

Investigation Report

Expert Assessment

Client: Hilti Corporation
Business Unit Installation Systems
Feldkircherstraße 100
9494 Schaan
Liechtenstein

Order-No. (Client): Mr. Riello

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The test results relate only to the items tested.

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1 Purpose of Investigation

On 28 January 2009, the MPA Universität Stuttgart was commissioned by the company Hilti AG to assess the corrosion performance of support structures and mounting systems for solar installations, under consideration of the various materials and installation situations envisaged.

The mounting systems are essentially made of aluminium, stainless steel and galvanised steel and are anchored in reinforced concrete or rammed into the ground. The systems are suitable for the mounting of framed solar modules as well as thin-layer, frameless modules. As from the summer of 2009, the mounting systems are due to be distributed worldwide.

Hence, the corrosion performance of the individual construction components and/or materials when exposed to the atmosphere, as well as the bimetallic corrosion performance of the material pairs and the corrosion performance in the soil were to be examined. The planned service life period is 25 years, also in the vicinity of sea water (Corrosion Category C4).

To enable assessment, the MPA Universität Stuttgart was provided with documents and sketches of the systems to be used and/or the construction components with the corresponding material specifications.

2 Description of the Systems and Materials

The design of the mounting systems for solar installations is modular. Essentially, four different systems shall be used. The exact material specifications of all construction components are listed in the supplements.

A Ground-mounting on concrete foundations

A system of aluminium channels, arranged crosswise, consisting of AlMg0,7Si (longitudinal channels, transversal channels), is fastened by means of connecting elements to aluminium support posts of different heights consisting of AlSiMg (support posts) in such a manner that the solar modules can be directed towards the sun at an angle of about 30°. The channels are connected together by means of the "sleeves", consisting of AlMg0,7Si via the "cross-connectors" made of AlSiMgMn with stainless steel bolts of the type V2A and nuts, type 1.4306.

The transversal channels are connected to the "support posts" by means of the "basic connector" MSP-AL BC, consisting of AlMg0,7Si. The connectors "MSP-AL BC" are fastened to the support posts by two "tooth plates", made of AlMg0,7Si and a stainless steel bolt fastening of the type V2A. The fastening of the "connector MSP-AL BC" to the "transversal channels" is secured by four bolts, type 1.4301, and two nuts made of AlMg0,7Si.

The rigidity of the front and rear "support posts" is reinforced by a "support channel", made of AlMg0,7Si, which is fastened to the supports by a stainless steel bolt fastening, type V2A (bolt M12x100) and V4A (nut M12).

The "support posts" are anchored to a reinforced concrete foundation by stainless steel bolts, type V2A (bolt M12x100) and V4A (nut M12) using "base plates". If the system is to be used without front "support posts", the transversal channel is anchored to the ground by a "ground connector". The "ground plates" and/or "ground connectors" are separated from the reinforced concrete by "insulating plates", consisting of EPDM.

The solar modules are fastened together and on the "longitudinal channels" by means of "middle clamps" and/or "end clamps" (MSP-EC, MSP-MC, MSP-TFL-AL-EC, MSP-TFL-AL-MC) made of AlMgSi in conjunction with 1.4301, 1.4306 and 1.4310 (spring).

B Ground-mounting on ground anchors

All construction components of System B correspond with those of system A. However, the construction is mounted not upon reinforced concrete, but instead upon ground anchors.

C Ground-mounting by means of pile-driven steel profiles

For this variant, the front and rear supports (ramming profiles) made of galvanised steel (S355J2), finished with a zinc coating of 45 µm in thickness, are rammed into the ground under consideration of the structural calculations. The "ramming profiles" and the "transversal channels" are fitted together by "MSP-AL-CC connectors" made of AlMg0,7Si (2-piece, connected by stainless steel bolts, type V2A). These are fitted to the "ramming profiles" by means of a bolt fastening (tooth plate, made of galvanized cast steel, galvanised bolt and nut).

The fastenings of the "MSP-AL-CC" connectors to the "transversal channels", of the "transversal channels" to the "longitudinal channels" and of the solar modules correspond to the comparable fastenings of System A and System B.

D Ground-mounting in concrete with cast-in steel profiles

All construction components of System D correspond with those of System C, except that, instead of the "ramming profile", "profile channels" (S355J2, zinc coating thickness 45 µm) are used, which are set in concrete on site.

3 Annotations regarding the evaluation and assessment of atmospheric corrosion

Atmospheric corrosion is characterised in that, on the one hand, a practically unlimited amount of oxygen is available and, on the other hand, however, only a small and irregularly occurring

amount of water influences the corrosion process. It is primarily influenced by the relative humidity of the air, the temperature as well as the content and properties of gaseous impurities and solids. With growing humidity and rising temperature, the speed of corrosion increases, whereby this effect is reinforced by increasing air pollution.

In regard to the corrosion of the metals, the sulphur dioxide content of the air is of primary importance. Based on the contents of the air in relation to corrosion-relevant parameters, such as chloride, sulphur dioxide and dust, corrosion is broken down according to DIN EN ISO 12944 into Corrosivity Classes from C1 (negligible corrosion) to C5 (very strong corrosion). In this context, for example, 95% of the land surface of the Federal Republic of Germany can be classified into the Corrosivity Categories C2 (low corrosivity) and/or C3 (moderate corrosivity).

Corrosivity Category C1 stands for dry, indoor spaces with no air pollution. Typical environments for Corrosivity Class 2 are atmospheres with low air pollution, such as those to be found largely in rural areas. Corrosivity Category C3 stands for urban and/or industrial atmospheres with moderate sulphur dioxide (SO₂) pollution and coastal areas with low salt content in the air. Industrial areas with strong SO₂ pollution and coastal areas with moderate salt content in the air are classified in Corrosivity Category C4. Corrosivity Category C5 is further subdivided into C5-I: industrial areas with high humidity and aggressive atmosphere and C5-M: coastal and off-shore areas with high salt content in the atmosphere.

The thickness reduction for non-alloy steel, zinc and aluminium determined after 1 year of outside exposure is shown in Table 1 (according to DIN EN 12500):

Table 1: Thickness reduction after the first year of outside exposure depending on the Corrosivity Category

Corrosivity Category	Non-alloy steel [µm]	Zinc [µm]	Aluminium [µm]
C2	> 1.3 to 25	> 0.1 to 0.7	≤ 0.2
C3	> 25 to 50	> 0.7 to 2.1	> 0.2 to 0.7
C4	> 50 to 80	> 2.1 to 4.2	> 0.7 to 1.8

Aluminium

Aluminium materials (pure aluminium and its alloys) belong to those metals that tend towards passivity. These are generally very resistant to atmospheric corrosion, because, due to their reaction with oxygen or steam, a thin oxide layer forms on their surface, protecting them against further attacks. In the long term, the effect of the atmosphere is only recognizable through pitting corrosion, accompanied by a negligible rate of mass loss.

The favourable performance of aluminium is explained by the fact that, although the corrosion mechanism in the atmosphere is more often than not a pitting mechanism, the constant interplay between corrosive attack and repassivation usually produces a more or less uniform corrosive effect.

The outstanding corrosion performance of aluminium in relation to the pH value from 4.5 to about 8.5 can be attributed to the extremely low solubility of the protective oxide layer in this area. However, in the presence of halogenides (e.g. chloride ions) the passivity of the aluminium materials towards the anodic side has a limit, i.e. the so-called pitting potential. After an incubation period, on exceeding the respective pitting potential, local pitting or surface corrosion occurs. Below this pitting potential limit, neither pitting nor surface corrosion can occur. Even in the event of mechanical damage to the oxide layer, no corrosion occurs. Instead, within the potential-dependent passive area, a spontaneous repassivation takes place.

When aluminium comes into contact with non-metal, a spread of crevice corrosion may occur. The critical crevice widths lie between 0.02 and 0.5 mm. With regard to environmental influences, crevice corrosion tends more often to attack aluminium under conditions such as those that would also favour corrosion in crevice-free zones, such as alkaline, acid and/or media containing chloride ions. The corrosion occurring in the crevice can be explained by aeration factors, i.e. by a lack of oxygen in the crevice. Conditions of a diminished supply of oxygen, impede the passivation process in the crevice. In engineering practice, the occurrence of crevice corrosion can be anticipated predominantly in coastal atmospheres and with exposure in atmospheres containing dust, soot and SO_2 . In structural engineering, when fastening elements are constantly or frequently subject to the effects of condensed water and harmful substances, such conditions can be generally regarded as unfavourable. In the crevices, humidity can be retained longer and harmful substances can become enriched.

Stainless Steel

Stainless steel owes its corrosion resistance to the formation of a submicroscopic, passive layer (passivity). In the context of this discussion, general corrosion can be excluded for all stainless steels.

For outdoor applications using stainless steel, pitting resistance is the decisive criterion for the choice of material. Since chloride is contained in practically all forms of dust, surface pollution and its accumulating concentration of chloride during the drying phase, it usually has a corrosive effect. Corrosive attacks are aggravated by acid condensates (sulphur and nitric oxides), the catalytic effects of dust (soot) or the electrochemical particles of foreign metal (non-alloy steel). It is immediately understandable that rough surfaces are more easily polluted and, therefore, more

vulnerable. Moreover, surfaces that are directly exposed to weathering and the accompanying precipitations are less susceptible than rear sides or under-sides, since the pollutants and chlorides that accumulate there are less regularly washed off.

Galvanised Steel

The good corrosion resistance of zinc and zinc coatings is due to the formation of a firmly adherent layer of protective coating. In the course of time, the coatings are slightly eroded by weathering, whereby they are constantly renewed from the zinc base, which, in turn, ultimately leads to a mass loss. Primarily, atmospheric exposure produces zinc oxide, which is transformed into zinc hydroxide by humidity in the air. From the carbon dioxide in the air, a protective layer is formed, which consists of a mixture of alkaline zinc carbonate and zinc hydroxide. With an increasing proportion of zinc carbonate, the layers become harder to dissolve, which considerably retards corrosion. With stagnating humidity or lack of oxygen, loose, porous corrosion products form, which mainly consist of $\text{Zn}(\text{OH})_2$. This, so-called white rust, has no protective properties. It occurs primarily through improper storage and transportation, bad ventilation and high humidity as well as resulting from contact with damp building materials, such as wood or heat insulation materials.

It is known that water-soluble ingredients (neutral salts, acids), depending on the atmosphere, are incorporated into the corrosion products of the zinc (Cl , SO_2) and that these influence the corrosion performance. In this, the sulphur dioxide content of the atmosphere is of primary importance, since, by forming easily soluble zinc sulphate, this dissolves the layers of protective zinc carbonate coating. In addition, in a marine atmosphere, alkaline zinc chloride may occur.

Zinc coatings produce a good cathodic protection effect in relation to steel. This cathodic protection only occurs when zinc and steel are electrically bonded together via a conductive electrolyte. The protective effect is all the greater the better the conductivity of the electrolyte.

The mass loss rates of zinc coatings are comparable with all manufacturing procedures and lie within a common range of spread. The duration of the protective effect of the zinc coatings is approximately proportional to the surface-related mass of the zinc coating.

4 Annotations concerning the evaluation and assessment of bimetallic corrosion

Bimetallic corrosion, or galvanic corrosion, is understood as the reinforced corrosion of a metallic area in relation to the self-corrosion of a corrosion element and is attributable to the pairing of two metals with electrochemically different behaviours one to the other.

The contact elements belong to the corrosion elements and consist of an anode, the active partner in the contact element, and a cathode, the noble partner in the contact element. The type of corrosion that occurs is bimetallic corrosion (formerly contact corrosion) having a corrosion appearance of an irregular, mostly trench-like, general attack. In the presence of good conductivity of the corrosive medium together with unfavourable surface conditions (large cathode/small anode), contact corrosion can quickly reach a degree that leads to corrosion damage.

Aluminium, in spite of its negative position in the electrochemical series, is relatively corrosion resistant, also in an aggressive environment. This is connected with the fact that, due to their passivation properties and low degree of electron conductivity, the oxide layers that are formed impede the dissolution of the metal as well as the reduction of oxygen. The protective effect of the oxide layers reaches its limit at that point when the aluminium materials are polarised by contact with "noble" metals (copper materials, stainless steel) beyond their pitting potential. In the case of bimetallic corrosion, aluminium is subject to stronger attack, particularly in the presence of aggressive electrolytes, such as water containing chloride ions. The partial cathodic reaction, which is strongly retarded on the aluminium, can then exert an almost unimpeded effect on the contact material. Aluminium then behaves, analogous to its position in the electrochemical series, like an active metal and, in this case, if other necessary conditions (high cathode/anode ratio, or additional crevice conditions) are fulfilled, can be more strongly attacked in the form of pitting or general corrosion.

Strong bimetallic corrosion is only to be expected in structural engineering if the electrolyte possesses a sufficiently high conductivity, i.e. if it is "aggressive". In the presence of water containing chloride ions, damage caused by bimetallic corrosion may occur when aluminium construction components are assembled together with stainless steel, copper materials, lead and non-alloy steel. Contact between aluminium and zinc should not cause increased corrosion of the aluminium.

5 Annotations concerning the evaluation and assessment of soil corrosion

For the type and speed of corrosion processes in the soil, the physical and chemical properties of the soil itself are responsible. In particular, the specific soil resistance, the water content, the pH value, the buffer capacity, the sulphide and chloride content and the soil homogeneity should be mentioned. Studies have shown that the formation of coating layers of hot-dip galvanised steel in sandy soil is completed after two years.

In the case of metals in the soil, the corrosion performance is primarily determined by the aeration capacity and the soil resistance. With increasing resistance (rising conductivity of the electrolyte)

the corrosion speed accelerates. The aeration capacity and resistance of the soil are lower with a higher content of fine particles and water. The soil resistance falls further with increasing salt content and rising temperature.

Soil conditions are classified into different soil categories, namely I for slightly aggressive, II for moderately and III for very aggressive soil. In this connection, poor aeration, a high electrical conductivity and a high salt and water content are typical for aggressive soil. Low aggressiveness of the soil is characterised by high soil resistance ($> 50000 \Omega \cdot \text{cm}$). Irregular aeration and the irregular distribution of salts may promote corrosive effects.

6 Evaluation of the corrosion performance of the support and fastening systems for solar installations

Solar modules are normally erected at an angle of approximately 30° , i.e. the surface of the collectors is directly exposed to the weathering and is washed clean by rainwater precipitation. The support structures to be assessed here, with the exception of the module clamps, are fully covered by the collectors and are normally not subject to the effects of water precipitation.

If the solar installation is optimally aligned, the collectors face towards the south. In central and west Europe north-westerly weather with a north-westerly wind predominates, so that the weather side is facing north-west. The erection angle of 30° is regarded as relatively flat, so that the outer surfaces of the support structure of the solar installation to be assessed can only be washed clean by precipitation as well in the event of extreme weather conditions. Due to the strongly profiled design of the construction components and the push-in type assembly (e.g. longitudinal channel - sleeves or longitudinal channel - cross connectors - transversal channel) the washing off and therefore the cleaning of all construction components and crevices by rain water is excluded.

From the technical point of view, the following corrosion risk potential for the individual materials emerges:

Aluminium

Generally speaking, aluminium construction components are highly resistant against atmospheric corrosion. Due to the stable resistance of the coating layers against diluted acids, aluminium materials are also subject to only minor corrosion caused by sulphuric acid formed from the SO_2 content of the air in a normally polluted atmosphere (up to Corrosivity Category C3).

In the presence of strongly polluted industrial air (Corrosivity Category C4 to C5-I), noticeable pitting may occur due to the effect of acid, formed by the absorption of SO_2 , especially when pollution particles have accumulated on the surface. Since the support structure for the solar

modules is normally not freely exposed to rain water, dust and other pollutants cannot be washed off so easily.

Pitting also predominantly occurs in marine atmospheres (Corrosivity Category C4 to C5-M), caused by the chloride ions that are enclosed in the air. However, here too, the depth of the pitting is normally only limited, which can be attributed to the sealing effect of the corrosion products that form in the pit holes. Particularly serious corrosion is only observed in industrial atmospheres near the coast. The AlMgSi alloys used here, in conformity with E DIN EN 13195, evidence good resistance in atmospheres containing chlorides.

In regard to crevice corrosion, the crevice between the aluminium profiles and the EPDM seals of the support posts must be considered. However, due to the horizontal alignment of the crevice, it is regarded as unlikely that sufficient humidity to enable corrosion can penetrate into the crevice.

In principle, with the assembly of aluminium construction components together with stainless steel in the presence of conductive electrolytes, a strong bimetallic corrosion is to be expected. The aluminium profiles are largely connected with bolts and occasionally with nuts and washers made of stainless steel. The contact surface of the stainless steel components (cathode) is small in relation to the surface of the aluminium profile (anode). Even in the event of a brief occurrence of conductive electrolytes, no corrosion or only slight bimetallic corrosion is to be expected, due to the favourable anodes/cathodes relationship. The prerequisite for this is that the "cross connectors" and the "module clamps" have adequate contact with the aluminium channels and support posts.

However, problems may occur in permanently damp crevices between the stainless steel fastenings and the aluminium construction components. Under unfavourable conditions, even in atmospheres of Corrosivity Category C3, corrosion of the aluminium can be expected. However, since in the case of the connection points under examination (aluminium/ stainless steel) these points are not directly exposed to precipitation, but instead are almost exclusively only exposed to air humidity, the formation of permanently damp crevices is regarded as unlikely.

Stainless Steel

For the majority of adverse atmospheric influences encountered in the building industry, stainless steels of the type V2A (austenitic chrome-nickel steels) provide adequate resistance to corrosion for the Corrosivity Categories C2 and C3. Stainless steels of the type V4A (austenitic chrome-nickel-molybdenum steels), due to their greater corrosion resistance, can also be used in industrial areas or in marine atmospheres (Corrosivity Categories C4 and C5).

A self-cleaning process of the steel surfaces by rain precipitation has a positive influence on corrosion performance. Experience shows that stainless steel construction components that are

not exposed to water precipitation corrode much more strongly than the same components that are fully exposed to rain water. The stainless steel connecting elements used here are substantially covered by the solar modules and, therefore, are not subject to the self-cleaning effect of precipitation.

Hence, connecting elements made of stainless steel of the type V2A are only considered adequately resistant in atmospheres classified up to Corrosivity Category C3. In the immediate vicinity of the coast or in industrial atmospheres (C4), stainless steel of this type should not be used in the application case under assessment.

Galvanised Steel

Zinc coatings on steel are crucial to performance primarily in regard to atmospheric corrosion. For estimating the protective duration of zinc coatings, it is sufficient to examine the thickness of the coating in relation to the respective, corrosive influences. Due to the approximately linear course of zinc corrosion, the duration of resistance is directly proportional to the thickness of the zinc coating. The thickness of the coatings of the galvanised construction components used in the case under assessment lies at about 45 µm. Hence, the service life of the galvanised channels can be roughly estimated on the basis of the thickness of the zinc coating in relation to the atmosphere, as shown in Table 1. In this respect, it should be considered that the values have been calculated from the corrosion in the first year, which, from experience, is higher than that in the succeeding years.

Independent of this, the corrosion performance of the support posts in the soil must be considered. For the reasons described under Point 5, zinc corrosion increases primarily with a rising quantity of fine particles and salt in the soil. A high proportion of fine particles in the soil also increases the water retaining capacity and/or decreases the drainage capacity, resulting, in the long term, in an increased water content in the soil. Hence, the type and scope of the corrosion of galvanised steel in the soil are decisively determined by the structure and the resulting hydraulic balance of the soil itself.

In Germany, information regarding the risk of corrosion for hot-dip galvanised steels is contained in DIN 50929. Due to the numerous factors influencing the corrosion of hot-dip galvanised components in the soil, a general observation is not possible. In the case of non-aggressive or mildly aggressive soil, classified under Category I, an corrosion rate for galvanised steel of 2 µm per year can be anticipated. In the case of moderately aggressive soil, the rate lies at 3 µm per year and with aggressive soil of the Category III at 36 µm per year.

7 Summary and Recommendations

The support structure for solar installations, consisting of components made of aluminium, galvanised steel and stainless steel, was assessed in regard to its resistance to corrosion in the atmosphere. To this end, all systems were examined in respect of the atmospheric corrosion, bimetallic corrosion and crevice corrosion performance of the materials used. In addition, for System C, the performance of galvanised steel in the soil also had to be determined.

From the corrosion point of view, there are no reservations regarding the corrosion performance in respect of the planned design of the support structure of the **Systems A, B and D** in atmospheres of the Corrosivity Category C2 and C3 and for the intended service life period of 25 years.

For applications in marine atmospheres (C4), it is recommended, for the reasons stated above, that exclusively steel of the Type V4A should be used for the stainless steel fastening elements. The use of AlMg0,7Si, AlSiMg, AlSiMgMn and AlMgSi is possible in principle, however, in accordance with the observations made above, corrosion may be expected in crevices, particularly in relation to stainless steel construction components. In the course of time, however, the corrosion products resulting therefrom should close the crevices so that, in the envisaged time period, the corrosion should not result in corrosion damage. Accordingly, the use of the support structure of the **Systems A and B** is possible, also in marine atmospheres (C4) for the planned service life period of 25 years.

From a corrosion point of view, there are no reservations against the use of the galvanised ramming profiles of **System C** with a zinc coating thickness of 45 µm in atmospheres of the Corrosivity Category C3 and in non-aggressive or mildly aggressive soil for the planned service life period of 25 years.

However, for applications already in moderately aggressive soil conditions, a service life period of only 15 years may be expected. In strongly aggressive soil conditions, the support system in the form presented here should not be used.

Prepared by

Approved and released by



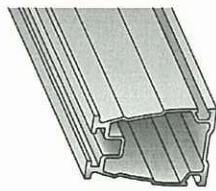
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Scientific Assistant



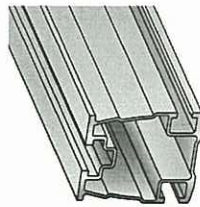
Dipl.-Ing. W. Beul
Head of Unit

MSP system for concrete / earth anchor foundation

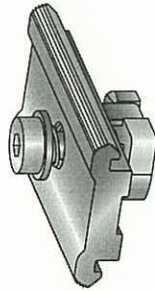
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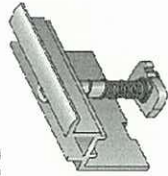
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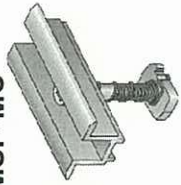
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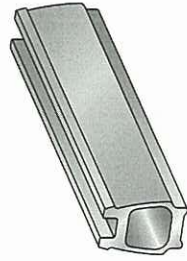
End Clamp
MSP-EC



Middle Clamp
MSP-MC



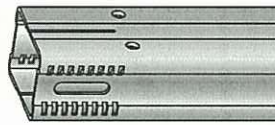
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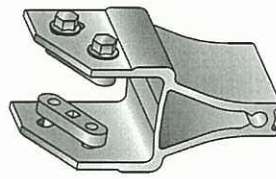
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Nut M12 A4
with flange



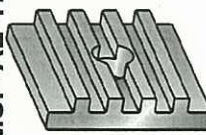
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MSP-AL-SP



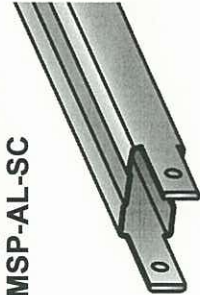
Basic connector
MSP-AL BC



Tooth plate
MSP-AL-TP



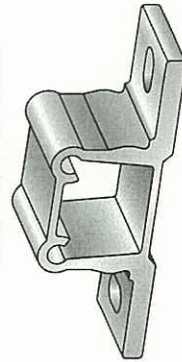
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MSP-AL-SC



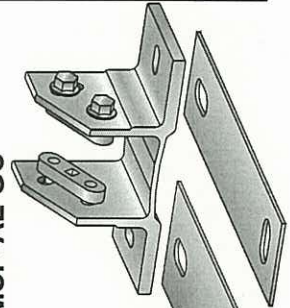
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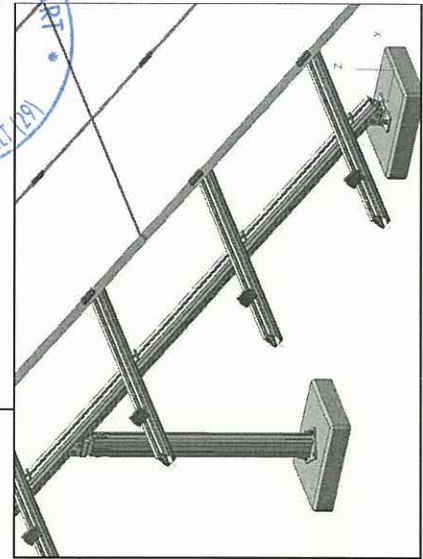
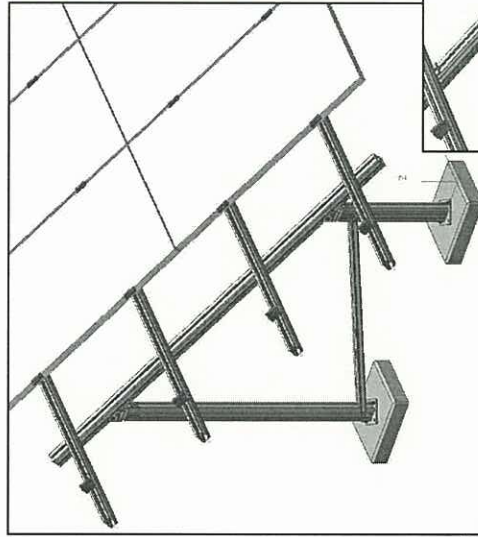
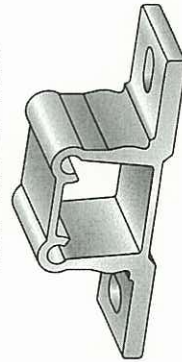
Insulating plates
•MSP-AL-GCI
•MSP-AL-BPI



Ground connector
MSP-AL GC

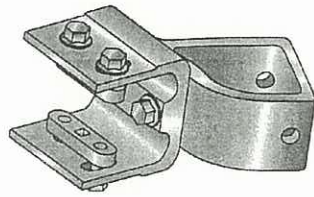


Base Plates
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•MSP-AL-BP M16

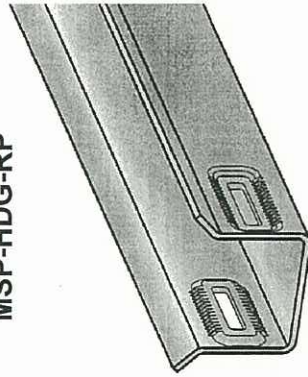


MSP system for ramming / cast-in concrete foundation

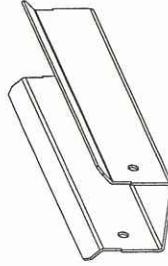
Comfort connector
MSP-AL CC



Ramming profile (5mm)
MSP-HDG-RP



Cast-in profile
MSP-HDG-CI (3mm)



Tooth plate
MSP-HDG-TP



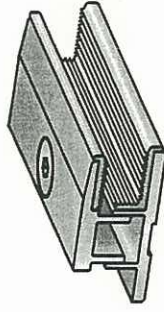
Bolt MSP-HDG M12x130
Nut M12 HDG with flange



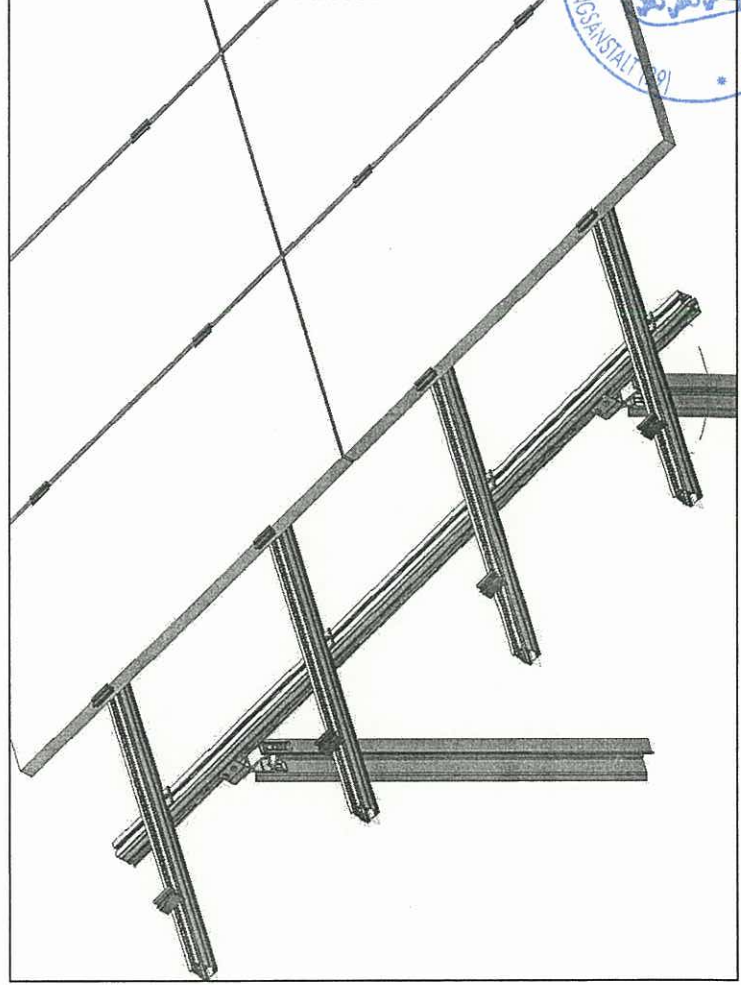
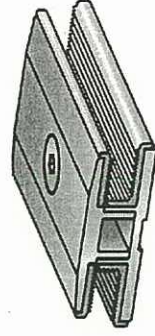
Bolt M12x110 HDG

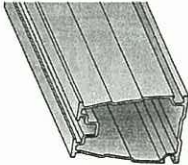
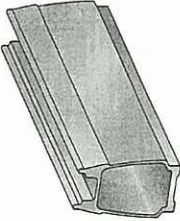
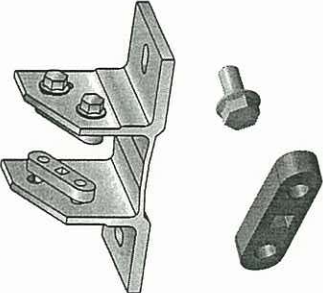


End Clamp
MSP-TFL-EC






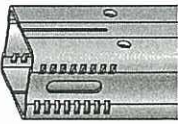
Middle Clamp
MSP-TFL-MC



Designation	Longitudinal Channel MSP-AL-LC 80 MSP-AL-LC 88 MSP-AL-LC 100 MSP-AL-LC 105	Sleeve MSP-AL-LS 80 MSP-AL-LS 88 MSP-AL-LS 100 MSP-AL-LS 105	Transversal Channel MSP-AL-TC	Ground Connector MSP-AL-GC
Design				
Material	EN AW-6063 T66	EN AW-6063 T66	EN AW-6063 T66	Connector: EN AW-6063 T66 Bolt M10x20: A2-70 Nut: EN AW-6063 T66
System	A,B,C,D	A,B,C,D	A,B,C,D	A,B

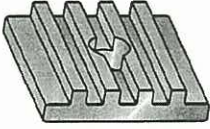

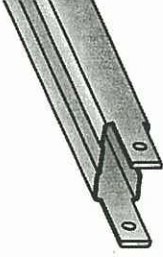

System A: Concrete foundation
System B: Earth anchor foundation
System C: Ramming foundation
System D: Cast-In foundation



Designation	Insulating plate MSP-AL-GCI	Base Plate MSP-AL-BP	Insulating plate MSP-AL-BPI	Support Post MSP-AL-SP
Design				
Material	EPDM	EN AW-6005 T6	EPDM	EN AW-6005 T6
System	A	A,B	A	A,B

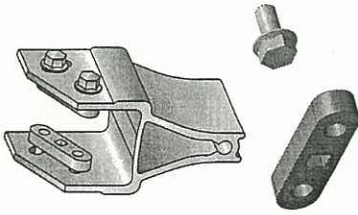
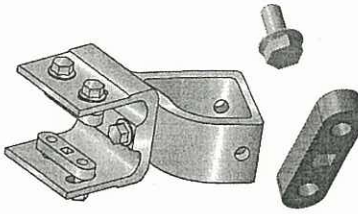
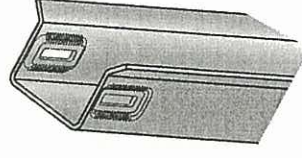

System A: Concrete foundation
 System B: Earth anchor foundation
 System C: Ramming foundation
 System D: Cast-In foundation



Designation	Tooth Plate MSP-AL-TP	Bolt M12x130 A2 Nut M12 A4 with flange	Support Channel MSP-AL-SC	Bolt M12x100 A2 Nut M12 A4 with flange
Design				
Material	EN AW-6005 T6	Bolt: A2-70 Nut: A4	EN AW-6063 T66	Bolt: A2-70 Nut: A4
System	A, B	A, B	A, B	A, B


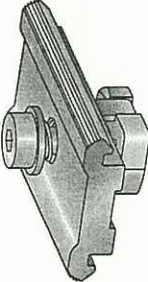
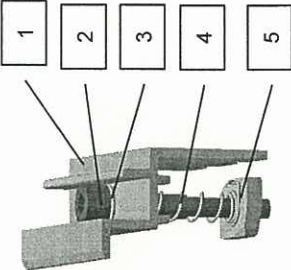
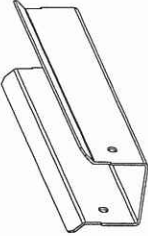
System A: Concrete foundation
 System B: Earth anchor foundation
 System C: Ramming foundation
 System D: Cast-In foundation



Designation	Basic Connector	Comfort Connector	Ramming Profile	Tooth Plate
	MSP-AL-BC	MSP-AL-CC	MSP-HDG-RP	MSP-HDG-TP
Design				
Material	Connector: EN AW-6063 T66 Bolt M10x20: A2-70 Nut: EN AW-6063 T66	Connector: EN AW-6063 T66 Bolt M10x20: A2-70 Nut: EN AW-6063 T66	S355J2, 5 mm 45 µm zinc coating	EN-GJMW-400-5 45 µm zinc coating
System	A, B, C, D	A, B, C, D	C, D	C, D


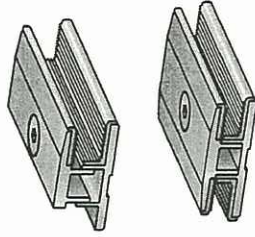
System A: Concrete foundation
System B: Earth anchor foundation
System C: Ramming foundation
System D: Cast-In foundation



Designation	Bolt M12x130 HDG Nut M12 HDG	Cross Connector MSP-AL-XC	Framed Modules Clamps End Clamp MSP-EC Middle Clamp MSP-MC	Cast-IN MSP-HDG-CI
Design				
Material	Steel 45 µm zinc coating	Connector: EN AW-6082 T6 Bolt: A2-70 Nut: X5CrNi18-10	1. EN AW 6060-T66 2. Screw: A2-70 3. Washer: X5CrNi18-10 4. Spring: X10CrNi18-8 5. Nut: X2CrNi19-11	S355J2 45 µm zinc coating
System	C, D	A,B,C, D	A, B, C, D	D

System A: Concrete foundation
System B: Earth anchor foundation
System C: Ramming foundation
System D: Cast-In foundation



Designation	Bolt M12x110 HDG Nut M12 HDG	Module Clamp MSP-TFL-AL-EC MSP-TFL-AL-MC
Design		
Material	Steel 45 µm zinc coating	Profile: EN AW 6060-T66 Spring: X10CrNi18-8 Nut: X2CrNi19-11 Screw: A2-70
System	D	A, B, C, D

System A: Concrete foundation
System B: Earth anchor foundation
System C: Ramming foundation
System D: Cast-In foundation

