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## Rules or Handbooks or Guidelines

### IO cabling rules

The intent of these cabling regulations is to ensure uniformity and homogeneity of the measures implemented in the ITER facility related to the protection of equipment and people against the unwanted effects of electric currents. These rules have to be respected scrupulously by the engineering services, consulting firms, the fitters (external companies, employees of the technical services or employees of the maintenance services, the laboratory agents) implementing or working on cabling ...

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v3.3	Approved	02 Nov 2016	corrected typo error



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## List of Acronyms

AFNOR	L'Association Française de Normalisation
CBN	(Meshed) Common Bonding Network
CEA	Commissariat à l'Energie Atomique
CMC	Crisis Management Component
DA	Domestic Agency
EIC	Environmental Important Component
EMC	Electro-magnetic compatibility
GBS	Geographical Breakdown Structure (Reference to tokamak Plasma)
I&C	Instrumentation and Control
IDM	ITER Document Management
IEC	International Electro Techniques Commission
IO	ITER Organisation
ISO	International Standards Organisation
LPZ	Lightning Protected Zone
PA	Procurement Arrangement
PBS	Plant Breakdown Structure
PEC	Protective Earth Conductor
PIC	Protection Important Component
PSE	Plant System Equipment
QA	Quality Assurance
RCC-E	Règles de Conception et de Construction des Matériaux électrique des Centrales Nucléaires
REI	R: Load carrying capacity (résistance mécanique ou stabilité) E: Integrity (étanchéité aux gaz et flammes) I: Insulation (isolation thermique)
SCADA	Supervisory, Control and Data Acquisition
SIC	System Important for Safety
SSC	Structures, System and Components
TID	Total Integrated Dose
TVS	Transient Voltage Suppressor
UTE	Union Technique de l'Electricité



## 1. Abstract.

The intent of these cabling regulations is to ensure uniformity and homogeneity of the measures implemented in the ITER facility related to the protection of equipment and people against the unwanted effects of electric currents.

These rules have to be respected scrupulously by the engineering services, consulting firms, the fitters (external companies, employees of the technical services or employees of the maintenance services, the laboratory agents) implementing or working on cabling systems in the ITER facility during the whole lifetime of the project.

This document deals with cables trays, cables and connector installation and segregation, cable trays earthing and E.M.C. directives. These rules shall be applied in the cabling engineering workflow for all subjects concerning or in relationship with cabling in the ITER facility. Not respecting these rules leads to deficient installation and extra workloads to recover conform installation, moreover, the extra cost engaged to modify and/or redo works will be prohibitive.

The standards, guidelines and directives used in the design of the present document are described in the baseline document ITER\_D\_4B523E-EDH Part 4: Electromagnetic Compatibility (EMC).



## 2. Introduction.

The purpose of this paper is to provide a guideline to all staff involved in cabling engineering, in order to obtain high E.M.C. performance and to ensure the safe operation of the facility.

Any electrical installation must be made according to good engineering E.M.C. practice.

An exception from these rules for particular cases shall be decided upon on a case by case basis by the Electrical Engineering Division.

An unauthorized violation of these rules may lead to an increased level of E.M.C. perturbations and possibly decreasing the degree of protection of the whole or part of the cabling of the site, and/or affect staff's safety.

It is, however, necessary to emphasise that any exceptional measures must not violate standards and the legislation in force concerning the protection of the equipment and the people towards the use of electric equipment.

All personnel working on electrical installations must have the suitable authorization in accordance with NFC 18-510 standard (January 2012) and related guides as :

- UTE C18-510-1U (June 2012) Collection of safety instruction for electrical networks
- UTE C18-510-2U (January 2013) Electrical safety requirements for operation on electricity generation installations or in their environment
- UTE C18-510-3U (September 2013) Electrical safety requirements for work activities on or near of electrical installations
- UTE C18-531 U (June 2012) Electrical safety requirements for non-electrical or simple operations in electrical environment
- UTE C18-540 U (June 2012) Electrical safety requirements for operation on low voltage installations except live parts working

These cabling rules are divided into several chapters:

- Architectural structures: dealing with the possible architectural cabling structure.
- Cable trays: dealing with the design and installation of cable trays or conduits all along the cable paths.
- Cable installation: dealing with the design and installation of cables in the cable trays or conduits.
- Segregation: dealing with the distribution of the different cable types in the cable trays and the distribution of cable trays all along the cable paths.
- E.M.C.: dealing with the electro-magnetic compatibility measures for the entire installation and along the whole path related to cables and cable trays and their interconnections with all metal structures (fluid pipes, air-conditioning conduits, building metal structures).

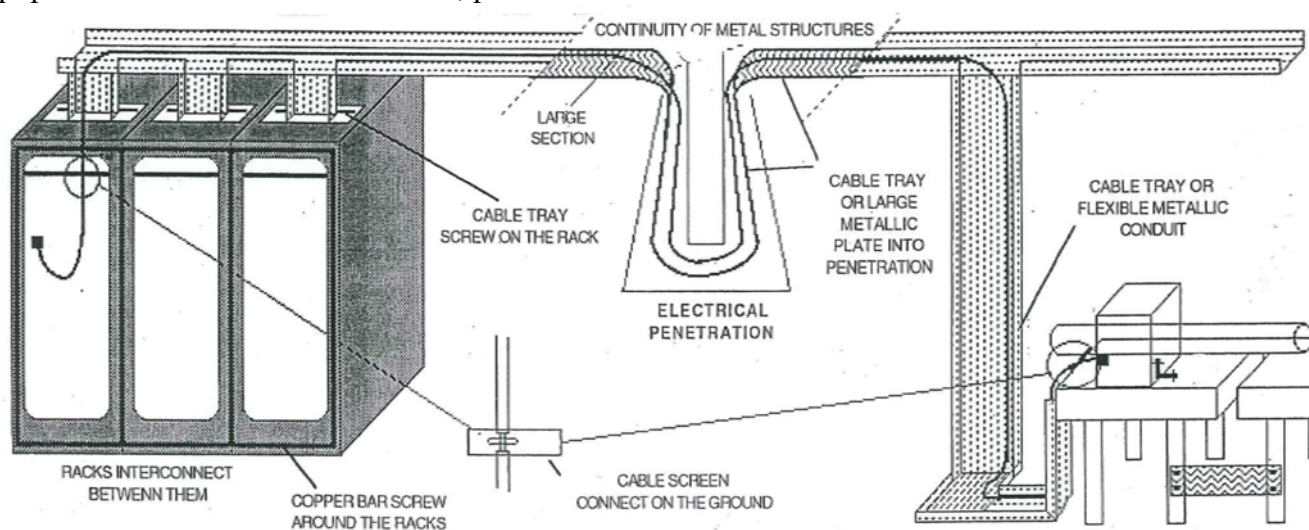


### 3. Architectural structure.

A typical installation configuration respecting E.M.C. measures is shown in Fig. 3.1.

All components are solidly bonded together in order to achieve a maximum reduction of perturbation effects. Also, all the cables shall be pulled in cable trays or any other type of mechanical and electrical containment.

As a “perturbation free” site cannot be achieved in reality, the level of perturbations which is tolerable in the site is defined in the Electrical Design Handbook (EDH), (ITER\_D\_4B523E - EDH Part 4) and the E.M.C. measures should be adapted accordingly. In the same way, the immunity of the on-site equipment is also defined in the EDH, part 4.



**Figure 3.1 Installation respecting E.M.C. measures**

The figure above may serve as a design template for a local structure as well as, in a scaled manner, for the more global structure. This configuration will minimize E.M.C. conducted perturbations if all components are also E.M.C. compatible and properly cabled.

However, particular solutions may be developed for local problems, when the emission levels are higher than previously specified or the immunity is lower. They must be treated locally on a case by case basis with a precise analysis of the perturbations and their acceptable level. Then, complementary measures may be implemented (filtering, shielding, data processing...).



## 4. Architectural rules.

This set of rules describes the layout that applies for cable connections between devices and cubicles, between cubicles or between devices. All cables are routed within a suitable EMC protection (pipes, cables trays or trunkings).

### 4.1 Connecting plant system equipment controllers and Codac I&C cubicles

Direct connections of I&C signals between Plant System equipment controllers are not recommended. This guideline aims to avoid any hidden common mode or dependence which could not be managed easily by the plant system I&C. If required by several Plant system equipment controllers, associated data have to be transmitted through the upper level Codac I&C controllers (see Fig. 4.1.1). Conversely, an extra ground connection is required if a cable (fieldbus or interlock cable for instance) directly connects PSE1 to PSE2.

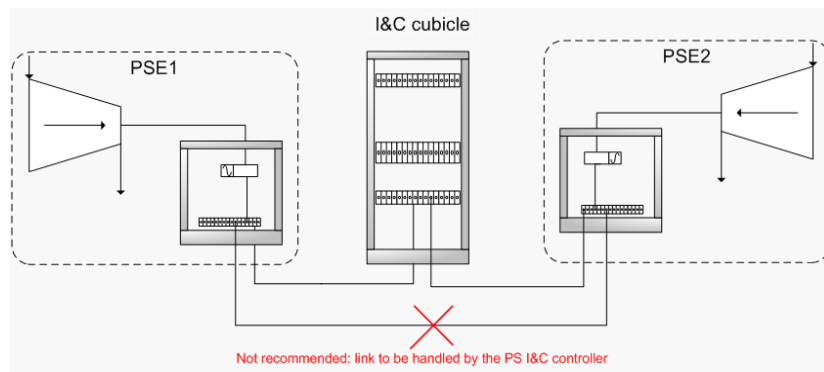


Figure 4.1.1 Direct connection between PSE of the same plant system is not recommended

### 4.2 Connecting plant system I&C

Direct cabled connections of I&C signals from a plant system I&C to another plant system I&C inside the same plant system or between two different plant systems are not allowed. The aim of this rule is to clearly define the plant system I&C boundary and delivery (see Fig. 4.2.1). I&C cables including at least 10% unused wires are recommended (see EMC cabling rules §9 for connections to CBN).

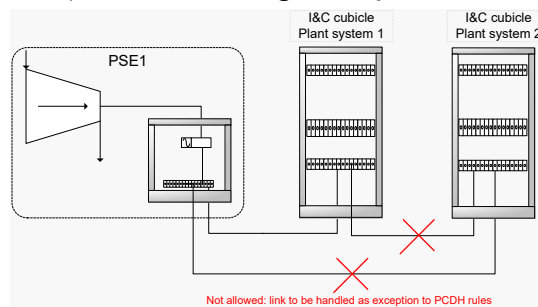


Figure 4.2.1 Connections from Plant system equipment (PSE) to two different I&C cubicles of different plant systems are not recommended.



### 4.3 Connecting buildings and for long distances

If the PSE and the I&C cubicle connected to it are not in same building or are located in the same building but at a different Electro-Magnetic Zone<sup>1</sup>, an optical fibre or any suitable galvanically isolated device shall be used. Application of this rule will avoid the introduction of any large earth loops. If this rule cannot be followed, all cable shields should be bonded at the entrance/exit of any buildings. Transient Voltage Suppressors (TVS) may be necessary at the border between two different Lightning Protected Zones.

I&C signal cabling addresses the electrical and optical connections which are required to transport I&C signals from the plant system equipment (PSE) to the I&C cubicles and between I&C cubicles.

There are four types of connection of Plant system equipment (PSE) to I&C cubicles: direct connection, connection through a SJC (signal junction cabinet), connection on a PSE<sup>2</sup> interface and connection through a plant system field-bus. These four configurations may be mixed for flexibility (see Fig. 4.3.1).

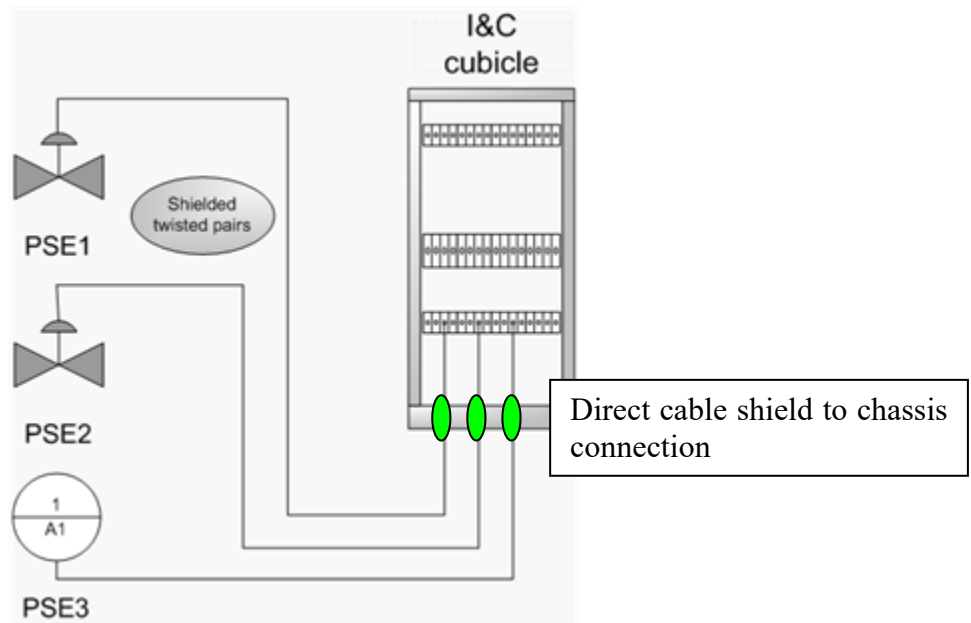


Figure 4.3.1 Direct connection from Plant system equipment to an I&C cubicle

This is the simplest way to connect Plant system equipment (PSE) and I&C cubicles. The I&C signal cables are shielded single or multi-twisted pairs cables. This configuration is suitable for PSE spread out in the vicinity of the plant system I&C cubicles without a high density of PSE. As possible, the same metal plate will be used for both input and output chassis connections.

<sup>1</sup> The Electro-Magnetic Zones are defined in Electrical Design Handbook (EDH) part 4 (ITER D 4B523E)

<sup>2</sup> Plant system equipment is any plant system device which is controlled or monitored by the plant system I&C. They range from a single sensor/actuator up to a fully integrated set of components including embedded interfaces for powering, local controls, safety and interlocks. For example, a compressor or a power supply with associated auxiliaries provided by the equipment supplier. Plant system equipment may have local panels for manual control or local monitoring, but no dedicated SCADA system.



#### 4.4 Rules applicable to Junction box/interfaces

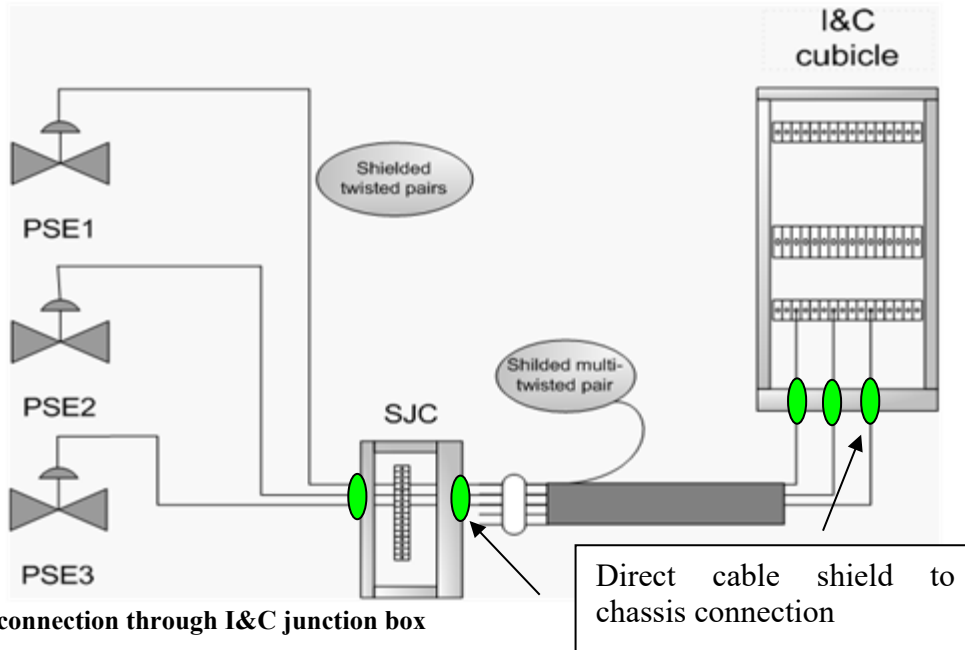


Figure 4.4.1 PSE connection through I&C junction box

This section describes the different SJC or junction boxes that shall be used in order to standardize the cables that will connect a PSE with I&C cubicles.

In this configuration, PSE are first cabled to a signal junction cabinet (SJC) or junction box. Then the SJC is cabled to the plant system I&C cubicle. This configuration is preferred for the case of high density of PSE of the same or similar signal type. In such a case similar signals are gathered in the same cable in order to reduce the number of discrete on-site cabling runs. The junction boxes could be a feed through in a penetration. In any case, a 360° connection between the cable braid and the metal box must be realized.



## 5. Cabling rules for cable tray installation

These rules describe the layouts which are to be used for cable tray routing (connections between plants, buildings, devices and cubicles, or between cubicles or between devices). The cable tray installation shall be done according to the norm IEC 61000-5-2 Ed 1.0 – 1997.

All cable trays, conduits or metal enclosures containing electrical equipment must be connected to the Common Bonding Network via bonding conductor(s) of sufficient size to carry the maximum earth current. The same applies to interconnections between cable trays following the same route.

The resistance between a cable tray-end and a cubicle, or whatever connected material, must be of low impedance.

Cable tray sections must be in accordance with the cable types and/or the number of cables installed in it, respecting the maximum filling ratio, according to the cable tray type.

The cable trays or conduits must have an electrical continuity (at least by 4 screws) all along their route even when changing direction, room or level. If a cable has to be routed into different cables trays, electrical connections must be insured between them at each pass.

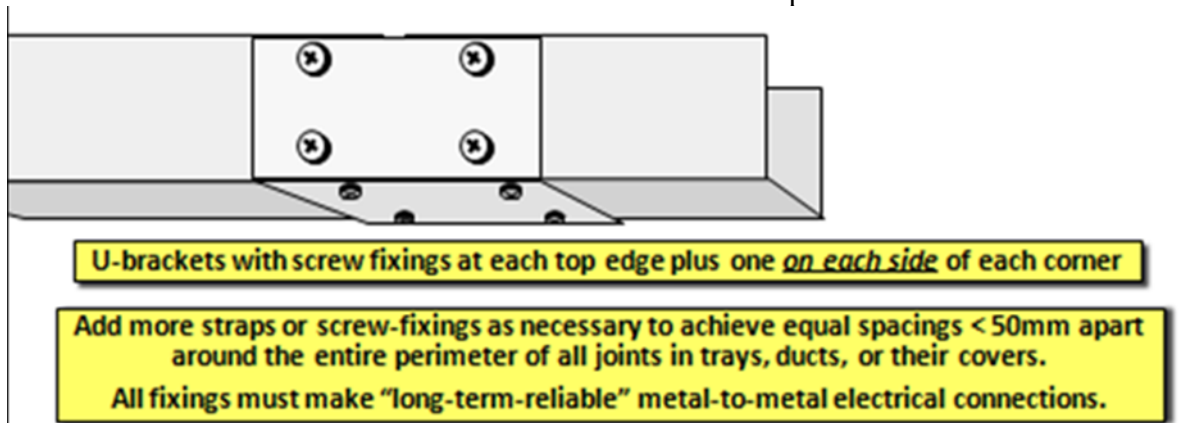


Figure 5.1. Example of a standard junction of two cable tray segments

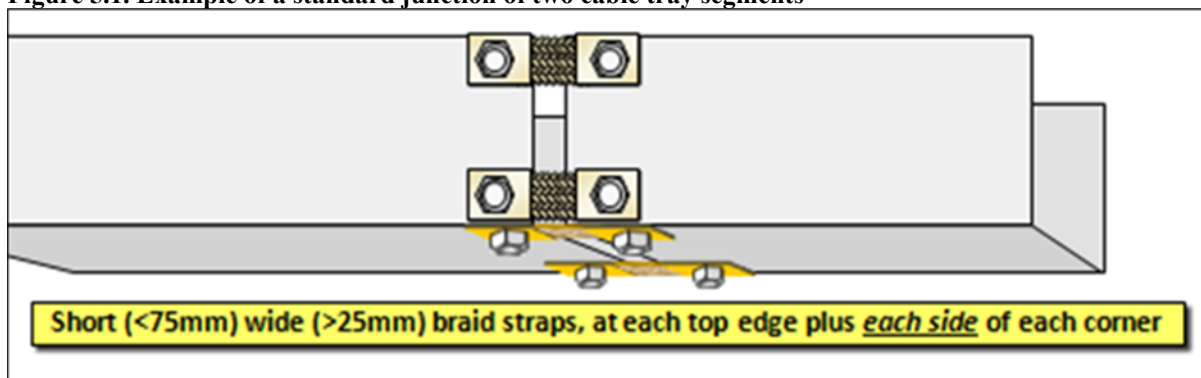


Figure 5.2. Example of a non-standard junction of cable trays, only in particular cases indicated in the cable trays manufacturing drawings, like Tokamak seismic isolation pit, or non-standard fittings. The straps in parallel shall be equally spaced, with maximum gap among them of 100 mm on the bottom of the tray (for trays wider than 200 mm)

If two cables belonging to incompatible families (for the definition of families, refer to EDH part 4, IDM\_D\_4B523E) have to share the same cable tray, a metal vertical cable tray divider must be installed. In any case a metal cover must be installed on sensitive cable trays (IEC 61000-5-2 sub-clause 7.7.4 Distance between conduits) to have an optimal E.M.C. protection.





## 5.1 Cable tray Bending radius

The cable tray sections must respect the minimum bending radius of the cable types on its entire horizontal surface. In general, the minimal bending radius of cables varies between 8 and 15 times the external diameter.

By convention, to avoid any misunderstanding and to simplify the cable tray design and installation, the bending radius for all cable trays and conduits should be at least 300 mm for Low Voltage, Sensitive and Noisy trays. The bending radius for Medium and High Voltage trays is 750 mm.

## 5.2 Cable tray dimension and quality

The cable tray walls must be higher than the external diameter of the cable or group of cables installed in it, respecting EMC 2014/30/UE. However, 50 mm height shall be the minimum required. Electro-galvanized protection is mandatory, however if the environment where the cable trays have to be installed has additional or specific characteristics, the final decision will be taken by the “Electrical Engineering Division” in charge of cabling. In any case the cable trays must be compatible in term of surface treatment between them. If not, an adaptive junction piece must be placed to improve electrical continuity. Their thickness must be at least to 1.5 mm to avoid any deformations or damages due to a potential bad treatment of external companies working along the cable tray paths during and between the cable trays installation phase and the cable pulling phase witch could be estimated in years. The cable tray shall be compliant to all the environmental conditions and the applicable safety requirements of the area (seismic, fire, etc).

Regarding conduits in the buildings, they shall be metallic, with the following sizes (diameters may change between different suppliers), and they shall respect the IEC 60981 or ANSI C80.1 for the rigid conduits (exceptionally, if the seismic qualification allows the standards IEC 61386 and IEC 60423 could be also used).

Title	Internal diameter (mm)	External diameter (mm)
CD16 (1/2 in)	16.1	21.3
CD20 (3/4 in)	21.2	26.7
CD25 (1 in)	27.0	33.4
CD34	35.4	42.2
CD40 (1 1/2 in)	41.2	48.3
CD50 (2 in)	52.9	60.3
CD63	63.2	73
CD75 (3 in)	78.5	88.9
CD100 (4 in)	102.9	114.3



Regarding flexible conduits, they shall follow IEC 61386 -1/23.

Regarding buried plastic duct banks, the sizes are (diameters may change between different suppliers)

Title	Internal diameter (mm)	External diameter (mm)
DB150	150	175
DB175	175	225
DB200	200	250

The interface between any device/cubicle and the conduit shall be done either with flexible conduits or with air-runs, but never with rigid conduits

### 5.3 Cable trays earthing

All cable trays must be equipped with an earth cable (usually bare copper cable 25 mm<sup>2</sup> cross section). It shall be fixed on the external part of the cable tray's wall. In case of several cable trays following the same route, a copper bar shall be installed at the same level as the power cable trays. An equipotential link between cable trays and the copper bar, as well as between cable trays shall be installed. An equipotential link shall be installed approximately every 10 meters following NFC 15-900. The cable trays shall be bonded to all building bonding terminals located in the buildings and underground galleries. The cable trays must be arranged be as shown in Fig. 12. Copper bars must be attached to the cable tray supports all along the cable tray paths. In any case, earth conductor cross section must be able to accept the maximum fault current during a short circuit.

In general, the cable tray networks must be bonded as frequently as possible to the metal structure where they are installed as well as all metal parts in buildings. These interconnections help to reduce the current loop effects and make a very good Common Bonding Network. Cable trays must not be considered as an earth conductor (NF C15-100).

All buildings and/or plant of buildings must be bonded on the CBN and the CBN must be connected to Earth. Earth connection points must be tested and must be have a disconnection mechanism. Any metal networks (air conditioning system, fluid pipes, etc.) must be connected to the CBN and connected to Earth. All Earth interconnections installed must be tested.

### 5.4 Cable trays configurations for the different ITER areas

Signal and power cables are routed in different cables trays according to the type of signal or power. ITER has based its cable distribution on the IEC 61000-5-2 recommendations for Earthing and Cabling, as shown below.



The segregation of the cable types (sensitive, noisy....) must be done taking into account crosstalk. If cables of different families have to follow the same route, they should be placed in different cable trays<sup>3</sup> (this solution is preferable to using the same cable tray equipped with dividers).

When cables have to go outside of the cable trays or other conduits, they must have a suitable protection in E.M.C. terms, e.g.: flexible metal pipe, copper cable or any other item offering a suitable low impedance PEC (as a metal plate or a piece of cable tray electrically connected at both ends for instance).

In all cases power cables must not be installed closer than one meter to sensitive cables if they are following the same routing without any protection.

An earth cable is considered as a noisy cable.

There will be four configurations of cable installations, depending on the classification of the room where the cable trays are located. In all configurations the PIC cables will never be mixed with non-PIC.

#### **5.4.1 Cable tray configuration in Critical areas and special ambiances**

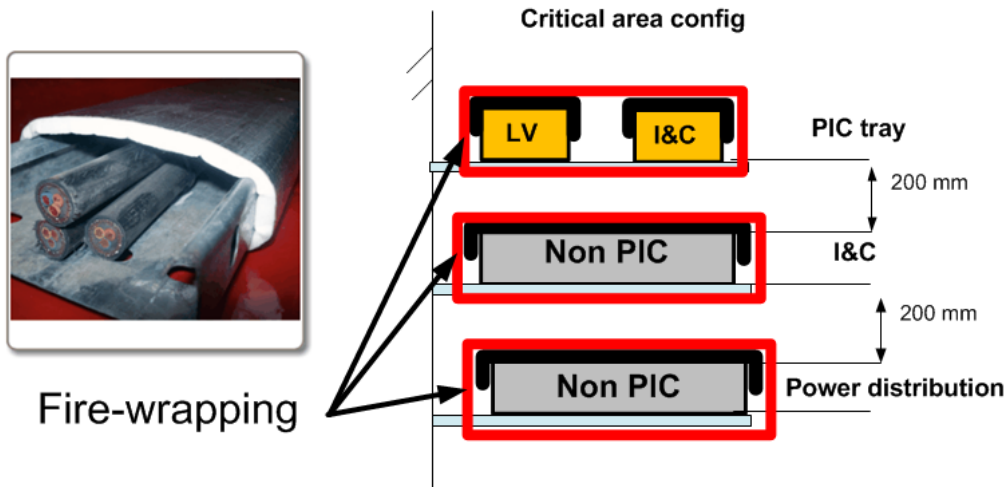
The ITER safety has identified several critical areas, which require that all cable trays are covered with a fire-wrapping around all cable trays (PIC and Non-PIC) in order to reduce the probability of the fire propagation through the cables installed in that cable tray (either due to a fire produced by cables or external initiator), in the case that a fire is produced in that room. Moreover, all cable trays in nuclear buildings shall have a metallic cover.

This fire wrapping should be of at least class1 decontamination type, and they shall allow subtracting the fire load of the cables in that room.

The list of rooms is defined in ITER\_D\_KF63PB - Safety requirement Roombook.

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<sup>3</sup> Properly shielded cables are not subject to common mode crosstalk.



**Figure 5.4.1.1 Configuration in critical areas and special ambiances. There is a fire wrapping around ALL cable trays to extract the cable fire load from the room.**

All the cable trays which require the fire-wrapping, this will be extended along the support up to the embedded plate, as shown in the next figure, in order to withstand fires according to the ISO-834 curve for a fire of at least two hours duration. Some relaxation can be accepted after analysis and justifications validated by IO Safety Department.

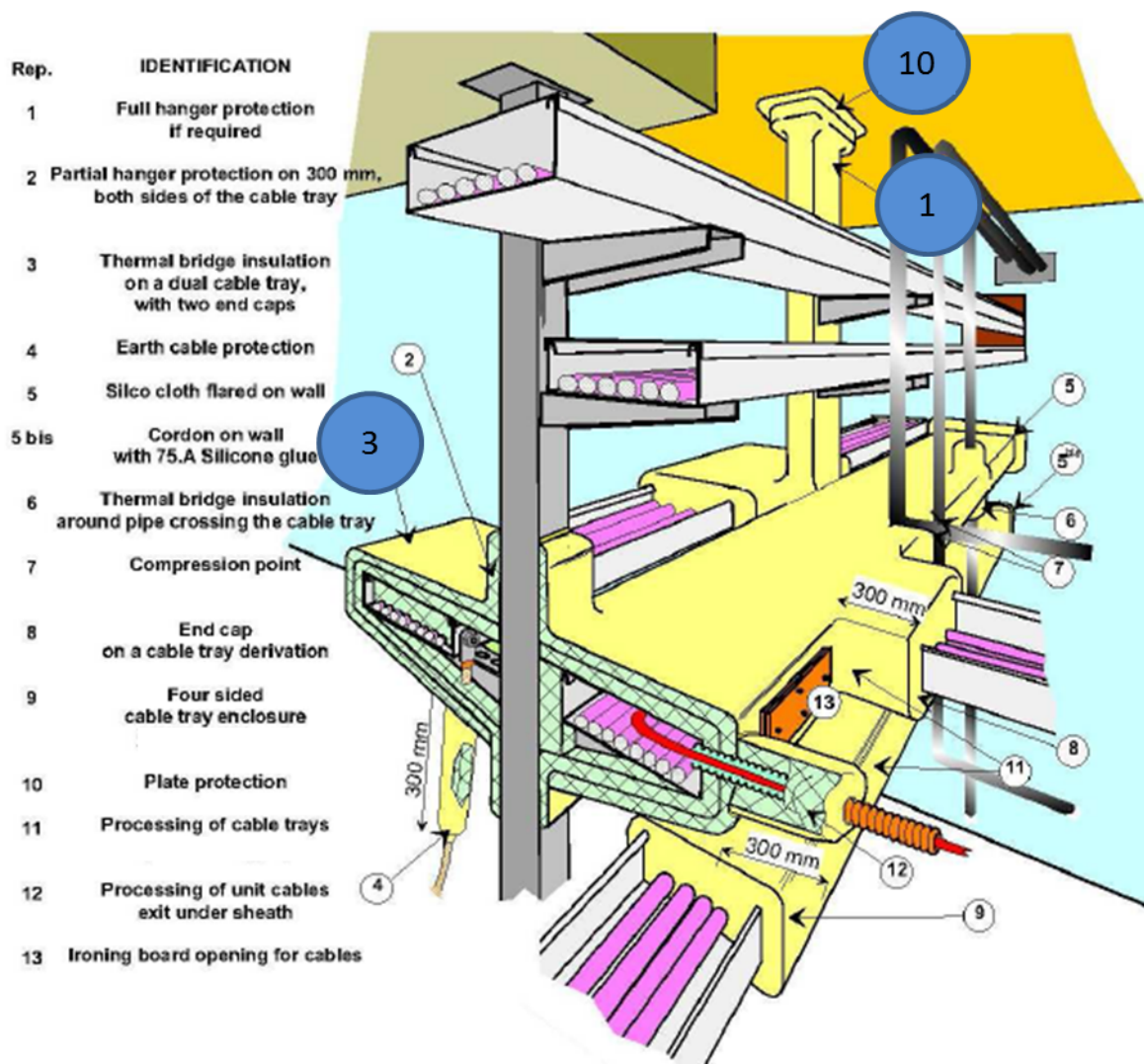


Figure 5.4.1.2. The fire-wrapping around the tray (bullet 3) will be extended along the support (bullet 1) and covering the embedded plate (bullet 10). The earth cable of the cable tray bonded to the building shall be protected 300 mm out of the cable tray.

The fire-wrapping around the cable trays for the cable functionality or subtraction of the fire load (like for example in the process rooms in tritium building) can be achieved with an envelope of ~40 mm and a thermal conductivity of 0.038 w/mK at 20 °C, 0.06 w/mK at 200 °C, 0.16 W/mK at 600 °C ([ITER\\_D\\_SDPGN3 - Cable tray fire wrapping](#)), if the cables inside are fire resistant according to IEC 60331-1/2 or NFC 3207- CR1.

The cables going out of the cable trays shall be also protected with a fire-wrapping envelope along the whole path (up to the sensor/actuator), except if they are installed inside a metallic conduit, and the cables are fire resistant according to IEC 60331-1/2 or NFC 32070- CR1. This applies only to short runs, but it's not applicable for cables passing fire sectors.

#### 5.4.2 Cable tray configuration PIC-SSC (Structures, system and components)

All cable trays (PIC, non-PIC, I&C and Power) shall be covered with a metallic cover.



This layout is required in all Rooms in nuclear buildings (11, 14, 21, 23), except the Critical areas listed in [ITER\\_D\\_KF63PB - Safety requirement Roombook](#) where the configuration indicated in 5.4.1 applies.

Regarding non-nuclear buildings 24, 44, 45, 57, 58, 71, 74, 75 that layout is required in the rooms with PIC components.

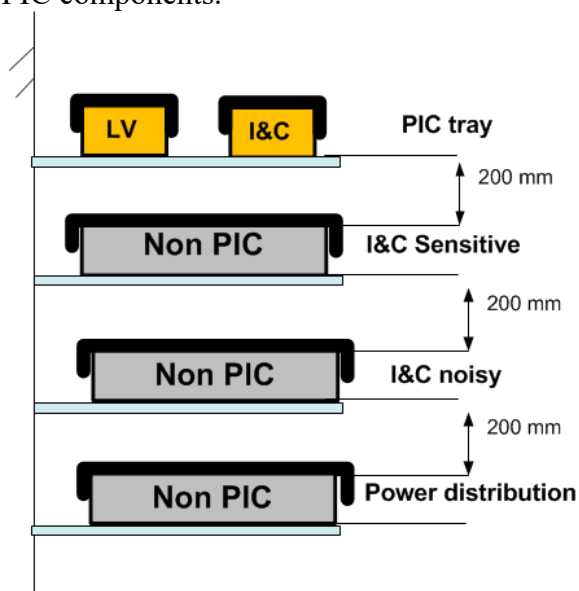


Figure 5.4.2.1 Configuration of cable trays in PIC-SSC areas

In addition, when two redundant safety trains are in the same fire sector, the intrusive train has also a fire-wrapping around the cable tray to guarantee the functionality of the cable under a fire condition according to the ISO-834 exposure curve during 2 hours.

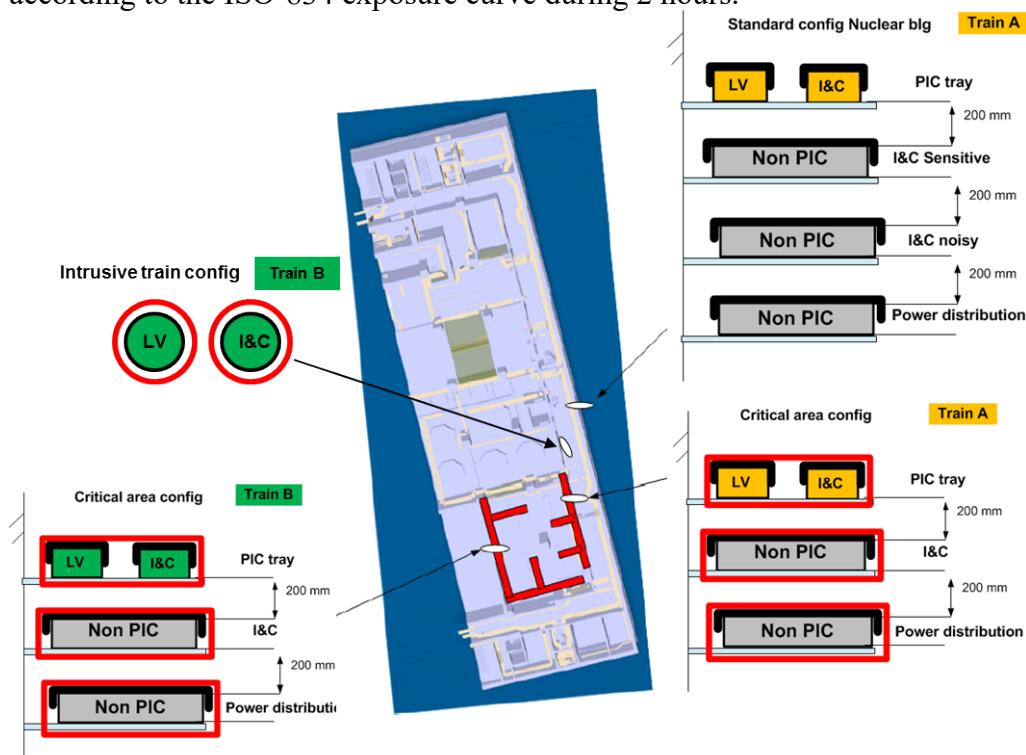


Figure 5.4.2.2. Fire protection design basis. This level of the Tritium building has the Safety train A as the main one. All the cable trays have the standard configuration in the nuclear buildings, where all the cable trays have a cover to minimize the fire propagation. In those regular areas, the intrusive Safety train will have all the cable trays or conduits a fire wrapping envelope to guarantee the cable functionality under a fire condition according to the ISO-834



exposure curve of 2 hours duration (Intrusive train configuration). The fire-wrapping protection is indicated in [ITER\\_D\\_SDPGN3 - Cable tray fire wrapping](#). In the critical areas, all the cable trays Safety and Non-Safety related are fire wrapped to extract the cable fire load (Layout in Critical area shown in 5.4.1).

#### 5.4.3 Cable tray configuration for NON PIC-SSC (Structures, system and components) with PIC cable trays passing through

This layout is required in some Rooms in non-nuclear buildings (blg71, blg74) and underground trenches without PIC equipment with PIC trays passing through. This configuration is not used in the areas with PIC components, whereas the configuration described in 5.4.2 shall be used. This configuration shall be excluded from all nuclear buildings.

All PIC cable trays shall be equipped with metallic cover, whilst non-PIC cable trays not required cover from safety point of view. The Non-PIC sensitive trays are covered for Electromagnetic compatibility reasons. Whenever possible, the lids should be laid staggered over the cable trays.

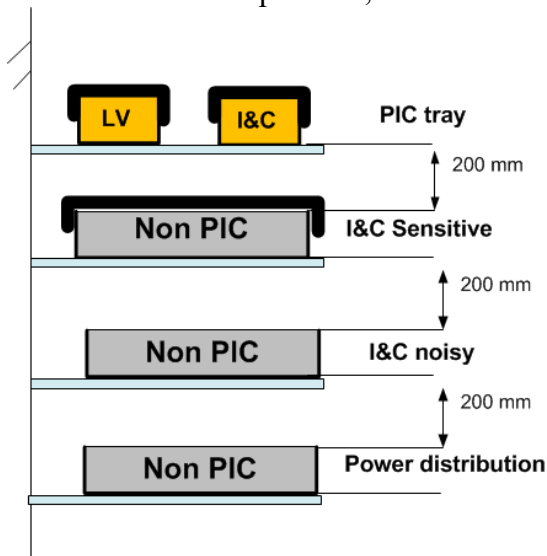


Figure 5.4.3.1 Configuration of cable trays in Non PIC-SSC with PIC trays passing through

#### 5.4.4 Cable tray configuration for NON PIC-SSC (Structures, system and components)

This layout is required in all Rooms in non-nuclear buildings (blg 13, 15, 17, 32, 33, 34, 36, 37, 38, 42 IP, 43 IP, 46, 47, 51, 52, 53, 61, 64, 67, 68, 69, LC01 ~ LC14, M01~MV06) without PIC equipment and without PIC trays passing through, and also for underground galleries without PIC trays. This configuration shall be excluded from all nuclear buildings.

Non-PIC cable trays not required cover from safety point of view. The Non-PIC sensitive trays are covered for Electromagnetic compatibility reasons. Whenever possible, the lids should be laid staggered over the cable trays.



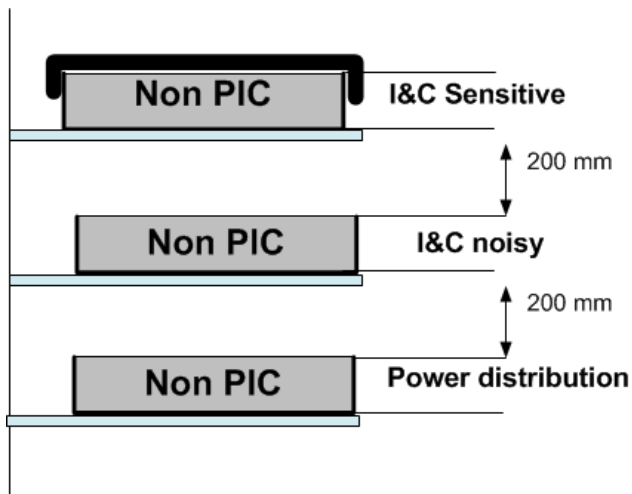


Figure 5.4.4.1 Configuration of cable trays in Non PIC-SSC without PIC trays passing through

#### 5.4.5 Cable tray configuration with fire screen

There are some areas with a qualified fire screen which avoids the propagation of the fire through the cable trays.



Figure 5.4.5.1 Configuration of cable trays with fire screen.





## 5.4.5 Installation methods

The following table shows the type of raceway for each segregation type, depending on the location.

Cable tray segregation	Description	Safety Class	Level	Pulling method	Type of tray	
					Nuclear building and site galleries	Non-nuclear building and site galleries
A6	A train 6.6 kV	PIC/SIC-A	Power	Maintained Spacing	Ladder Cover	Ladder Cover
AL	A train LV	PIC/SIC-A	Power & Control	Random fill	Solid bottom Cover	Ladder Cover
AS	A train sensitive	PIC/SIC-A	Instrumentation	Random fill	Solid bottom Cover	Solid bottom Cover
AH	A train HV or HC	PIC/SIC-A	Power	Maintained Spacing	Ladder Cover	Ladder Cover
AP	A pneumatic	PIC/SIC-A	Pneumatic	Random fill	Ladder Cover	Ladder Cover
B6	B train 6.6 kV	PIC/SIC-B	Power	Maintained Spacing	Ladder Cover	Ladder Cover
BL	B train LV	PIC/SIC-B	Power & Control	Random fill	Solid bottom Cover	Ladder Cover
BS	B train sensitive	PIC/SIC-B	Instrumentation	Random fill	Solid bottom Cover	Solid bottom Cover
BH	B train HV or HC	PIC/SIC-B	Power	Maintained Spacing	Ladder Cover	Ladder Cover
BP	B pneumatic	PIC/SIC-B	Pneumatic	Random fill	Ladder Cover	Ladder Cover
CL	HCC train A LV	HCC-A	Power & Control	Random fill	Solid bottom Cover	Solid bottom Cover
CS	HCC train A sensitive	HCC-A	Instrumentation	Random fill	Solid bottom Cover	Solid bottom Cover
DL	HCC train B LV	HCC-B	Power & Control	Random fill	Solid bottom Cover	Solid bottom Cover
DS	HCC train B sensitive	HCC-B	Instrumentation	Random fill	Solid bottom Cover	Solid bottom Cover
PL	PIC/CMC or PIC/EIC LV	PIC-Non SIC	Power & Control	Random fill	Solid bottom Cover	Ladder Cover
PS	PIC/CMC or PIC/EIC sensitive	PIC-Non SIC	Instrumentation	Random fill	Solid bottom Cover	Solid bottom Cover
N6	No train 6.6 kV	Non-PIC	Power	Maintained Spacing	Ladder Cover	Ladder
NL	No train LV	Non-PIC	Power	Random fill	Ladder Cover	Ladder
NN	No train noisy	Non-PIC	Control	Random fill	Ladder Cover	Ladder
NS	No train sensitive	Non-PIC	Instrumentation	Random fill	Solid bottom Cover	Solid bottom cover
NH	No train HV or HC	Non-PIC	Power	Maintained Spacing	Ladder Cover	Ladder
NP	No-train pneumatic	Non-PIC	Pneumatic	Random fill	Ladder Cover	Ladder Cover
XR	Interconnection Train A~B (Fiber Optic only)	PIC-A/B	Instrumentation	Random fill	Solid bottom Cover	Solid bottom Cover
HV	High Voltage 66 kV	Non-PIC	Power	Maintained Spacing	Ladder Cover	Ladder
MP	22kV (Medium voltage) for PPEN Systems	Non-PIC	Power	Maintained Spacing	Ladder Cover	Ladder
MS	22kV (Medium voltage) for SSEN Systems	Non-PIC	Power	Maintained Spacing	Ladder Cover	Ladder

**Figure 5.4.5.1 Installation method on each location. In addition all raceways located outdoor shall have a cover.**

All cables in ladder tray shall never be vulnerable to noise. Also, those cables shall be either filtered or with cable braid.

## 5.5 Cable trays in raised floor

When cable trays have to run through or under raised floor areas, an easy access all along the cable tray paths in these areas must be kept (no material should be placed or stored on the corresponding false floor plates access). A necessary space must be devoted to workers on the cable trays under the false floor (cable tray modifications, pulling and crimping cables) to avoid walking on it. In practice, cable trays must be installed under one row of false floor plates and a free space under next floor plate's row (left or right) must be left. This configuration will give to workers the necessary space to work in good conditions. As already described higher, the segregation between cable trays type must be in accordance with IEC 60709 sub clause 6.2.4 and IEC 61000-5-2 sub-clause 7.7.4 Distance between conduits. The false floor structure must be E.M.C. compatible (feet/supports interlinked between them and connected to ground plant, back of false floor plates must be metal covered or metal made, the head of the supports / feet must not have any insulating interface; back of false floor plates must be directly in contact with



the head supports/feet). In this case the false floor could be considered as an enclosure and will give a good cables protection in E.M.C. terms. The rules to connect the cable trays to their destinations are the same as the ones described in Chap 5. As a reminder, walking on cable trays is strictly forbidden.

### 5.6 Cable tray organization in technical gallery

The minimum size of the technical gallery and technical gallery accesses must be sufficient for technical staff works (including cable trays and/or services installations). The size of this gallery (connecting two buildings) must be in conformity with size requested at the origin for the full lifetime of the facility. Hence, the dimension of the technical gallery must allow for a person working on the cable trays while carrying a ladder or a toolbox. The free space must be 900 mm from the external part of the cable trays or other materials to the opposite technical gallery wall as shown in Fig. 5.6.1. A corridor of 2,200 mm height by 700 mm width is mandatory in French “Code du travail” to allow evacuation of injured person transported on stretcher. That’s the reason for having additionally at least 200 mm for workers equipped with tools. If items are installed on both sides of the gallery, the free space of 900 mm must be kept in between the front ends of these materials as shown on Fig. 5.7.4. Some examples of dimension of technical galleries are given (see References [1], [2], [3]). The segregation between cable tray types must be in accordance with IEC 61000-5-2 sub clause 7.7.4. Distance between conduits and their organization must be carried out as shown in fig. 5.4.2.

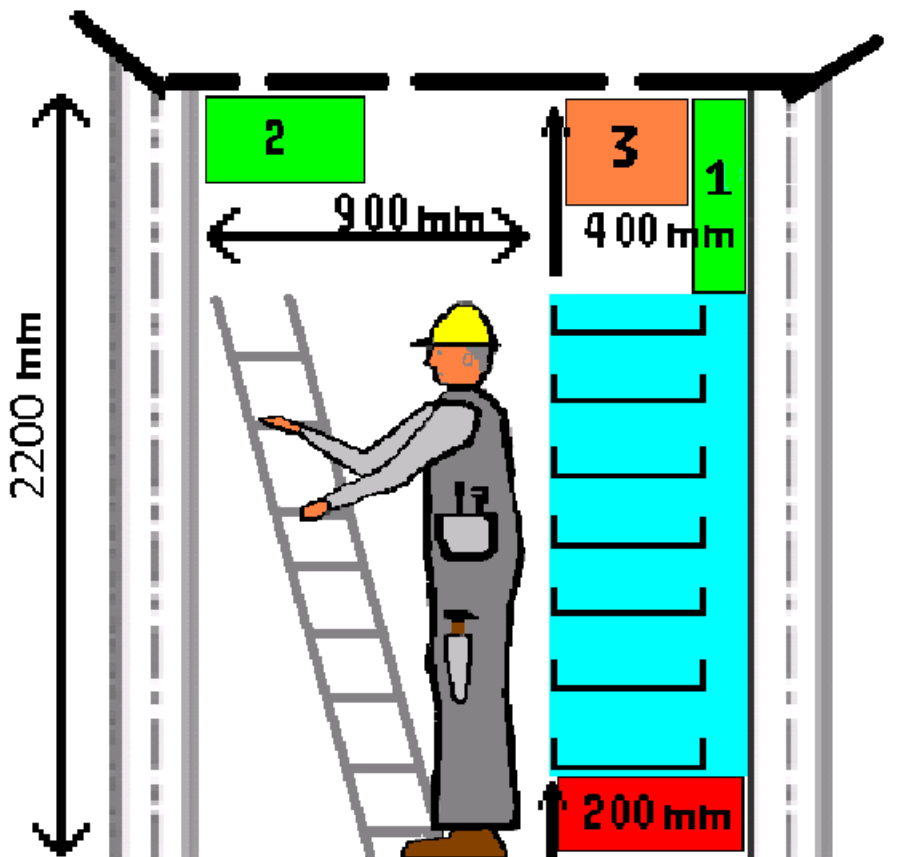


Figure 5.6.1 Cross section of technical gallery. The green volume number 1 of Height 400mm and Width 150mm and green volume number 2 of Width 200mm and Height 450 can be used continuously. The orange volume number 3 of



Height 400mm and Width 600mm (Width depending on the cable tray width) can be used none continuously as shown in Fig. 5.6.2. The Blue volume is dedicated to cabling, and cannot be used. The red volume cannot be used, and it is Height 200 mm and width 750 mm (for 600 mm width trays, located at 150 mm of the wall). The white volume is reserved for technical activities and for human displacements with necessary tools.

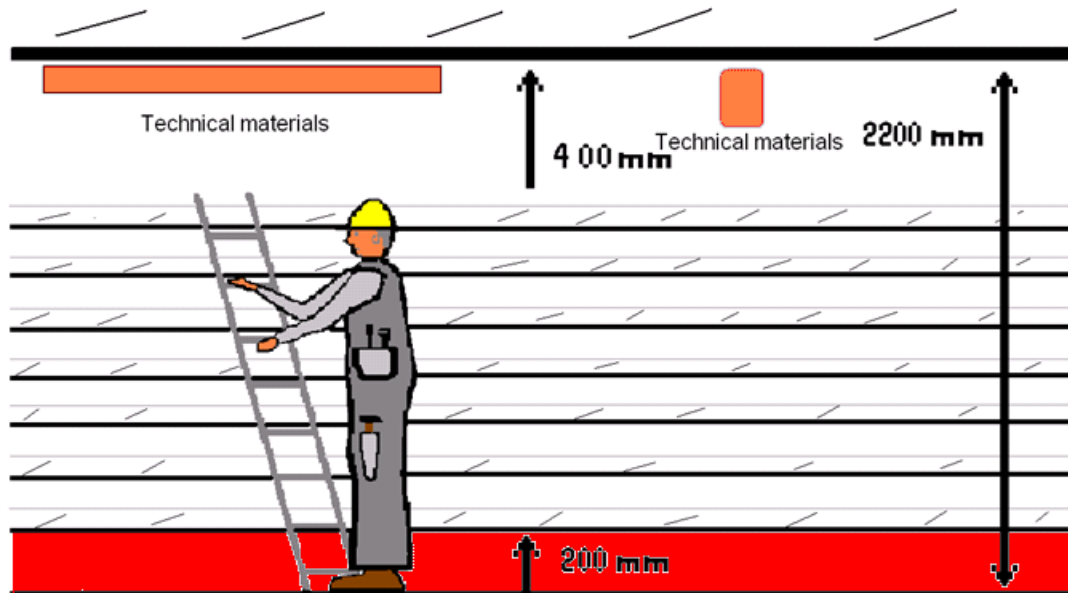


Figure 5.6.2 Longitudinal section of cable tray organization in technical gallery. The maximum size of technical materials (in orange) must be: Height 400mm, Length 1000mm and Width 600mm (depending on the cable tray size). This layout could be repeated every 3 meter. The volume represented in red must not be used.

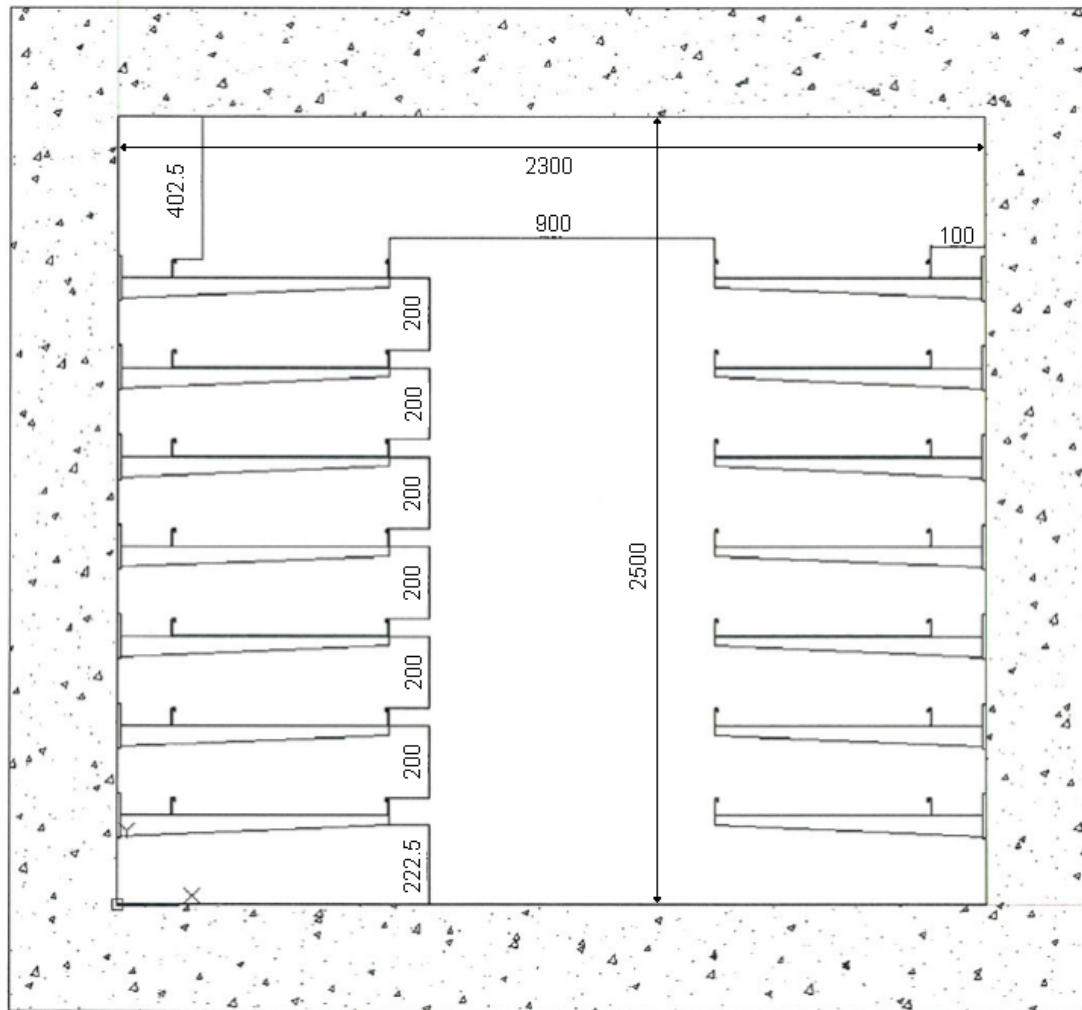
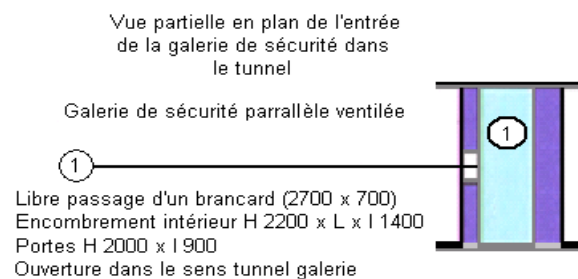


Figure 5.6.3 Technical gallery cross section equipped with cable trays at both sides

Hereafter there is an example of gallery size built next to road tunnels. For more information see References [1], [2], [3].



Extract of the AFTES conference held on 27th March 2009  
(Association Française des Tunnels et de l'Espace Souterrain)



**Figure 5.6.4 Example of tunnel section (for complete source document see References [1], [2], [3])**

The minimum distance from gallery floor to the lower cable tray's row must not be less than 200 mm (this volume could never be used, see Fig.5.6.1). The distance from the upper cable tray's row to the ceiling's gallery must not be less than 400 mm. The clearance area of 400mm from the roof to the upper cable tray's row can be used from time to time for example for technical material installation, or other systems which will not use this space continuously as shown in Fig.5.6.1. The maximum length occupancy will be 1 meter every 3 meter as shown in Fig. 5.6.2. Emergency accesses must be built every 50 meters. These accesses will be composed by manholes and ladders which could be fixed if necessary to the cable trays. The manhole dimension must be 1x1 meter to allow access to technical personnel with necessary working tools (ladder, toolbox, etc.) as shown in Fig. 5.7.3. It must also permit an evacuation of injured person evacuated on stretcher. In any case the tunnel dimensions must be in accordance with DTU (Documents Techniques Unifiés), especially concerning the free space for human displacements.

### **5.7 Cable tray organization in buried trenches**

When cable trays have to connect two buildings and have to go through accessible trenches, the minimum size of the trenches must allow human access along the cable trays placed in these trenches for the full lifetime of the installation. Hence, the dimension of the trenches must allow for a person working on the cable trays without having to walk on them. As explained in Chap 5.6, the same rules will be apply: the free space must be 900 mm from the external part of the cable trays to the opposite trench wall, or, if cable trays are installed on both wall sides, the 900mm must be left on the middle part. An emergency access must be built every 50 meters in case of long trench. These accesses will be allowed by manholes and ladders which could be fixed if necessary to the cable trays. Walking on cable trays is strictly forbidden.

If trenches contain only one row of cable tray, it is acceptable to have access to the cable tray from the ground level without the need for an excavated access space along the cable tray path. Moreover, these trenches must always have a free space equal to 1 meter (in Fig. 5.7.2) on both sides: one side to place the trench cover when trench will be open during a service (this 1 meter could be reduce depending on the cover's dimension but not be less than at least, 700mm) and the opposite side of the trench must be available to allow worker's access to cable trays from the ground level. The minimum distance from the trench floor to the lower cable tray must not be less than 200 mm and cable tray must not be located deeper than 400 mm from the trench ceiling, as shown in Fig. 5.7.2. In any case, for a good working practice these covers must be opened on its entire path when cables are pulled. The temporary storage of trench covers must be at the opposite side of the trench access to avoid accidents (swiping on covers, hitting covers with feet) in as shown in Fig. 5.7.2.

If the trench contains more than one row of cable tray, a space must be left in front of them to allow an access to workers inside the trench all along cable tray's path and 900mm free space will be requested. As described above, if necessary, an access will be built with manhole and ladder in the same way.

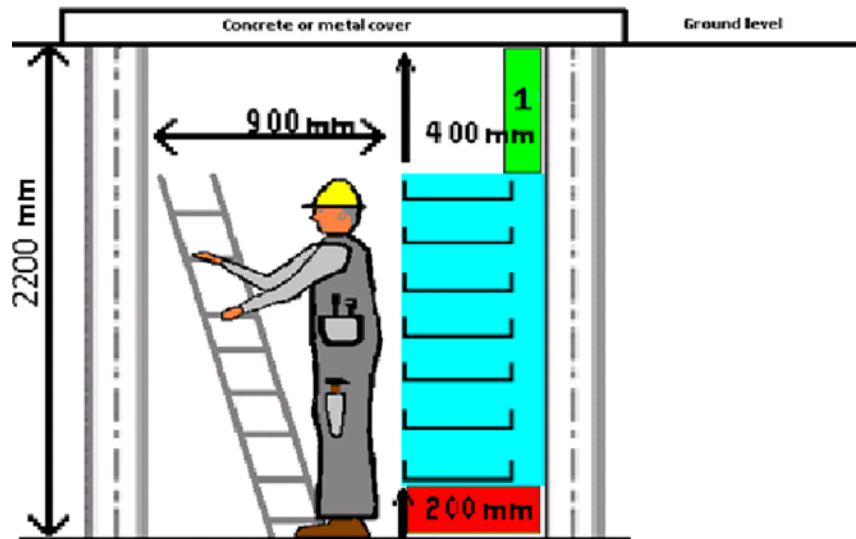


Figure 5.7.1 Cross section of buried trenches with several cable tray rows. The green volume number 1 of Height 400mm and Width 150mm and green volume number 2 of Width 200mm and Height 450 can be used continuously. The Blue volume is dedicated to cabling. The red volume cannot be used and is depending on the cable tray size. The white volume is reserved for technical activities and for human displacements with necessary tools.

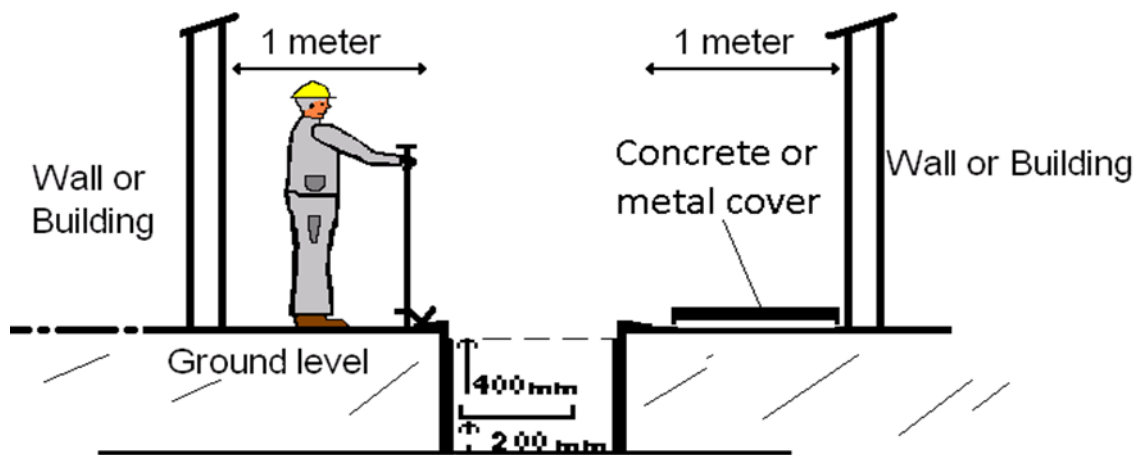


Figure 5.7.2 Cable tray organization in trenches accessible from the ground level

The width of the trench will be in accordance with the cable tray sizes and the storage area for covers will be in accordance with the cover sizes but not less than 700mm. Trenches must be accessible during whole lifetime of the facility and all along their paths.





Figure 5.7.3 Manhole access from the outside to the technical gallery



Figure 5.7.4 Technical gallery between experiment hall and service building

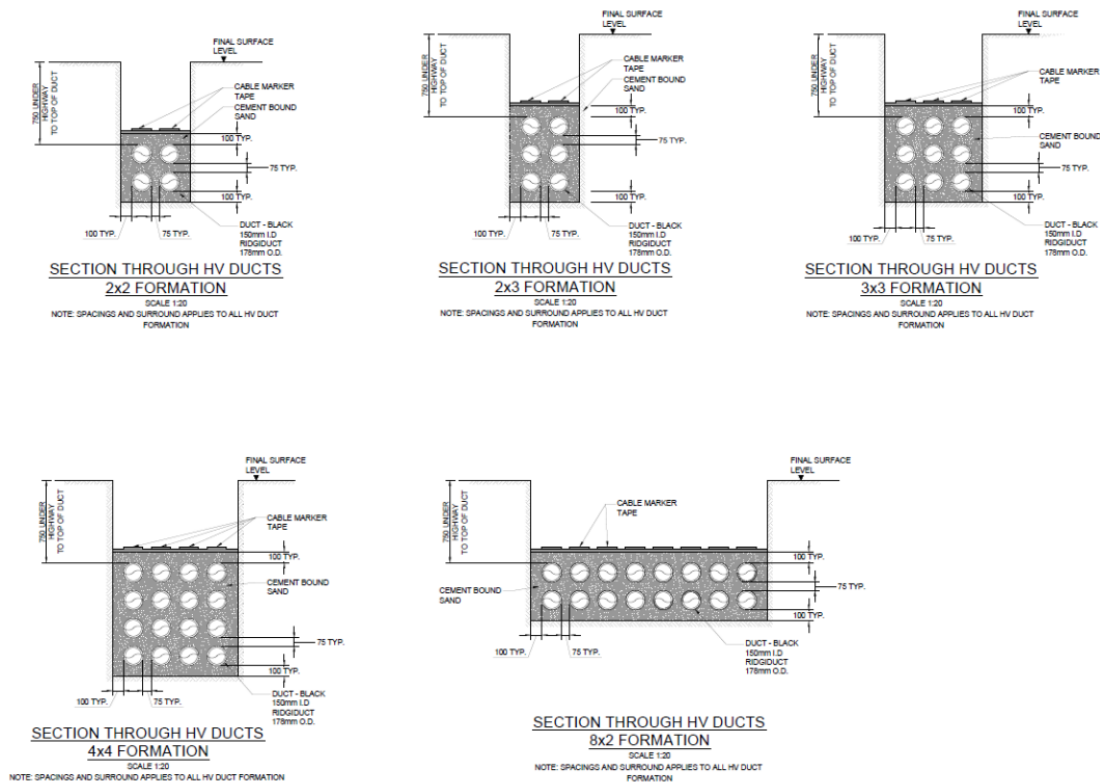
## 5.8 Buried Duct banks

The buried cable may be pulled in duct banks under request. Duct banks sections must be in accordance with the cable types and/or the number of cables installed in it respecting a filling ratio for the Low Voltage Cables. Standard sizes of the duct banks are 200 mm and 150 mm inner diameter.

The duct banks could be either metallic or non-metallic. Measurement signals shall be installed only in metallic duct banks or at more than 1 meter from the power cables.



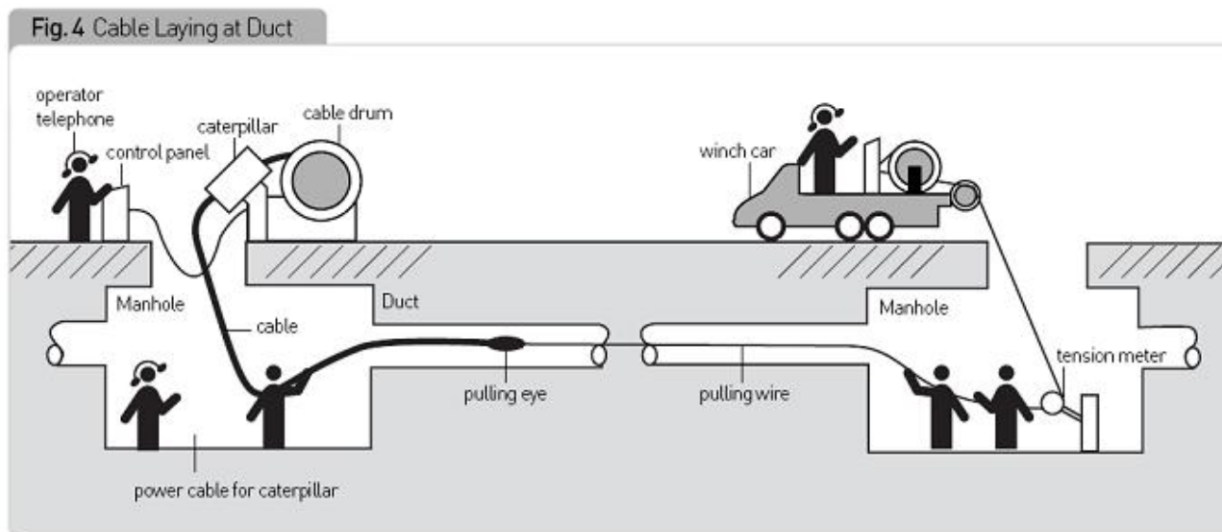
The spacing between the outer sides of the duct banks should be at least 75 mm, being a minimum distance of 100 mm from the duct banks the concrete end. The following picture shows several typical sections.



**Figure 5.8.1 Typical section of duct banks arrangement**

The duct banks require a pulling chamber on each end of the duct bank path for cable pulling. A clear work space not less than 900 mm wide shall be provided where cables are located on both sides, and not less than 750 mm where cables are only on one side (NEC NFPA-70). The vertical headroom shall not be less than 1.8 m, unless opening is within 300 mm.





**Figure 5.8.1 Arrangement of workers in pulling chamber during cable pulling in buried duct banks**

A pulling chamber shall be created at both ends of the buried duct banks and every 60 m in straight sections. In addition, a pulling chamber should be installed every 90 degrees bend of buried duct bank. Depending on the duct banks configuration (number of bends, cable size, etc.), some of those figures could be relaxed, under the authorization of the Electrical Division.

## 5.9 Labelling of cable trays

All labelling should follow [ITER\\_D\\_4ALJEU - ITER Site Signage & Graphics Standards](#), in particular its section “4.5.3.5 Raceway”.

- Labelling should be utilized as necessary to adequately maintain and preserve the item, including indication of the presence of special environments or the need for special controls (ISO 9001:2008).
- All the cable trays shall be labelled accordingly to the installation sheet. A label has to be placed with tags fixed on the wings at every interface with other named cable trays.
- The background colour with non-safety trays is grey; the safety trays of A-train have an orange background, being green the colour for the safety trays of B-train, as per document [ITER\\_D\\_4ALJEU - ITER Site Signage & Graphics Standards](#), in particular its section “4.5.3.5 Raceway”.
- The labels on High Voltage cable trays must be installed respecting RCC-E 2012 Edition sub clause D6000.
- The cable trays segments have a maximum length of 10 m in buildings. Routing points shall be located at the intersections of all Tees and Crosses. The cable tray segments have a maximum length of 25 m for underground cable trays.

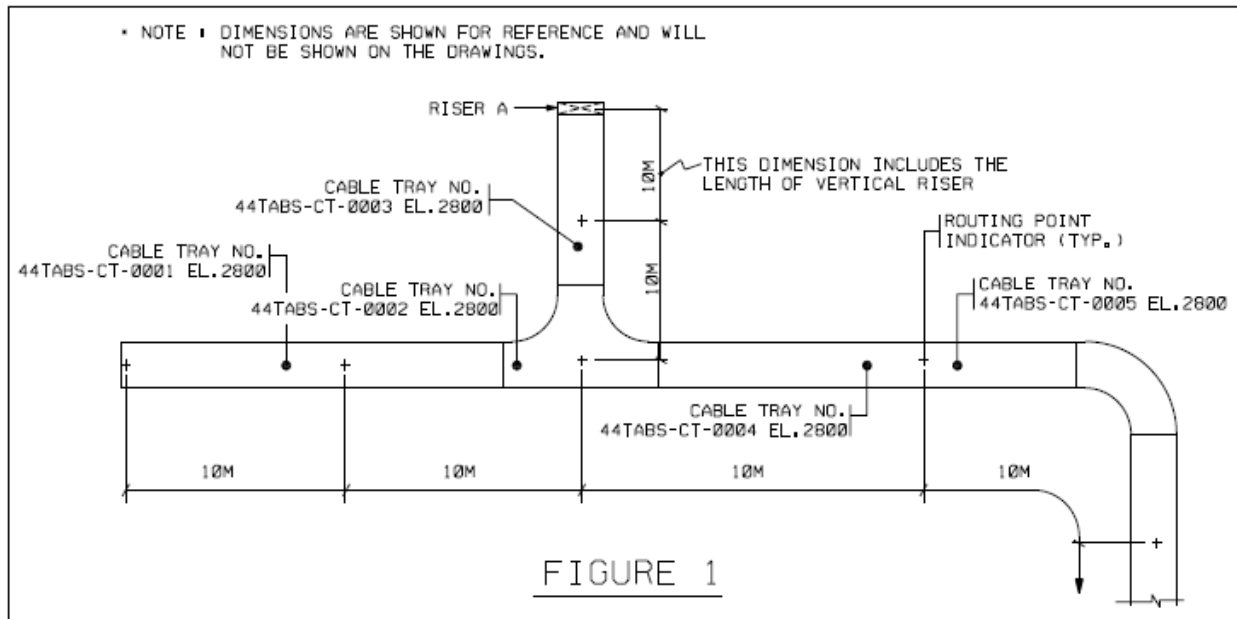


Figure 5.9.1 Tagging of cable tray segments

### 5.10 Cable tray Opening sealing

The opening technology for electrical cables and tray will depend on the environmental conditions. The solution will be mostly triggered by the maximum over-pressure in case of accident.

Regarding areas with the maximum absolute pressure is 2 bars, cables installed on the cable tray pass through the opening without discontinuity. The cable tray is also continuing through the opening and the free space of opening is completely filled by silicone foam/mortar. The following picture shows the arrangement of the trays inside of the opening, with a minimum distance between cable tray to the opening edge at least 60 mm horizontally and vertically, and among trays 150 mm vertical gap.

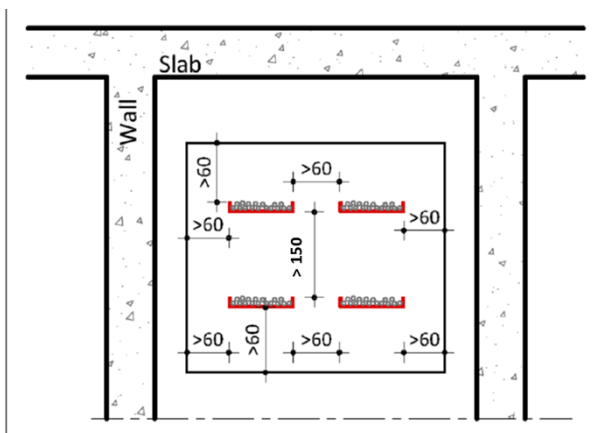
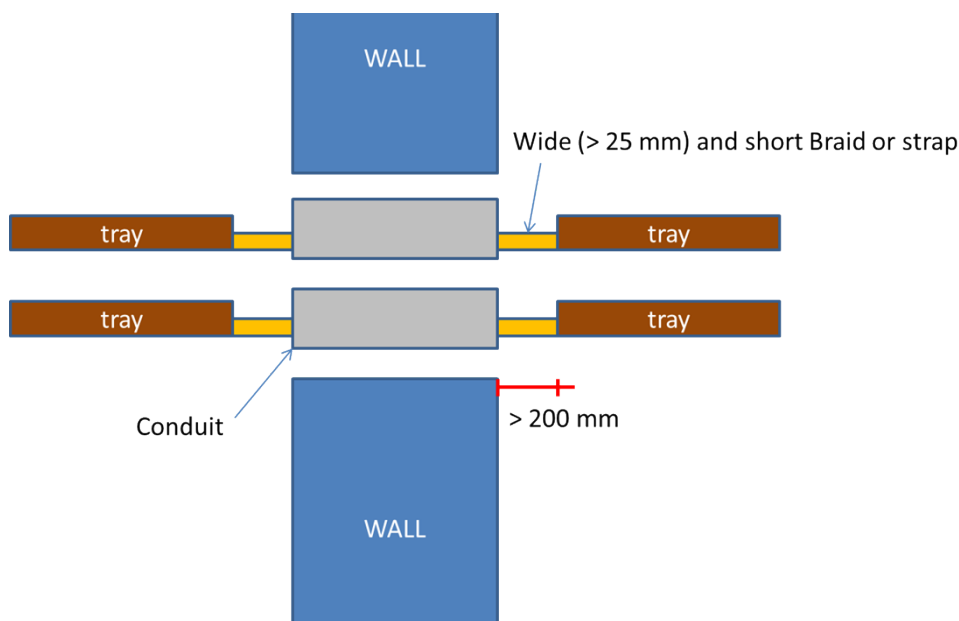


Figure 5.10.1 Recommendation for distance between cables tray and towards edge of opening (Dimension in mm)



If it's necessary to interrupt a cable tray, such interruption should be done at 200 mm before face of wall/slab. Then, inside of the opening there metallic conduits of equivalent cross section of the interrupted cable trays entering into the openings. The electrical connection between the tray and the conduit shall be done with wide (> 25 mm) and short braids, according to IEC 61000-5-2.



**Figure 5.10.2 Recommendation for interruption of cable tray (dimension in mm)**

In non-nuclear areas, the openings could be sealed with multilayer rubber modules. The cable tray is interrupted before the opening and each individual cable is inserted in an individual rubber module with removable layers silicon. It is required to be fixed a frame around the opening by welding, screws or bolting (drilling the wall).

The nuclear areas with over pressure higher than 2 bars will require an electrical penetration assembly, where both cable and tray are interrupted at the opening entrance. The penetration assembly is welded to a picture frame around the opening or to a metal sleeve embedded in concrete.

For more detailed information about the sealing products and systems see

[ITER\\_D\\_HR24QV - Opening Sealing Material for cable trays.](#)

In case of opening for REI120, if dimensions are > 800mm x 1200mm, opening should be divided with vertical or horizontal elements in reinforced concrete. For openings out of fire sector, maximum dimensions would be 1200mm x 2000mm. Objective of this reduction of big openings is to permit a good stability of infillings: separation elements would be sized with no loads of the primary structure.



## 6. Cabling rules applicable for cable installation.

### 6.1 Cable naming

The TTT codes for the cables are listed in the following:

- CAM: Measurement sensitive signals.
- CAS: Instrumentation & control cables.
- CAO: Fiber optics.
- CAP: Power distribution.
- CAE: Earth cable.
- CPI: Pneumatic tubing
- CExxx : Cable estimation link

The recommended numbering system for the ITER cables is the following:

- 0000 to 6999: Non safety classified cables
- 7000 to 7999: Safety classified cables of train A (71xx for PIC/SIC-1 and 72xx for PIC/SIC-2)
- 8000 to 8999: Safety classified cables of train B (81xx for PIC/SIC-1 and 82xx for PIC/SIC-2)

The cable type, according to IO cable catalogue (ITER\_D\_355QX2), recommended types should be as following:

- a) CAM → T1xx (according with the number of pairs). By default a section of 0.5 mm<sup>2</sup> should be taken.
- b) CAS →
  - a. Twisted pairs: T2xx (according with the number of pairs). By default a section of 0.5 mm<sup>2</sup> should be taken.
  - b. Fieldbus
  - c. MSxx: for the multiwires
- c) CAO → FOxMM for fiber optics shorter than 300 m and FOxSM for over 300 m length
- d) CAP →
  - a. MUxx, SUxx for the Low Voltage Power distribution (230/400 V)
  - b. MSxx, SSxx for Medium Voltage Power distribution (6.6 kV and 22 kV)
  - c. SSxx for High Voltage (66 kV)
  - d. FDU and SNR for the fast discharge unit and Switching resistors
- e) All PIC cables should be of type xxF or xxE



## 6.2 Cable standards

All ITER cables shall be NF C320-70 C1 or the equivalent IEC ones:

- a) Reduced flame propagation (according to IEC 60332-3 –flame spread for cable bunches- or NF 32070 C1)
- b) Flame retardant (according to IEC 60332-1 –flame propagation on single cables-)
- c) Low smoke (according to IEC 61034)
- d) Zero Halogen (according to IEC 60754-1)
- e) Non toxicity (according to IEC 60754-2)

In addition to these standards, all PIC cables shall be:

- a) Fire resistant (according to IEC 60331-1/-2 or NFC 3207- CR1).

Finally, all cables in High Radiation areas (more than 10 kGy) shall be qualified according with IEEE 383 or IEC 60544-2 for the dose values indicated in [ITER\\_D\\_KF63PB - Safety requirement Roombook](#). The following table summarizes the standard required depending on the geographical location of the cable and its safety classification.



		PIC cable	Non-PIC cable
<b>Non-Nuclear area</b>		<ul style="list-style-type: none"> <li>IEC 60331-1/-2 or NF C320-70 CR1</li> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> </ul> <p>(cable class F)</p>	<ul style="list-style-type: none"> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> </ul> <p>(cable class N)</p>
<b>Nuclear area Blg 11, 14, 21, 23, 24, 74</b>	Mild Environment	<ul style="list-style-type: none"> <li>IEC 60331-1/-2 or NF C320-70 CR1</li> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> </ul> <p>(cable class F)</p>	<ul style="list-style-type: none"> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> </ul> <p>(cable class N)</p>
<b>Nuclear area Harsh environment Blg11, 14, 21, 23</b>	High radiation (TID > 10 kGy) and/or ATEX	<ul style="list-style-type: none"> <li>IEC 60331-1/-2 or NF C320-70 CR1</li> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> <li>TID xx Gy IEEE 383 or IEC 60544-2</li> </ul> <p>(cable class E)</p>	<ul style="list-style-type: none"> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> <li>TID xx Gy IEEE 383 or IEC 60544-2</li> </ul> <p>(cable class R)</p>
<b>Vacuum environment</b>	Cryostat Ex-vessel	Not applicable	<ul style="list-style-type: none"> <li>Vacuum Quality Class 2</li> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> <li>TID 10 MGy IEEE 383 or IEC 60544-2</li> </ul> <p>(cable class C)</p>
	Cryostat In-vessel	Not applicable	<ul style="list-style-type: none"> <li>Vacuum Quality Class 1</li> <li>IEC 60332-1 &amp; 3 or NF C320-70 C1</li> <li>IEC 61034</li> <li>IEC 60754-1 &amp; 2</li> <li>TID xx Gy IEEE 383 or IEC 60544-2</li> </ul> <p>(cable class V)</p>

**Figure 6.2.1 Cable standards to be applied for the cable qualification.**

Regarding cables where their requirements/qualification indicated in [ITER D\\_KF63PB - Safety requirement Roombook](#) does not fit in the above table, they will be managed as special cables.



## 6.3 Colour coding

### 6.3.1. Identification of cores of electrical Cables

The core colour coding shall follow the IEC 60445 or HD308 S2 for cables with a core coloured green/yellow.

**Table 1 – Cables and cords with a green-and-yellow core**

Number of cores	Colours of cores <sup>b</sup>				
	Protective	Live			
3	Green-and-yellow	Blue	Brown		
4	Green-and-yellow	-	Brown	Black	Grey
4 <sup>a</sup>	Green-and-yellow	Blue	Brown	Black	
5	Green-and-yellow	Blue	Brown	Black	Grey

<sup>a</sup> For certain applications only.

<sup>b</sup> In this table an uninsulated concentric conductor, such as a metallic sheath, armour or screen wires, is not regarded as a core. A concentric conductor is identified by its position and, therefore, need not be identified by colour.

**Figure 6.3.1.1 Conductor colours according to IEC 60445 for cable with a green-and-yellow core.**

The earth conductor in low voltage power distribution cables shall be jacketed yellow/green. The neutral cable conductor in a cable shall be blue if used.

The cables without any core coloured green/yellow shall follow the EN-50334.



6.1 All cores in the cable shall be marked according to this specification, except that if the cable contains any core coloured green/yellow, it shall not be numbered.

6.2 The inscription shall be legible and of a colour which clearly contrasts with the base colour of the core on which it is marked.

6.3 The use of the colours green or yellow as base colours is not permitted.

6.4 In a cable which has 37 cores or less, all cores, except the green/yellow one if included, shall have a uniform base colour of the core and a clearly contrasting uniform colour of the inscription. The numbers shall commence with No. 1 and proceed in sequence up to a maximum of 37.

6.5 In a cable having more than 37 cores:

- the core number may increase sequentially maintaining the same base colour and the same inscription colour up to a maximum of 99 cores;
- the cores may be regarded for the purpose of identification as being divided into two or more sets containing at least 19 and not more than 37 cores.

The sets shall be distinguished from each other by the use of different clearly contrasting combinations of base colour and inscription colour.

The cores in each set shall be numbered sequentially. The colour combination is permitted to change within a given layer of cores.

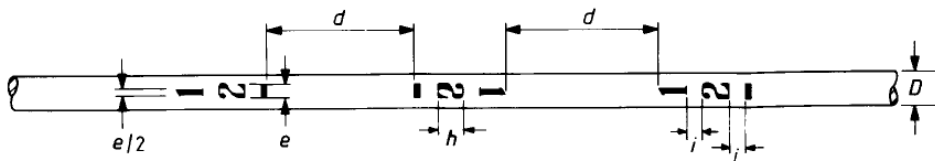


Figure 1 - Axial arrangement of marks

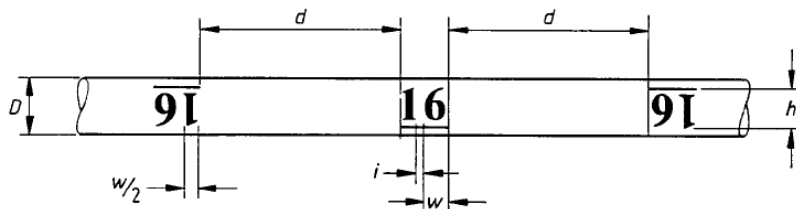


Figure 2 - Transverse arrangement of marks

Figure 6.3.1.2. Core identification for cables without green-and-yellow core according to EN-50334





### 6.3.2. Internal Wiring

The recommended colour coding to be used inside of the equipment should follow IEC 60204-1.



Figure 6.3.2.1 Conductor colours according to IEC 60204 for internal wiring.

## 6.4 Cable labelling and identification

This section indicates the labelling of the cables and their identification. The goal of this section is to minimize the human factor risks via the usage of specific rules (colour, tagging, etc.) in propagation of the human factors project requirements.

Labels should be put on cables according to RCC-E 2012-December Edition sub clause D6000 (marking and identification of cables and conductors).

The identification of all ITER cables shall be in accordance with the requirements established in the following IO documents:

- ITER\_D\_28QDBS [R3] “ITER numbering system (for parts/components)”
- ITER\_D\_2FJMPY “ITER function category and Type for ITER Numbering System”
- EDH Guide A: Electrical Installations for SSEN Client Systems (2EB9VT v2.3).

All ITER cable extremity labels should contain at minimum the following information:

- TEXT: PPPPPP-TTT-NNNN = Cable functional reference (name)
- TEXT: XX = Cable segregation
- QR code that contains the following attributes:
  - o Cable functional reference (name): PPPPPP-TTT-NNNN
  - o Cable segregation: XX
  - o Safety Class: PIC/SIC1-TA, PIC/SIC1-TB, PIC/SIC2-TA, PIC/SIC-2 TB, PIC/SIC-2-TA\_NR (Non Redundant), PIC/SIC-2-TB\_NR, PIC/CMC-TA, PIC/CMC-TB, PIC/CMC-NR, PIC/EIC-TA, PIC/EIC-TB, PIC/EIC-NR, Non-PIC, HCC-TA, HCC-TB, SR,



- o Cable type code
- o From Equipment Tag
- o From Equipment Room
- o To Equipment Tag
- o To Equipment Room

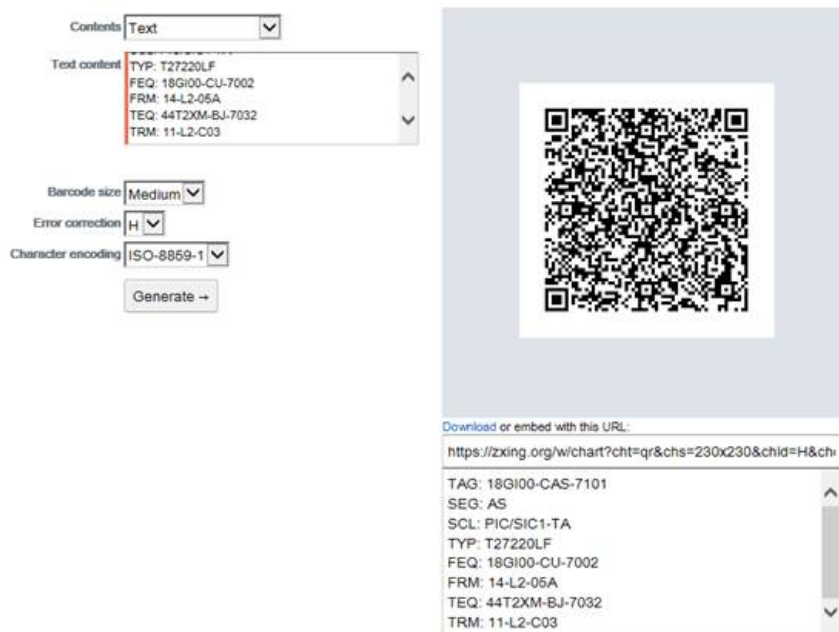


Figure 6.4.1 Example of the QR code.

#### 6.4.1 Label Position

All cables will have a label on each extremity (~10 cm from the connector). The cables without connector (which will be connected later) should be labelled at 50 cm from the edge.

#### 6.4.2 Label size and formatting

All labels should be easily readable and able to be scanned.

In order to easily differentiate between safety related and regular cables all labels should have coloured background as follows:

PIC Train A	Orange
PIC Train B	Green
Safety HCC Train A	Pink
Safety HCC Train B	Light Blue
Non PIC	grey



Recommended layout of the label at the cable extremities:



Figure 6.4.2.1 Example of the label containing recommended information and QR code.

### 6.4.3. Label and related tie wraps types and material properties

All labels and tie wraps should be:

- halogen free
- suited for industrial/harsh environment
- protected against tampering (should contain a security seal)

The cable extremity labels should be tie-on, flat surface that can support a QR code (see below for an example)

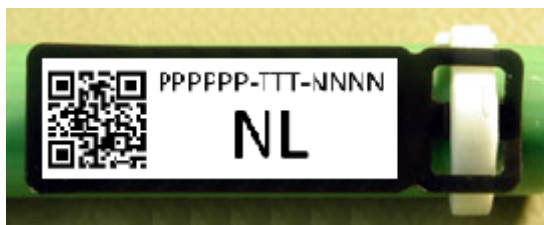


Figure 6.4.3.1 Example of label at the cable extremity

### 6.4.4 Safety Cables

Beside cable extremities identification, safety related cables shall be identified every 5 meters to reflect the safety train information, as required by RCC-E. The cables are identified by 5cm wide paint strokes, which are applied approximately 5 metres apart before installation. The orange colour cable shall be used for PIC Train A cables, whilst the green colour to be used for PIC Train B cables

### 6.4.5 Cable jacket marking

Identifying information shall be imprinted on outer jacket at intervals of no more than 3 m and shall include the following:

- Manufacturer's Name
- Manufacturer's Traceability
- Rated Circuit Voltage
- Number and Size of Conductors
- Insulation Material
- Jacket Material



- Year of Manufacture
- ITER Cable Type Code



**Figure 6.4.5.1** Example of ITER cable jacketing marking, with the manufacturer's name and product reference, number and size of conductors, rated voltage, ITER type code, manufacturer's traceability, year of manufacture and sequential length. The blue jacket identifies the control cables.

Sequential length shall be provided by numbers in sequence at 1 m intervals on the cable jacket.

#### 6.4.5 Cable colour jacket

Identifying information shall be imprinted on outer jacket at intervals of no more than 3 m and shall include the following, for all electrical cables rated at less than 1 kV:

- Non- PIC related Low Voltage Power AC or DC (cable type code SUxx or MUxx): black
- Non- PIC related Instrumentation (cable type code T1xx, TNxx, TKxx): grey
- Non- PIC related Control (cable type code T2xx, T3xx, MSxx): blue
- Non- PIC field bus & network (cable type code Nx, Px): violet
- Non-PIC phone and interphones (cable type code S1x, S2x): brown
- PIC-related, including fire for non-PIC (cable type code xxE and xxF): orange

#### 6.5 Power distribution cables

When single core power cables are installed in parallels in the same cable tray, they shall be of similar nature (e.g. power, cross section, length, etc.). It is recommended to install as few as possible cables in parallel.

Regarding Low Voltage Cables (up to 1 kV AC, 1.5 kV DC) the NFC 15-100 Standard shall be followed. The maximum number of cables in parallel is 4 per phase, according to NFC 15-100. The usage of 3 cables in parallel per phase is forbidden. The cables are installed randomly.

Regarding Medium Voltage Cables (up to 36 kV), for cable rated voltage up to 18/30 kV, the NF C13-200 standard shall be followed. The cables are always installed in trefoil formation.

Regarding High Voltage Cables (more than 36 kV), for cable rated voltage more than 18/30 kV, the NF C33-254 and CEI 60287 standards shall be followed

It has to emphasize that installing numerous cables in parallel may lead to a bad distribution of the current circulation which can lead to abnormal heating. (See IEC 60287-1-2 1993 electric cables)

Pay attention: for lighting, a reinforced cross-section for the neutral conductor is needed (due to H3).

Cables of the same circuit should be routed as close together as possible and correctly bonded to support electrodynamics efforts in case of short-circuit. A trefoil routing of power cables with frequent wire wraps is recommended (maximum 2 m span).

Cables of the same family should be grouped in cable bunches with ties.



All cables must be put inside ladder trays or metal conduits (also acting as mechanical protection).

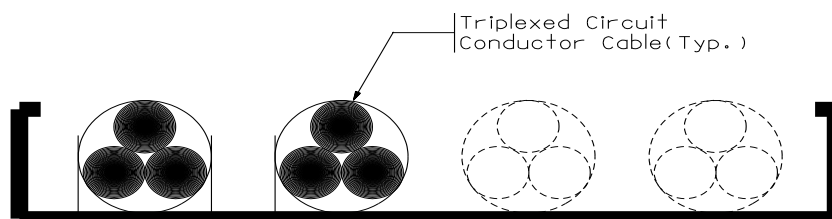


Figure 6.5.1 Distribution of medium and high voltage power distribution cables arrangement, in trefoil formation.

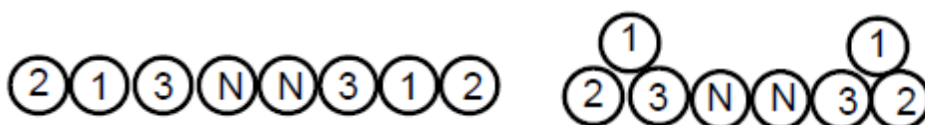


Figure 6.5.2 Distribution of Low voltage power distribution cables arrangement, in multilayer flat formation and trefoil.

This configuration allows for enough space to crimp ties for each cable, but the overall space needed is large.

In case of terrain movement between buildings, when the cable length requires having “cable handling room” along cable paths, loops equal to 1 meter shall be added to prevent cable stretching. At the cable entrance and cable departure of buildings, a dedicated space must be foreseen for these loops of 1 meter as well. In those places, cable trays shall not be continued, but a PEC must be installed instead on each side of the cables (i.e. at least 2 PECs are needed).

The low voltage power distribution cables do not have an overall screen, only if a correct filter is at the supplied equipment.

The power cables between motor frequency drives and loads or a step motor shall have an overall screen in any case.

The low power cables for the sensors are considered as I&C cables and they shall be shielded.

## 6.6 I&C cables

The instrumentation and control cables could be randomly pulled in cable trays in respecting their family’s separation. As reminder, the overall dimension of the cables contained in the same bunch cannot exceed the cable tray’s wings dimension.

The cables could be equipped with their connectors at both sides when their lengths are easily measurable and cable tray paths easily accessible. When their lengths are more than 40 meters a connector could be installed at one side only. The extra length to leave to the other side varies depending on the equipment to connect. The suitable extra length on cables should be 2 meters at both ends when materials are not already placed.

A 500 mm extra cable length could be stored as loops in cable trays (when possible) where the cable is connected (sensors, captors, etc.) or where the cable enters in electrical cabinets when location of material is known. In these cases the end of the cables must be protected with thermo-retractable ends to avoid dust or water penetration. On the sensor or machine sides, the extra length of cable must be 0.5 meter. In the other case the extra length will be defined by Electrical Engineering Division.



## 6.7 Cable Segregation code path table

The following table shows which type of cables could be included on each type of tray.

Tray \ Cable	A6	AH	AL	AN	AS	AP	B6	BH	BL	BN	BS	BP	CL	CS	DL	DS	PL	PS	NQ	N6	NH	NL	NN	NS	NP	XR	HV	MP	MS
A6	○																												
AH		○																											
AL			○	○									○				○												
AS				○	○									○				○								○			
AP						○																							
B6							○																						
BH								○																					
BL									○	○					○		○												
BS										○	○				○		○									○			
BP												○																	
CL													○																
CS														○															
DL															○														
DS																○													
PL																	○												
PS																		○											
NQ																			○										
N6																			○	○	○							○	○
NH																					○								
NL																						○	○						
NN																						○	○	○					
NS																							○	○					
NP																									○				
XR																										○			
HV																											○		
MP																												○	○
MS																												○	○
									○																				
									○																				

○ allowed, but not recommended (1st option)

○ allowed, but not recommended (2nd option)

Figure 6.7.1. *Compatibility between cable segregation and cable tray segregations*



Cable types		Cable tray types	
A6	PIC/SIC train A 6.6 kV	A6	PIC/SIC train A 6.6 kV
AL	PIC/SIC train A LV	AL	PIC/SIC train A LV
AN	PIC/SIC train A noisy (control)		
AS	PIC/SIC train A sensitive (instrumentation)	AS	PIC/SIC train A sensitive (instrumentation)
AH	PIC/SIC train A HV or HC	AH	PIC/SIC train A HV or HC
AP	PIC/SIC train A pneumatic (control)	AP	PIC/SIC train A pneumatic (control)
B6	PIC/SIC train B 6.6 kV	B6	PIC/SIC train B 6.6 kV
BL	PIC/SIC train B LV	BL	PIC/SIC train B LV
BN	PIC/SIC train B noisy (control)		
BS	PIC/SIC train B sensitive (instrumentation)	BS	PIC/SIC train B sensitive (instrumentation)
BH	PIC/SIC train B HV or HC	BH	PIC/SIC train B HV or HC
BP	PIC/SIC train B pneumatic (control)	BP	PIC/SIC train B pneumatic (control)
CL	HCC train A LV	CL	HCC train A LV
CS	HCC train A sensitive (instrumentation)	CS	HCC train A sensitive (instrumentation)
DL	HCC train B LV	DL	HCC train B LV
DS	HCC train B sensitive (instrumentation)	DS	HCC train B sensitive (instrumentation)
PL	PIC/CMC or PIC/EIC LV	PL	PIC/CMC or PIC/EIC LV
PS	PIC/CMC or PIC/EIC sensitive	PS	PIC/CMC or PIC/EIC sensitive
XR	PIC/SIC Interconnection Train A and B (Fiber Optic only)	XR	PIC/SIC Interconnection Train A and B (Fiber Optic only)
NQ	non-PIC ITER high voltage cables	NQ	non-PIC ITER high voltage cables
N6	non-PIC 6.6 kV	N6	non-PIC 6.6 kV
NL	non-PIC LV	NL	non-PIC LV
NN	non-PIC noisy (control)	NN	non-PIC noisy (control)
NS	non-PIC sensitive (instrumentation)	NS	non-PIC sensitive (instrumentation)
NH	non-PIC HV or HC	NH	non-PIC HV or HC
NP	non-PIC pneumatic (control)	NP	non-PIC pneumatic (control)
HV	High Voltage 66 kV	HV	High Voltage 66 kV
MP	22kV (Medium voltage) for PPEN Systems	MP	22kV (Medium voltage) for PPEN Systems
MS	22kV (Medium voltage) for SSEN Systems	MS	22kV (Medium voltage) for SSEN Systems

Figure 6.7.2. *Description of cable and cable tray types*



## 6.8 Cable length Calculation

The cable length is calculated with the software tool KCMS. This tool imports the data from the electrical diagrams developed in SSD and the cable tray network developed with CATIA.

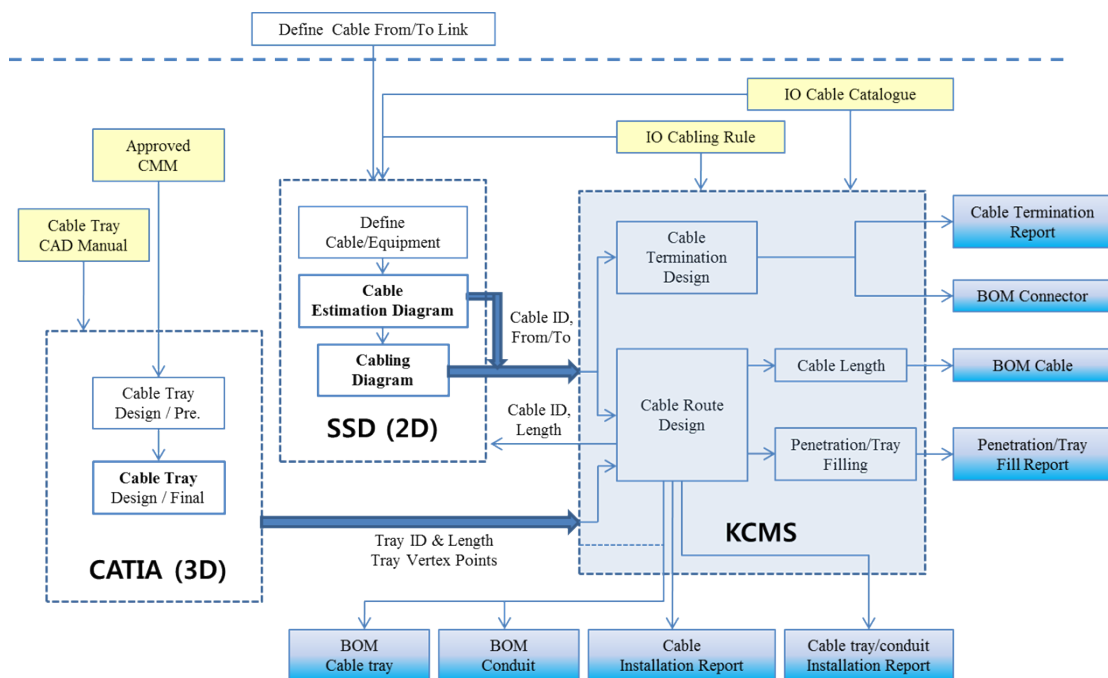


Figure 6.8.1. *Software architecture for the Cable Engineering Design*

The cable length (Cable\_Total\_Length) is calculated with:

$$\text{Cable\_Total\_Length} = \text{routed\_length\_3d} + \text{allowance}$$

$$\text{Where } \text{routed\_length\_3d} = \text{kcms\_3d\_length} + \text{from\_equip\_end\_length} + \text{to\_equip\_end\_length}$$

- kcms\_3d\_length is the length measured in 3D with the routing tool KCMS, placing the cable in the middle of the cable tray, from the location of the equipment FROM till the location of the equipment TO. The equipment coordinate is extracted from CATIA, and it is usually the centre of mass of the equipment.
- from\_equip\_end\_length is the length of the cable inside of the equipment FROM
- to\_equip\_end\_length is the length of the cable inside of the equipment TO

The following table shows the length of the cable inside of the equipment

Equipment Type	End Length(m)
Switch Gear, Distribution board, Motor Control Center. Etc. (CMC, BD)	6
Cubicle (CU)	4





<b>Wall mounted Panel (CNP, BP)</b>	2
<b>Equipment (Motor, Pump, Switch, etc)</b>	2
<b>Instrument (sensor, valve, switch, connector, etc)</b>	1
<b>Terminal Box, Junction Box, feedthrough (BJ)</b>	2

Allowance: additional cable length due to bending, crossings, etc. of the cables inside of the cable tray.

- If (routed\_length\_3d) < 15 m ➔ Allowance = (routed\_length\_3d)\*0.18 + 0.3 m
- If (routed\_length\_3d) > 15 m ➔ Allowance = (routed\_length\_3d)\*0.04 + 2.4 m

The cable path between cable tray and the instrument will be in a dedicated conduit, which the contractor will install on site, according to the environment. This segment is called “AIR-RUN/CONDUIT”, and its length is calculated as path 2 m + 1.25\*( $\Delta x + \Delta y + \Delta z$ ) between the cable tray exit point and the equipment location.

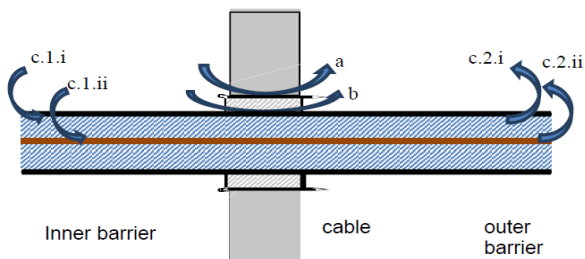


## 6.9 Cable gas leak confinement

The cables passing through confinement barriers shall be sealed at both ends to satisfy the leak requirements of the corresponding rooms.

The opening is properly backfilled with products to satisfy the requirement, but the cable shall be sealed to avoid leaks either between cable coating and insulation or between insulation and cable cores.

### 5.2.2 Electrical penetration weak points



**Figure 6.9.1. Gas leaks through the cable**

The cables shall be terminated on each end with qualified Atex glands or with equivalent low leakage connectors, with the approval of the IO/Electrical Division.



**Figure 6.9.2. Atex gland, pressure tested and qualified up to 30 bars, for all cable types: power, instrumentation, control**



**Figure 6.9.3. Another option with overmolded connectors with low leak.**  
Regarding the power cables, the termination kits may be used.



**Figure 6.9.4. Termination kit for power cables**

Each wire of the cable shall be correctly terminated with a blind terminal and heat shrink, in order to avoid any leak through the strands of the wire. This requirement is not required for the solid core wires, which is the recommended option for cross-section lower than 2.5 mm<sup>2</sup>.

## 6.10 Cable Clamp

The single core power cables shall be attached to the cable trays or supporting structures with cable clamps, sized for short-circuit currents according to IEC 61914.



## 6.11 Local trays

The local trays indicate the support of one or several cables (in limited number) from the main cable tray to the electrical equipment to connect (around 5 m). These local trays have generally a width of 50 or 100 mm. Sometimes metallic conduits can be used to support the cable. The conduits could be flexible (up to 1.8 m, according with NFPA 70 230.43 recommendation) or rigid. Stainless steel flexible conduit shall be used in nuclear buildings whilst liquid-tight flexible conduit may be used in non-nuclear areas. It's installer responsibility the location of the condulets or pulling boxes for the cable pulling.

More detailed requirements about conduits are specified in [ITER\\_D\\_T6VNV8 - Electrical Conduit basic installation guideline](#) and shall be followed.



**Figure 6.11.1. Example of interface between cable trays and conduits. Flexible conduits shall be used for Instrumentation and safety cables, being the aerial connection for non-safety power cables.**





**Figure 6.11.2. Example of interface between conduits and electrical panels.**

In non-nuclear areas perforated trays or telex rails could be used.



**Figure 6.11.3. Example of local trays in non-nuclear areas.**

Those local trays will be installed according with the field conditions.

At the end of the worksite, an as built layout of these local trays will be created, to identify these local trays (per room), and know the list of cables running in every local tray.



## 7. Selection of cables and connectors.

The choice of the cables has to be done taking into account:

a) The signals to transport:

- Bandwidth and carrier.
- Pulsed signals: duration, repetition rate, burst rate, rise and fall time, upper and lower limit of frequency range of interest.
- The signal level: measurement and control at low level, such as thermocouple signals (microvolt range), computer outputs (24 V range); AC power (1 000 V).
- Impedance, Signal losses, Crosstalk
- Compatibility between cable and connector
- Need for a low transfer impedance (a high shielding effectiveness).
- Length between equipment
- The routing of the cable could have an impact on the cable type choice (complex routing, direction changes, length)

All cables should be “halogen free” depending of the building or environment where they have to be installed so the required norms are:

- IEC 60332-1 and -3 are flame and fire retarding
- IEC 60754-1-2 Tests on gases evolved during combustion of materials from cables (Determination of degree of acidity of gases for materials by measuring Ph and conductivity) Halogen free
- IEC 61034 low smoke

In addition, power distribution cables shall be also compliant to:

- IEC 60287 1-1 Calculation of the current rating
- E.g. IEC 60502 2 HTA Voltage 6-10 kV

A combination of criteria for power cables may apply; e.g. IEC 60502-2 armored power cable of type ‘flame retarding’.

A table describing the applicable voltage range for cables is shown in RCC-E 2012 Edition sub clause C1100.

b) The type of possible perturbations:



- Single or double shielding
- Twisted pairs protected by copper braid. Aluminium foils are only accepted as inner shields (protected by an outer braid).
- Single general shielding
- In appropriate cables trays (e.g. sensitive signal cables in cable trays with cover)
- The twisted cables are preferred due to a lower cross-talk compared with the non-twisted
- Mechanical protection
- Digital signal multi-pair cables may be shielded by an overall shield.
- For analogue signals multi pair cables shall be composed of individually screened twisted pairs (an aluminium foil for instance) and overall shielding braid.

The instrumentation and control cables should be twisted pair with an overall screen, either for analogue, digital, field buses or discrete signals (relay coils, limit switches, Reed relays, interlocks), as it's a provided a good immunity for low frequency disturbances. For the high frequency signals, the coaxial or triaxial cables are preferred.

The discrete signals are usually robust against external noise sources. Those slow signals (pulses of milliseconds, not microseconds) could be in multiwire shielded cables (instead of twisted pairs), if the following conditions are satisfied:

- Immunity against external High Frequency sources: Check that end receivers tolerate High Frequency pulses as well as digital inputs of conventional PLCs. In practice, this means that the received signal is filtered by low-pass linear robust then the signal reshaped by a Schmitt trigger (comparator with hysteresis). When in doubt, the safest solution is to use twisted pair as expected.
- Immunity against common impedance coupling: Never share a common return two signals without calculating the risk of common impedance coupling. A common ground to several signals required to work at very low current (less than 20 mA) if we want to avoid very unpleasant surprises. In case of doubt any signal should have its own return in the same cable (not mandatory to be twisted).
- Immunity against internal crosstalk: Calculate the risk of not open from a low current relay (relay or AC 110 V, for example) if it transmits a high AC voltage (230 V / 50 Hz, for example) in the same cable. The risk - if the cable is long - is that low-power relay is closed by the capacitive current between two neighbouring cable. The risk disappears with twisted pairs.

Regarding the long cable runs, it's recommended that cable core section is 0.5 mm<sup>2</sup> (20 AWG) for instrumentation signals, and 0.9 mm<sup>2</sup> (18 AWG) for control signals.

The choice of the connectors is determined by:





- The signal level: measurement and control at low level, such as thermocouple signals (microvolt range), computer outputs (24 V range); AC power (1 000 V).
- Mechanical protection
- Compatibility with cable types
- Environment where they are installed (corrosive atmosphere, dusty atmosphere, mechanical risks)
- Quality of signal (pins/contacts surface treatment)
- Number of manipulations (plug/unplug)
- All connectors must be E.M.C. compatible (metal made and 360° shielding connection)
- A same connector type cannot be used in two different classes. ...





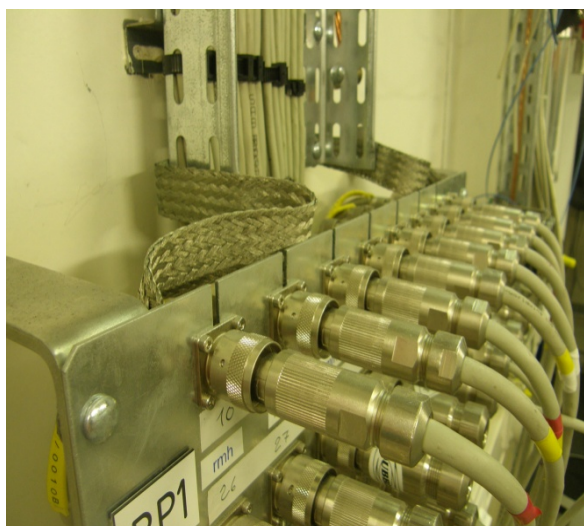
## 8. Cable connections

All signal cables must be shielded and the external shield must be bonded to the chassis of the equipment.

For power cables the connection points must be as close as possible to the entrance point of the electrical cubicles and all wires must be connected to the same plate. (Differential Mode compact circuit IEC 61000-5-2 sub clause 7.9.1 Connection to the ports of apparatus)

In general all cables must be connected in the same compartment or area in electrical cubicles, as possible on the same metal plate.

However, cable connections between equipment may be done by using an interface panel, which is equipped with different socket types depending on the applications. It would also be an easy solution to connect cables arriving in electrical cubicles respecting E.M.C. measures, assuming that all internal cabling follows these rules.



**Figure 8.1** Example of interface panel

Interface panel connections are a very good solution when standardization is required (see Fig. 8.1).

In this case all cables that enter into electrical cubicles must pass through panel connections with exceptions only in case the electrical configuration of the available space does not allow for interface panels. In any case, the cables that are not passing through interface connections must be bonded at the entrance of the electrical cubicles with suitable E.M.C. glands. Partial contacts (not 360 degrees) are unacceptable. All Earth wires in cables must be connected to the appropriate chassis connection points. Pigtails to connect shielding or Earth wires are unacceptable. Any socket will be screwed (with an electrical contact) to a metal plate.

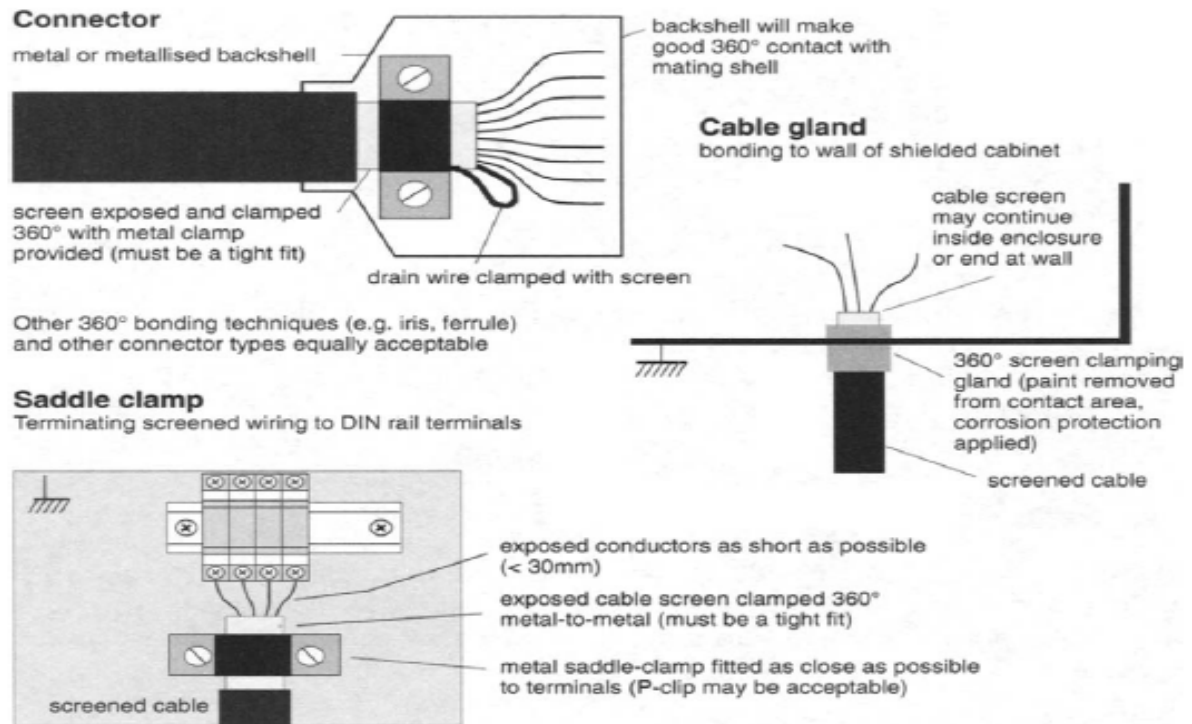


Figure 8.2 Several options to connect the shields

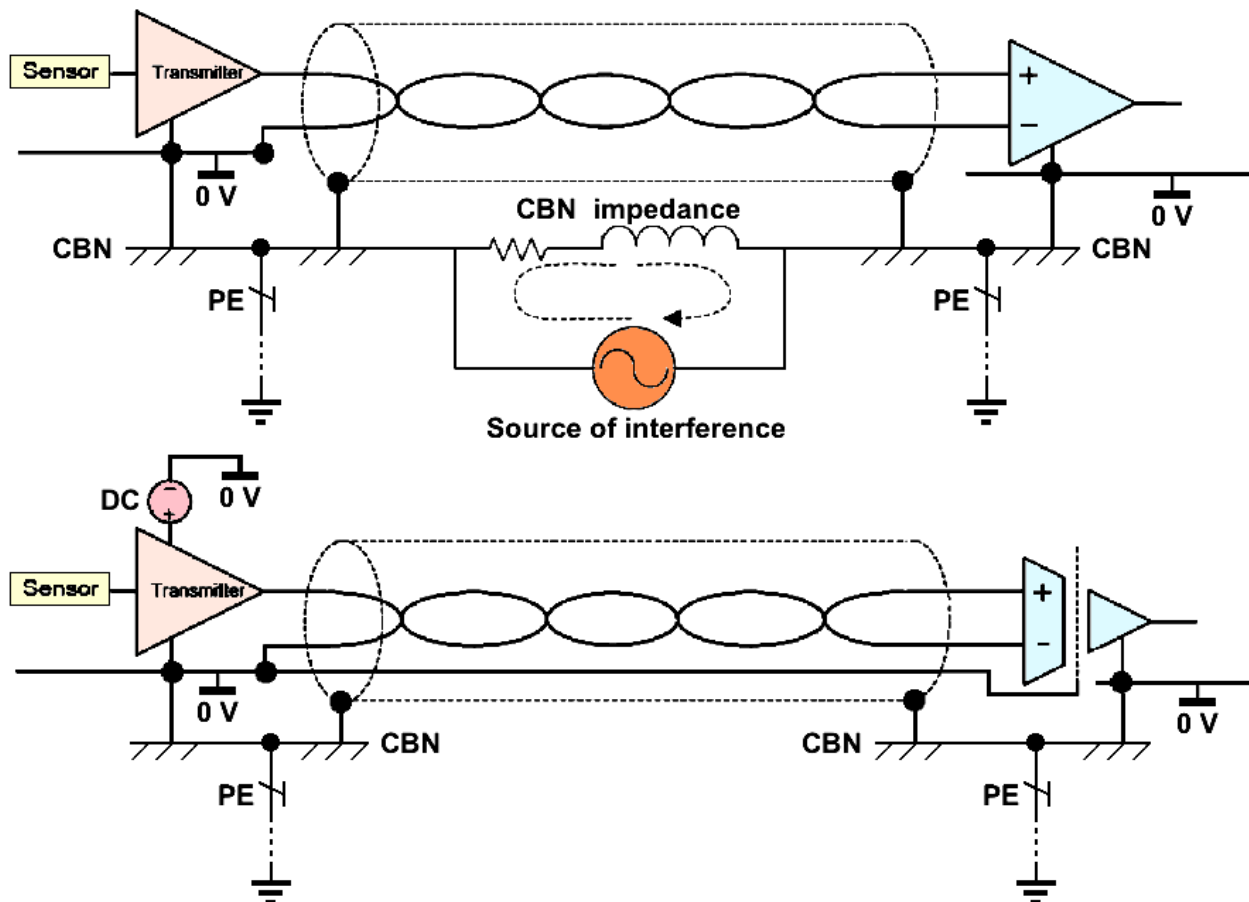


Figure 8.3 Example of cabling a device with its amplifier, and how the shields shall be bonded on both sides. All standard ITER symbols are present: Common bonding network, Earth, 0 V and Protective Earth conductor

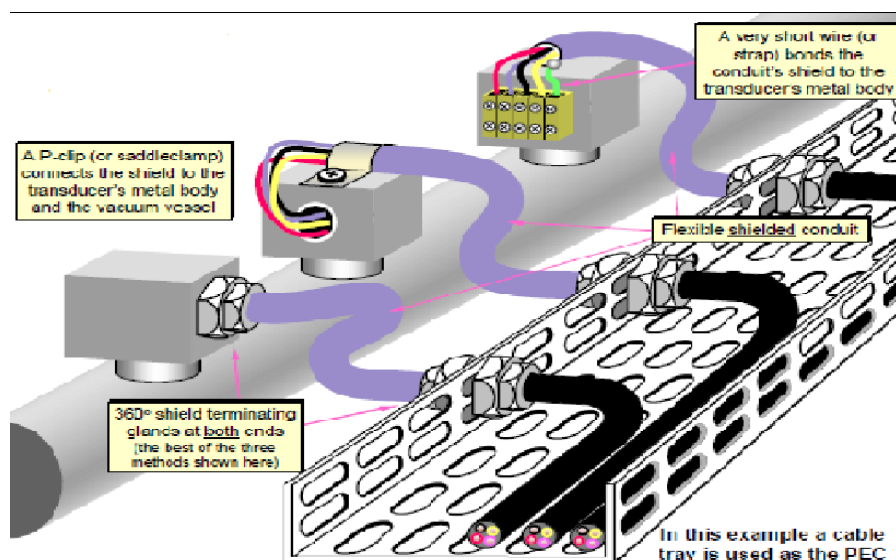
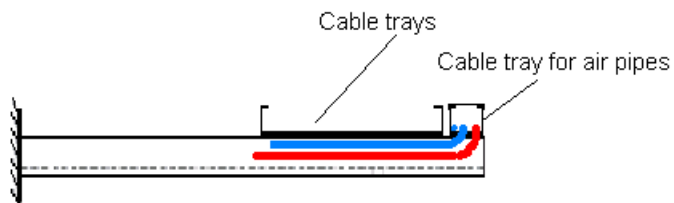


Figure 8.4 Several manners to join sensors, captors, etc. and connect the shields

## 8.1 Components supply with air pressure



When components like valves, need to be supplied with air pressure pipes, a special enclosure like cable tray must be foreseen along the air pressure pipes path. This configuration allows intervening on the different networks without perturbing the others. This enclosure located in front of the cable tray containing cables as shown in Fig. 8.1.1 will use the same support system. The air pipes which have to join the components are passing through large knitting which allows correct bending radius as shown in Fig. 8.1.2.



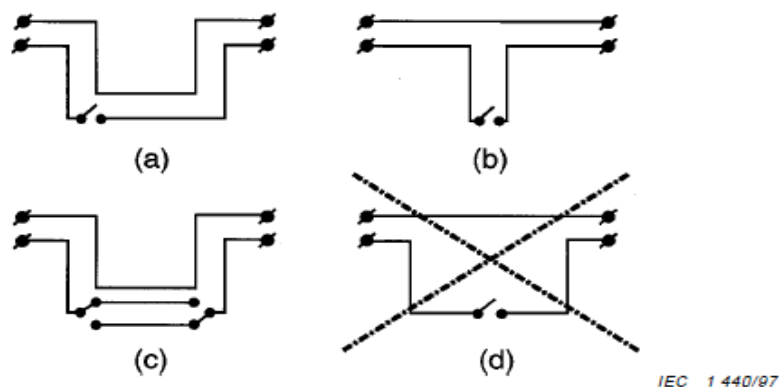
**Figure 8.1.1 Cross section of cable tray with cover**



## 9. E.M.C.

This section describes the set of rules related to the E.M.C. issues.

- Forward and return cables or signals in multi-pair cables must be kept together (IEC 61000-5-2, sub-clause 7.3.b). All signals shall be bundled by pairs (not common return conductor for more than one signal). (for some digital applications - e.g. RS232 - this rule should be understood as “not common return conductor for more than one cable”).



NOTE – There are several solutions (a, b, c) to keep the DM circuit compact when switches are installed. The lead position indicated in (d) should not be used.

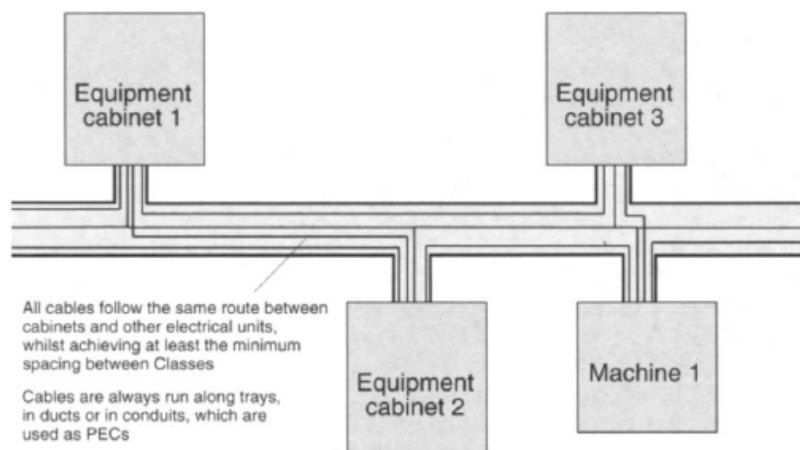
Figure 9.1 Forward and return cables shall be routed together

- All cables or wires must be maintained and attached (crimped) on the equipotentiality of the structures and CBN (IEC 61000-5-2, sub-clause 7.3.c).
- A conductor earthed at least at both ends, should be installed parallel to the cables between apparatus (IEC 61000-5-2, sub-clause 7.3.e).
- All cables or wires not used must be connected to the CBN at both ends (for very sensitive cable families see details in the IEC 61000-5-2 sub clause 7.2.3).
- Maintaining different cable families at a suitable distance (minimum 150 mm, IEC 61000-5-2 sub clause 7.7.4).
- Shielding sensitive and noisy cable families to protect them against common mode crosstalk perturbations.
- Avoid using same connector and cable types for two different families. Avoid excessive separation (i.e. > 1 m as possible) of cable belonging to the same installation.
- Always cross cables of different families at 90 degrees.
- Avoid in the same cable or bunch of cables sensitive cables/wires and noisy cables/wires (which could not be either in the same tray/conduit).
- Noisy cables don't need to be shielded if they are properly filtered.

All interconnections of materials (cable trays to cubicles or any electrical conduits to the destination equipment) must be bound with his entire surface (if possible) and by a good electrical contact (welding, screws...). The two parts in contact must be compatible in term of making and surface treatment to avoid corrosion. Screwed contacts are preferred to simple pressure contacts. If surface treatment (for instance painting) has to be removed, it must be done. After works linking the two parts, an appropriate protection to recover the initial surface treatment (galvanized painting for cable trays when necessary, painting on electrical cubicles, etc.).



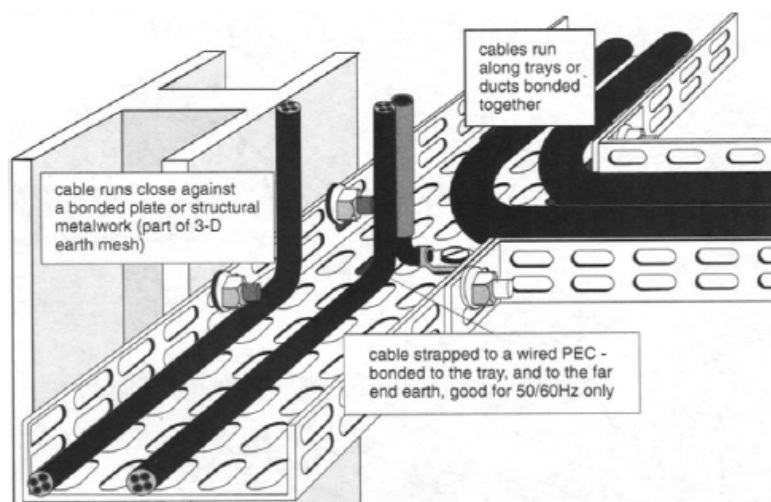
All cables between different types of equipment should ideally follow a single route along a single PEC, whilst also maintaining their segregation as shown below. This configuration reduces the possible loop effects. (DM compact circuit IEC 61000-5-2 sub clause 7.9.1 Connection to the ports of apparatus)



**Figure 9.2 Routing between equipment should follow the same path**

All items used as PEC must be connected at both ends (at 360 degrees for pipes and shielded connectors) whenever possible, short connections for earth cables, large metal plates for cable trays (of size comparable to cable tray size, if possible), an equivalent conductor type for copper bar with adaptive piece for contact compatibility. All metal structure can be used as a PEC.

- to the cables tray or any metal conduits where they are coming from
- to the metal body of the components to power and/or control by screwing, welding or connecting by a wire of length as short as possible.



**Figure 9.3 Different ways to have a cable following a PEC, creating a part of the CBN**





These connections must be done with appropriate items to collect all the external shield of cables. In any case these connections must be done on 360 degrees.



**Figure 9.4 Spring clips installed on cables**

External shielding must not be stopped at the bounding point but must be connected to it. Furthermore, all external shielding shall be made of appropriate materials (a braid is recommended) and must be connected to the connector body (E.M.C. compatible with screen connection on 360 degrees) or directly to the cover of these materials at the appropriate connection points with as short as possible metal parts. Wide metal plates are preferred. In any case all bonding points or earth connection points (rails, copper bars) outside or inside of electrical cubicles must be connected (electrically) directly to the metallic structure of the cubicles to be compatible with E.M.C. measures and CBN (large flat straps are usually used).

It is preferable to have two large flat PECs for connections instead one. In any case, as direct as possible connection between metallic parts is mandatory. If cables contain an earth wire, it must be connected to the appropriate earth connection point at both sides (earth wires are always insulated with yellow/green color).

When a cable passes from one cable tray into another, an electrical connection (copper strap or braid) will be added. The area of the loop between the cable out of the cable tray and the strap should remain smaller than  $0.2 \text{ m}^2$ . The minimum width for this strap or braid should be at least 25 mm.

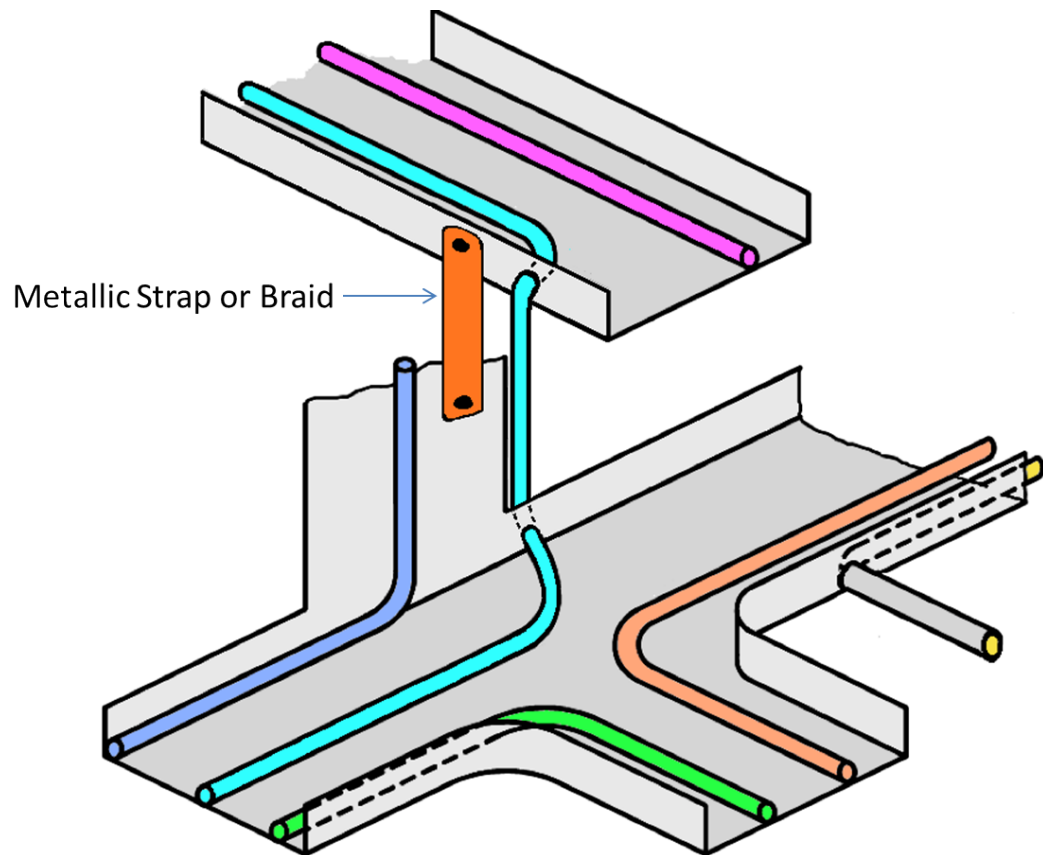


Figure 9.5 Braid between two cable trays when a cable passes from a tray to another without a metallic electrical conduit.





## 10. Cabling diagram and equipment location

All PBS are responsible to provide the following deliverables for the cable routings:

- SSD diagram with all cable information (TTT code), equipment tagged and location, cable type (according with ITER\_D\_355QX2 - IO cable catalogue) and cable segregation (according with ITER\_D\_34GBZB - SRD-44 (Cable Trays)). If there are several cables which should be routed together (for example the three phases of single core codes of power distribution), there should be created 1 link, and the quantity of cable will be the amount of independent single core cables.
- 2D drawings defining equipment location and their coordinates (in millimetres, referred to Tokamak Center, GBS) ending points those cables.

The following shows an example of this information:

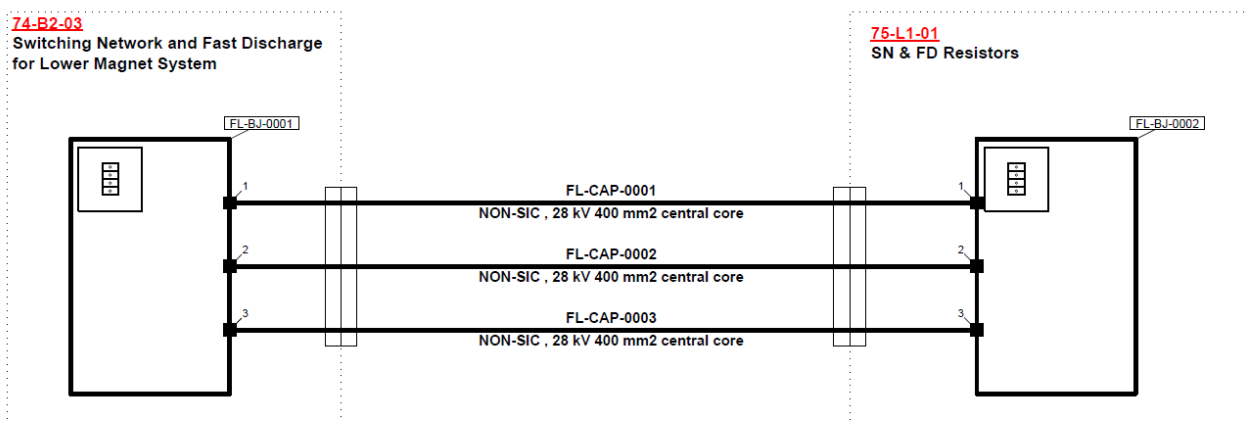


Figure 10.1 SSD Cabling diagram, with equipment tagged and location.

PBS	TTT	NNNN	CABLE_TYPE	FROM_EQUIPMENT	FROM_EQUIPMENT_LOCATION	TO_EQUIPMENT	TO_EQUIPMENT_LOCATION	SEGREGATION
41C1FL	CAP	1	FDU	41C1FL-BJ-0001	74-B2-03	41C1FL-BJ-0002	75-L1-01	44NSN2
41C1FL	CAP	2	FDU	41C1FL-BJ-0001	74-B2-03	41C1FL-BJ-0002	75-L1-01	44NSN2
41C1FL	CAP	3	FDU	41C1FL-BJ-0001	74-B2-03	41C1FL-BJ-0002	75-L1-01	44NSN2

Figure 10.2 SSD extract, with equipment tagged and location, cable type and cable segregation.

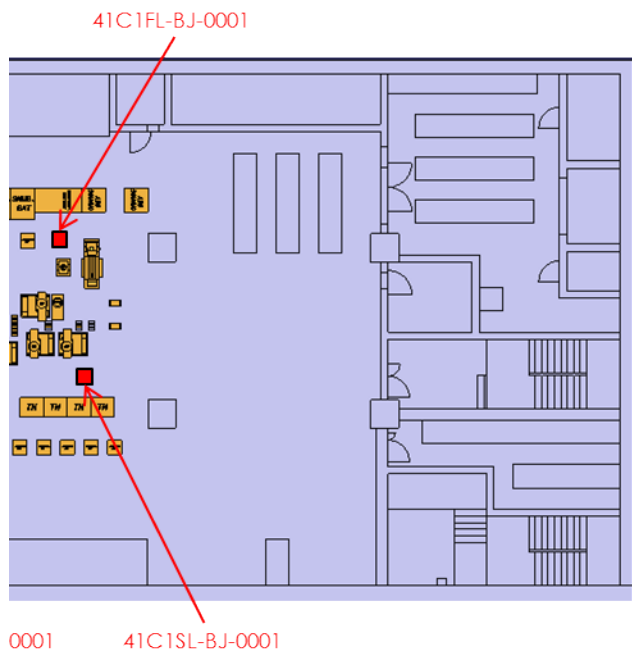


Figure 10.3 Location of equipment origin in building 74-B2

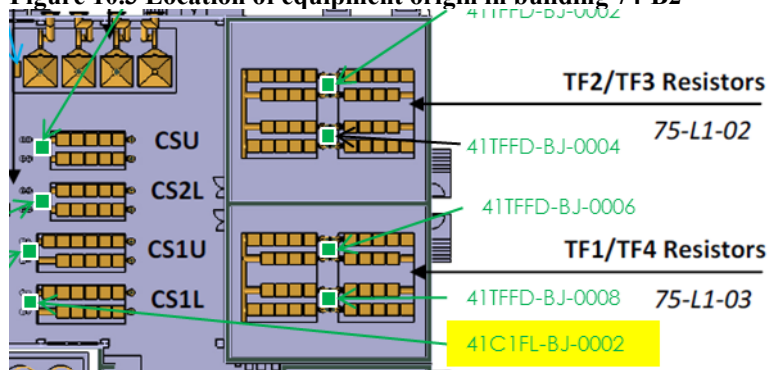


Figure 10.4 Location of equipment destination in building 75-L1, which is highlighted.

equipment	LocationX	LocationY	LocationZ
41C3FL-BJ-0002	-77,035	-63,700	-1,080
41C3FU-BJ-0002	-77,035	-67,700	-1,080
41C2FU-BJ-0002	-62,535	-63,700	-1,080
41C2FL-BJ-0002	-62,535	-67,700	-1,080
41C1FU-BJ-0002	-62,535	-71,700	-1,080
41C1FL-BJ-0002	-62,535	-75,700	-1,080
41P1FD-BJ-0002	-74,860	-105,330	-1,080
41V1F2-BJ-0002	-74,860	-109,330	-1,080
41V1F4-BJ-0002	-61,042	-96,021	-1,080
41V1F5-BJ-0002	-61,042	-100,021	-1,080
41P6FD-BJ-0002	-58,842	-105,330	-1,080
41V1F3-BJ-0002	-58,842	-109,330	-1,080
41TFFD-BJ-0012	-47,226	-62,698	-1,080
41TFFD-BJ-0018	-45,430	-58,698	-1,080

Figure 10.5 Equipment coordinates

