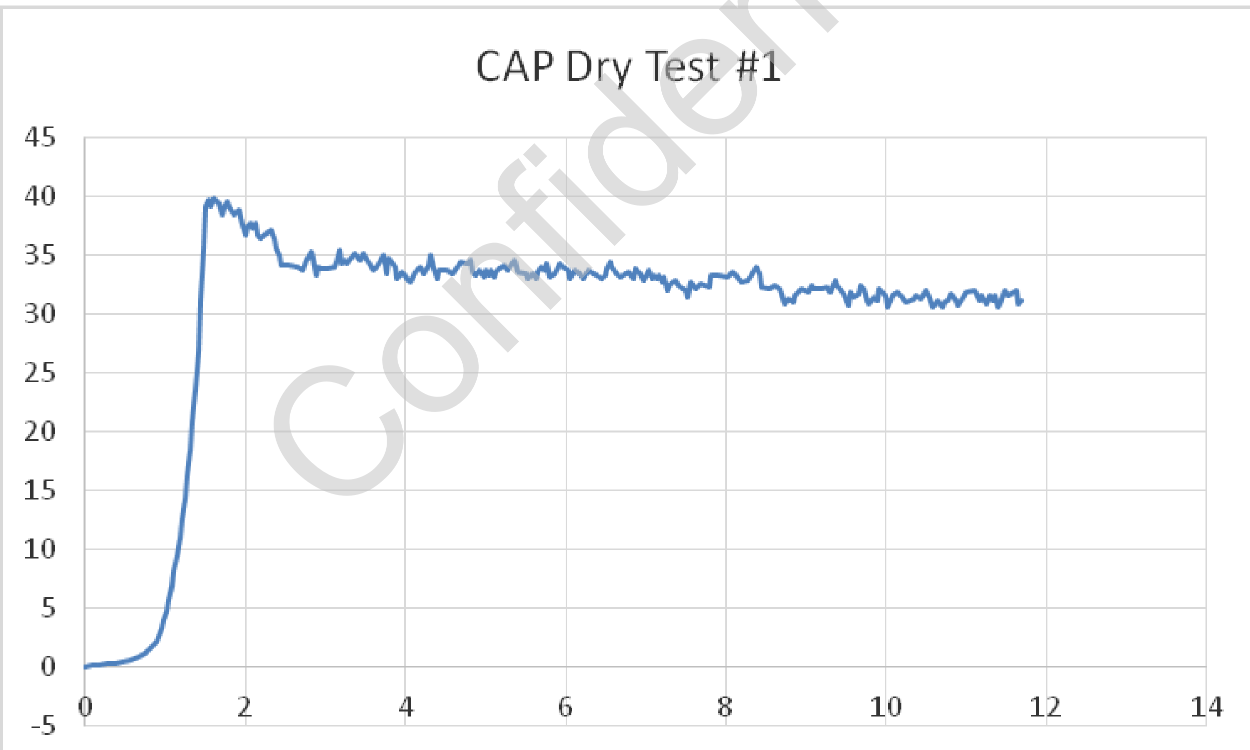
Cap Wet Testing Results (Continued)



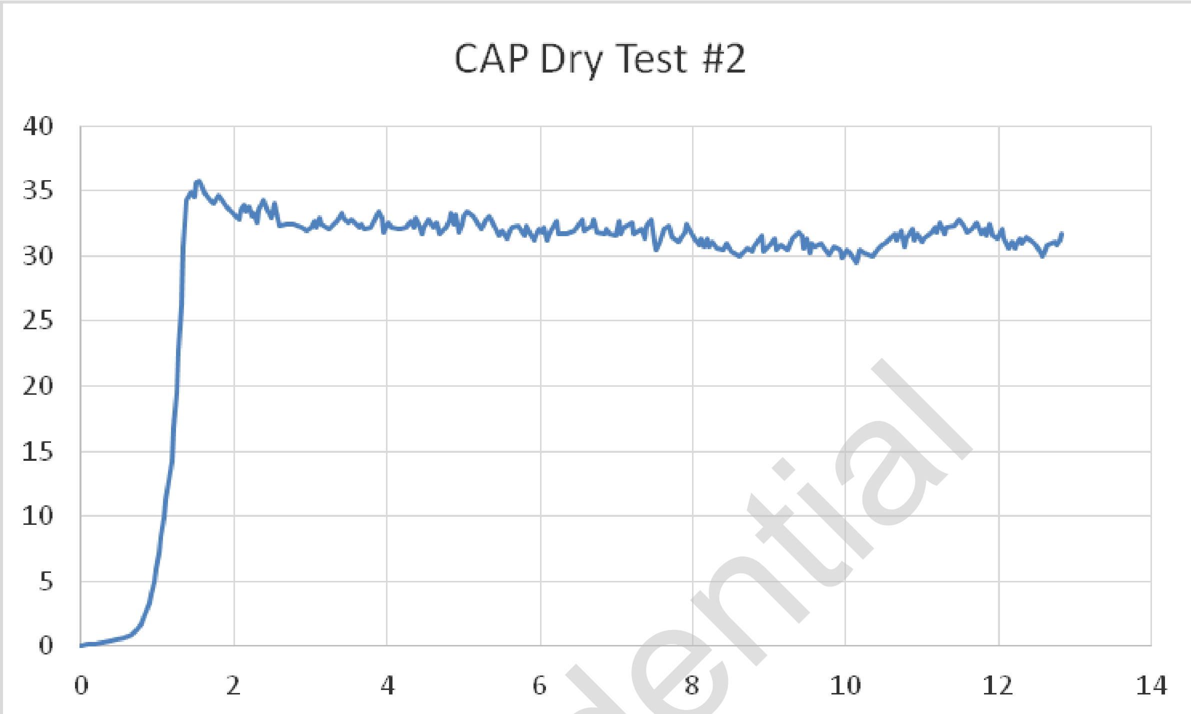


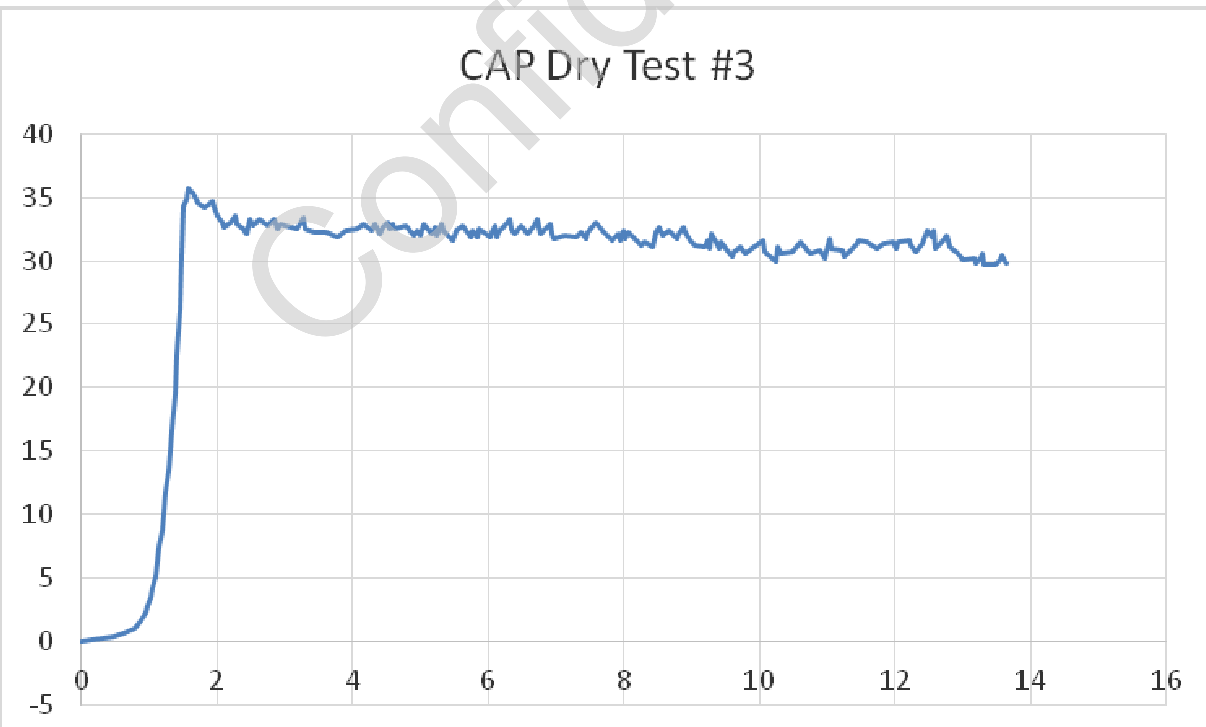
Cap Dry Testing Results

Cap Dry				
Specimen	*Frictin*	*Force (lbs)*	*Weight (lbs)*	*Cof*
Cap Dry Test #1	Static	39.5	89	0.44
Cap Dry Test #1	Kinetic	32.8	89	0.37
Cap Dry Test #2	Static	35.0	89	0.39
Cap Dry Test #2	Kinetic	31.8	89	0.36
Cap Dry Test #3	Static	35.7	89	0.40
Cap Dry Test #3	Kinetic	31.9	89	0.36
Average	**Static**	**36.7**	**89**	**0.41**
Average	**Kinetic**	**32.2**	**89**	**0.36**



Cap Dry Testing Results (Continued)





Picture #1:

FastRack FR 510 During Friction Test Calebration Run over TPO Representative Roofing Assembly

******End of Report******

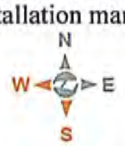
AK Solar Products

A Division of AK Stamping Company
1159 U.S. Route 22 • Mountainside, NJ 07092
908-232-7300
www.akstamping.com/solar

Sollega FastRack and AKS Grounding Mid Clamps: Guidelines for Use and Functionality

This document will detail the intended use and functionality of AK Solar Grounding Mid Clamps (AKS part numbers A3001, A3002, A3004, Sollega P/N SMC) with the Sollega FastRack510 PV mounting system.

Functionality
AKS Grounding Mid Clamps SMC are installed on the Sollega FastRack510 system as shown in the Sollega installation manual:




1.


2.

1. Attach Grounding Mid-Clamps (SMC) into the cage nuts where shown using the 3" bolt (B3) and lock washer (L).

2. Ensure that the teeth of the Grounding Mid-Clamp (SMC) are securely attached onto the top surface of the module frame and that the bolt is tightened to 10 lbs/ft of torque.

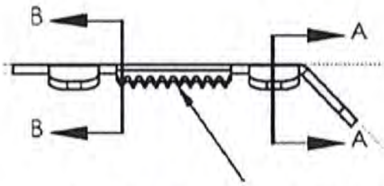
Please Note:
Only one Grounding Mid-Clamp needed per module

When installed in this manner, the Grounding Mid Clamps create an electrical bond and ground path between the adjacent PV modules. This ground path is continued throughout the row of modules when additional Mid Clamps are installed.
When installed in the Sollega FastRack510 system, the Grounding Mid Clamps **are not** intended to secure the modules or provide any sort of mechanical loading capability. This is provided by the Sollega Pull Clamps and End Clamps specified in the FastRack510 installation manual.

AK Solar Products

A Division of AK Stamping Company
1159 U.S. Route 22 • Mountainside, NJ 07092
908-232-7300
www.akstamping.com/solar

Bonding Effectiveness
As mentioned earlier, the AKS Grounding Mid Clamps create an electrical bond between adjacent modules. Teeth on the Mid Clamps (noted by the arrow in the illustration below) penetrate the module frame, providing a secure and robust bond between the Mid Clamp and the module.



Penetrating teeth of Grounding Mid Clamp

Module to module bonding effectiveness of AKS Grounding Mid Clamps have been tested by UL (file number E356152) for the following tests under standard 2703:
The following tests were conducted:

TEST	CLAUSE	REFERENCE (E356152)
Bonding Path Resistance Test:	Subject 2703 cl. 13	T4, dated 2012-09-07
Temperature Cycling Test	Subject 2703 cl. 17	T4, dated 2012-09-07
Bonding Path Resistance Test - Following The Temperature Cycling Test:	Subject 2703 cl. 13	T4, dated 2012-09-07
Humidity Cycling Test	Subject 2703 cl. 18	T4, dated 2012-09-07
Bonding Path Resistance Test - Following The Humidity Test:	Subject 2703 cl. 13	T4, dated 2012-09-07
Metallic Coating Thickness Test (Ground clamp & machine Screw)	Subject 2703 cl. 20	T4, dated 2012-09-07
Bonding Conductor Test (Sequence; 135%, 200%, Limited Short-Circuit) [Followed By Bonding Path Resistance Test]:	Subject 2703 Cl. 22 Subject 2703 cl. 13	T4, dated 2012-09-07

In the test report, UL conducted a "module-to-module bonding evaluation (with electrical isolation for the P6 crossrail)"; it is AKS' opinion that these test setups and module to module bonding test results are 100% applicable to the Sollega FastRack510 mounting system which does not contain crossrails.

AK Solar Products

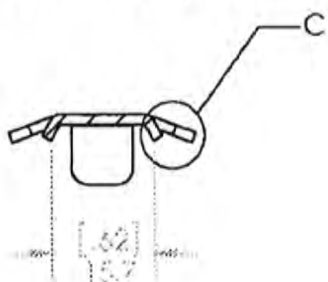
A Division of AK Stamping Company
1159 U.S. Route 22 • Mountainside, NJ 07092
908-232-7300
www.akstamping.com/solar

The result of these tests is that AKS grounding mid clamps were found to provide effective grounding from module to module to a 20-Amp fuse rating:

```
Test Record Summary:

The results of this investigation indicate that the products evaluated comply
with the applicable requirements and, therefore, such products are judged
eligible to bear UL's Mark as described on the Conclusion Page of this
Report.
```

Use / reuse of clamps
AKS Grounding Mid Clamps are manufactured of 0.060" 316/316L stainless steel, rolled to a half hard temper. The hardness of this material is many times greater than that of the 5052 aluminum used to manufacture PV module frames.
During internal testing, AKS has observed that neither the bend line that sets the position of the teeth (circle C below), nor the 0.62" teeth to teeth dimension, nor the integrity of the teeth themselves are compromised after more than 5 cycles of torqueing to the specified 10 ft/lbs and subsequent loosening / removal of the clamps.



Because of the robust mechanical specifications of the clamps, and AKS internal testing, AKS Grounding Mid Clamps can be reused after initial installation when used in accordance with the recommended torque ratings.

Should you require clarification on any of the information above, please do not hesitate to contact us at 908 232-7300 or info@akstamping.com.

Mark Andrews

VP Engineering

Intertek

Listing Constructional Data Report (CDR)

1.0 Reference and Address			
Report Number	101005952LAX-001	Original Issued: 28-Jun-2013	Revised: None
Standard(s)	UL 467 - Issue:2007/09/21 Ed:9 UL Standard for Safety Grounding and Bonding Equipment		

Applicant	AK Stamping Company Inc	Manufacturer	**AK Stamping Company Inc**
Address	1159 route 22 East Mountainside, NJ 07092	Address	1159 route 22 East Mountainside, NJ 07092
Country	USA	Country	USA
Contact	Mr. Ken Eisenberg	Contact	Mr. Ken Eisenberg
Phone	(908) 393 7523	Phone	(908) 393 7523
FAX	(908) 232 5202	FAX	(908) 232 5202
Email	keisenberg@akstamping.com	Email	keisenberg@akstamping.com

2.0 Product Description	
Product	Bonding and Grounding Equipment
Brand name	NA
Description	Products covered in this report are grounding clamp and spacers. Grounding clamps and spacers are used to bond PV panels to the racking system that they are mounted on. Grounding clamps are used between one module frame to another module frame. Bonding clips are used between rail of racking system and frame of PV module. Grounding clamps achieve bonding through side teeth that penetrate anodized coating of aluminum frame. Grounding clips achieve bonding between the PV panel frame and the mounting rack by using multiple serrated metal punch outs that pierce that anodized coating on the panel frame. The serrated punch outs are on both sides of the product which comes into contact with the panel frame and rail to ensure continuity. Bonding straps achieve bonding through usage of hardware (including washers, nuts, and bolts). Final installation must be in accordance to NFPA NEC 70 and applicable local jurisdiction Bonding straps are used between separate rails to ensure continuity of bonding connection.
Models	Mid clamp, Ground clamp, Spacer
Model Similarity	Mid clamp and Ground clamp are intended to be used together with PV frames only. Spacer is intended to be used as bonding point between rail and PV frames.
Ratings	NA
Other Ratings	To be used with 10 AWG conductor only

3.0 Product Photographs

Photo 1 - Ground Clamp

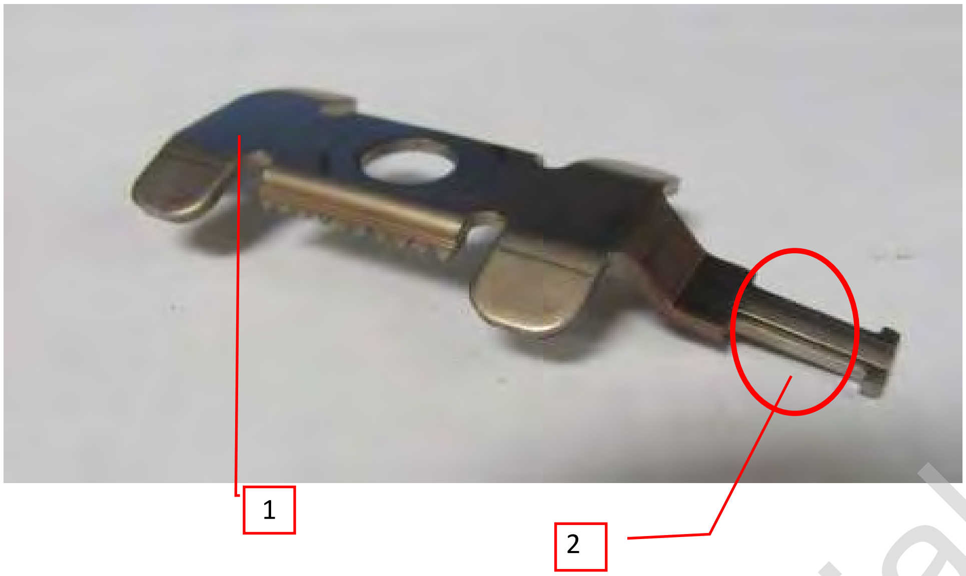


Photo 2 - Spacer

4.0 Critical Components						
Photo #	Item no.[1]	Name	Manufacturer/ trademark[2]	Type / model[2]	Technical data and securement means	Mark(s) of conformity[3]
1	1	Ground Clamp	AK Stamping	Mid Clamp	Material is 0.06" Zinc-plated, hardened 1075 carbon steel. To be used with cable clamp housing and 10-32 hex head slotted SS zinc-plated screw. Refer to illustration 1 for details.	NR
1	2	Ground Clamp Terminal	Various	Various	Tin Coated copper terminal as shown in illustration 1. Suitable for connection of 10 AWG	UL
1	3	Mid Clamp (Not Shown)	AK Stamping	Ground Clamp	Material is 420 Stainless Steel, Annealed. Heat treated to 50 RC min. Refer to illustration 2 for details.	NR
2	4	Spacer	AK Stamping	Spacer	Material is 0.012" 301 Stainless Steel, ½ hard. Outer diameter option of 0.75", 1.0", or 1.25". Refer to illustration 3, 4, and 5 for details.	NR

NOTES:

1) Not all item numbers are indicated (called out) in the photos, as their location is obvious.

2) "Various" means any type, from any manufacturer that complies with the "Technical data and securement means" and meets the "Mark(s) of conformity" can be used.

3) Indicates specific marks to be verified, which assures the agreed level of surveillance for the component. "NR" - indicates Unlisted and only visual examination is necessary. "See 5.0" indicates Unlisted components or assemblies to be evaluated periodically refer to section 5.0 for details.

5.0 Critical Unlisted CEC Components

No Unlisted CEC components

6.0 Critical Features

Recognized Component - A component part, which has been previously evaluated by an accredited certification body with restrictions and must be evaluated as part of the basic product considering the restrictions as specified by the Conditions of Acceptability.

Listed Component - A component part, which has been previously Listed or Certified by an accredited Certification Organization with no restrictions and is used in the intended application within its ratings.

Unlisted Component - A part that has not been previously evaluated to the appropriate designated component standard. It may also be a Listed or Recognized component that is being used outside of its evaluated Listing or component recognition.

Critical Features/Components - An essential part, material, subassembly, system, software, or accessory of a product that has a direct bearing on the product's conformance to applicable requirements of the product standard.

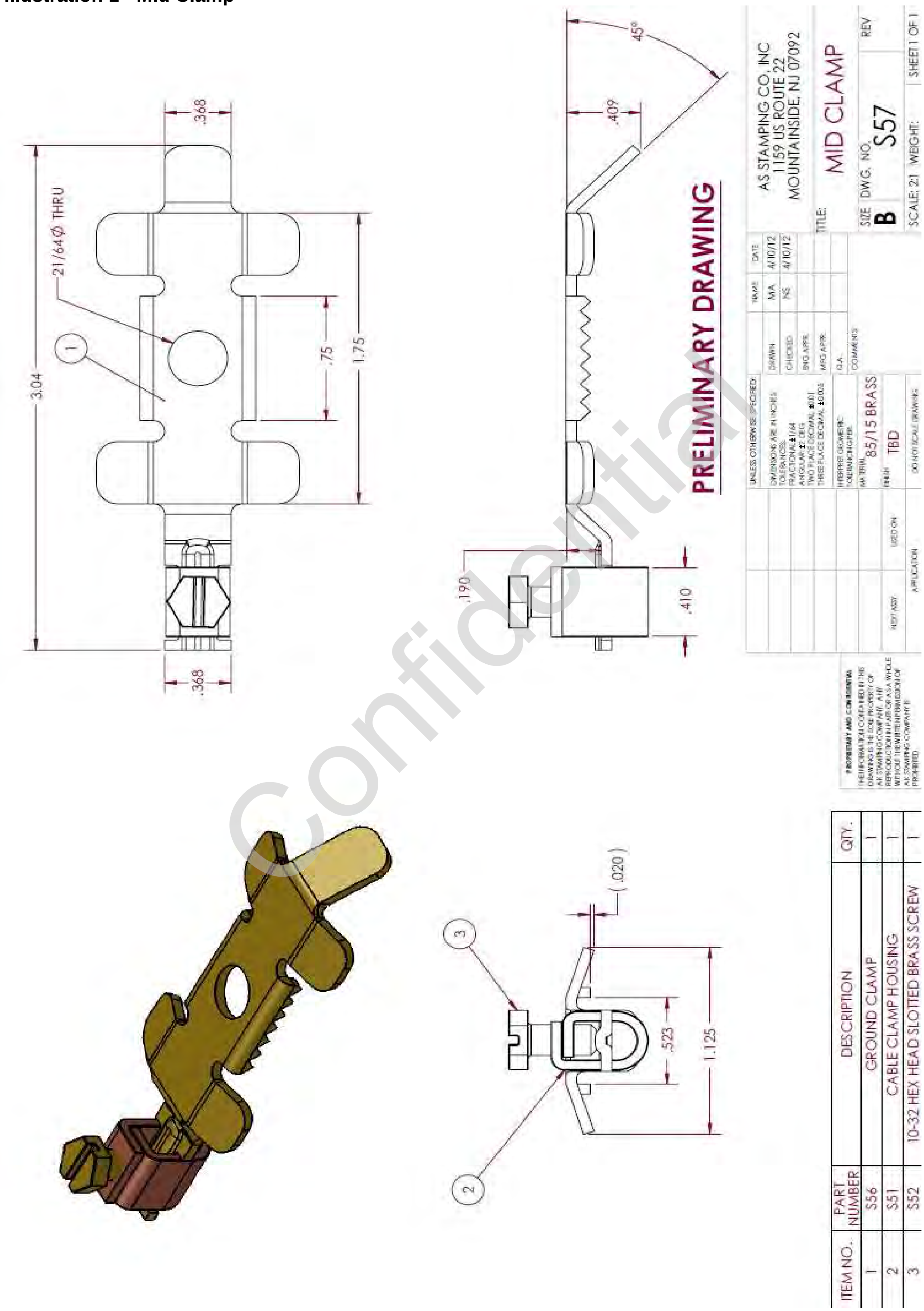
Construction Details - For specific construction details, reference should be made to the photographs and descriptions. All dimensions are approximate unless specified as exact or within a tolerance. In addition to the specific construction details described in this Report, the following general requirements also apply.

1. Corrosion Protection - Only stainless steel is used in the product, no corrosion protection is required.
2. Grounding - The grounding conductor to be used with the system is 10 AWG.
3. Markings -
   Markings to be verified as stamped into the product are:

   a) Manufacturer name
   b) Model or catalog number
   c) ETL mark.
4. Installation, Operating and Safety Instructions - Instructions for installation and use of this product are provided by the manufacturer.
   Mid clamp and Ground clamp are to be torque down to 12-15 ft.lbs. Refer to illustration 6, 7, and 8 for details.

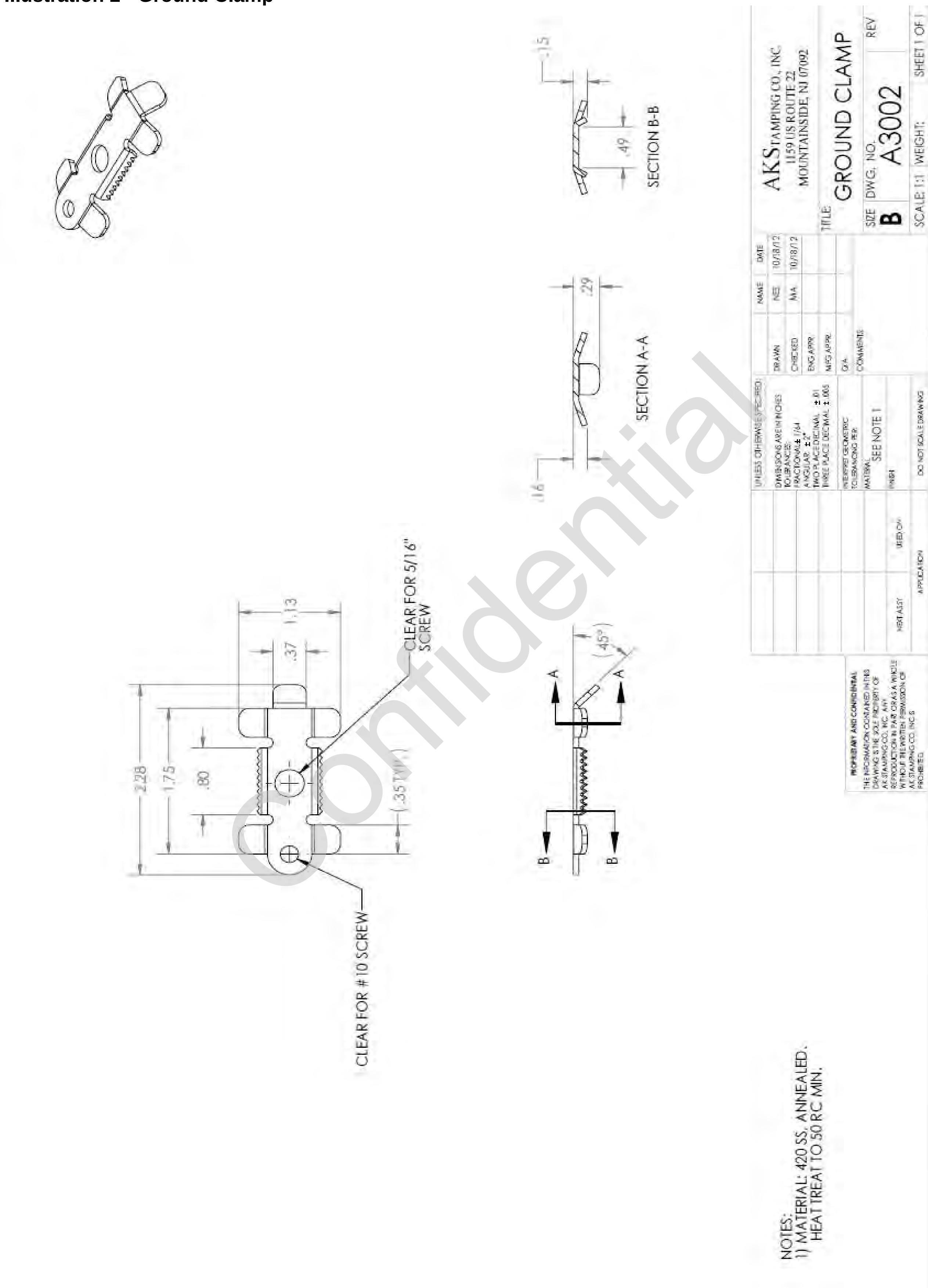
7.0 Illustrations

Illustration 1 - Mid Clamp



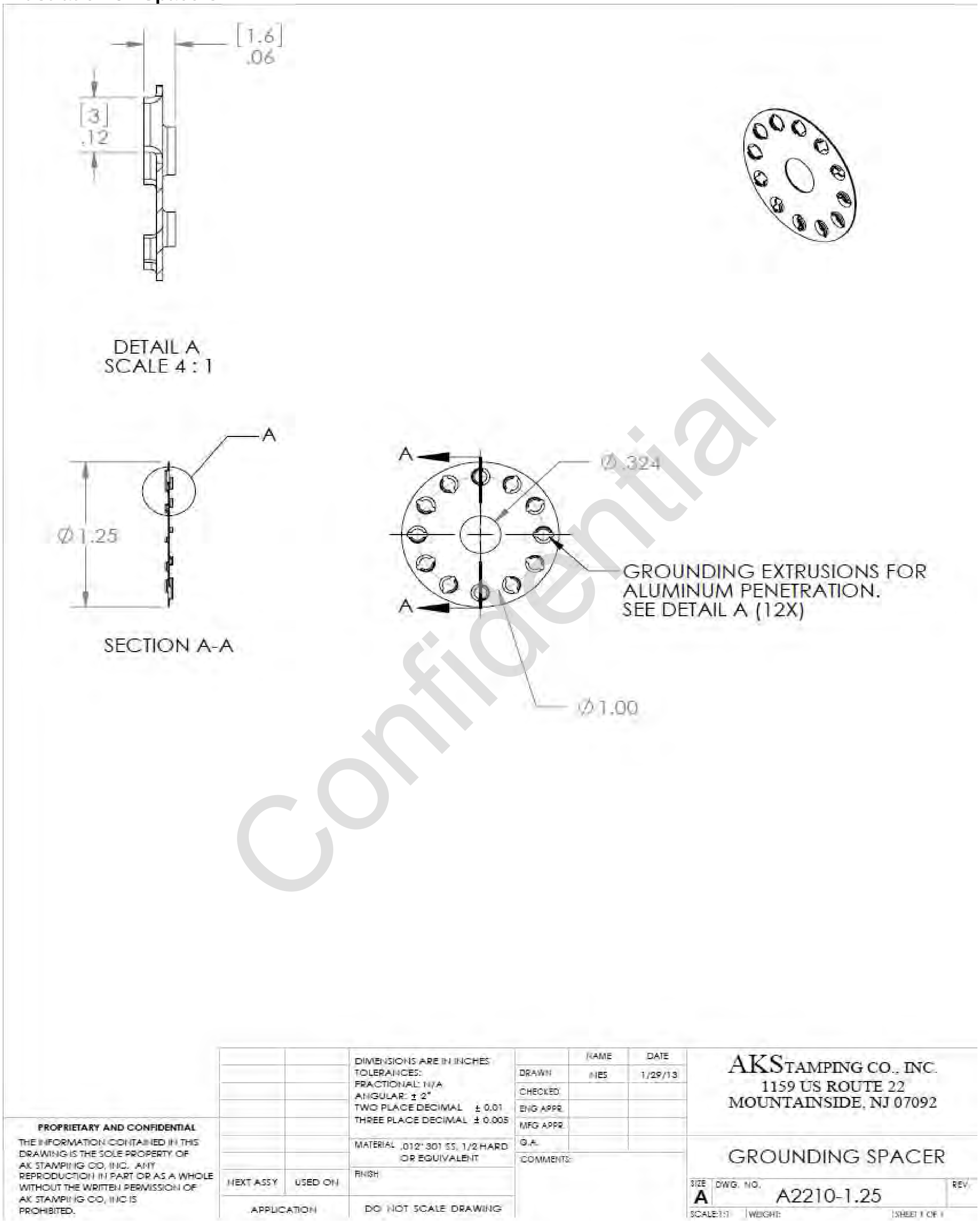
7.0 Illustrations

Illustration 2 - Ground Clamp



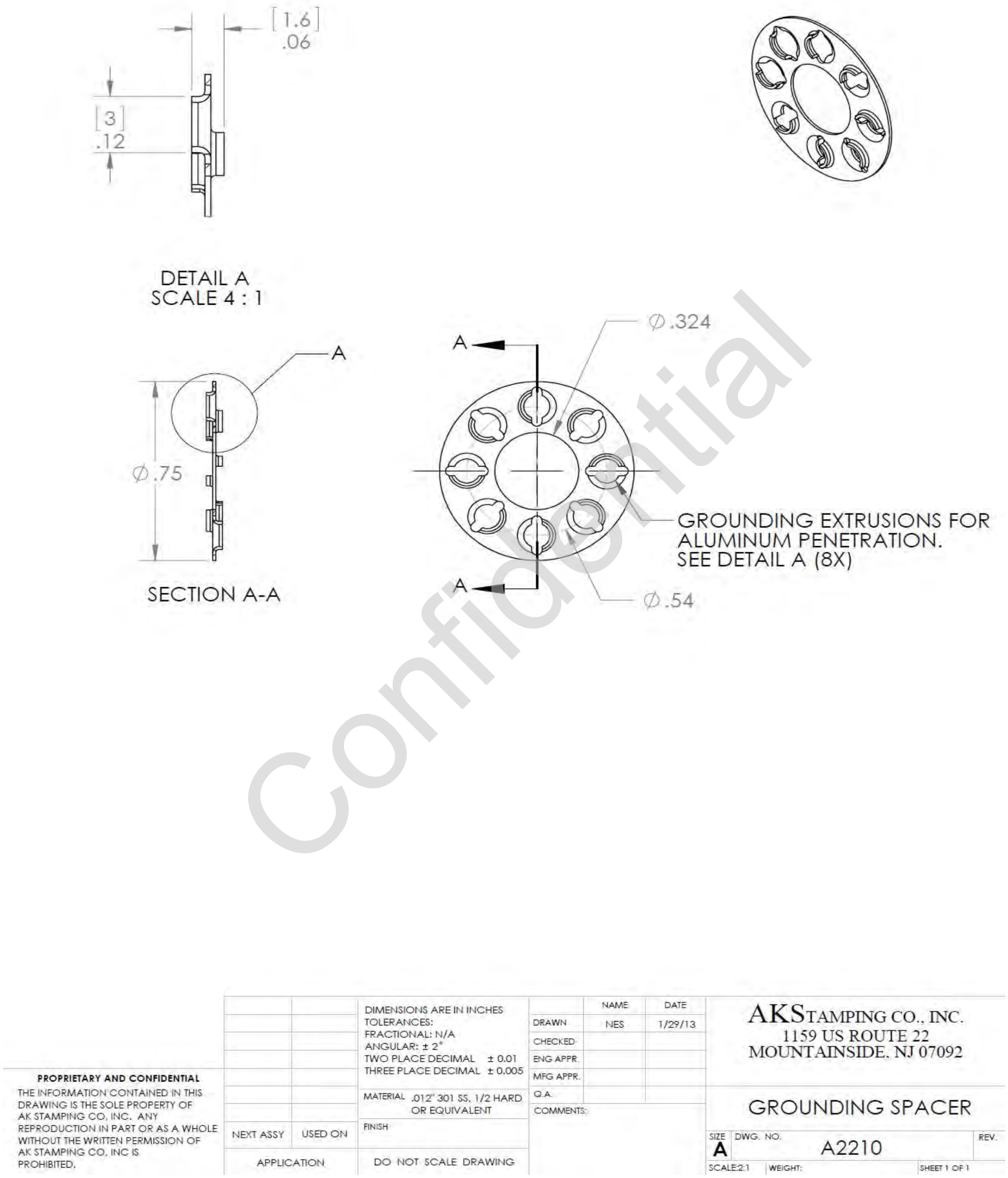
7.0 Illustrations

Illustration 3 - Spacers



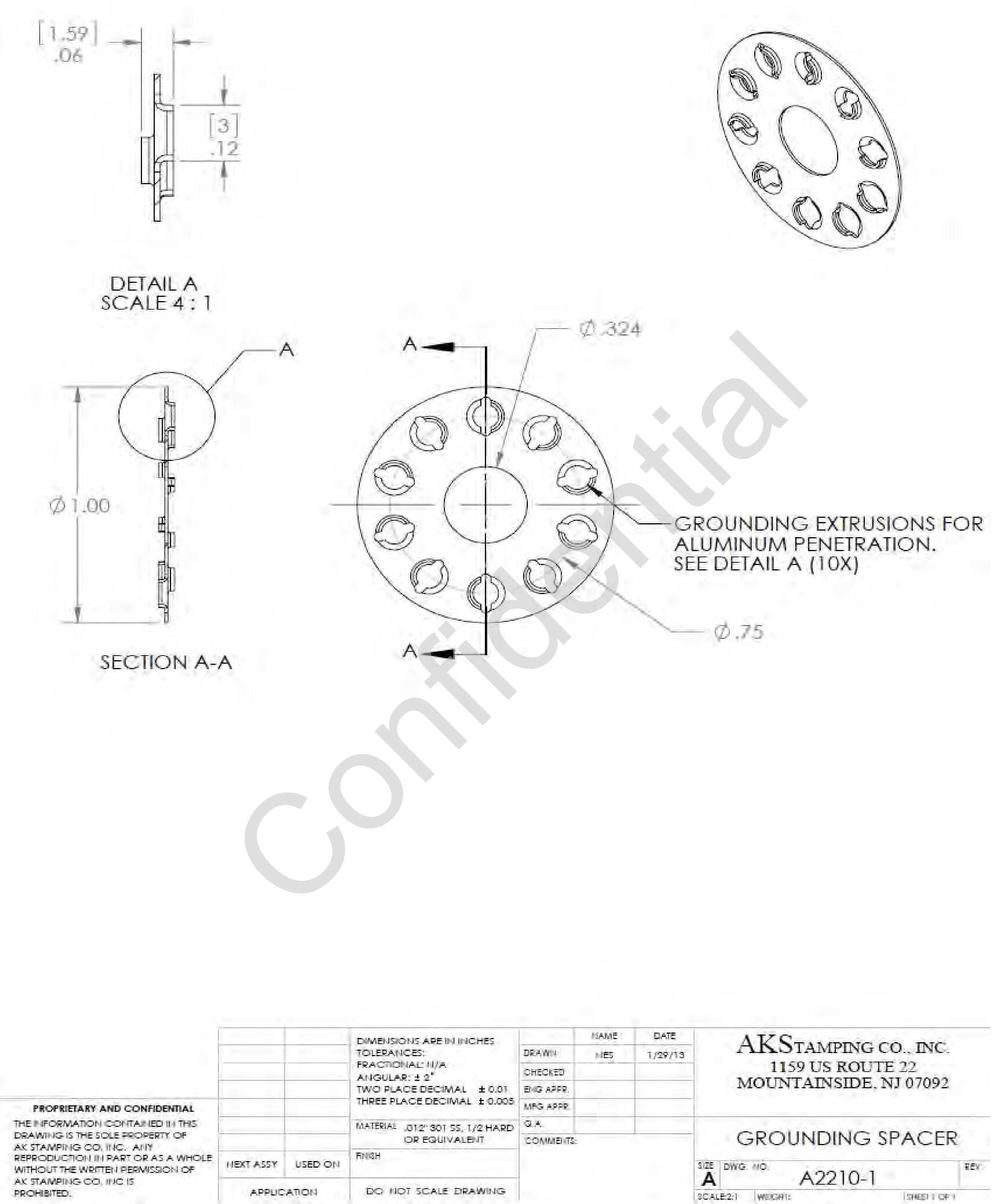
7.0 Illustrations

Illustration 4 - Spacers



7.0 Illustrations

Illustration 5 - Spacers



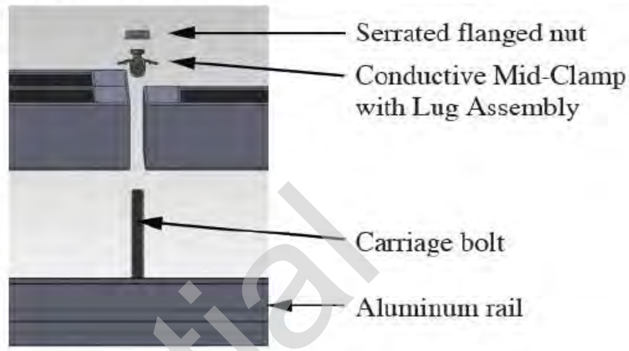
7.0 Illustrations

Illustration 6 - Installation Manual for Mid Clamp

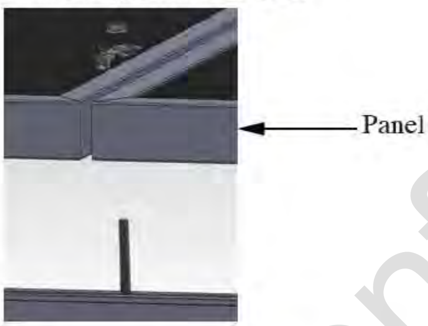
SOLAR CONDUCTIVE MID-CLAMP
INSTALLATION GUIDE

1. Slide carriage bolt into aluminum rail.

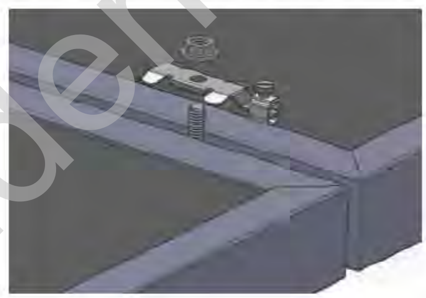
2. Align parts as shown.



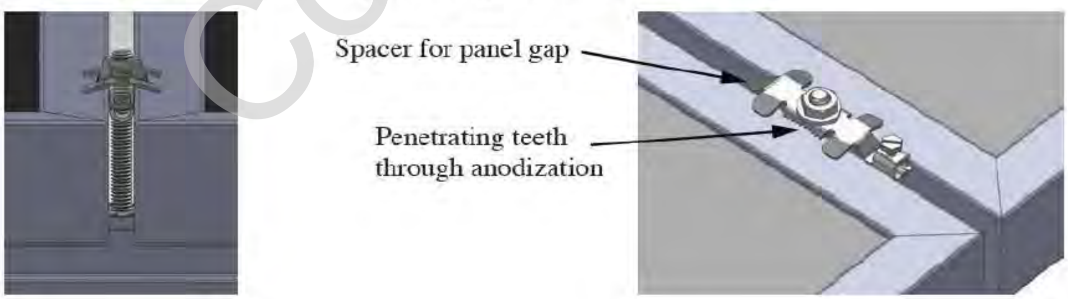
3. Position panels over rail.



4. Place conductive mid-clamp over carriage bolt.



5. Lock down with serrated flange nut. Tighten to 12-15 ft. lbs.



*Mid-clamp installation shown without illustrating lug assembly usage.

AK Stamping Company Inc.
1159 U.S. Route 22
Mountainside, New Jersey 07092

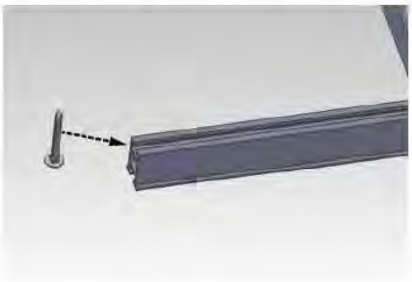
Telephone: +1 (908) 232-7300
Fax: +1 (908) 232-5202
Email: sales@akstamping.com

7.0 Illustrations

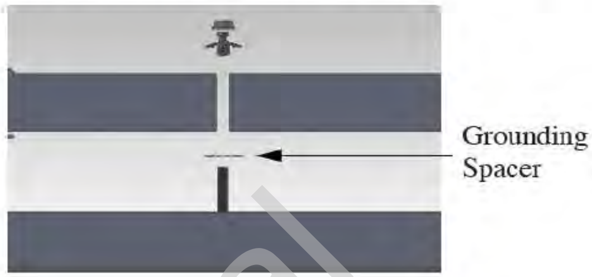
Illustration 7 - Installation Manual for Grounding Spacer

SOLAR GROUNDING SPACER
INSTALLATION GUIDE

1. Slide carriage bolt into rail.

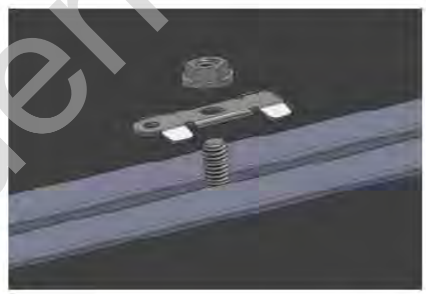


2. Place grounding spacer over carriage bolt.



3. Position panels over rail.

4. Place mid-clamp over carriage bolt.



5. Lock down with serrated flange nut. Tighten to 12-15 ft. lbs.

AK Stamping Company Inc.
1159 U.S. Route 22
Mountainside, New Jersey 07092
Telephone: +1 (908) 232-7300
Fax: +1 (908) 232-5202
Email: sales@akstamping.com

8.0 Test Summary					
Evaluation Period	June 21, 2013 to June 27, 2013			Project No.	G101005952
Sample Rec. Date	7-Jun-2013	Condition	Production	Sample ID.	LAN1306071045
Test Location	25791 Commercentre Drive, Lake Forest, CA 92630				
Test Procedure	Testing Lab				
Determination of the result includes consideration of measurement uncertainty from the test equipment and methods. The product was tested as indicated below with results in conformance to the relevant test criteria.					
The following tests were performed by Intertek Lake Forest, CA facility to bonding clip, bonding straps, and mid clamps:					

Test Description	UL 467
Short time current test	7.5

8.1 Signatures			
A representative sample of the product covered by this report has been evaluated and found to comply with the applicable requirements of the standards indicated in Section 1.0.			
Completed by:	Charles Tumengko	Reviewed by:	Matt Pavloff
Title:	Engineering Team Leader	Title:	Reviewer
Signature:		Signature:	

9.0 Correlation Page For Multiple Listings	
The following products, which are identical to those identified in this report except for model number and Listee name, are authorized to bear the ETL label under provisions of the Intertek Multiple Listing Program.	
BASIC LISTEE	AK Stamping Company Inc
Address	1159 route 22 East Mountainside, NJ 07092
Country	USA
Product	Bonding and Grounding Equipment

MULTIPLE LISTEE 1	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	
MULTIPLE LISTEE 1 MODELS	BASIC LISTEE MODELS

MULTIPLE LISTEE 2	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	
MULTIPLE LISTEE 2 MODELS	BASIC LISTEE MODELS

MULTIPLE LISTEE 3	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	
MULTIPLE LISTEE 3 MODELS	BASIC LISTEE MODELS

10.0 General Information

The Applicant and Manufacturer have agreed to produce, test and label ETL Listed products in accordance with the requirements of this Report. The Manufacturer has also agreed to notify Intertek and to request authorization prior to using alternate parts, components or materials.

COMPONENTS

Components used shall be those itemized in this Intertek report covering the product, including any amendments and/or revisions.

LISTING MARK

The ETL Listing mark applied to the products shall either be separable in form, such as labels purchased from Intertek, or on a product nameplate or other media only as specifically authorized by Intertek. Use of the mark is subject to the control of Intertek.

The mark must include the following four items:

1) applicable country identifiers "US" and/or "C" or "US", "C" and "EU"
2) the word "Listed" or "Classified" or "Recognized Component" (whichever is appropriate)
3) a control number issued by Intertek
4) a product descriptor that identifies the standards used for certification. Example:

For US standards, the words, “Conforms to” shall appear with the standard number along with the word, “Standard” or “Std.” Example: “Conforms to ANSI/UL Std. XX.”

For Canadian standards, the words “Certified to CAN/CSA Standard CXX No. XX.” shall be used, or abbreviated, “Cert. to CAN/CSA Std. CXX No. XX.”

Can be used together when both standards are used.

Note: A facsimile must be submitted to Intertek, Attn: Follow-up Services for approval prior to use. The facsimile need not have a control number. A control number will be issued **after signed Certification Agreements** have been received by the Follow-up Services office, approval of the facsimile of your proposed Listing Mark, satisfactory completion of the Listing Report, and scheduling of a factory assessment in your facility.

MANUFACTURING AND PRODUCTION TESTS

Manufacturing and Production Tests shall be performed as required in this Report.

FOLLOW-UP SERVICE

Periodic unannounced audits of the manufacturing facility (and any locations authorized to apply the mark) shall be scheduled by Intertek. An audit report shall be issued after each visit. Special attention will be given to the following:

1. Conformance of the manufactured product to the descriptions in this Report.
2. Conformance of the use of the ETL mark with the requirements of this Report and the Certification Agreement.
3. Manufacturing changes.
4. Performance of specified Manufacturing and Production Tests.

In the event that the Intertek representative identifies non-conformance(s) to any provision of this Report, the Applicant shall take one or more of the following actions:

1. Correct the non-conformance.
2. Remove the ETL Mark from non-conforming product.
3. Contact the issuing product safety evaluation center for instructions.

10.1 Evaluation of Unlisted Components

Because Unlisted Components are uncontrolled, and they do not fall under a third party follow up program, Intertek may require these components to be tested and/or evaluated at least once annually, more often for certain components, as part of the independent certification process. The Unlisted Components in Section 5.0 require testing and/or evaluation as indicated.

Note to Intertek Follow Up Inspector: The Component Evaluation Center, CEC, will notify you in writing when these components must be selected and sent to the CEC for re-evaluation

Ship the samples to:
Intertek Testing Services NA Inc.
ETL Component Evaluation Center
45000 Helm Street, Suite 150
Plymouth Twp., MI 48170 USA
Attn: Component Evaluation Center
Sample Disposition: Due to the destructive nature of the testing, all samples will be discarded at the conclusion of testing unless, the manufacturer specifically requests the return of the samples. The request for return must accompany the initial component shipment.ı

11.0 Manufacturing and Production Tests
No manufacturing or production tests are required.

12.0 Revision Summary				
The following changes are in compliance with the declaration of Section 8.1:				
Date/ Proj # Site ID	Project Handler/ Reviewer	Section	Item	Description of Change
				None

QAI LABORATORIES
CERTIFICATION TESTING INSPECTION

8385 Whiteoak Ave
Rancho Cucamonga CA 91730
(909) 483-0250 ph. | (909) 483-0336 fx.
www.qai.org

Findings Letter

January 5, 2016

ATTN: Lee Rothschild
Sollega
2480 Mission Street, Suite 107B
San Francisco, CA 94110

Subject: Evaluate the bonding path between the AK stamping mid clamp, and the NEO Solar Power Module

Models: D6P250B3A manufactured by NEO Solar Power

Standard: UL 467- Grounding and Bonding Equipment as required by UL 2703

Dear Mr. Rothschild:

This letter is to inform you of the findings during the testing conducted on December 8, 2015. Please note that this is the letter that will provide the results of our testing.

See below for test results.

Short-Time Current As Per UL 467 (Clause 7.5, 8.5, and 9.5):

Test procedure:
To ensure the device is robust enough when subjected to the current and time specified for the maximum conductor size that the device is designed to be used with, this is following guidance from table 5 of UL 467.

Test parameters:
Maximum size conductor: 6 AWG (aluminum)
Test Current (from Table 5): 880 Amps
Duration (from Table 5): 6 seconds

Test Results			
Sample #	Test Current (A)	Time (s)	Observed Result
1	880	6	Bonding path remained intact. No signs of damage.
2	880	6	Bonding path remained intact. No signs of damage.
3	880	6	Bonding path remained intact. No signs of damage.

The following parts made up the assembly which was tested:

Part #	Description
FR-SMC-S316	Grounding Mid Clamp – 316 Stainless steel
FR-B2-S304	5/16" x ¼" Hex Bolt – 304 Stainless Steel
FR-B5-S304SE	5/16" x 2-3/4" Partially Threaded Hex Bolt – 304 Stainless Steel
FR-CN-Z	5/16" Cage Nut – Zinc Plated
NEO Solar Power	PV module frame

To Comply:

A) The test assembly shall have continuity when measured between a point on the ground rod, rebar, wire, conduit, pipe, enclosure, brass fitting, or outlet box 6.4mm from the connection of a grounding or bonding device and a similar point on the conductor.
B) The test samples shall not crack, break, or melt when subjected to the current specified.

Please note that after any changes are made to the product, the product must be re-evaluated by QAI to identify possible non-conformities that may not have been apparent due to either the above findings, or any changes made in the product.

Once a 100% compliant file has been established, the re-inspection of a compliant unit will be required.

Tested By: Igor Duspara	Reviewed By: Jose Elias
Title: Electrical Engineer	Title: Operations Manager
Signature:	

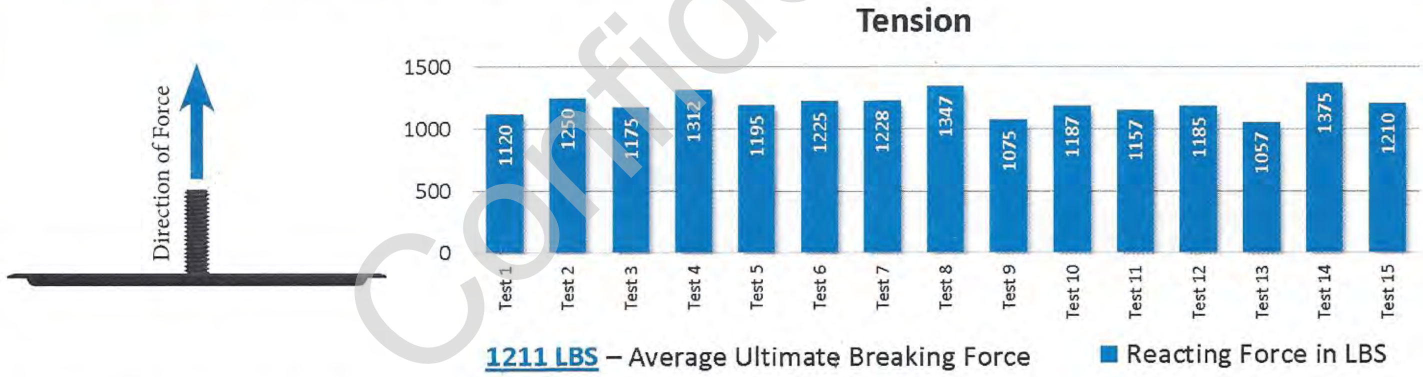
Anchor Products Shear & Tension Testing

Scope: On July 17, 2014, Anchor Products conducted Tension & Shear Testing on thirty (30) U-Anchor Plates, randomly chosen from our inventory. Fifteen in tension and fifteen in shear. (Note: Shear testing was conducted at the base of the stud where it meets the plate.) Each plate has a standard 3/8"-16 x 1-1/2" stainless steel bolt welded on to it.

Attending Technician: Gary Calderwood, Director of Engineering - Anchor Products, LLC.
Witnessed By: Ronald K. Farleman, Professional Engineer - Nautilus Engineering

Tested in accordance with TAS 117-95, Appendix B - *Test Procedure for Dynamic Pull-Through Performance of Roofing Membranes over Fastener Heads or Fasteners with Metal Bearing Plates*, © FBC, 1995

Results are recorded in reacting force in lbs.



Results: *Failure Mode:* In all cases, the failure occurred at the weld junction between the bolt and plate.

Analysis: Upon analysis of test results, it is our professional opinion that the U-Anchor Plate - when installed in accordance with Anchor Product's published installation requirements - will yield similar results as outlined above.

U-Anchor 2400 & U-Anchor 2600 provide consistent performance for all commercial roof types with a minimally invasive attachment solution that is accepted by roofing manufacturers.

Anchor Product's support staff are positioned throughout the US to assist with rooftop identification, project specific testing, and offer access to a network of authorized contractors for any commercial rooftop system.

Ronald K. Farleman, P.E.

Anchor Products™
PO Box 1551, Colleyville, TX 76034 | 888-575-2131
www.anchorp.com | info@anchorp.com

250 West 96th Street
Indianapolis, IN 46260
Phone: 317-575-7000
Fax: 317-575-7100

September 18, 2014

Anchor Products
1701 West Northwestern Highway
Suite 100
Grapevine, TX 76051

RE: U-Anchor 2000

To Whom It May Concern:

We hereby confirm that Firestone Building Products has reviewed the U-Anchor 2000 attachment system. The U-Anchor 2000 attachment system can be used with any Firestone single-ply membrane as an enhancement attachment, including for solar racking systems, provided the target is a Firestone single-ply membrane and it is installed per Firestone Building Products current specifications by a Firestone licensed applicator. Please contact your solar racking system provider for specifications and installation instructions for their systems.

This letter only refers to the compatibility of the U-Anchor 2000 attachment system with the Firestone roofing system. This is not an endorsement or representation of any warranty regarding the overall performance of the U-Anchor 2000 attachment system itself.

Please contact the Firestone Technical Department at 800-428-4511 for more information on selection and use of the above mentioned product.

Sincerely,

Beth Nann
Technical Building Solutions, Manager

Firestone
BUILDING PRODUCTS

250 West 96th Street
Indianapolis, IN 46260
Phone: 317-575-7000
Fax: 317-575-7100

June 5, 2014

Anchor Products
1701 West Northwestern Highway
Suite 100
Grapevine, TX 76051

RE: U-Anchor 2400

To Whom It May Concern:

We hereby confirm that Firestone Building Products has reviewed the U-Anchor 2400 attachment system. The U-Anchor 2400 attachment system can be used with any Firestone thermoplastic membrane as an enhancement attachment, including for solar racking systems, provided the target is a Firestone thermoplastic membrane and it is installed per Firestone Building Products current specifications by a Firestone licensed applicator. Please contact your solar racking system provider for specifications and installation instructions for their systems.

This letter only refers to the compatibility of the U-Anchor 2400 attachment system with the Firestone roofing system. This is not an endorsement or representation of any warranty regarding the overall performance of the U-Anchor 2400 attachment system itself.

Please contact the Firestone Technical Department at 800-428-4511 for more information on selection and use of the above mentioned product.

Sincerely,

Beth Nann
Technical Building Solutions, Manager

HellermannTyton

156-00468

Article Number: 156-00468

Cable Tie and Edge Clip, 50lb, 8.0" Long, EC5, Panel Thickness .04"-.12", PA66UV, Black, 100/bag

RoHS

Download drawing   Download spec sheet

Base Data

Local Order Number	156-00468
Type	T50REC5B
Color	Black (BK)
Features and Benefits	• Edge Clip applies easily to plastic and metal sheets without the need for a mounting hole. • Edge Clip provides low insertion force and high extraction force ideal for assembly environments. • Two piece assembly allows the mount to slide along the strap ensuring proper orientation.
Product Description	This cable tie and edge clip assembly is ideal for use where holes are not acceptable or where adhesives will fail due to temperature problems. Edge clips are widely used for fixing and bundling cables and wires within automotive, trucking, heavy equipment, solar panel, wind power, and white goods equipment manufacturing.
Short Description	Cable Tie and Edge Clip, 50lb, 8.0" Long, EC5, Panel Thickness .04"-.12", PA66UV, Black, 100/bag

Product Dimensions

Minimum Tensile Strength (Imperial)	50.0 lbs
Minimum Tensile Strength (Metric)	225 N
Length L (Imperial)	8.0 "
Length L (Metric)	200.0 mm
Length L2 (Imperial)	0.6 "
Length L2 (Metric)	14.0 mm
Fixation Method	EdgeClip, sideway, assembled, 2 piece
Identification Plate Position	none
Releasable Closure	No
Variant	Inside Serrated
Width W (Imperial)	0.18 "
Width W (Metric)	4.6 mm
Width W2 (Imperial)	0.4 "
Width W2 (Metric)	10.0 mm
Height H (Imperial)	0.05 "
Height H (Metric)	1.2 mm
Height H2 (Imperial)	0.4 "
Height H2 (Metric)	10.8 mm
Bundle Diameter Min. (Imperial)	0.2 "
Bundle Diameter Min. (Metric)	4.0 mm
Bundle Diameter Max. (Imperial)	2.0 "
Bundle Diameter Max. (Metric)	50.0 mm

Panel Thickness Max. (Imperial)	0.12 "
Panel Thickness Max. (Metric)	3.0 mm
Panel Thickness Min. (Imperial)	0.04 "
Panel Thickness Min. (Metric)	1.0 mm
Thickness T (Imperial)	0.05 "
Thickness T (Metric)	1.2 mm

Logistics and Packaging

Quantity Per	bag
Package Quantity (Metric)	100
Carton Quantity	2500

Material and Specifications

Material	Polyamide 6.6 UV-stabilized (PA66UV) Polyamide 6.6 high impact modified, heat and UV stabilized (PA66HIRHSUV)
Material Shortcut	PA66HIRHSUV PA66UV
Material Cable Tie	Polyamide 6.6 UV-stabilized (PA66UV)
Flammability	UL94 HB UL94 V2
Operating Temperature	-40°F to +230°F (-40°C to +110°C) -40°F to +185°F (-40°C to +85°C)
ROHS Compliant	Yes

Sollega

SuperSeal Coating

SuperSeal is the most corrosion resistant conversion coating yet to be introduced to the metal finishing industry. SuperSeal can provide over 500 hours of salt spray protection to red rust when applied over zinc plated and chromated parts.

PAVCO® has been a leading developer and supplier of chemistries for the metal finishing industry since 1948. Beyond our first rate technologies, PAVCO® strives to offer numerous value added service advantages that allow the most efficient and enjoyable supplier-customer relationship possible. Our new website is proof of this ongoing commitment.

Sollega utilizes SuperSeal on our stainless steel fasteners to add an additional layer of corrosion resistance as well as reduce the "galling" effect that can happen with stainless steel fasteners.

Sollega™

ARRA Compliance - Made in USA

Certificate of Compliance

Buy American Act

April 10, 2016

To : Valued Customer

Sollega Inc., manufacturer of solar racking hardware is a certified domestic owned and operated busines. Headquartered in San Francisco California with manufacturing locations in California and Ohio, Sollega's product line is completely manufactured in the USA and meets the guidelines established under the Buy American Act and North American Free Trade Agreement.

Sincerely,

Elie Rothschild

CEO, President

Sollega Inc.

Western USA: 415.648.1299 | Eastern USA: 212.417.0321 | info@sollega.com | www.sollega.com

Contact Information

Sollega Inc.
2480 Mission Street, Suite 107B
San Francisco, CA 94110
P: 415.648.1299
F: 415.648.1299
www.Sollega.com
info@sollega.com

Head of Engineering
Leland Rothschild
E: lee@sollega.com
P: 415.648.1299 x157

CAD Drafter
Juan Carlos Chavez
E: juancarlos@sollega.com
P: 415.648.1299 x122

Sales Manager
Elie Rothschild
E: elie@sollega.com
P: 415.648.1299 x137