

DEP SPECIFICATION

ELECTROMAGNETIC COMPATIBILITY (EMC)

DEP 33.64.10.33-Gen.

September 2010

(DEP Circular 22/12 has been incorporated)

DESIGN AND ENGINEERING PRACTICE



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TABLE OF CONTENTS

1.	INTRODUCTION	4
1.1	SCOPE.....	4
1.2	DISTRIBUTION, APPLICABILITY AND REGULATORY CONSIDERATIONS	4
1.3	DEFINITIONS	4
1.4	CROSS-REFERENCES	8
1.5	SUMMARY OF MAIN CHANGES.....	8
1.6	COMMENTS ON THIS DEP	8
1.7	DUAL UNITS.....	9
2.	BASIC EMC REQUIREMENTS.....	10
2.1	BASIS OF DESIGN.....	10
2.2	EMC MANAGEMENT AND EPCC REQUIREMENTS	10
3.	EARTHING AND BONDING	11
3.1	PLANT EARTH GRID	11
3.2	BONDING OF CONCRETE AND STEEL STRUCTURES	12
3.3	EQUIPMENT ROOM EARTHING AND BONDING	18
3.4	SUBSTATION EARTHING AND BONDING.....	21
3.5	EARTHING AND BONDING OF FIELD EQUIPMENT AND JUNCTION BOXES....	22
3.6	CABLE ENTRY FRAMES AND BONDING OF METALLIC SERVICES	23
4.	CABLING AND WIRING	25
4.1	CABLE CLASSIFICATION.....	25
4.2	CABLE BONDING	26
4.3	CABLE END TERMINATIONS	26
4.4	JUNCTION BOXES	26
4.5	CABLE GLANDS	27
4.6	TRUNKING AND TRAYS.....	28
4.7	CABLE TRENCHES AND PEC REQUIREMENTS	28
4.8	CABLE SEGREGATION.....	30
4.9	SEGREGATION OF POWER SUPPLIES	34
5.	EQUIPMENT EMC SPECIFICATIONS	36
5.1	GENERAL.....	36
5.2	EMISSION REQUIREMENTS	36
5.3	IMMUNITY REQUIREMENTS	37
5.4	PERFORMANCE CRITERIA	38
5.5	INSTALLATION INSTRUCTIONS	40
5.6	TESTING AND INSPECTION.....	40
6.	SPECIFIC EMC MEASURES.....	41
6.1	EMC REQUIREMENTS FOR SWITCHED DEVICES	41
6.2	EMC REQUIREMENTS FOR NUMERICAL PROTECTION RELAYS AND INSTRUMENT SYSTEMS IN SUBSTATIONS.....	42
6.3	EMC REQUIREMENTS FOR SYSTEMS NEAR OVERHEAD HV LINES	42
6.4	EMC REQUIREMENTS FOR STRUCTURES WITH CATHODIC PROTECTION	42
6.5	MAGNETIC FIELDS FROM BUS BARS AND TRANSFORMERS	44
6.6	ELECTRICAL WELDING	44
6.7	EMC ASPECTS OF RADIO FREQUENCY SOURCES	45
7.	REFERENCES	47

APPENDICES

APPENDIX A	EMC MANAGEMENT AND EPCC REQUIREMENTS	50
APPENDIX B	EXAMPLE OF EQUIPMENT EMC CHECKLIST	56

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for ElectroMagnetic Compatibility (EMC) measures for electrical and electronic systems and installations. Specifications are provided for earthing and bonding, equipment emission and immunity, and mitigation methods to reduce electromagnetic interference and ensure undisturbed operation of plant control, excitation and supporting systems. The overall objective is to simplify the implementation of EMC and optimise the EMC cost/risk balance with a view to maximum plant availability.

This is a revision of the DEP of the same number dated September 2002; see (1.5) regarding the main changes.

1.2 DISTRIBUTION, APPLICABILITY AND REGULATORY CONSIDERATIONS

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This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/distribution installations.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

In addition to the definitions of IEC 60050, the following technical definitions are used in this DEP.

apparatus	a finished combination of devices (or equipment), with an intrinsic function intended for the final user and intended to be placed on the market as a single commercial unit
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bonding	the act of connecting together exposed conductive parts and extraneous conductive parts of apparatus, systems or installations that are essentially the same potential
cable entry frame	a dedicated framework fitting into a concrete or steel wall and providing a water tight, fire resistant and EMC proof feed-through of electrical and instrument cables into a building or equipment room
cable ladder	above ground, ladder-type cable support system with or without cover
cavity floor	computer floor or false floor
common mode voltage	the mean of the phasor voltages appearing between each conductor and a specified reference, usually earth or frame
common-mode circuit	the full current loop or closed circuit for the common-mode current, including the cable, the apparatus, and the nearby parts of the earthing system
degradation (of performance)	an undesired departure in the operational performance of any device, equipment or system from its intended performance
differential mode	the voltage between any two of a specified set of active conductors
earth	the conductive mass of the earth, whose electrical potential at any point is conventionally taken as equal to zero
earth electrode	a conductive part or a group of conductive parts in intimate contact with and providing an electrical connection with earth
earthing network	conductors of the earthing system, in contact with the soil, connecting apparatus, systems or installations to earth electrode or to other means of earthing
earthing	the act of connecting exposed conductive parts of apparatus, systems or installations to the earth electrode or other elements of earthing
earthing system	the three-dimensional electrical circuit which performs the earthing
electromagnetic compatibility	the ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment
electromagnetic disturbance	any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter
electromagnetic emission	the propagation of electromagnetic energy from a source
(electromagnetic)	the totality of electromagnetic phenomena existing at a given

environment	location
electromagnetic interference	degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance
electromagnetic levels	levels as defined by the EM environment
(electromagnetic) susceptibility	the inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance
EMC cable gland	metallic cable gland ensuring 360° contact between cable screen/armour and gland plate
EMC earthing	the act of connecting exposed conductive parts of apparatus, systems or installations to the elements of earthing to ensure EMC
emitter	device emitting electromagnetic disturbances
enclosure	a housing surrounding a device, cabinet, room, etc.
equipment	a general term for apparatus, appliance, system, etc.
immunity (to a disturbance)	the ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance
installation	several combined items of apparatus or systems put together at a given place to fulfil a specific objective but not intended to be placed on the market or put into service as a single functional unit
instrument earth	single point earthing system for instrument systems
lightning electromagnetic pulse	voltage or current induced into cable and other conductors by the radiated field from a lightning flash some distance away
lightning strike	a lightning flash that discharges to earth
lightning stroke	one of the single distinguishable current impulses of a lightning flash
parallel earthing conductor	a conductor usually laid along the cable route to provide a low-impedance connection between the earthing arrangements at the end of the cable route
safety earthing	plant safety earthing, the act of connecting exposed conductive parts of apparatus, systems or installations to the earth electrode or other elements of earthing to ensure electrical safety
source	device emitting electromagnetic disturbances; another expression for emitter
static electricity earthing	the act of connecting exposed conductive parts of apparatus, systems or installations to the elements of earthing to prevent the built-up of static electricity and resulting ESD

susceptor	device susceptible to electromagnetic disturbances
system	several items of apparatus combined to fulfil a specific objective and intended to be placed on the market or put into service as a single functional unit
system cabling	a wiring concept, consisting of cables, plugs and sockets, as detailed in DEP 32.37.20.10-Gen.
transfer impedance	the ratio of the voltage coupled into one circuit to the current appearing in another circuit or another part of the same circuit
tray	above ground, open cable support system, such as U-shaped flat-bottomed, perforated plate or ladder type
trench	underground cable routing system provided with a mechanical protection on top of the cables.
trunking	aboveground, U-shaped cable support system with cover. It is flat-bottomed and has a top cover secured by cover clips/fasteners
victim	device susceptible to electromagnetic disturbances; another expression for susceptor
zone (EM)	an area of an industrial plant in which equipment and systems of a certain EM level are installed.

1.3.3 Abbreviations

AH	-	Analyser House
CCR	-	Central Control Room
CCRB	-	Central Control Room Basement
CCTV		Closed Circuit TV
CM	-	Common Mode
CP	-	Cathodic Protection
CRT	-	Cathode Ray Tube
DCS	-	Distributed Control System
DM	-	Differential Mode
EFT	-	Electrical Fast Transient
ELF	-	Extremely Low Frequency
EM	-	Electro Magnetic
EMC	-	Electro Magnetic Compatibility
EMI	-	Electro Magnetic Interference
EN	-	European Norm (Standard)
ENMC	-	Electrical Network Monitoring and Control
EPCC	-	Engineering, Procurement, Construction and Commissioning
ESD	-	Electro Static Discharge
FAR	-	Field Auxiliary Room
FAT	-	Factory Acceptance Test

FCC	-	Federal Communications Commission
FGS	-	Fire and Gas System
GIS		Gas Isulated Switchgear
HF	-	High Frequency (> 1 MHz)
HV	-	High Voltage
IPS	-	Instrumented Protective System
ISM	-	Industrial Scientific and Medical
ITE	-	Information Technology Equipment
JB	-	Junction Box
LCD	-	Liquid Cristal Display
LEMP	-	Lightning Electro Magnetic Pulse
LF	-	Low Frequency (< 1 MHz)
LPS	-	Lightning Protection System
LPZ		Lightning Protection Zone
M	-	Mutual inductance
MDF	-	Main Distribution Frame
MOV	-	Motor Operated Valve
PE	-	Protective Earth
PEC	-	Parallel Earthing Conductor
PEN	-	Protective Earth Neutral (combined conductor)
PLC	-	Programmable Logic Controller
QP	-	Quasi Peak
RF	-	Radio Frequency
RFID	-	Radio Frequency IDentification
SAT	-	Site Acceptance Test
SPD	-	Surge Protection Device
SS	-	Sub Station
UPS	-	Uninterruptible Power Supply
VSDS	-	Variable Speed Drive System
WLAN	-	Wireless Local Area Network
Z _t	-	Transfer impedance

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets. All publications referred to in this DEP are listed in (7.).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated September 2002. This has been a major revision and it is impractical to list the changes here.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://swww.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

**Amended per
Circular 22/12**

Dual units have been incorporated throughout this DEP.

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. BASIC EMC REQUIREMENTS

2.1 BASIS OF DESIGN

As more specifically explained in IEC/TR 61000-5-2, the following technical EMC requirements apply:

A multipoint earthing system shall be installed throughout the plant, incorporating all earthing functions such as safety earth, lightning protection earth, intrinsic safety earth, static electricity earth and functional earth for instrument systems. The basis of this multipoint earthing system is the plant earth grid, with a 10 m x 10 m (33 ft x 33 ft) mesh for all buildings, process areas, storage tanks, flare stacks and pipe racks;

- No separate earthing system with dedicated earth electrodes shall be installed. For sensitive instrument systems (EM level 1, according to DEP 32.37.20.10-Gen.), a starpoint earthing system may be installed. The starpoint earthing shall be bonded to the above earthing system and protected by a multipoint earthing system;
- The armouring and screening of all cables shall be bonded to the earth grid at both ends. There are two exceptions:
 - the screening of sensitive instrument signal lines of EM level 1, according to DEP 32.37.20.10-Gen., may be bonded at one end (MDF). The cable armouring shall in all cases be bonded at both ends,
 - HV single core cables may be bonded at one end to prevent high induced screen currents, provided protective measures are taken with regards to induced screen voltages. For long HV single core cables, bonding at both ends and additional cross bonding between the three phases should be considered.
- Throughout the design, the focus shall be on bonding of all structural elements, including concrete reinforcement, steel constructions, piping, tanks, equipment cabinets, junction boxes and cable trunking to the earth grid to provide a low impedance ground plane reference for a wide range of frequencies;
- Equipment emission and immunity requirements shall be specified in accordance with the EM zone allocation plan. EM levels should be based on the industrial environment in accordance with IEC 61000-6-4 for emission and IEC 61000-6-2 for immunity;
- Lightning protection shall be in accordance with IEC 62305-3. For the protection of electronic equipment, the zoning concept shall be in accordance with IEC 62305-4. Armoured and shielded cables and bonding at LPZ interfaces should be used rather than using SPDs.
- Cables shall be protected by PECs by means of interconnected cable tray sections or, as a minimum, a parallel earth wire in cable trenches.
- Cables shall be segregated according to their disturbing potential / susceptibility.

2.2 EMC MANAGEMENT AND EPCC REQUIREMENTS

The Contractor shall follow the EPCC approach as more specifically described in (Appendix 1) of this DEP.

3. EARTHING AND BONDING

3.1 PLANT EARTH GRID

Further to the requirements of DEP 33.64.10.10-Gen. and based on the guidelines of IEC/TR 61000-5-2, an earth grid shall be installed throughout the plant, where buildings, process areas and structures are located. In detail, the earth grid shall meet the following requirements:

- The mesh size of the earth grid shall be 10 m x 10 m (33 ft x 33 ft) or smaller and shall extend to at least 10 m (33 ft) from buildings, production areas, storage tanks, flares, overhead cable trunking and pipe racks. A typical layout of an earth grid is shown in Standard Drawing S 68.033.
- Underground earthing conductors shall be suitably protected against direct contact with the soil so as to prevent electrolytic corrosion of plant equipment. If it can be ensured that corrosion problems and cathodic protection draining will not occur, bare underground earthing conductors may be used to obtain a low resistance to earth. Underground bare copper conductors should be solid.

NOTES: 1. In most cases, a bare copper plant earth grid offers a sufficiently low earth resistance and thus requires no additional earth electrodes. If the plant earth grid is insulated, the earth resistance is determined by the combined earth resistance of the concrete reinforcement of foundations and driven piles and the earth resistance of dedicated earth rods.

2. Under and around high voltage substations, a bare copper earth grid may be required, in accordance with DEP 33.64.10.10-Gen., in order to limit step and touch potentials in the event of earth faults.

- If the 10 m x 10 m (33 ft x 33 ft) earth grid consists of insulated earth conductors, vertical earth electrodes shall be installed, homogeneously distributed over the grid, with a spacing depending on soil resistivity. The electrode depth should not be greater than 15 m (49 ft). The distance between driven earth electrodes shall be at least the depth of the electrodes. A typical grid and earth electrode layout is shown in Standard Drawing S 68.033.

NOTES: 1. Earth electrodes should not be installed in groups to obtain a low earth resistance value for a specific inspection pit.

2. A larger earth electrode depth will not be efficient due to the limited penetration of high frequency currents in the soil as a result of skin effect.

- For tall exposed structures such as flare stacks, exhausts, storage tanks and telecom towers, supporting earth electrodes shall be installed at the base of these structures and integrated with the plant earth grid to lead direct lightning currents to earth.
- Individual earth grids within a distance of 30 m (98.5 ft) shall be interconnected with at least two conductors, each having a minimum cross section of 70 mm² (0.11 in²). This requirement also applies to earth grids of co-located plants. In the event of extensions of an existing plant earth grid, where conductors join old and new earthing networks, attention shall be paid to the presence of dissimilar metals of earth electrodes, the possible resulting corrosion and to the possible inadvertent effects on cathodic protection systems.
- The concrete reinforcement of paving slabs may be used as an earthing and bonding grid. If so, the following requirements apply:
 - reinforcing bars of minimum diameter 10 mm (3/8 in) shall be electrically interconnected by welding or clamping. If welding or clamping is not possible, an additional wire mesh consisting of reinforcing bars of minimum size 10 mm (3/8 in) diameter, wire lashed to the reinforcement, shall be used with a maximum mesh size of 10 m x 10 m (33 ft x 33 ft);
 - all earthing and bonding connections between the slab reinforcement grid, foundations, driven piles, construction elements and earth plates shall be inspected before concrete pouring. Inspection results shall be recorded in an inspection report, to be approved by the Principal.

NOTE: The presence of a slab reinforcement grid may cause draining of DC currents from co-located cathodic protection systems. Due attention shall be paid to corrosion and CP aspects.

- All metallic structures such as vessels, exhausts and pipe racks and enclosures of electrical equipment on top of the earth grid or concrete slab shall be bonded to the earth grid with a maximum interconnection length of 10 m (33 ft). Bonding shall be in accordance with Standard Drawings S 68.003 and 68.032.

3.2 BONDING OF CONCRETE AND STEEL STRUCTURES

3.2.1 Reinforced concrete structures

In accordance with IEC 62305-3, reinforcing bars of walls, floors, foundations, driven piles etc. having a minimum diameter of 10 mm (3/8 in) should be electrically interconnected by welding or clamping. If welding or clamping is not possible, an additional wire mesh consisting of mild steel rods or reinforcing bars of minimum diameter 10 mm (3/8 in) shall be used with a maximum mesh size of 5 m x 5 m (16.5 ft x 16.5 ft). The additional wire mesh shall be connected to a large number of reinforcing rods by wire-lashing. Figure 3.1 illustrates a general overview of the bonding measures.

- NOTES:
1. Welding of reinforcing steel rods may be prohibited due to the consequent weakening of the mechanical strength of the structure. If so, clamping or wire lashing techniques shall be applied.
 2. Studies indicate that it can be assumed that at least every third wire-lashing forms an electrically conducting link, so that practically all rods of the reinforcement are electrically interconnected. Measurements carried out on reinforced concrete structures support this conclusion. In this context, further reference is made to IEC 62305-3.
 3. Steel reinforcing bars of 10 mm (3/8 in) diameter have a cross section of 78 mm² (0.12 in²) and thus a higher DC resistance with respect to a 8 mm diameter copper conductor, which is generally applied for LPS purposes. However, for frequencies in the kHz to MHz range, the inductance of the conductor is dominant, resulting in a lower impedance of the steel reinforcing bar relative to the copper conductor.
 4. Depending on mesh size and reinforcing bar dimensions, a reinforcement grid offers shielding against LEMP (Lightning Electro Magnetic Pulse). Owing to the significantly lower induced voltages in conductor loops installed inside the building or room, electrical equipment is reasonably well protected against the induced voltages arising from magnetic fields. The building or room shall be totally enclosed by steel-reinforced concrete and the shielding of any cabling coming from outside shall be bonded at the perimeter of the Faraday cage construction.

All reinforcing bars shall be bonded, through the additional wire mesh, to the plant earth ring with a maximum mesh size of 10 m x 10 m (33 ft x 33 ft).

Bonding conductors with a minimum cross section of 50 mm² (0.08 in²) and a maximum spacing of 10 m (33 ft) shall electrically bond the reinforcement grids of upper floors and roofs to the horizontal and vertical mesh.

Prefabricated concrete elements larger than 5 m x 5 m (16.5 ft x 16.5 ft) shall be supplied with earth plates to be bonded to the main concrete reinforcement.

Metal plating or cladding at the perimeter of buildings, metal gutters, post guard steel pipes and metal down-pipes located on the roof shall be bonded to the concrete reinforcement bars and thus be integrated with the external lightning protection installation. Interconnections shall be made with a maximum mesh size of 10 m x 10 m (33 ft x 33 ft). Bonding conductors shall have a minimum cross section of 50 mm² (0.08 in²).

The concrete reinforcement shall be connected to foundation anchors, machine foundations, motor basements, etc. by means of clamping or welding.

If joints between the reinforcing rods in concrete and the bonding conductor are made by means of clamping, two bonding conductors or one bonding conductor with two clamps to different reinforcing bars should always be used for safety reasons, because the joints cannot be inspected after the concrete has set.

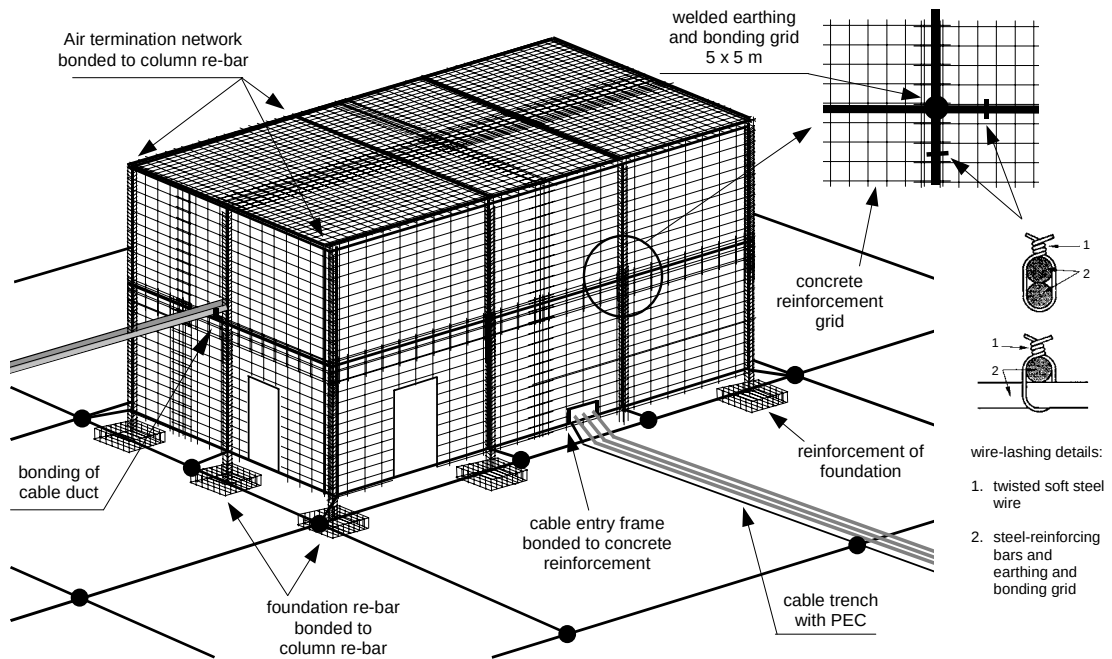


Figure 3.1 Reinforcement grid and bonding details of a blast proof concrete construction

If the structures comprise multiple sections with thermal expansion joints, with allowance for settling of the structure sections, bonding conductors shall be provided between the reinforcement of the various structural sections across the thermal expansion joints at intervals not exceeding 5 m (16.5 ft).

On top of the roof, the air termination network, installed according to IEC 62305-3, shall be bonded to the concrete reinforcement with a maximum spacing of 10 m (33 ft).

All metallic services entering the building, as well as the LPS air termination network on top of roofs, shall be bonded to the reinforced concrete grid directly at the perimeter of the building, using bonding conductors with a minimum cross section of 50 mm² (0.08 in²). The location of bonding terminations in the structure (e.g. by means of earth plates) shall be specified by the Contractor in an early planning stage of the design of the building and the LPS and shall be approved by the Principal.

Where the bonding conductors of the reinforcement are brought through the concrete wall, particular attention shall be paid to protection against corrosion.

- NOTES:
1. The simplest corrosion protection measure is the provision of a silicon rubber or bitumen finish in the vicinity of the exit point from the wall, e.g. 50 mm (2 in) or more in the wall and 50 mm (2 in) or more outside the wall.
 2. In extremely corrosive atmospheres, the bonding conductor projecting from the wall should be of stainless steel.
 3. If cast-in type nuts or carbon steel pieces are used, these shall be protected against corrosion on the outside of the wall. Serrated lock washers should be used to make electrical contact through the protective finish of the nut.

All welding, clamping and wire-lashing connections shall meet the requirements of IEC 62305-3.

All earthing and bonding connections of foundations, driven piles, vertical and horizontal reinforcement grids, construction elements, earth and bonding plates shall be inspected prior to concrete pouring. Inspection results shall be recorded in an inspection report.

3.2.2 Steel structures

Steel structures of piperacks, compressor shelters and buildings shall be used as a natural component of the LPS and the earthing system to obtain protection against direct lightning strokes and lightning induced currents, in line with the requirements of IEC 62305-3. The following bonding requirements apply (Figure 3.2):

- the reinforcing bars of foundations and driven piles shall be interconnected to form an earth termination network;
- the foundation earth shall be supplied with earth plates with a spacing of maximum 10 m (33 ft). Connections shall be made to the earth grid;
- steel construction elements shall be interconnected with a maximum mesh size of 10 m x 10 m (33 ft x 33 ft). Preferably, welded connections should be made;
- at the upper floors, the reinforcement grids shall be electrically connected to horizontal and vertical steel girders with a maximum spacing of 10 m (33 ft);
- prefabricated concrete elements larger than 5 m x 5 m (16.5 ft x 16.5 ft) shall be supplied with earth plates to be connected to the steel structure;

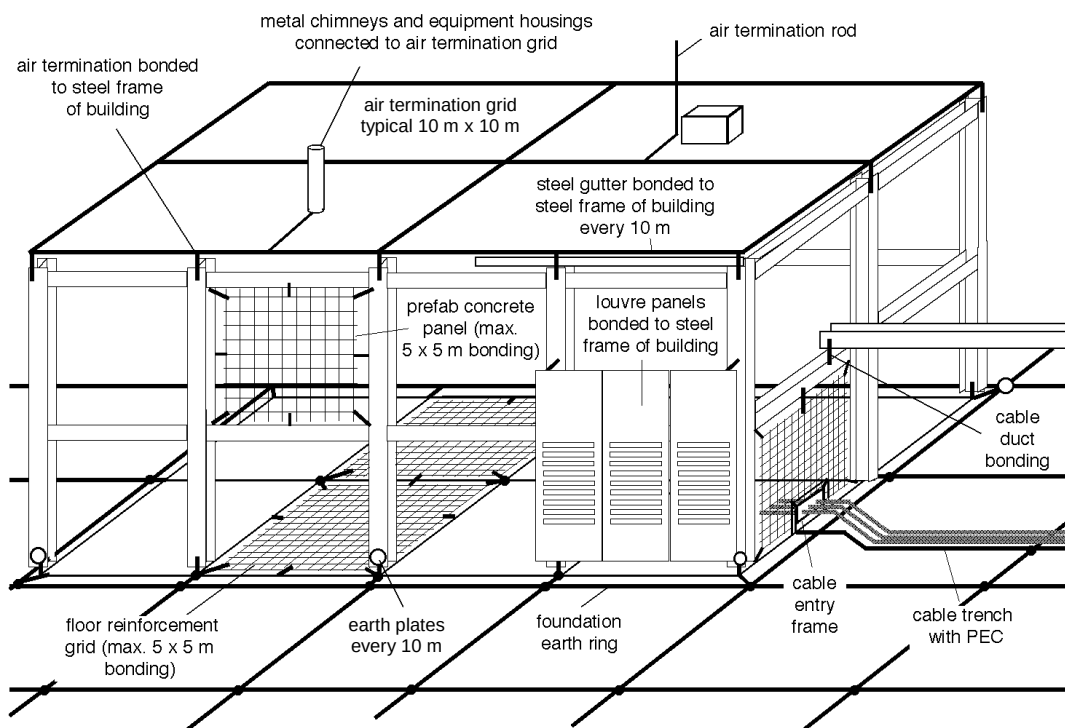


Figure 3.2 Earthing and bonding measures of buildings with steel constructions

- metal cladding and ventilation panels at the perimeter of buildings shall be electrically connected to the steelwork with a maximum spacing of 10 m (33 ft) ;
- metal plating, cladding, metal gutters, post guard steel pipes and metal down pipes located on the roof shall be integrated with the external lightning protection installation with a maximum mesh size of 10 m x 10 m (33 ft x 33 ft).;
- on top of the roof, an air termination network, installed according to IEC 62305-3, shall be connected to the steelwork with a maximum spacing of 10 m;

- pipe bridges and in particular cable trays and cable ladders shall be bonded to the steel structure or reinforced concrete grid directly at the periphery of the building;
- all bonding straps shall have a minimum cross section of 50 mm² (0.08 in²). With respect to the recommended materials for the bonding straps and the manufacture of lightning protection components, reference is made to IEC 62305;
- vertical girders next to each other with elastic joint filler shall be bonded with flexible bonding straps with a minimum cross section of 50 mm² (0.08 in²).

NOTE: A Faraday cage construction will act as low inductance down conductors to protect against direct lightning strikes. The maximum mesh size will determine the highest frequency for which the cage construction will also offer electromagnetic shielding against LEMP.

3.2.3 Tank earthing and bonding

Storage tank reinforced concrete constructions and steel enclosure tanks shall be connected to the plant earth grid. A typical earthing and bonding arrangement is shown in Standard Drawing S 68.001.

The following earthing and bonding requirements apply to storage tanks and similar storage facilities:

- the reinforcing bars of foundations and driven piles, where applicable, shall be interconnected to form an earth termination network. The foundation earth shall be supplied with earth plates at a maximum spacing of 15 m (49 ft) around the circumference of the tank. Bonding connections shall be made to the earth grid;
- the earth resistance, measured at the basement of the tank, shall meet the requirements of DEP 33.64.10.10-Gen. The earth resistance shall be measured for each individual tank with the main earth grid disconnected;
- for reinforced concrete walls and foundations of storage tanks, IEC 62305-3 shall apply;
- for lightning protection of concrete tanks, an air termination network shall be installed on top of the tank roof, around the circumference of the tank. This network shall be bonded to the wall reinforcement grid at a maximum spacing of 10 m around the circumference of the tank;
- steel brackets of steel wall storage tanks shall be bonded to the foundation reinforcement or reinforcement of vertical piles, where applicable;
- storage tanks with non-conductive walls shall be supplied with an air termination network and down conductors at a maximum spacing of 10 m (33 ft) around the circumference of the tank. The down conductors shall be connected to an earth ring 1 m away from the tank wall;
- steel railing, cranes, fixed staircases and platforms around or on top of the tank shall be bonded to the concrete reinforcement, to the steel wall or to the air termination network and down conductors where applicable, at a maximum spacing of 10 m (33 ft);
- earthing and bonding details for fixed roof tanks with floating screens shall be in accordance with Standard Drawing S 51.072. Earthing and bonding details for floating roof tanks shall be in accordance with Standard Drawing S 51.103;
- metallic enclosures of electrical equipment and instruments shall be bonded to the tank earthing;
- PECs from cable trenches and overhead cable trunking between tank electrical equipment and FARs shall be bonded to the tank earthing as shown in Standard Drawing S 68.001.
- piping from tanks shall be bonded to the tank earthing system;
- all bonding connections shall be copper, with a minimum cross section of 50 mm² (0.08 in²).

3.2.4 Earthing and bonding of pipe racks, flare stacks, telecom towers and mechanical equipment

Structural steelworks of pipe racks, flare stacks, telecom towers and mechanical equipment shall be part of the earthing and bonding system to obtain protection against direct lightning strokes and lightning induced currents. The following requirements apply (see Figure 3.3):

- The reinforcing bars of concrete foundations and driven piles shall be bonded to form an earth ring. The foundation earth shall be supplied with earth plates at a maximum spacing of 10 m (33 ft). Connections shall be made to the plant earth grid;
- steel construction girders of piping bridges shall be bonded to the basement reinforcement at a maximum spacing of 10 m (33 ft);
- metal plating, cladding, metal gutters, post guard steel pipes and metal down pipes located on piping bridges shall be integrated with the external LPS with a maximum mesh size of 10 m x 10 m (33 ft x 33 ft);
- steel brackets of flare stacks shall be bonded to the foundation reinforcement and reinforcement of vertical piles, where applicable;
- the earth resistance, measured at the basement of the pipe rack shall meet the requirements of DEP 33.64.10.10-Gen. The earth resistance shall be measured for each bridge or stack with the main earth grid disconnected. If a piping bridge with electrical cable and instrument cable trunking is connected to a flare stack, a storage tank, or other tall lightning exposed structure, additional earth electrodes may be required to "peel off" the lightning currents and reduce the current flow to a co-located building, as indicated in Figure 3.3;
- cable trunking and cable ladders shall be bonded to the steel structure at a maximum spacing of 10 m (33 ft). Attention shall be paid to corrosion aspects where stainless steel trunking is mounted on top of steel supports. Where insulating spacers are installed to prevent corrosion, bonding straps shall be applied across these spacers every 10 m (33 ft), with due attention paid to the materials being employed;
- cable trunking should not be located on top of piping bridges. If cable trunking is located at the highest point of a piping bridge, and thus exposed to direct lightning strikes, closed trays with steel covers shall be used. Cable tray sections shall be interconnected using U-shaped coupling plates;
- bonding straps shall be installed across isolating flanges of above-ground steel pipe sections.

NOTE: Bonding of isolated pipe sections may be allowed at the interface between underground and above ground piping in order to ensure the proper operation of cathodic protection systems. In this case, a spark gap should be installed. If the use of a spark gap is not feasible due to hazardous area requirements, the CP rectifier(s) should be subjected to regular inspections, in particular in lightning prone areas, see also section (6.4).

- steel pipe structures shall be bonded to the plant earth grid or to the PEC at the following locations; see Figure 3.4:
 - at either side of the pipe in the absence of a plant earth grid, e.g. outside the process areas to flare stacks, loading stations etc.;
 - at either side of the pipe where the pipe is protected by overhead steel structures, e.g. inside a process area;
 - at a maximum spacing of 30 m (98.5 ft), where the pipe is exposed to direct lightning strokes;
 - at a spacing of maximum 10 m (33 ft) where the pipe contains instruments such as flow meters.

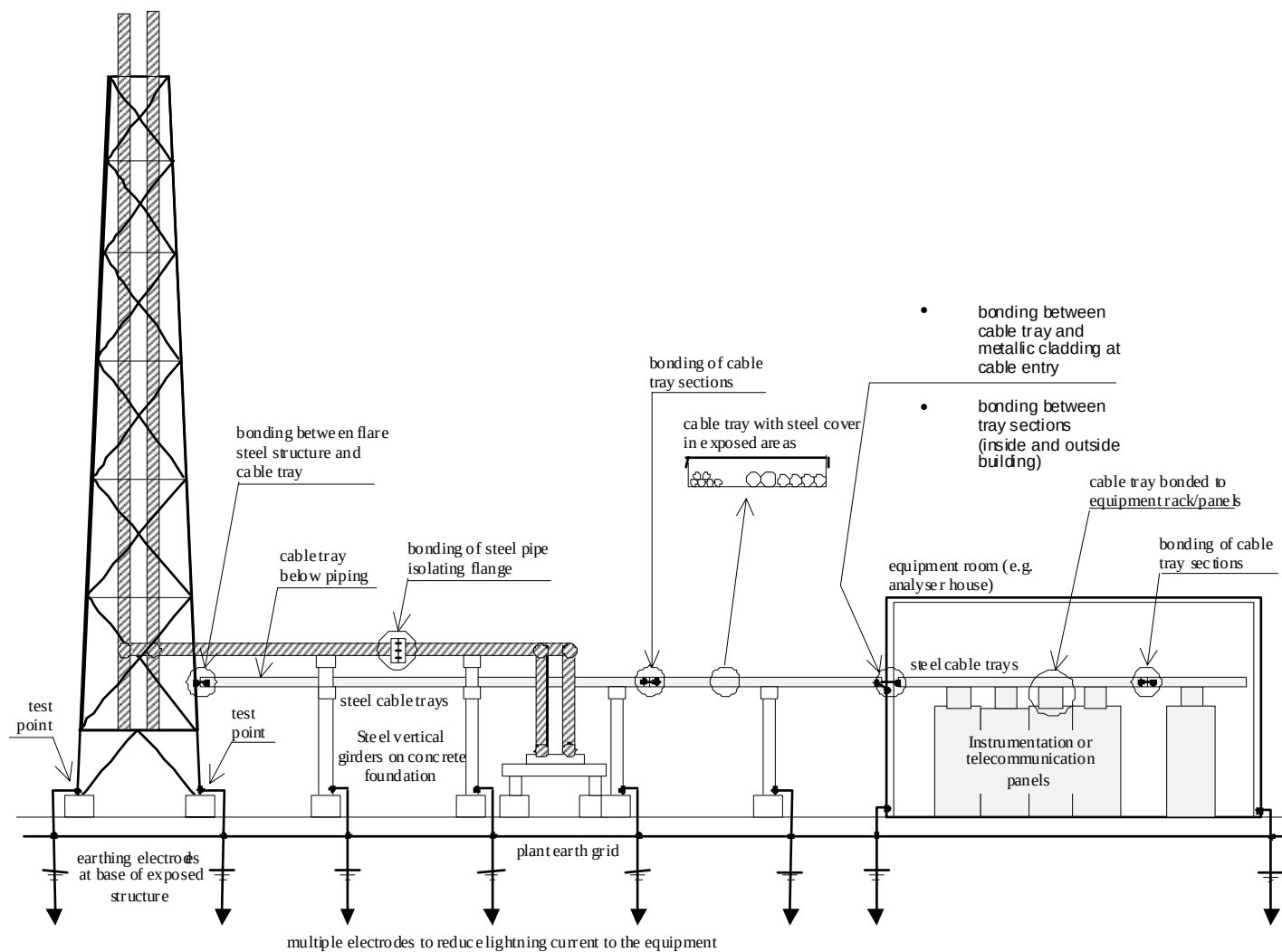


Figure 3.3 Typical bonding aspects of pipe rack arrangement and a flare stack