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Electrically propelled road vehicles — Magnetic field wireless power transfer — Safety and interoperability requirements

Véhicules routiers électriques — Transmission d'énergie sans fil par champ magnétique — Exigences de sécurité et d'interopérabilité

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, SC 37, *Electrically propelled vehicles*.

This first edition cancels and replaces ISO/PAS 19363:2017, which has been technically revised. The main changes compared to the previous edition are as follows:

— MF-WPT classes and z- classes eliminated;

— compatibility classes introduced;

— reference devices changed to off-board devices and description updated;

— communication and functional requirements deleted.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document prescribes the usage of the wireless power transfer technology to charge electrically propelled road vehicles and has been developed based on ISO/PAS 19363.

Status of technological development:

This document specifies requirements for on-board components of a wireless power transfer systems. It gives guidance in terms of safety and performance and additionally addresses interoperability to off-board components from different manufacturers to, for example support the development of public wireless charging infrastructure. Even if the technology itself is well known, the implementation in a vehicle is new and demands to meet the very specific requirements of the automotive industry. This document is based on limited experience with series development and production. Current and future product developments will continuously prove (and disprove) the applicability of this document to further improve the contents, especially regarding the interoperability between systems from different manufacturers.

Cooperation during document development:

This document has been developed in intense cooperation with IEC/TC 69 WG7, which is establishing the IEC 61980 series. The IEC 61980 series covers the requirements for the off-board components in correspondence to the application of on-board components according to this document. Furthermore, SAE J2954 is standardising wireless power transfer systems in the United States of America. An exchange between the groups was continuously sustained during the document development. Even though there is no complete harmonization at this stage, several contents are comparable.

Electrically propelled road vehicles — Magnetic field wireless power transfer — Safety and interoperability requirements

1 Scope

This document defines the requirements and operation of the on-board vehicle equipment that enables magnetic field wireless power transfer (MF-WPT) for traction battery charging of electric vehicles. It is intended to be used for passenger cars and light duty vehicles.

This document addresses the following aspects for an EV device:

— safety requirements;

— transferred power and power transfer efficiency;

— ground clearance of the EV device;

— functionality with associated off-board systems under various conditions and independent of manufacturer;

— test procedures.

EV devices that fulfil the requirements in this document are intended to operate with supply devices that fulfil the MF-WPT related requirements in the IEC 61980 series.

NOTE 1 Charging of a vehicle in motion is not considered in this edition.

NOTE 2 Bi-directional power transfer is not considered in this edition.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6469-3:2018, *Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

IEC 61980-2, *Electric vehicle wireless power transfer (WPT) Systems — Part 2: specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems*

IEC 61980-3, *Electric vehicle wireless power transfer (WPT) systems — Part 3: Specific requirements for the magnetic field power transfer systems*

ICNIRP 2010, *Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz)*

CISPR 11, *Industrial, scientific and medical equipment — Radio-frequency disturbance characteristics — Limits and methods of measurement*

IEC 60664 (all parts), *Insulation coordination for equipment within low-voltage systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
alignment
relative position in x- and y-direction of the *secondary device* (3.15) to the *primary device* (3.9) for a given *secondary device ground clearance* (3.16)

Note 1 to entry: The coordinate system conforms with ISO 4130.

3.2
alignment tolerance area
intended *WPT* (3.22) operating area in x- and y-direction for a given *secondary device ground clearance* (3.16)

3.3
centre alignment point
geometrical centre of the *alignment tolerance area* (3.2)

Note 1 to entry: The position of the centre alignment point of an *MF-WPT system* (3.8) depends on the specific centre alignment points of the *primary device* (3.9) and *secondary device* (3.15).

3.4
electrically propelled vehicle
EV
vehicle with one or more electric drive(s) for vehicle propulsion

[SOURCE: ISO 6469-3:2018, 3.15, modified — The abbreviation "EV" has been added.]

3.5
EV device
on-board component assembly of *WPT system* (3.23)

Note 1 to entry: See Figure 1.

3.6
EV power circuit
EVPC
on-board component assembly, comprising the *secondary device* (3.15) and *EV power electronics* (3.7), as well as the electrical and mechanical connections

Note 1 to entry: See Figure 1.

3.7
EV power electronics
on-board component that converts the power and frequency from the *secondary device* (3.15) to the DC power output of the *EVPC* (3.6)

Note 1 to entry: See Figure 1.

3.8
magnetic field WPT system
MF-WPT system
WPT system (3.23) using magnetic field

3.9
primary device
off-board component that generates and shapes the magnetic field for *WPT* (3.22)

Note 1 to entry: See Figure 1.

3.10
protection area
volume in and around the vehicle that has uniform requirements with regard to effects of exposure to electromagnetic fields

3.11
rated output power
maximum power the *EVPC* (3.6) is designed to deliver consistently during a charging cycle

3.12
rechargeable energy storage system
RESS
rechargeable system that stores energy for delivery of electric energy for the electric drive

EXAMPLE Battery, capacitor, flywheel.

[SOURCE: ISO 6469-1:2019, 3.22]

3.13
reference EVPC
EVPC (3.6) that serves for testing purposes

3.14
reference supply power circuit
supply power circuit (3.19) that serves for testing purposes

3.15
secondary device
on-board component that captures the magnetic field

Note 1 to entry: See Figure 1.

3.16
secondary device ground clearance
vertical distance between the ground surface and the lowest point of the *secondary device* (3.15) including the housing

Note 1 to entry: Note to entry: The lower surface does not need to be planar or parallel to the ground surface

3.17
steady state
state of a system at which all state and output variables remain constant in time while all input variables are constant

[SOURCE: IEC 60050-351:2006, 351-24-09]

3.18
supply device
off-board component assembly of *WPT system* (3.23)

Note 1 to entry: See Figure 1.

3.19
supply power circuit
off-board component assembly, comprising the *primary device* (3.9) and *supply power electronics* (3.20), as well as the electrical and mechanical connections

Note 1 to entry: See Figure 1.

3.20
supply power electronics
off-board component that converts the power and frequency from the supply network to the power and frequency needed by the *primary device* (3.9)

Note 1 to entry: See Figure 1.

3.21
voltage class B
classification of an electric component or circuit with a maximum working voltage of (>30 and ≤1 000) V AC (rms) or (>60 and ≤1 500) V DC, respectively

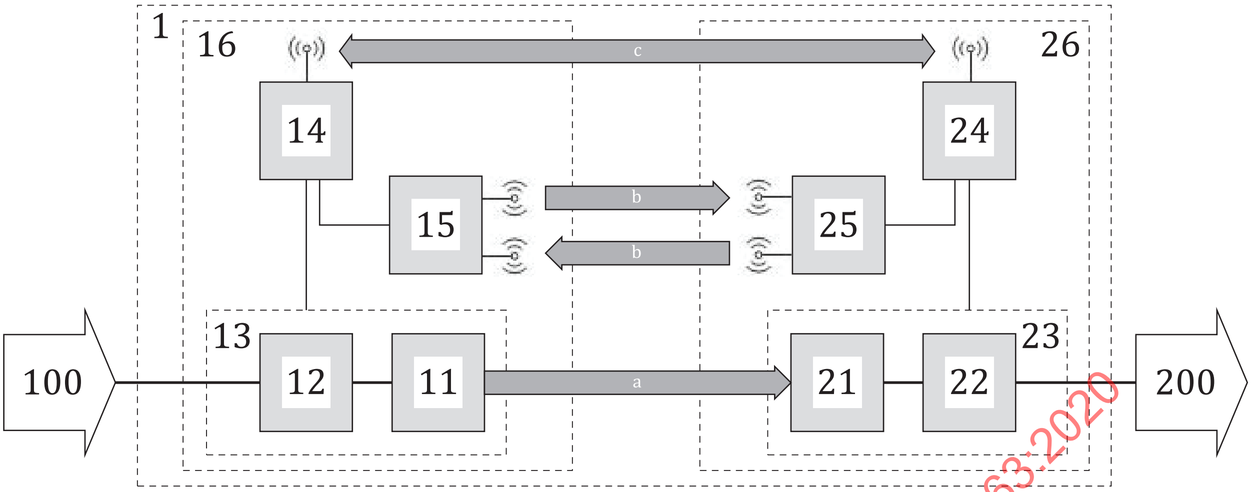
3.22
wireless power transfer
WPT
transfer of electrical energy from a power source to an electrical load without galvanic connection

3.23
WPT system
system comprising all necessary components for *WPT* (3.22) and control

4 System structure

To establish a general baseline for the requirements defined in this document, in IEC 61980-2 and in IEC 61980-3, the MF-WPT system is structured into functional entities. Figure 1 shows this structure of functional entities in an exemplary architecture.

NOTE Figure 1 is not meant to give an indication on hardware packaging.



Key

1 MF-WPT system

11 primary device
12 supply power electronics
13 supply power circuit
14 supply equipment communication controller (SECC)
15 supply device P2PS controller
16 supply device
100 supply network

21 secondary device
22 EV power electronics
23 EV power circuit
24 EV communication controller (EVCC)
25 EV device P2PS controller
26 EV device
200 RESS

NOTE The functional elements 14, 15, 24, and 25 are addressed in IEC 61980-2.

a Wireless power flow.

b Wireless P2PS interface.

c Wireless communication interface.

Figure 1 — Example of system structure

5 Requirements regarding environmental conditions

Components of the EV device installed at the underbody of the EV shall have IP degree IP6K7 and IP6K9K according to ISO 20653.

The environmental requirements applicable to a particular EV device shall be identified and agreed between the vehicle manufacturer and the supplier. The EV device shall withstand and retain its degree of protection under the typical mechanical loads and stresses the EV device is subjected to in its intended mounting position.

NOTE ISO 16750 (all parts) and ISO 21498 (all parts) contain information for guidance.

6 Classification

This document specifies requirements that address the following aspects of MF-WPT systems:

— system safety (Clause 10),

— system performance (Clause 7), and

— interoperability.

Requirements regarding system safety and system performance are relevant and applicable for safe operation of any MF-WPT system (including dedicated single-supplier solutions) while still assuring some base level of performance.

The interoperability requirements supplement the safety and performance requirements in order to allow for interoperability of a supply device and an EV device provided by independent suppliers.

Two compatibility classes have been specified to accommodate these design considerations:

— Compatibility class A: EV devices of this class are intended for interoperable application and are required to meet a set of safety and performance requirements. Cross-supplier interoperability is tested with the normative reference supply power circuits as specified in this document.

— Compatibility class B: EV devices of this class are not intended for interoperable application but still are required to meet the set of safety requirements; performance requirements may be different than those of compatibility class A. EV devices of this class are tested with supplier-specified supply power circuits.

7 MF-WPT power transfer requirements

7.1 General

Unless otherwise specified the requirements in Clause 7 refer to EVPCs of both compatibility classes.

Conformance to the requirements in 7.2 to 7.6 is tested according to 7.7, whereas EVPCs of compatibility class A are tested with the normative reference supply power circuits described in Annexes A and B, and EVPCs of compatibility class B are tested with supplier specific supply power circuits.

The supplier shall specify the rated conditions of an EVPC according to Table 1.

Table 1 — EPVC rated conditions

<table>
<tr><th colspan="2">Specifications of EVPC</th><th>Compatibility class A</th><th>Compatibility class B</th></tr>
<tr><td colspan="2">Frequency range</td><td colspan="2">Operation within 79 – 90 kHz</td></tr>
<tr><td colspan="2">Secondary device ground clearance range</td><td>EVPC specific within 100 mm – 250 mm</td><td>EVPC specific</td></tr>
<tr><td rowspan="2">Alignment tolerance area</td><td>x-direction</td><td>±75 mm</td><td>EVPC specific</td></tr>
<tr><td>y-direction</td><td>±100 mm</td><td>EVPC specific</td></tr>
<tr><td colspan="2">Centre alignment point(s)</td><td colspan="2">EVPC specific</td></tr>
<tr><td colspan="2">Output voltage range</td><td colspan="2">EVPC specific within voltage classes A and B according to ISO 6469-3.</td></tr>
<tr><td colspan="2">Rated output power</td><td>EVPC specific up to 11,1 kW</td><td>EVPC specific</td></tr>
</table>

NOTE 1 Typically, the output voltage range of the EVPC is aligned with the voltage range of the RESS.

NOTE 2 7.3 gives additional information for the determination of centre alignment point(s).

7.2 Frequency

MF-WPT for EVs is allowed to operate in the frequency range of 79 - 90 kHz. The operating frequency during power transfer is set by the supply device based on negotiations with the EV device.

7.3 Geometrical operating space

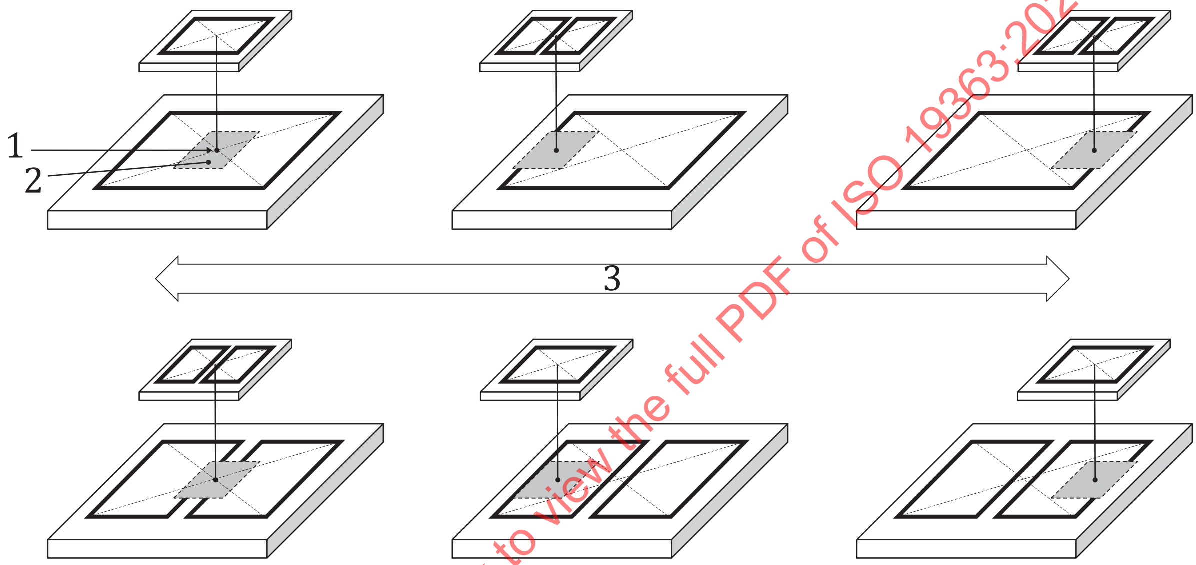
An EVPC shall meet the requirements of 7.4 and 7.5 within its geometrical operating space defined by its secondary device ground clearance range and the alignment tolerance area according to Table 2.

EVPCs of compatibility class B may have a specific alignment tolerance area that deviates from the values in Table 2.

Table 2 — Alignment tolerance area

Axis	Alignment tolerance area [mm]
x	±75
y	±100

In case of MF-WPT between a primary device and a secondary device of different topologies, several centre alignment points can exist. Examples are shown in Figure 2.



Key

1 centre alignment point of the EVPC

2 alignment tolerance area

3 direction of travel

Figure 2 — Example for centre alignment points between different coil topologies

The centre alignment points of supply power circuits are determined according to IEC 61980-3.

The centre alignment point(s) of the EVPC shall be specified with respect to the centre alignment points provided by the supply power circuit.

The requirements in this document apply to all centre alignment points specified for an EVPC.

The vehicle manufacturer may specify only one centre alignment point for alignment with a primary device of a different topology.

NOTE The selection of a single point can be due to a variety of reasons, for example the influence of the EV on the distribution of the magnetic field or the position of the EV within a parking spot.

7.4 Requirements for output power

An EVPC shall be able to deliver power up to its rated output power when operated with a supply power circuit.

An EVPC shall support the maximum ramp up rate of the supply power circuit. The maximum ramp up rate of supply circuits for EVPCs of compatibility class A is specified in IEC 61980-3.

7.5 Requirements for power transfer efficiency

Power transfer efficiency is the ratio of the output power of the EVPC (output of block #23 in Figure 1) divided by the input power of the supply power circuit (input to block #13 in Figure 1).

An EVPC shall support the minimum power transfer efficiency according to Table 3 when operated at rated output power with a supply power circuit.

An EVPC should support the minimum power transfer efficiency according to Table 3 when operated at power levels below the rated output power. Typical local supply network connections should be considered.

Table 3 — Minimum power transfer efficiency

Alignment	Minimum power transfer efficiency
Centre alignment point	85 %
Within alignment tolerance area	80 %

7.6 Requirements for output voltage

7.6.1 Performance requirements at different output voltage levels

An EVPC shall meet the requirements of 7.4 and 7.5 within its geometrical operating space according to 7.3 throughout its specific voltage range when operated with a supply power circuit.

7.6.2 Voltage ripple and voltage overshoot

The DC output voltage overshoot, the peak voltage and the voltage ripple amplitude of an EVPC shall be agreed between the vehicle manufacturer and supplier, taking into account the implication on the RESS and other on-board components.

NOTE A typical value for DC output voltage overshoot is ±1 %/ms, a typical value for the peak voltage is 10 % of the nominal DC output voltage and a typical value of the DC output voltage ripple amplitude is ±8 V.

7.7 MF-WPT power transfer test procedure

7.7.1 General

This subclause describes the test setup and procedure to be applied for conformance testing of the requirements specified in 7.2 to 7.6.

7.7.2 Test setup

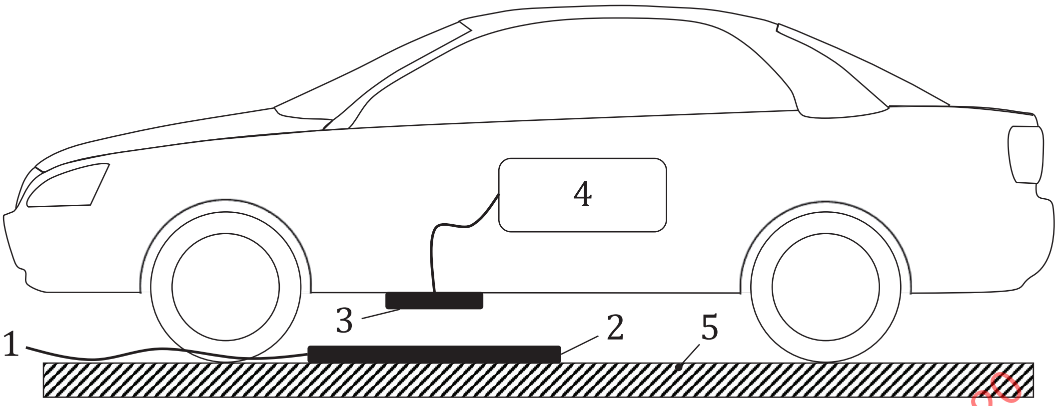
7.7.2.1 Apparatus

7.7.2.1.1 General

MF-WPT is influenced by the materials in the close surroundings, especially by the material structure of the EV. Reliable testing results can only be achieved, when influencing materials of the EV are adequately represented in the test setup. This can either be accomplished by testing on vehicle level or by including relevant parts of the vehicle when testing is done at component level according to 7.7.2.1.3.

7.7.2.1.2 Vehicle level testing

Figure 3 exhibits an exemplary test setup for vehicle level testing.



Key

1 connection to supply network
2 supply power circuit
3 EVPC under test
4 RESS or representative simulated load
5 ground

Figure 3 — Exemplary test setup for vehicle level testing

The EVPC shall be fixed to the EV at its intended mounting position.

NOTE This includes the positions of all components of the EVPC, in case they are not within one housing.

The load shall either be a RESS or a representative simulated DC load.

The supply power circuits to be used for testing the EVPC are described in 7.7.2.2.

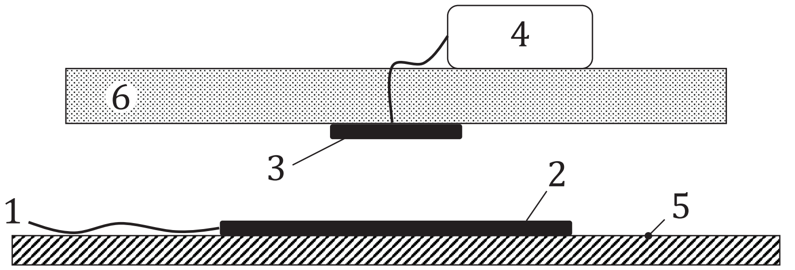
The alignment shall be changeable in x-, y-, and z-direction to enable measurements at the alignment points according to Table 4. Alignment adjustment may be realised by either moving the EV, moving the supply power circuit or moving both.

The components of the test bench and the ground shall not significantly influence the MF-WPT. The entire test setup may also be lifted to a height that avoids potential influences of the ground.

7.7.2.1.3 Component level testing

As an alternative for vehicle level, the testing may also be done on component level.

Figure 4 exhibits the components required for MF-WPT testing in an exemplary test setup for component level testing.



Key

1 connection to supply network

2 supply power circuit

3 EVPC under test

4 load

5 ground

6 vehicle mimic

Figure 4 — Exemplary test setup for component level testing

Compared to vehicle level testing, a vehicle mimic shall be used instead of an EV.

The vehicle mimic shall include all components of the EV the EVPC is intended to be mounted to, that significantly influence MF-WPT. This includes, for example shielding components or metallic beams exposed to the magnetic field.

All other requirements described in the test setup for vehicle level testing in 7.7.2.1.2 shall apply to component level testing as well.

7.7.2.2 Supply power circuits to test against

An EVPC of compatibility class A shall be tested with the normative reference supply power circuits described in Annexes A and B.

An EVPC of compatibility class B shall be tested with a supply power circuit specified and provided by the supplier.

NOTE 1 A supply power circuit specified and provided by the supplier can also be a normative reference device.

NOTE 2 For information purposes, Annex C describes an example for a different implementation of a supply power circuit.

NOTE 3 Approaches to define interoperability by additional requirements beyond testing against normative reference supply power circuits are under development (see Annexes of IEC 61980-3).

7.7.2.3 Test conditions

Testing is carried out in the following conditions:

— the ambient temperature of (20 ± 5) °C; and

— the MF-WPT system is in steady state.

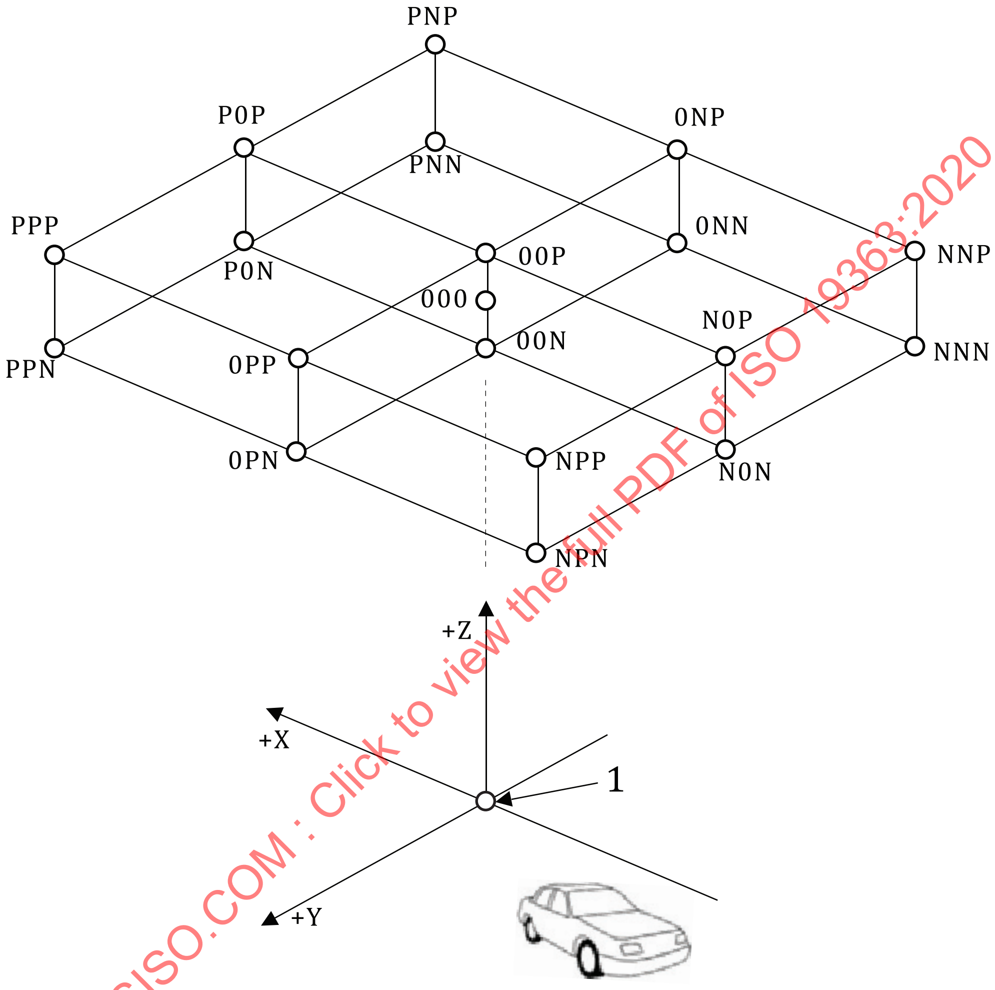
7.7.3 Test procedure

7.7.3.1 General

The measurements described in 7.7.3.2 to 7.7.3.4 are conducted within the rated conditions specified by the supplier according to Table 1.

7.7.3.2 Alignment points

The alignments points for conformance testing are depicted in Figure 5 and Table 4. In one of the points at maximum misalignment in x- and y-direction, additional testing or appropriate simulations shall be performed with +3° yaw and −3° yaw. The positive direction of the yaw angle is counter-clockwise and the negative direction is clockwise around the centre alignment point, looking from above (towards the negative z-direction).



Key

1 centre alignment point of the EVPC

Figure 5 — Alignment points

NOTE The coordinate system conforms with ISO 4130, where the EV driving direction is in the negative x-direction.

The coordinates of the alignment points in Figure 5 are given in Table 4, where:

— "max" is the maximum secondary device ground clearance;

— "min" is the minimum secondary device ground clearance; and

— "mid" is the mean value of the maximum and minimum secondary device ground clearance range.

Table 4 — Alignment points

Alignment point as per Figure 5	X [mm]	Y [mm]	Secondary device ground clearance range
P P P	+75	+100	max
P P N			min
P 0 P		0	max
P 0 N			min
P N P		−100	max
P N N			min
0 P P	0	+100	max
0 P N			min
0 0 P		0	max
0 0 0			mid
0 0 N			min
0 N P		−100	max
0 N N			min
N P P	-75	+100	max
N P N			min
N 0 P		0	max
N 0 N			min
N N P		−100	max
N N N			min

For EVPCs of compatibility class B, the values for x and y shall be in accordance with the specific alignment tolerance area of the EVPC (see 7.3).

7.7.3.3 Output power and power transfer efficiency

At each alignment point described in 7.7.3.2 the supply power circuits according to 7.7.2.2 shall be operated with the MF-WPT input power that is needed by the EVPC to provide its rated output power. These measurements shall be performed at the following voltage levels:

— minimum voltage of output voltage range +50 % of output voltage range, and

— maximum voltage of output voltage range -10 % of output voltage range.

EXAMPLE For an output voltage range of 200 V to 400 V the corresponding voltage levels are 300 V and 380 V.

For EVPCs of compatibility class A, the normative reference supply power circuits shall be operated at 85 kHz. In case the performance requirements are not met, the frequency may be adjusted within the range according to 7.2.

For EVPCs of compatibility class B, the supply power circuit shall be operated at the frequency according to the specifications of the supplier within the range according to 7.2.

NOTE The MF-WPT input power of the normative supply power circuits is limited according to the specifications in Annexes A and B, or, in case of compatibility class B testing, by the specifications of the supplier, respectively.

The test is passed when the EVPC provides 90 % of its rated output power at all measurements and fulfils the power transfer efficiency requirements according to 7.5 at all measurements. Examples are given in Table 5.

When testing an EVPC of compatibility class A with the normative reference supply power circuit in Annex A, exceptions apply for the following cases, where the rated output power of the EVPC cannot be reached due to the limited MF-WPT input power of the normative reference supply power circuit:

1) The rated output power of the EVPC is higher than 3,7 kW.

2) The rated output power of the EVPC is equal or less than 3,7 kW.

For case 1), the test is deemed to have passed when the MF-WPT input power of the normative reference supply power circuit reaches 3,33 kW (90 % of 3,7 kW) and the EVPC provides any output power.

For case 2), the test is passed when the MF-WPT input power of the normative reference supply power circuit reaches 90 % of the rated output power of the EVPC and the EVPC fulfils the power transfer efficiency requirements according to 7.5 at all measurements.

Table 5 — Examples for power transfer testing pass criteria of EVPCs of compatibility class A

Rated output power of EVPC [kW]	Supply power circuit tested with	Minimum measured output power to fulfil the output power requirements [kW]	Minimum MF-WPT input power of the supply power circuit [kW]	Maximum MF-WPT input power to fulfil efficiency requirements
2,8 kW	Annex A	2,52	—	yes[a]
	Annex B		—	yes[a]
3,7 kW	Annex A	—	3,33	yes[a]
	Annex B	3,33	—	yes[a]
7 kW	Annex A	—	3,33	—
	Annex B	6,3	—	yes[a]
11,1 kW	Annex A	—	3,33	—
	Annex B	—	9,99	yes[a]

[a] At alignment points 00P, 000, and 00N: measured output power > 85% of MF-WPT input power. At all other alignment points: measured output power >80 % of MF-WPT input power.

7.7.3.4 Output voltage

In order to verify the requirements for the DC output voltage (as per 7.6.2), the following test shall be applied:

It is recommended to connect the EVPC to an RESS, as used in the EV the EVPC is designed for.

The EVPC shall be placed in one of the alignment points with maximum misalignment. The power shall be ramped up from zero to the rated output power of the EVPC with the maximum rate of supply power circuits according to 7.4. The test is passed, when the DC output voltage is within the requirements of 7.6.2 during the entire test procedure.

8 Requirements for communication and MF-WPT activities

According to IEC 61980-2 the operation process for MF-WPT is modelled as a WPT session, which is organized by a sequence of activities.

These activities are executed respectively supported by communication between the EV device and the supply device, but also imply additional hardware requirements for components of an EV device beyond the specifications in this document. The requirements for an EV device related to the execution of the activities are described in IEC 61980-2. An EV device shall fulfil the applicable requirements given in IEC 61980-2.

9 EMC requirements

An EVPC shall conform to the limits described in CISPR 11, when operated with a supply device.

The measurement shall be done at worst-case operating conditions of the EVPC. D.2 gives guidance on how to determine these worst-case operating conditions.

NOTE CISPR 11 is currently developing specific requirements for MF-WPT systems.

10 Safety requirements

10.1 Protection in case of unintended power transfer

The MF-WPT system shall be treated as an electric power source, that can be de-energized.

Unintended power transfer is either:

— power supply from an uncoordinated or unknown supply device; or

— power supply from a supply device in excess of the request of the EV device.

Whenever the EVPC is required to be de-energized, the EV or EV device shall activate means to prevent the supply device from transferring power.

Examples for such means are:

— protection measures against overcharge of the RESS (e.g. disconnection relay);

— protection measures against overcurrent of the EVPC and RESS (e.g. disconnection relay); or

— protection measures against overvoltage of the EVPC (e.g. emergency short circuit device).

Conformance is checked by inspection.

NOTE The specification for detection and reaction timing of the EV device is at the discretion of the supplier. Requirements for reaction times of the supply device are specified in IEC 61980-3.

10.2 Protection against electric shock

10.2.1 General

This clause applies only to voltage class B electric circuits of an EV device.

Design and testing for protection against electric shock shall be in accordance with ISO 6469-3, unless otherwise specified in 10.2.

The EV device shall fulfil the requirements for non-maintained isolation resistance according to ISO 6469-3:2018, 6.3.2.2.

Protection against electric shock shall be implemented as specified by the vehicle manufacturer.

NOTE Requirements on post-crash electrical safety are specified in ISO 6469-4.

10.2.2 Insulation coordination

Insulation coordination shall consider the maximum internal operational and over voltages inside the EV device. Either of the following shall be implemented:

— robust design with the capability to physically withstand possible operational and over voltages; or

— means to limit the voltages to values the insulation coordination of the components is based on.

The frequency of the alternating current in the EVPC, which is considerably higher than 50 Hz or 60 Hz, shall be considered for the insulation coordination, temperature-resistance of the materials used and dimensioning of active parts and insulation.

Clearance, creepage distance and solid insulation of voltage class B components and wiring shall be designed according to the applicable sections of IEC 60664.

10.3 Protection against thermal incidents

10.3.1 General

Thermal loads to the insulation and active parts of the EV device shall be considered under

— all operational situations;

— shut off situations of the vehicle; and

— unintended power transfer situations.

10.3.2 Overload protection and short-circuit protection

The overload protection and short circuit protection shall be according to ISO 6469-3.

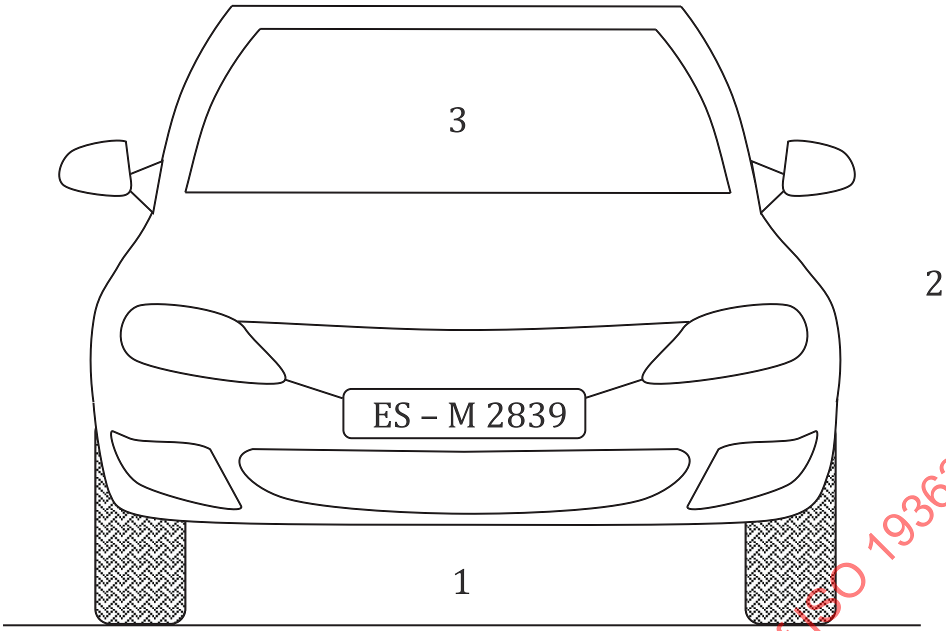
10.4 Protection of persons against electromagnetic effects

10.4.1 General

This subclause specifies requirements to protect persons against the effects resulting from exposure to electromagnetic fields. This covers the protection against harmful effects of exposure to electromagnetic fields and the protection of the functionality of active implantable medical devices (AIMDs). Annex D provides guidance on how fulfilment of the specified requirements can be demonstrated.

10.4.2 Protection areas

The space inside, under and around the vehicle is divided into three protection areas according to Figure 6.



Key

1 protection area 1: area underneath the vehicle

2 protection area 2: area surrounding the vehicle; public area to the side, front, rear and top of the vehicle

3 protection area 3: vehicle interior

Figure 6 — Protection areas

10.4.3 Requirements for protection of persons against exposure to hazardous electromagnetic fields

In protection area 2 and 3, persons shall not be exposed to electromagnetic fields above the applicable limits from the ICNIRP Guidelines.

NOTE In protection area 1, protection against exposure to hazardous electromagnetic fields is the responsibility of the supply device.

The basic restrictions of ICNIRP Guidelines 2010, Table 2 or the reference levels of ICNIRP Guidelines 2010, Table 4 shall be met.

10.4.4 Requirements to protect the functionality of AIMDs

Pacemakers and implanted cardiac defibrillators are required to remain fully functional and operational when magnetically induced voltages in pacemaker leads, in the range of 3 kHz to 150 kHz are less than $V_{\text{MAX\_INDUCED\_RMS}} = \frac{3\sqrt{2}}{2}$ mV × Frequency (kHz), (e.g. 180,31 mV RMS at 85 kHz). This formula is based on the assumption that the voltage is induced into a 225 cm^2 lead loop and determines the limits that need to be met by MF-WPT systems.

NOTE ISO 14117 contains requirements for pacemakers and implants.

To enable simplified and repeatable measurements, these induced voltage levels have been transferred to a conservative averaged magnetic flux of 15,0 µT or a magnetic field strength of 11,9 A/m (for 79 kHz to 90 kHz) within a 225 cm^2 plane.

In protection areas 2 and 3, an EVPC shall comply with these limits when operated with a supply power circuit at worst-case operating conditions. Annex D gives guidance for conformance demonstration and for how to determine the worst-case operating conditions.

10.5 Protection against overheating

Means to prevent the overheating of components of the EV due to the magnetic field generated by the supply device shall be provided, if necessary. Examples of protection means are shielding, thermal sensing or cooling.

Conformance shall be declared by the vehicle manufacturer.

11 Owner’s manual and marking

11.1 Owner's manual

The following information shall be included in the owner’s manual:

a) description of the MF-WPT system operation and location of the secondary device on the vehicle;

b) functional operations to be performed by the user; and

c) any special precautions required by operators wearing AIMDs;

d) the rated conditions as specified in Table 1.

11.2 Marking

Marking of voltage class B components and wiring shall be in accordance with ISO 6469-3.

Annex A
(normative)

Reference supply power circuit for EVPCs with a rated output power ≤3,7 kW

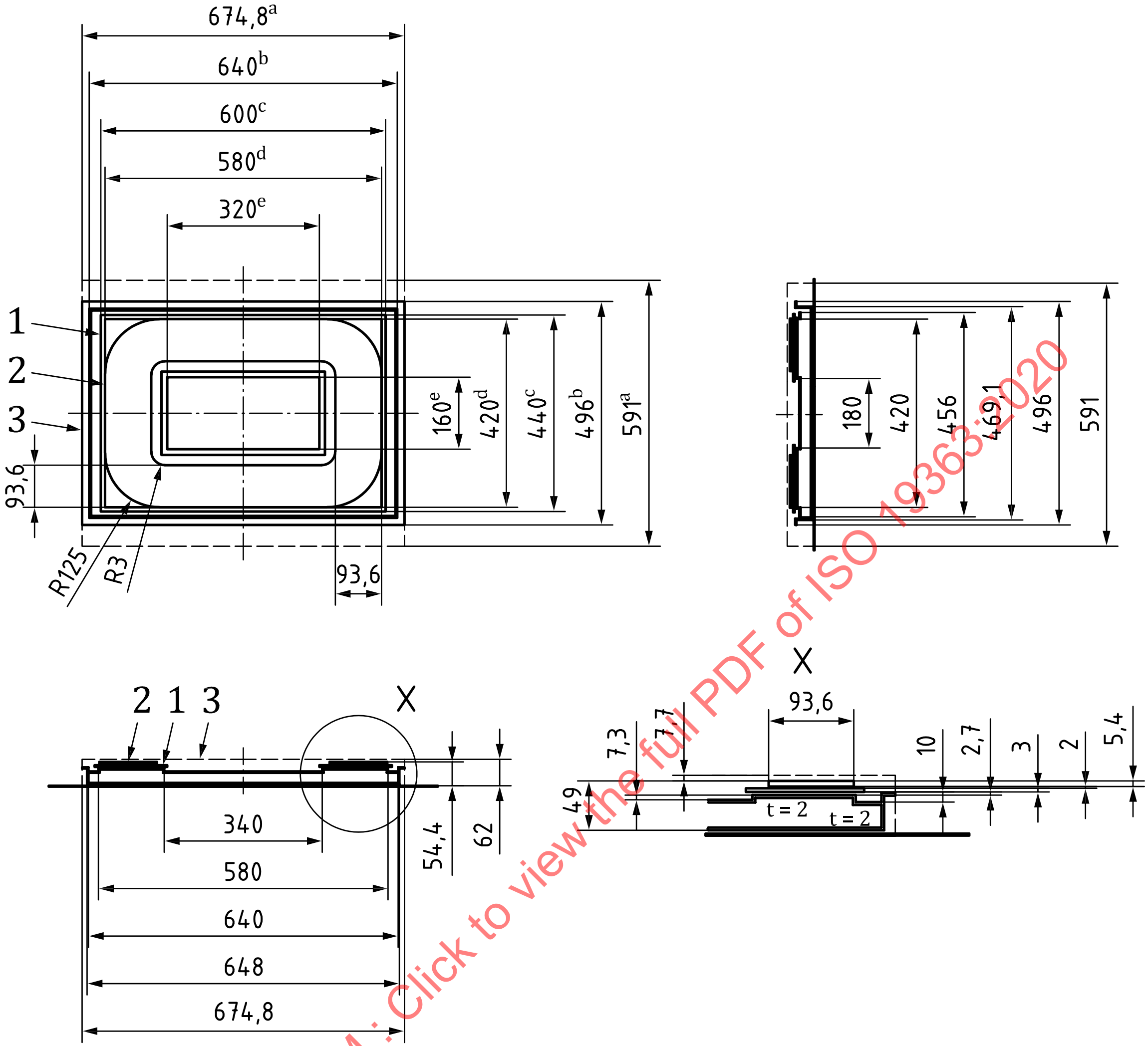
A.1 General

This annex describes the reference supply power circuit for an EVPC with a rated output power of ≤3,7 kW. It is designed for on-ground mounting and operates over the system frequency range of 79 kHz to 90 kHz.

A.2 Mechanical design of the primary device

Figure A.1 shows the mechanical dimensions of the primary device.

Dimensions in millimetres



Key

1 ferrite

2 coil (15 turns)

3 outer case (for reference)

a Outer case dimension.

b Shielding dimension.

c Outer core dimension.

d Coil dimension.

e Inner core dimension.

Figure A.1 — Mechanical dimensions

The centre of this primary device (0/0 point of coordinate system) is at the midpoint of the "d" dimensions in Figure A.1 and corresponds to the centre of the coil.

The coil dimension of the primary device shown in Figure A.1 above is 420 mm in x-direction (direction of travel of the vehicle) and 580 mm in y-direction.

The litz wire is 4 200 mm × 0,05 mm with an overall diameter of approximately 5 mm.

The ferrite tiles are made of N96 material. The dimensions and the layout of the tiles are shown in Figure A.2.

Dimensions in millimetres

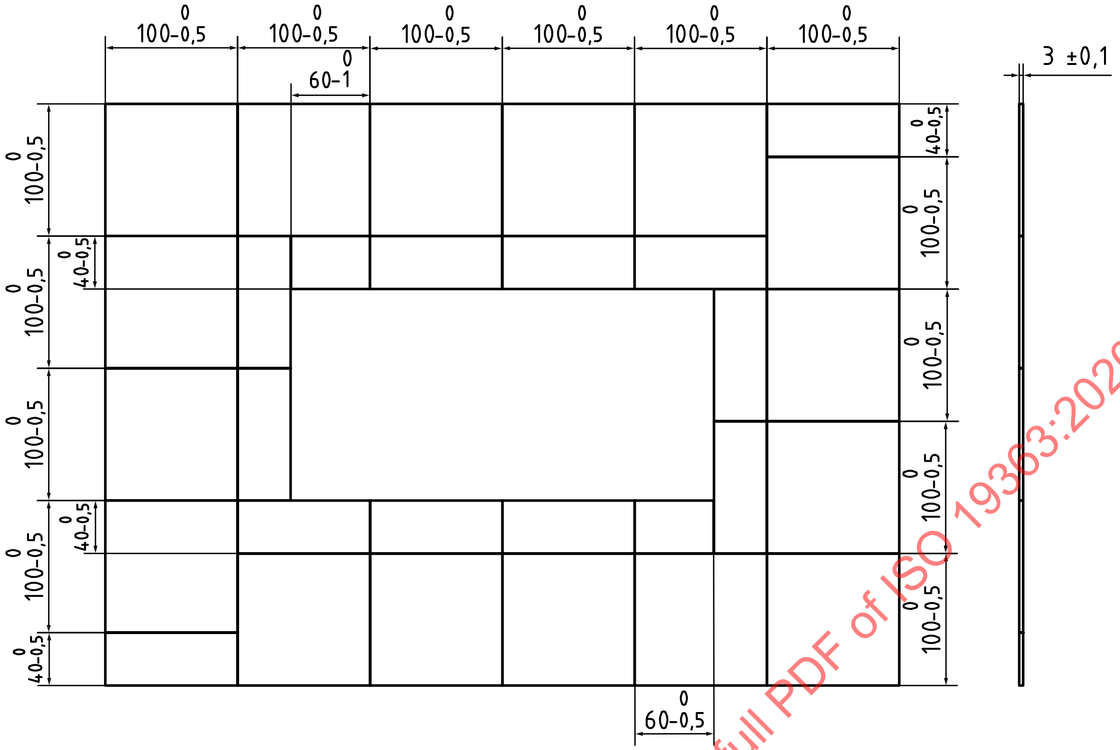
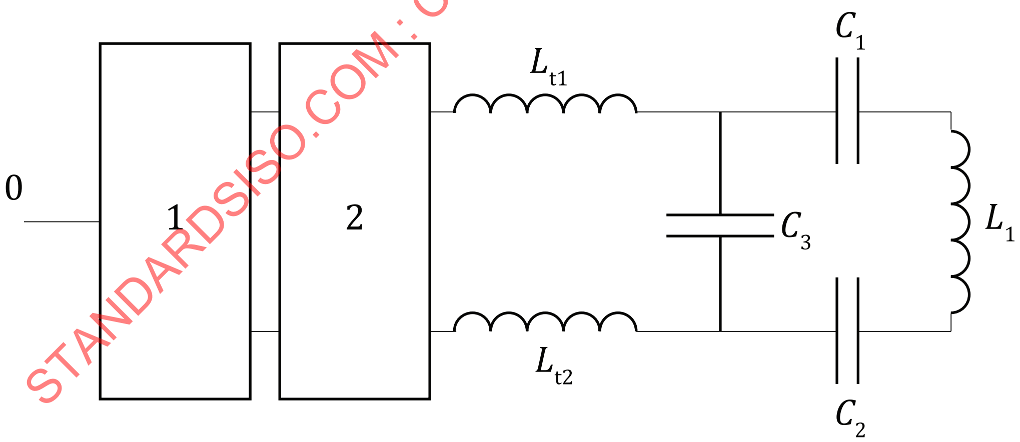


Figure A.2 — Ferrite tile dimensions and layout

A.3 Electrical design of the reference supply power circuit

Figure A.3 shows the electrical schematic of the reference supply power circuit.



Key

0	connection to supply network
1	PFC
2	inverter
L_1	primary device inductance
L_{t1} and L_{t2}	tuning inductances
C_1 – C_3	tuning capacitors

Figure A.3 — Electrical schematic of reference supply power circuit

Table A.1 shows the values of components, currents and voltages in Figure A.3.

Table A.1 — Values of components, currents and voltages

Component/ parameter	Value
primary device inductance (L_1)	See Table A.2
tuning inductance (L_{t1})	23,5 µH
tuning inductance (L_{t2})	23,5 µH
tuning capacitor (C_1)	40,4 nF
tuning capacitor (C_2)	40,4 nF
tuning capacitor (C_3)	120 nF
maximum PFC output current	9 A DC
maximum primary device current	30 A rms
PFC output voltage	450 V DC

An example of an inverter suitable to the reference supply power circuit of Figure A.3 is shown in Figure A.4. A typical value for a maximum inverter output current is 30 A rms.

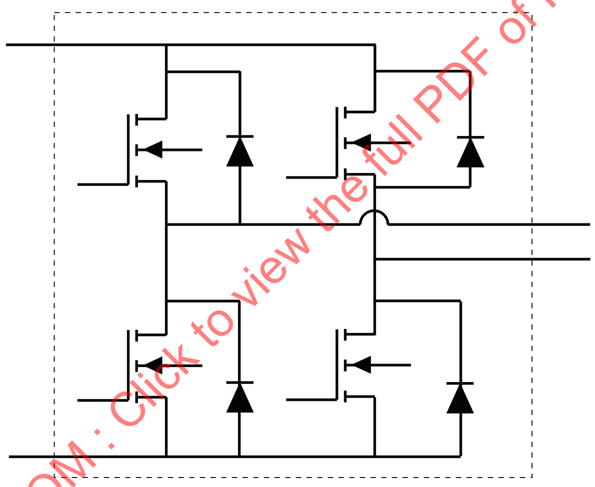


Figure A.4 — Example of electrical schematic of an inverter suitable to the coil design given in A.1

A.4 Coupling and inductance information

This subclause gives information on the coupling and inductance behaviour of the reference supply power circuit when operated with circular reference EVPCs for MF-WPT1 specified in IEC 61980-3.

The values in Table A.2 and A.3 were determined with an aluminium shield (700 mm in x-direction, 900 mm in y-direction) and a vehicle mimic plate (1 500 mm in x-direction, 1 500 mm in y-direction) attached to the reference EVPCs.

NOTE The given values can deviate in a real vehicle environment.

The lead cable length assumed for the inductance values given in Table A.2 is 1 m.

Table A.2 — Primary device inductance with MF-WPT1 reference EVPCs

Z class of reference EVPC	L_1 (min) [µH]	L_1 (max) [µH]
Z1	185	217
Z2	212	223

Table A.2 *(continued)*

Z class of reference EVPC	L_1 (min) [μH]	L_1 (max) [μH]
Z3	224	227

Table A.3 — Coupling with MF-WPT1 reference EVPCs

Z class of reference EVPC	k (min)	k (max)
Z1	0,100	0,249
Z2	0,085	0,221
Z3	0,084	0,243

Annex B
(normative)

Reference supply power circuit for EVPCs with a rated output power ≤11,1 kW

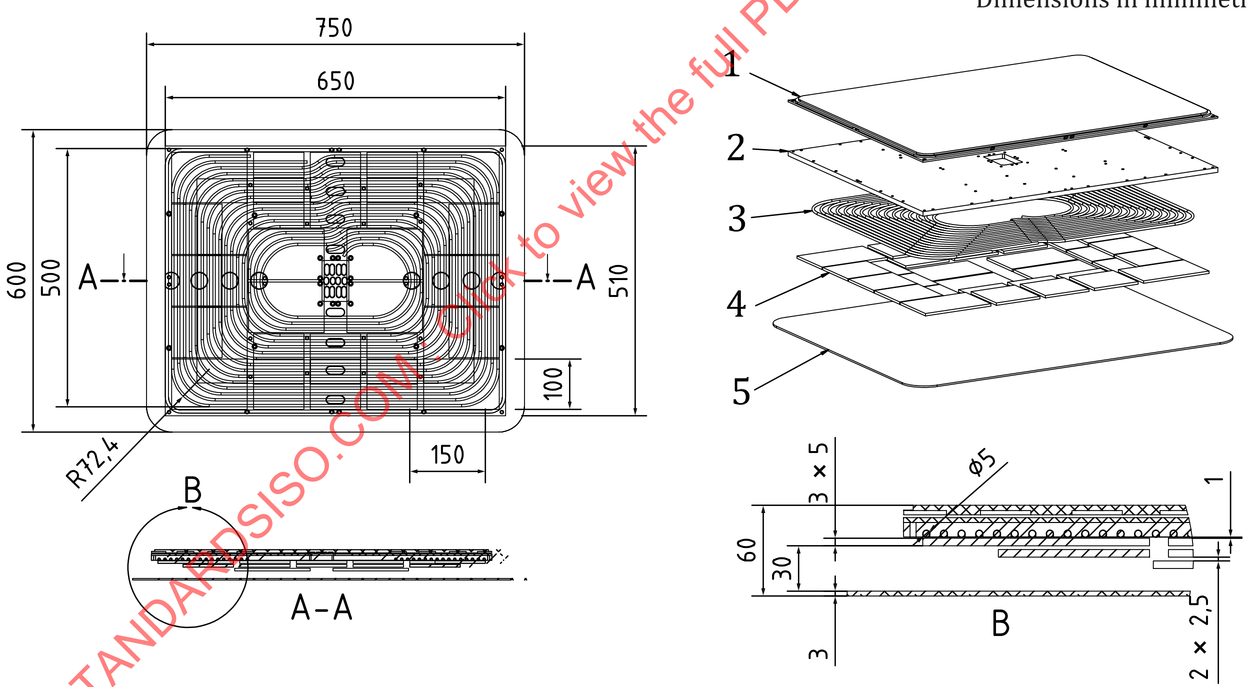
B.1 General

This annex describes the reference supply power circuit for an EVPC with a rated output power of ≤11,1 kW. It is designed for on-ground mounting and is intended to operate at the nominal frequency of 85 kHz but performs over the system frequency range as specified in 7.2.

B.2 Mechanical design of the primary device

Figure B.1 shows the mechanical dimensions of the primary device.

Dimensions in millimetres



Key

1 top cover
2 litz tray
3 litz wire
4 ferrite tiles
5 aluminium plate

Figure B.1 — Mechanical dimensions

The centre of this primary device (0/0 point of coordinate system) is at the midpoint of the coil in Figure B.1.

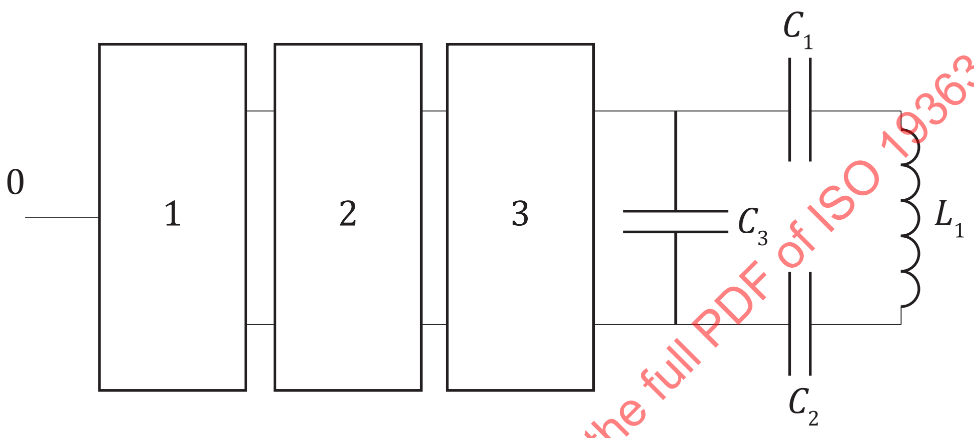
The coil dimension of the primary device shown in Figure B.1 above is 500 mm in x-direction (direction of vehicle travel) and 650 mm in y-direction.

The litz wire is 4 200 mm/0,05 mm with an overall diameter of approximately 5 mm. The coil consists of eight turns bifilar.

The ferrite layers in the GA are made of ferrite tiles of N95 material with the dimensions (100 × 150 × 5) mm and (100 × 100 × 5) mm.

B.3 Electrical design of the reference supply power circuit

Figure B.2 shows the electrical schematic of the reference supply power circuit.



Key

0 connection to supply network
1 PFC
2 inverter
3 compensation network
L_1 primary device inductance
C_1 - C_3 tuning capacitors

Figure B.2 — Electrical schematic of reference supply power circuit

Table B.1 shows the values of components, currents and voltages in Figure B.2.

Table B.1 — Values of components, currents and voltages

Component/ parameter	Value
primary device inductance (L_1)	See Table B.4 and B.5
tuning capacitor (C_1)	320 nF
tuning capacitor (C_2)	320 nF
tuning capacitor (C_3)	270 nF
maximum primary device current	75 A rms

Table B.2 shows typical values for the characteristics of the PFC

Table B.2 — PFC characteristics

Component/ parameter	Value
maximum PFC output current	29 A DC
PFC output voltage range	380 – 500 V DC

An example of an inverter suitable to the reference coil system is shown in Figure B.3.

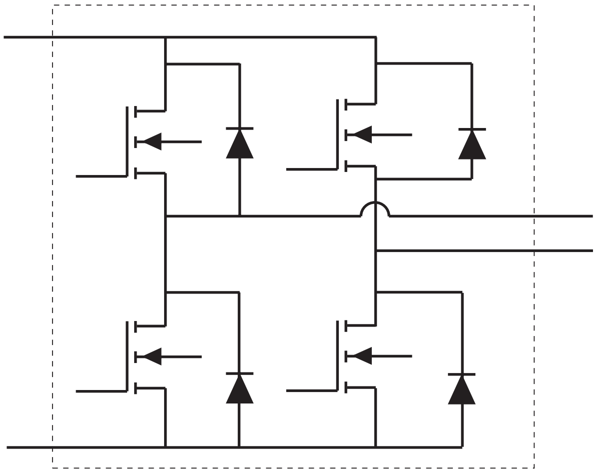


Figure B.3 — Example of electrical schematic of an inverter suitable to the coil design given in B.1

Table B.3 shows typical values for the inverter characteristics

Table B.3 — Inverter characteristics

Component/ parameter	Value
maximum inverter output current	40 A rms

Figure B.4 shows an example of a compensation network suitable for the coil design given in B.1 Typical range for the variable reactances (jX/2) is (4 – 16) $j$ohms.

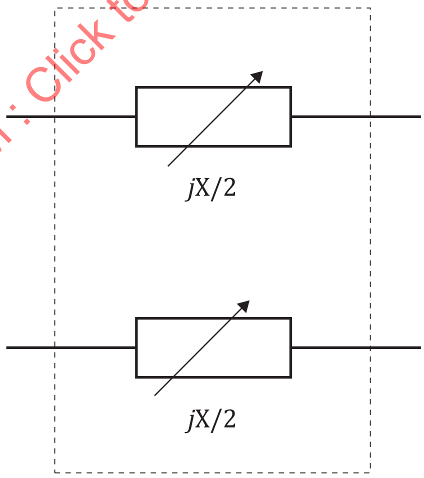


Figure B.4 — Example of electrical schematic of a compensation network suitable to the coil design given in B.1

B.4 Coupling and inductance information

This subclause gives information on the coupling and inductance behaviour of the reference supply power circuit when operated with circular reference EVPCs for MF-WPT2 and MF-WPT3 specified in IEC 61980-3.

The values in Tables B.4 to B.7 were determined with an aluminium shield (800 mm in x-direction, 800 mm in y-direction) and a vehicle mimic plate (1 500 mm in x-direction, 1 500 mm in y-direction) attached to the reference EVPCs.

NOTE 1 The given values can deviate in a real vehicle environment.

The lead cable length assumed for the inductance values given in Tables B.4 and B.5 is 0,3 m.

NOTE 2 The reference supply power circuit can also be operated at 3,7 kW with these reference EVPCs for MF-WPT2 or MF-WPT3. The inductance and coupling values are consistent (independent from the transferred power) and are therefore not specifically indicated for MF-WPT1.

Table B.4 — Primary device inductance with MF-WPT2 reference EVPCs

Z class of reference EVPC	L_1 (min) [µH]	L_1 (max) [µH]
Z1	29,6	35,8
Z2	35,1	38,1
Z3	37,4	38,7

Table B.5 — Primary device inductance with MF-WPT3 reference EVPCs

Z class of reference EVPC	L_1 (min) [µH]	L_1 (max) [µH]
Z1	30,0	36,2
Z2	35,1	38,1
Z3	37,4	38,7

Table B.6 — Coupling with MF-WPT2 reference EVPCs

Z class of reference EVPC	k (min)	k (max)
Z1	0,109	0,238
Z2	0,090	0,221
Z3	0,087	0,229

Table B.7 — Coupling with MF-WPT3 reference EVPCs

Z class of reference EVPC	k (min)	k (max)
Z1	0,119	0,246
Z2	0,090	0,221
Z3	0,087	0,229

Annex C
(informative)

Example for a different implementation of a supply power circuit

C.1 General

For information purposes, this annex describes an example for a different implementation of a supply power circuit, compared to Annexes A and B. It is designed for on-ground mounting and is intended to operate at the nominal frequency of 85 kHz.

NOTE Frequency tuning to compensate, for example, for height and alignment variation is not applied.

C.2 Mechanical design of the primary device

Figures C.1 and C.2 show the mechanical dimensions of the primary device.

Dimensions in millimetres

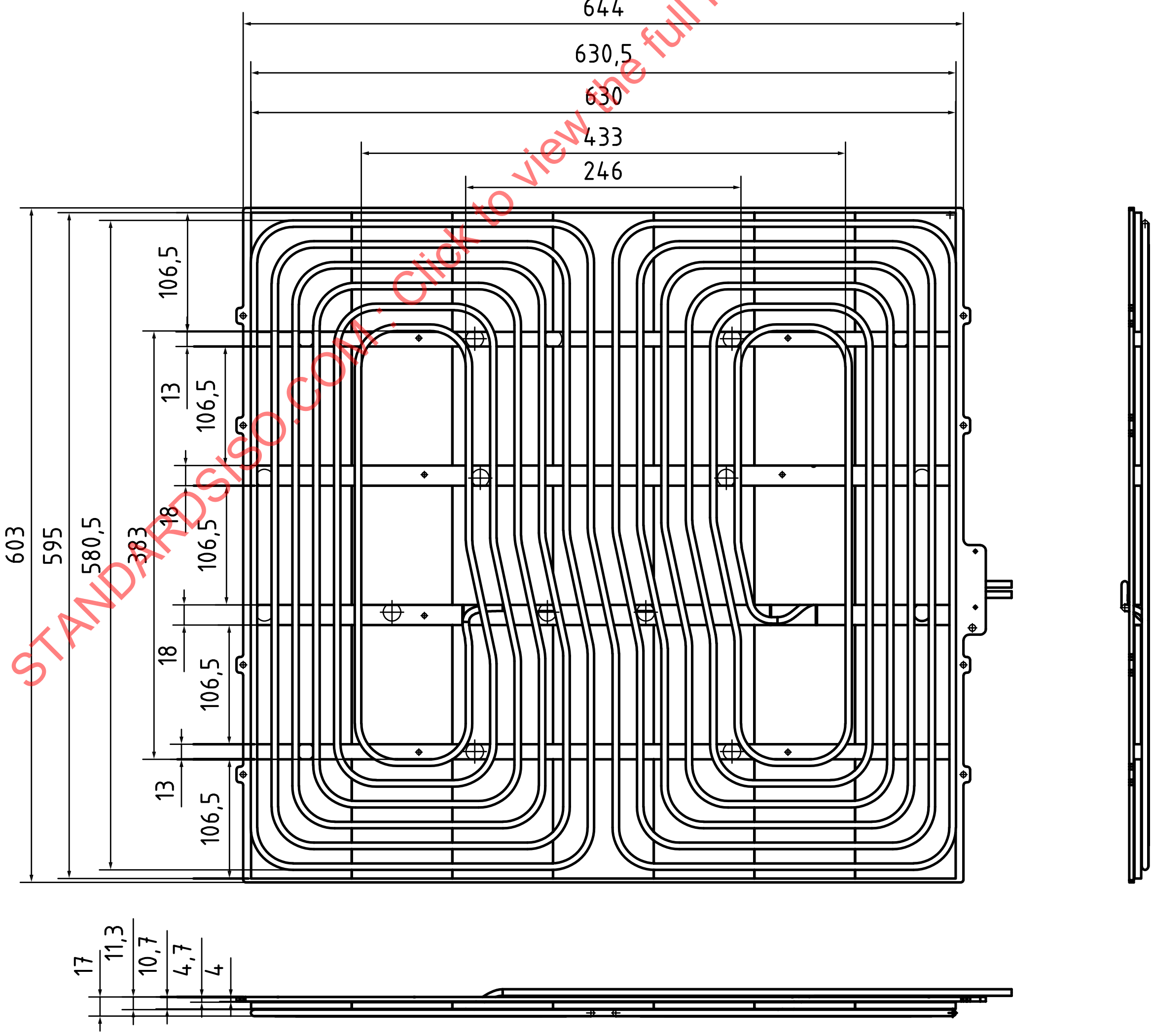
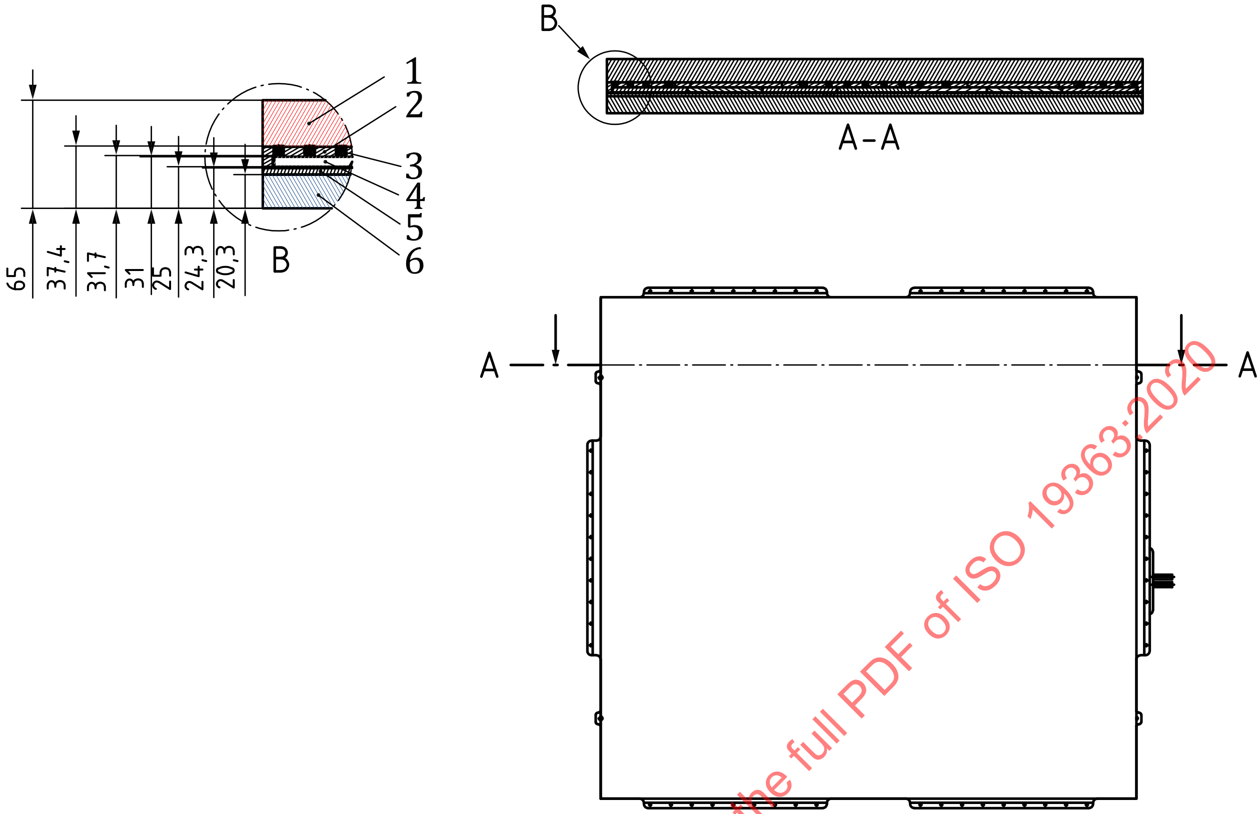


Figure C.1 — Mechanical dimensions

Dimensions in millimetres



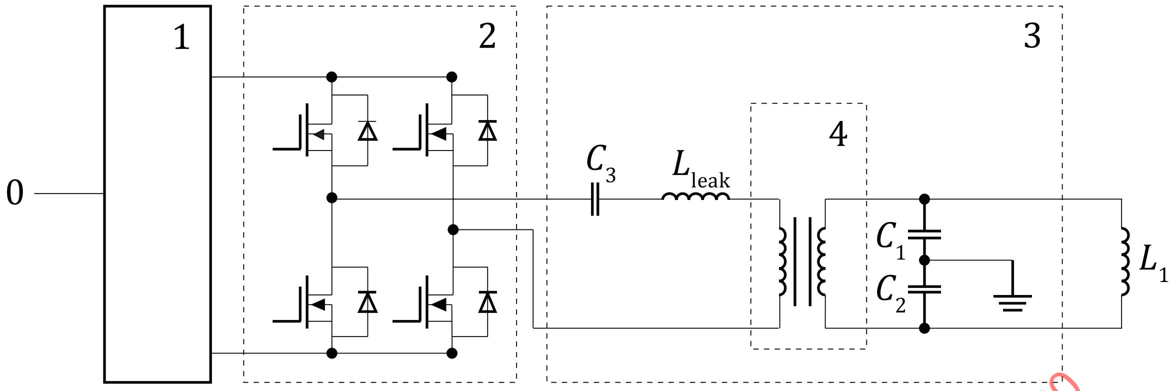
Key

1 top cover
2 litz tray
3 litz wire
4 ferrite tiles
5 aluminium plate
6 bottom cover

Figure C.2 — Details for mechanical dimensions

C.3 Electrical design of the supply power circuit

Figure C.3 shows the electrical schematic of the supply power circuit.



Key

0	connection to supply network
1	PFC
2	inverter
3	impedance matching network
4	HF transformer
L_1	primary device inductance
L_{leak}	HF transformer leakage inductance
C_1 and C_2	tuning capacitors
C_3	DC blocking capacitor

Figure C.3 — Electrical schematic of supply power circuit

Table C.1 shows the values of components, currents and voltages in Figure C.3.

Table C.1 — Values of components, currents and voltages

Component/ parameter	Value
primary device inductance (L_1)	See Tables C.2 and C.3
HF transformer leakage inductance (L_{leak})	22 µH
primary / secondary inductance of HF transformer	1,7 / 11,9 mH
turn ratio of HF transformer	1:2,7 (N1:N2 = 9:24)
tuning capacitor (C_1)	98,4 nF
tuning capacitor (C_2)	98,4 nF
DC blocking capacitors (C_3)	360 nF

C.4 Coupling and inductance information

This subclause gives information on the coupling and inductance behaviour of the supply power circuit when operated with DD reference EVPCs for MF-WPT2 and MF-WPT3 specified in IEC 61980-3.

The values were determined with an aluminium shield (1 100 mm in x-direction, 1 100 mm in y-direction) and a vehicle mimic plate (1 500 mm in x-direction, 1 500 mm in y-direction) attached to the reference EVPCs.

NOTE 1 The given values can deviate in a real vehicle environment.

The lead cable length assumed for the inductance values given in Table C.2 and Table C.3 is 3 m.

NOTE 2 The supply power circuit can also be operated at 3,7 kW with these reference EVPCs for MF-WPT2 or MF-WPT3. The inductance and coupling values are consistent (independent from the transferred power) and are therefore not specifically indicated for MF-WPT1.

Table C.2 — Primary device inductance with MF-WPT2 reference EVPCs

Z class of reference EVPC	L_1 (min) [μH]	L_1 (max) [μH]
Z1	54,9	62,5
Z2	62,5	65,8
Z3	65,6	68,5

Table C.3 — Primary device inductance with MF-WPT3 reference EVPCs

Z class of reference EVPC	L_1 (min) [μH]	L_1 (max) [μH]
Z1	56,9	64,3
Z2	68,3	72,3
Z3	67,9	71,7

Table C.4 — Coupling with MF-WPT2 reference EVPCs

Z class of reference EVPC	k (min)	k (max)
Z1	0,162	0,344
Z2	0,134	0,318
Z3	0,126	0,314

Table C.5 — Coupling with MF-WPT3 reference EVPCs

Z class of reference EVPC	k (min)	k (max)
Z1	0,170	0,388
Z2	0,160	0,385
Z3	0,140	0,344

