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Client: K2 Systems GmbH, Renningen, Germany

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Report No.: KSR04-11-1

Wind Loads on the "S-Dome 6.10" and "S-Dome 6.15" Solar Ballasted Roof-Mount Systems of K2 Systems GmbH

Design wind loads for uplift and sliding in compliance with the American standards ASCE 7-10, ASCE 7-16 and ASCE 7-22 and with the European standard EN 1991-1-4

The present report consists of 7 pages.

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K2 Systems GmbH, Renningen, Germany, develop and manufacture mounting systems for photovoltaic panels. An analysis of wind tunnel data based on testing of generic solar ballasted roof mount systems was conducted to determine the design wind loads for the “S-Dome 6.10” and “S-Dome 6.15” solar ballasted roof mount systems. The analysis was performed by I.F.I. Institut für Industrieaerodynamik GmbH (Institute for Industrial Aerodynamics), Institute at the Aachen University of Applied Sciences in accordance with the test procedures described in the American Standards ASCE 7-10, ASCE 7-16, ASCE7-22, ASCE 49-12 and ASCE 49-21 as well as with the German Standards DIN EN 1991-1-4:2010-12, DIN EN 1991-1-4/NA:2010-12 and with the wind tunnel guideline of the Wind Engineering Association of Germany, Austria and Switzerland, WtG, as well as EN 1991-1-4:2005.

The result of these analyses are pressure coefficients that apply to solar ballasted roof-mount systems to account for wind actions on these systems, as EN 1991-1-4 does not provide any guidance for such structures and ASCE 7-10, ASCE 7-16 and ASCE 7-22 only give broadly simplified and conservative values. With regard to wind loads on solar roof-mount systems the simultaneous wind action on top and bottom surfaces of the modules, venting and other aerodynamic characteristics are of particular importance. In this manner, pressure coefficients for the design of solar roof-mount systems differ significantly from pressure coefficients that apply to roofs and roof coverings as these only account for single-sided loading and not for the special geometry of solar roof-mount-systems.

The modules of the “S-Dome 6.10” and “S-Dome 6.15” solar ballasted roof mount systems have tilt angles of approx. 7° to 11° and 9.8° to 15°, respectively, and are installed on a substructure in landscape orientation. The systems consist of solar PV panels which are tilted south and have wind deflectors with mean angles of approx. 80° to 83°. The modules have chord lengths between 950 mm and 1170 mm or 1305 mm, respectively. The most important geometric dimensions are shown in Figure 1 to Figure 4 for the “S-Dome 6.10” system and in Figure 5 to Figure 7 for the “S-Dome 6.15” system.

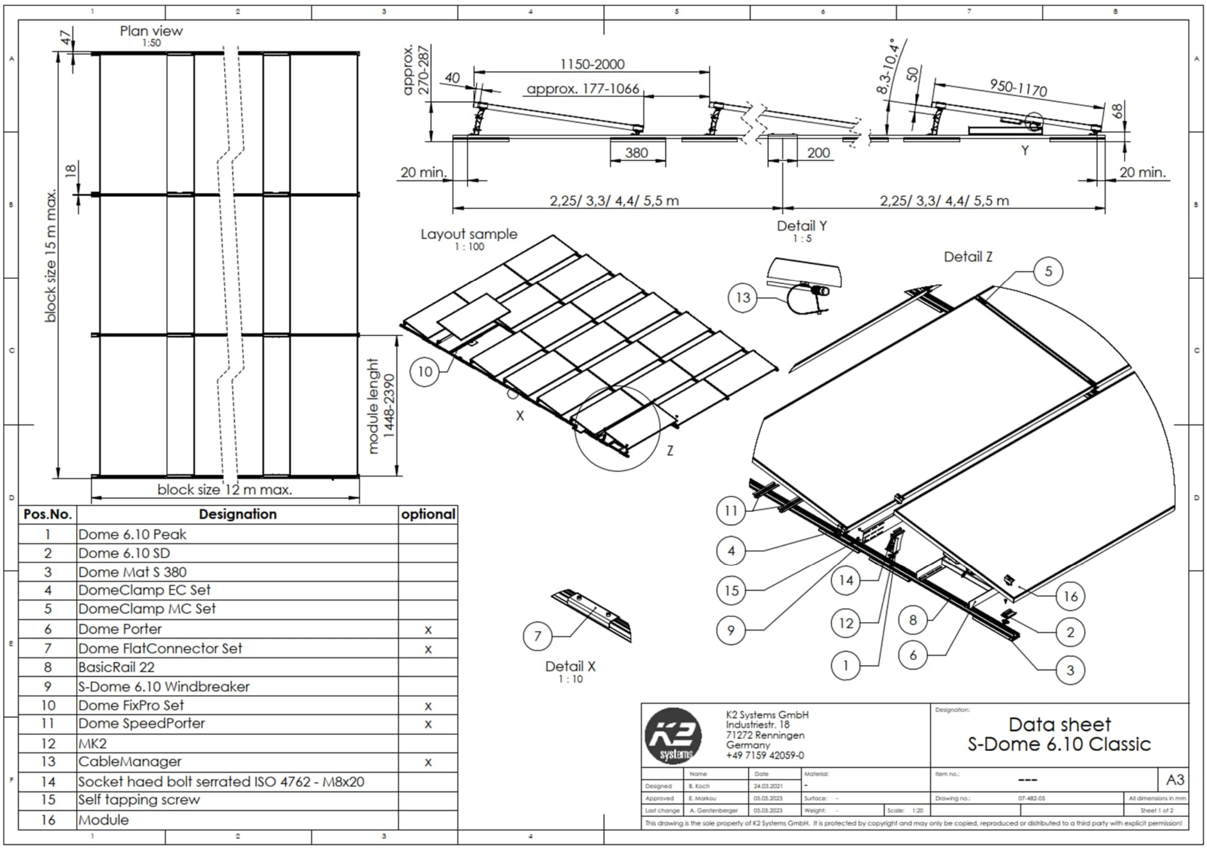


Figure 1: System data sheet for the “S-Dome 6.10 Classic” solar ballasted roof mount system

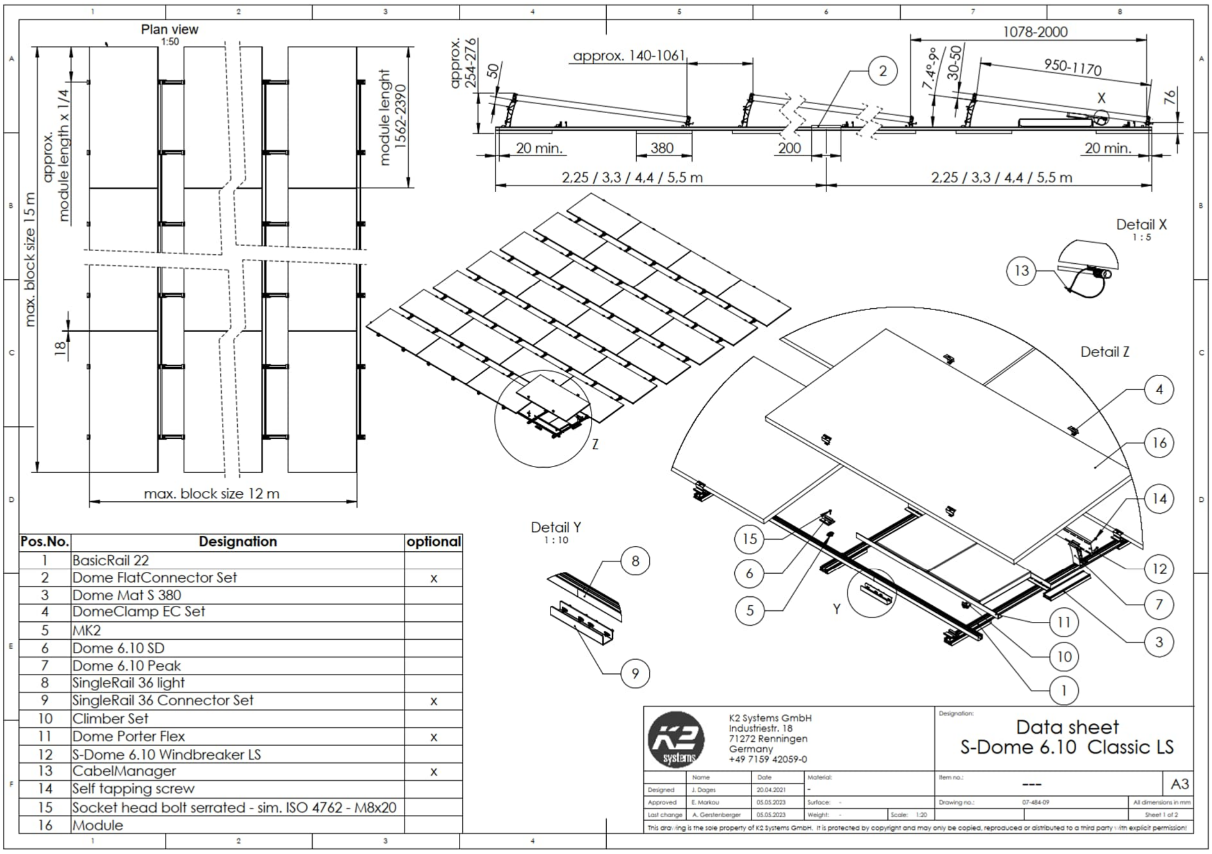


Figure 2: System data sheet for the “S-Dome 6.10 Classic LS” solar ballasted roof mount system

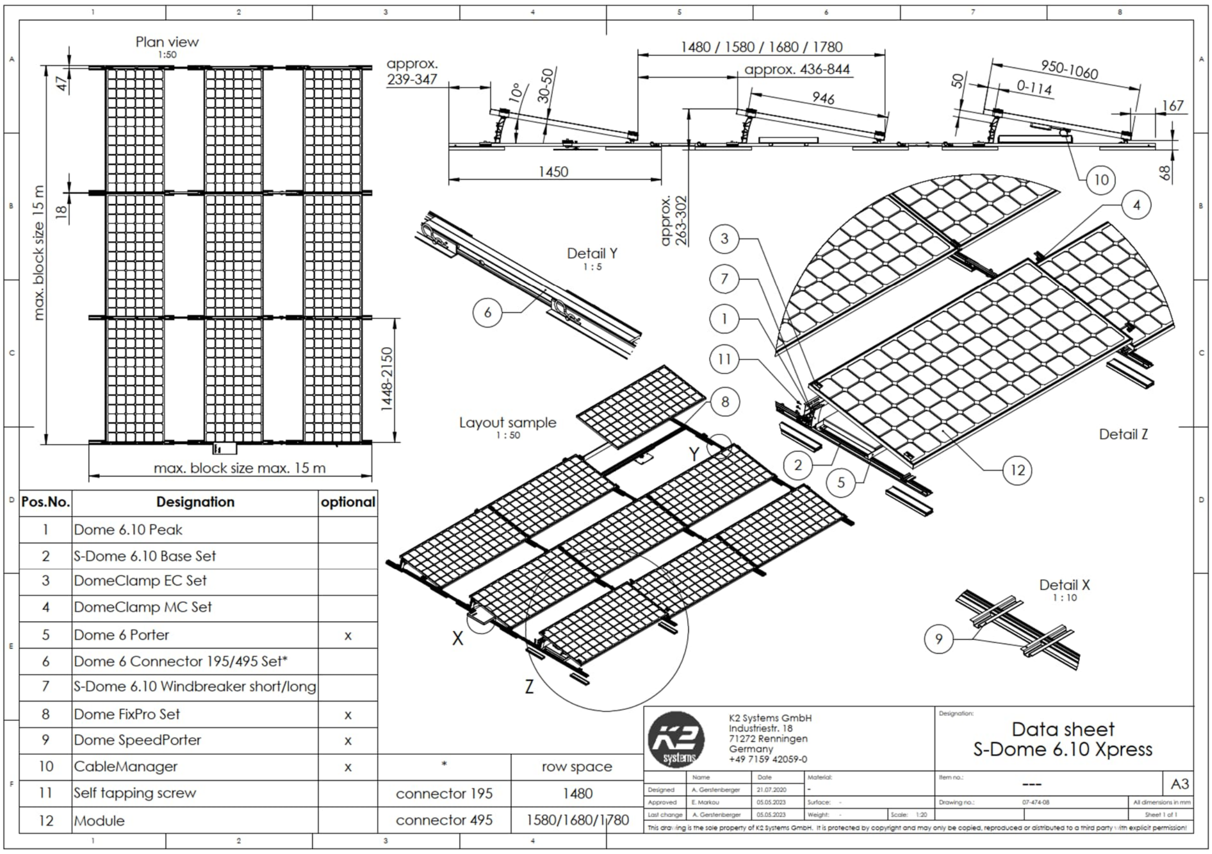


Figure 3: System data sheet for the “S-Dome 6.10 Xpress” solar ballasted roof mount system

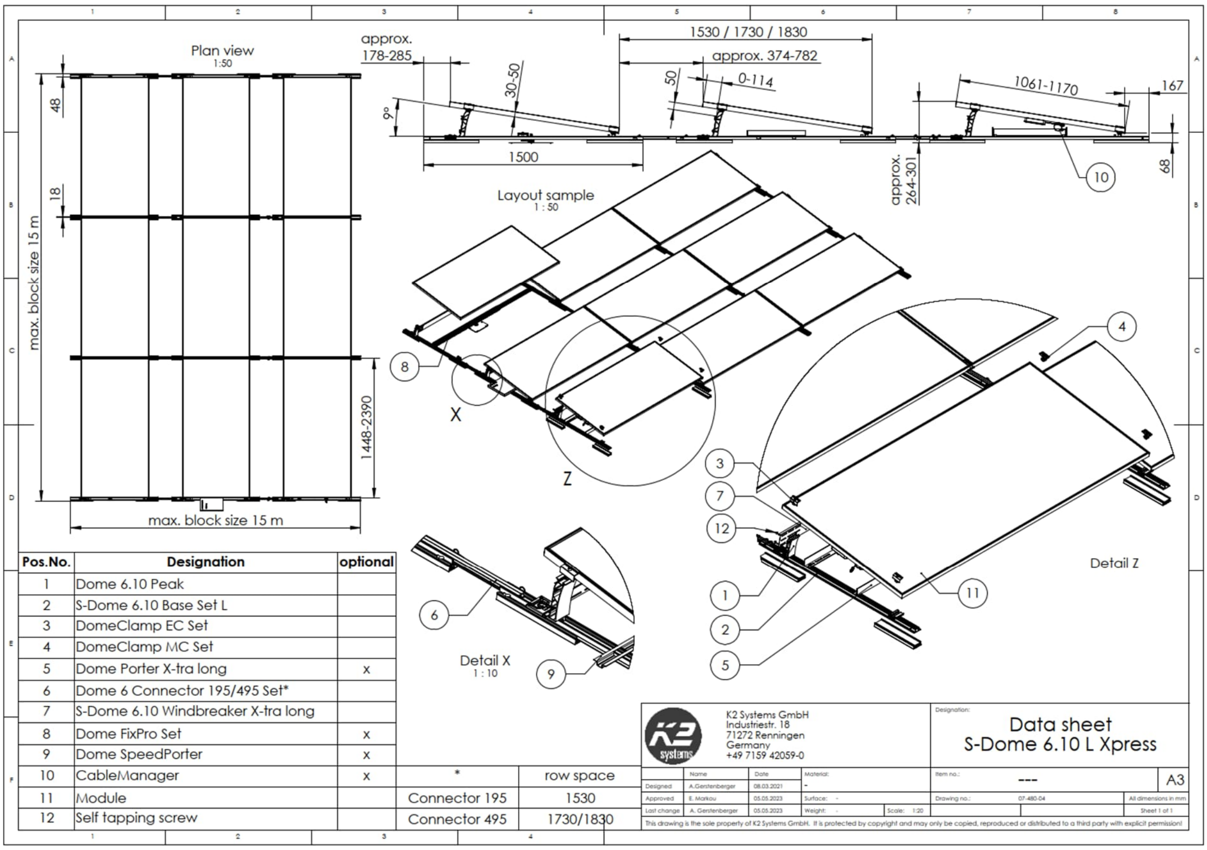
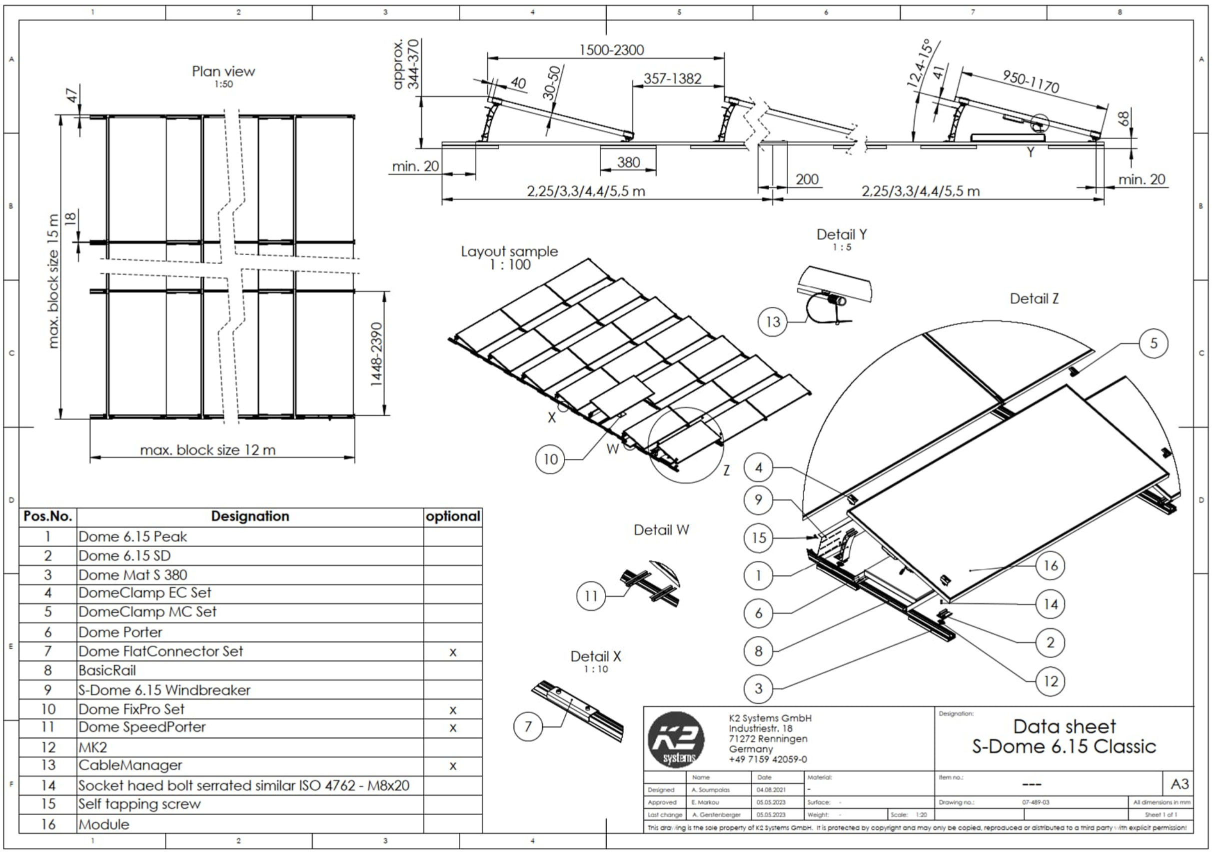
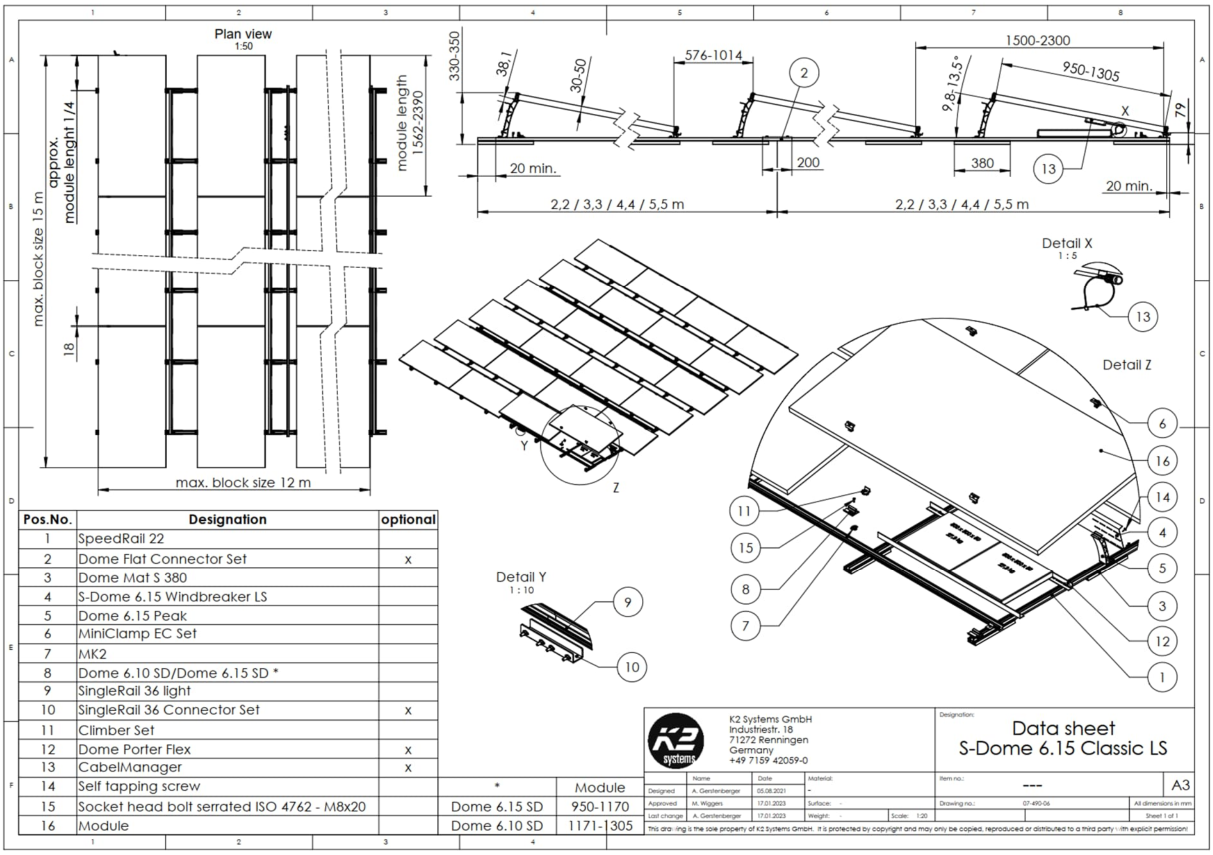


Figure 4: System data sheet for the “S-Dome 6.10 L Xpress” solar ballasted roof mount system



Pos.No.	Designation	optional
1	Dome 6.15 Peak	
2	Dome 6.15 SD	
3	Dome Mat S 380	
4	DomeClamp EC Set	
5	DomeClamp MC Set	
6	Dome Porter	
7	Dome FlatConnector Set	x
8	BasicRail	
9	S-Dome 6.15 Windbreaker	
10	Dome FixPro Set	x
11	Dome SpeedPorter	x
12	MK2	
13	CableManager	x
14	Socket haed bolt serrated similar ISO 4762 - M8x20	
15	Self tapping screw	
16	Module	

Figure 5: System data sheet for the “S-Dome 6.15 Classic” solar ballasted roof mount system



Pos.No.	Designation	optional
1	SpeedRail 22	
2	Dome Flat Connector Set	x
3	Dome Mat S 380	
4	S-Dome 6.15 Windbreaker LS	
5	Dome 6.15 Peak	
6	MiniClamp EC Set	
7	MK2	
8	Dome 6.10 SD/Dome 6.15 SD *	
9	SingleRail 36 light	
10	SingleRail 36 Connector Set	x
11	Climber Set	
12	Dome Porter Flex	x
13	CabelManager	x
14	Self tapping screw	
15	Socket head bolt serrated ISO 4762 - M8x20	
16	Module	

*	Module
Dome 6.15 SD	950-1170
Dome 6.10 SD	1171-1305

Figure 6: System data sheet for the “S-Dome 6.15 Classic LS” solar ballasted roof mount system

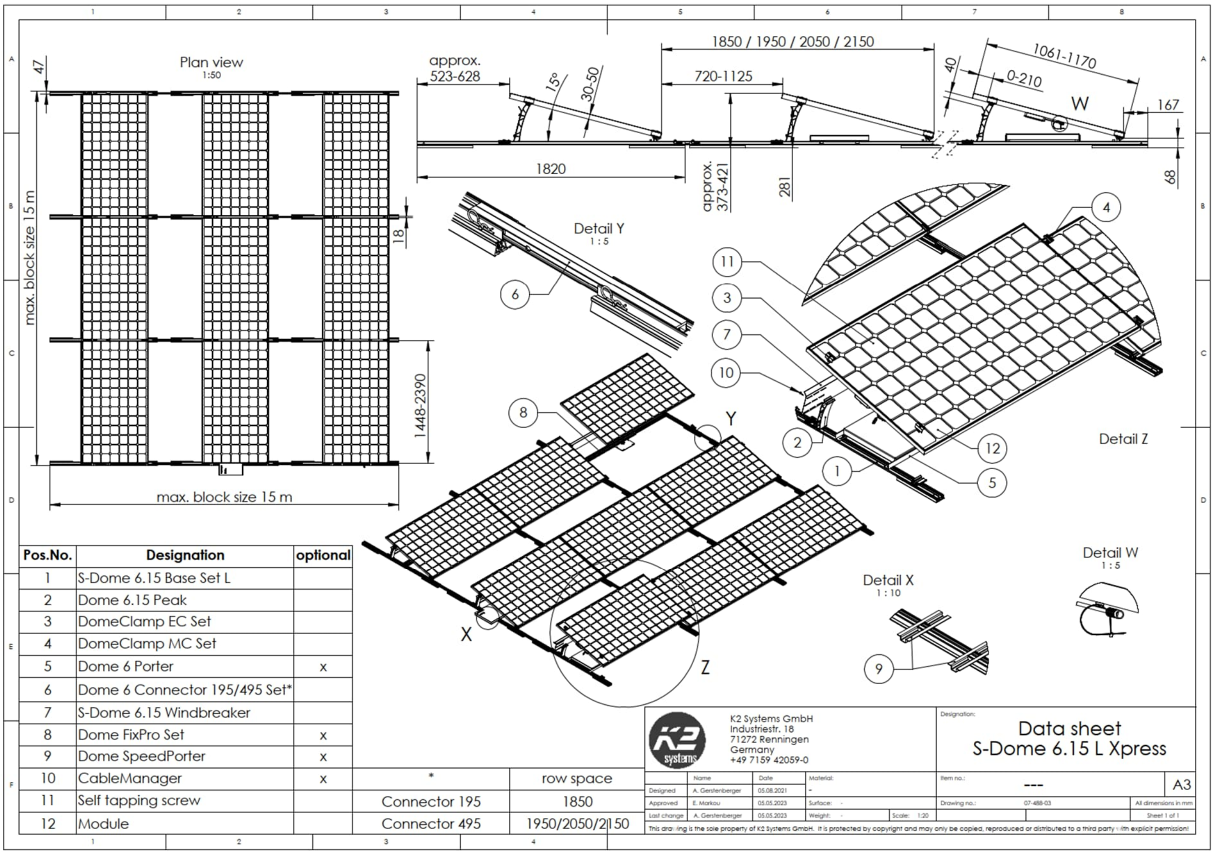


Figure 7: System data sheet for the “S-Dome 6.15 L Xpress” solar ballasted roof mount system

The test results are likely to be appropriate for upwind Exposures B, C and D on flat-roofed buildings with a maximum roof angle of 7°, assuming use in compliance with ASCE 7-10, ASCE 7-16 and ASCE 7-22, and for upwind terrain categories 0 through IV on flat-roofed buildings with a maximum roof angle of 10°, assuming use in compliance with EN 1991-1-4:2005 and corresponding National Annexes. Pressure coefficients are given separately for different roof and array zones as well as for different wind sectors. These results are only to be used for arrays with setback from the roof edges of $a \geq 2 \cdot (h_s - h_p)$, where h_s is system height and h_p is parapet height. Smaller offsets require additional safeties to be incorporated into ballast calculation.

In order to determine the wind loads, the net pressure coefficients, c_p, have to be multiplied with the peak velocity pressure at roof height of the industrial building. In case of the American standards, the corresponding peak velocity pressure, q_z, at roof height z, is calculated depending on the basic wind speed, the velocity pressure exposure coefficient, the topographic factor, the wind directionality factor, the ground elevation factor and the roof height in accordance with ASCE 7-10, section 30.3.2 and with ASCE 7-16 and ASCE 7-22, section 26.10.2 for calculation of the design wind loads. In case of the European standard, the corresponding peak velocity pressure, q_p, at roof height z, is calculated using the National Annexes to EN 1991-1-4:2005. For calculation of q_p in Germany, see DIN EN 1991-1-4:2010-12 and DIN EN 1991-1-4/NA:2010-12.

Peak suctions and peak wind loads on solar panels located on flat roofs are usually not caused by winds normal to the building walls, but by vortices originating from the roof corners due to oblique winds, see also Figure 8. The pressure coefficients were determined for a set-up where wind direction 0° corresponded to wind blowing on the north façade of the flat-roofed building. However, the results may also be applied if the main axis of the array is skewed with the building edges. Moreover, the present design loads for wind actions apply without restriction to solar arrays deployed on buildings which are considered rigid. For rooftop obstructions, array interruptions, stepped (multi-level) roofs, L-shaped and other non-rectangular roofs, and for taller neighboring structures provisions for design pertaining to wind effects are given.

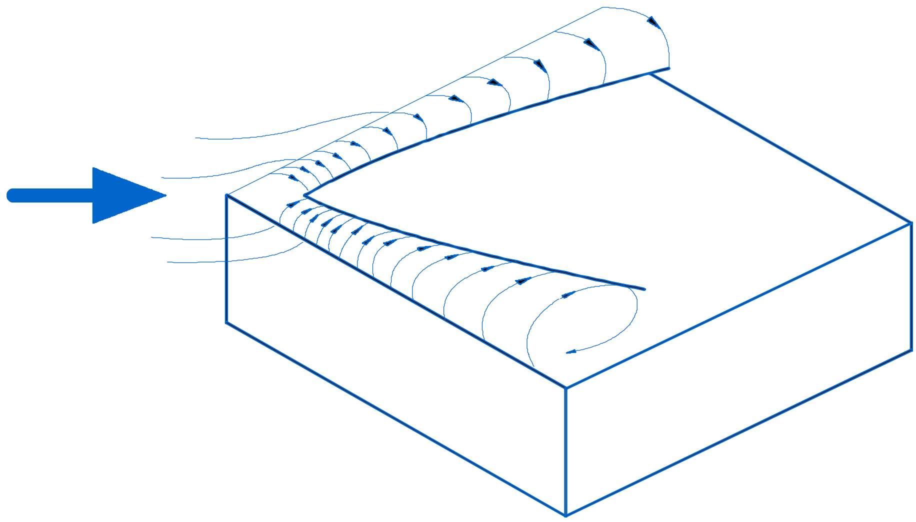


Figure 8: Vortices originating from the windward roof corner causing the peak suctions on flat roofs and on roof mount solar panels

The methodology of the wind tunnel testing and of the analysis is given in more detail in report KSR04-1-2 for the “S-Dome 6.10” system and in report KSR04-6-2 for the “S-Dome 6.15” system. This methodology is based on state-of-the-art wind tunnel testing procedures outlined in novel codes such as ASCE 7-22, ASCE 49-21 and SEAOC-PV-2-2017 and has become a global standard in recent years. I.F.I. have significantly contributed to SEAOC-PV-2-2017 "Wind Design For Solar Arrays", the guideline of the Structural Engineering Association of California the contents of which have been widely adopted by ASCE 7-16, the previous version of the US building code, and are still found in the most recent version, ASCE 7-22. In addition, I.F.I. have published numerous scientific papers related to wind design for low-profile solar photovoltaic arrays on flat roofs. These publications are based on wind tunnel studies conducted on numerous different solar roof and ground mount systems, the results of which were applied over the past decade to solar projects in Europe, the U.S. and all over the world.

Recent publications issued by I.F.I. which are related to wind loading on solar arrays are among others

- “Peak net pressure coefficients on roof-parallel photovoltaic arrays mounted on a low-rise, 10° gable roof”, International Conference on Wind Engineering (ICWE14), Porto Alegre, Brazil, 2015
- "Peak negative pressure coefficients on low-tilted solar arrays mounted on flat roofs: The effects of building size and model scale", European African Conference on Wind Engineering EACWE, Liège, Belgium, 2017
- "Peak wind loads on single-axis PV tracking systems", International Conference on Wind Engineering (ICWE15), Beijing, China, 2019
- “The effect of a wind deflector on the wind loads of a photovoltaic roof mount system”, 8th European and African Conference on Wind Engineering (EACWE8), Bucharest, Romania, 2022