

# IEEE Guide for the Design of Cable Raceway Systems for Electric Generating Facilities

IEEE Power and Energy Society

Sponsored by the  
Energy Development and Power Generation Committee  
and  
Insulated Conductors Committee

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USA

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# IEEE Guide for the Design of Cable Raceway Systems for Electric Generating Facilities

Sponsors

**Energy Development and Power Generation Committee**  
and  
**Insulated Conductors Committee**  
of the  
**IEEE Power and Energy Society**

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**Abstract:** Guidance for the design and installation of cable raceway systems for all types of electric generating facilities is provided. Recommendations, methods, and best engineering practices for the design of cable raceway systems including selection of equipment, materials, and the configuration of raceway are described.

**Keywords:** cable, conduit, electrical design, generating facility, IEEE 422, raceway configurations, raceway design, raceway installation, tray

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## Introduction

This introduction is not part of IEEE Std 422-2012, IEEE Guide for the Design of Cable Raceway Systems for Electric Generating Facilities.

IEEE Std 422<sup>TM</sup> was originally issued in 1977 and revised in 1986, but was administratively withdrawn by IEEE in the mid 1990s as a result of not being re-affirmed or revised in the interim. This document was originally developed as a guide for the design and installation of wire and cable systems in generating stations with the objective of minimizing failures and their consequences. It was not intended for use in the design of wire and cable systems in switchyards or substations, which is covered in IEEE Std 525<sup>TM</sup>. The guide was originally written to apply to both nuclear and non-nuclear electric power generating stations except for the special requirements of wire and cable installations in Class 1E systems of nuclear stations for which the user was referred to IEEE Std 690<sup>TM</sup>. Most of the existing nuclear plants make reference to IEEE Std 422-1986 in their governing documents and use the guidance of IEEE Std 422-1986 in their designs, especially for non-nuclear applications, such as water treatment, cooling towers, administrative, and warehouse structures, etc. It is not the intent of this revision to change what was done in the past, or require any new design changes to existing operating nuclear plants, or to prohibit the use of the guidance in this document when it is referenced in nuclear plant governing documents. The intent of this revision is to clarify the applicability of this document to future nuclear plant designs.

The general practice at many existing nuclear facilities was to use one cable raceway design criteria within the vital areas rather than having one criterion apply to the non-safety systems, and another criterion apply to the structures and components of the safety related systems. Thus having two documents, IEEE Std 422 and IEEE Std 690, apply to the vital areas within nuclear plants allows for the possibility of two sets of overlapping or conflicting requirements to govern the design of cable raceway systems, especially considering that safety related and non-safety related cables are often routed in same room and may even go to the same end device. Therefore, the user is advised to verify the applicability of this document when doing nuclear plant cable raceway design work to prevent using it in situations where IEEE Std 690 applies.

Therefore, a revision to IEEE Std 422 has been undertaken to remove those design requirements (such as associated circuits) that are specific to only nuclear power generating stations with the understanding that a similar revision to IEEE Std 690 is in progress to capture any nuclear design requirements (such as associated circuits) which apply to nuclear plants but do not apply to non-nuclear generating stations. In addition, it should be noted that the 1986 version of IEEE Std 422 contained some information regarding cable installation practices which has now been incorporated into IEEE Std 1185<sup>TM</sup>-2010, and therefore has been removed from this revision of IEEE Std 422. For additional guidance on raceway design and installation requirements for nuclear facilities, also see IEEE Std 628<sup>TM</sup>.

In addition to fossil fueled generating stations, this document applies to hydroelectric, solar, photovoltaic, wind, ocean, geothermal, and other renewable power generating stations but not to residential, commercial facilities, or emergency standby generators that serve their own facilities. This document may be of benefit for the proper design of cable raceway systems in industrial, commercial, governmental, and public facilities when similar cable raceway systems are used.

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## 1. Overview

### 1.1 Scope

This document provides guidance for the design and installation of cable raceway systems for all types of electric generating facilities.

### 1.2 Purpose

The guide provides recommendations, methods, and best engineering practices for the design of cable raceway systems including selection of equipment, materials, and the configuration of raceway.

## 2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std C2-2012, National Electrical Safety Code ® (NESC®)<sup>1, 2</sup>

NFPA 70®-2011, National Electrical Code ® (NEC®)<sup>3</sup>

### 3. Definitions and acronyms

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.<sup>4</sup>

#### 3.1 Definitions

**cable shielding:** A magnetic or nonmagnetic, conductive material applied over the insulated conductor or conductors to confine the electric field of the cable to the insulated conductor or conductors or to protect the insulated conductors from external electromagnetic or electrostatic interference.

**cocoon (cable system enclosure):** A cable wrap or enclosure used to protect cables from fire hazards and used to permit cable separation distances less than that normally required and which is typically made of a fire resistant material.

**conductor (strand) shield:** The conductor shield consists of a layer of semi-conductive polymer or a material with a high dielectric constant that is extruded over the conductor. The conductor shield reduces the dielectric stress at the inside surface of the insulation and prevents partial discharges by filling in the voids and irregularities of the conductor surface and by providing a smooth, equi-potential surface at the inside surface of the insulation.

**design life (of a cable):** The time encompassing the service life of a cable and the anticipated margin beyond during which a cable is expected to operate and perform its intended function.

**design life (of a power generating station):** The time during which satisfactory station performance can be expected for a specific set of design operating conditions.

**drop-out fitting:** An attachment to a cable tray that maintains the proper cable minimum bend radius at the point that the cable exits from a tray. These fittings are available in configurations that can be attached to the bottom, side, or end of a tray.

**insulation shield:** The insulation shield is a layer of semi-conductive polymer or a material with a high dielectric constant that is applied to the outer surface of the insulation in order to establish an equi-potential surface on the outside of the insulation. This ensures that there are no areas of concentrated electric field due to sources outside of the cable, and minimizes the dielectric stress within the cable insulation.

**minimum pulling bend radius:** The minimum allowable value of the radius of an arc that an insulated conductor, insulated wire, or insulated cable can be bent under tension while the cable is being installed.

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[http://www.ieee.org/portal/innovate/products/standard/standards\\_dictionary.html](http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html).

**minimum training bend radius:** The minimum allowable value of the radius of an arc that an insulated conductor, insulated wire, or insulated cable can be bent under no tension for permanent installation.

**service life (of a cable):** The time during which satisfactory cable performance can be expected for a specific set of service conditions.

### 3.2 Acronyms

ABS	Acrylonitrile-butadiene-styrene fabricated conduit
EMI	Electromagnetic interference
EMT	Electrical metallic tubing
EPC-40	Electrical plastic conduit for type DB applications, fabricated from PE; or for type DB and Schedule 40 applications, fabricated from PVC
EPC-80	Electrical plastic conduit for Schedule 80 applications, fabricated from PVC
EPT	Electrical plastic tubing for type EB applications, fabricated from PVC
FMC	Flexible metallic conduit
FRE	Fiberglass reinforced epoxy fabricated conduit
HDPE	High density polyethylene
IMC	Intermediate metal conduit
LFMC	Liquid-tight flexible metal conduit
NEC®	National Electrical Code®
NESC®	National Electrical Safety Code®
PE	Polyethylene
PVC	Polyvinylchloride
RFI	Radio frequency interference
RMC	Rigid metal conduit
RTRC	Reinforced thermosetting resin conduit
Schedule 40	Duct designed for normal-duty applications above grade
Schedule 80	Duct designed for heavy-duty applications above grade
Type DB	Duct designed for underground installation without encasement in concrete
Type EB	Duct designed to be encased in concrete

## 4. Cable selection

### 4.1 General

This clause provides guidance for cable performance and should be considered in the selection of cable for installation in power generating stations. A balance of cable characteristics matched to the environmental conditions of the plant, as well as good installation, design, and construction practices are essential to ensure a reliable cable system which will operate during the expected design life of the power generating plant. See Section 16 of the NESC<sup>5</sup> for general information regarding conductors that should be used in power plants.

### 4.2 Cable circuit classifications

Medium voltage power cable circuits are designed to supply power to utilization devices of a plant auxiliary system rated 2400 V to 34.5 kV.

Low voltage power cable circuits are designed to supply power to utilization devices of a plant auxiliary system rated 2000 V or less.

Control cable circuits are designed to provide low current levels for intermittent operation to change the operating status of a utilization device of the plant auxiliary system and are rated less than 1000 V.

Instrumentation, thermocouple extension, and communication cables are used for transmitting variable current or voltage signals (analog) or for transmitting coded information (digital).

Fiber optic cable circuits are used for the transmission of light by glass or plastic fibers for signaling, control, and instrumentation purposes.

Specialty cable circuits are designed to accommodate high frequency and high data rates and are selected based on the application from cable types such as coax, triax, twinax, ethernet, category, data cables, etc.

### 4.3 Service conditions

Since cable systems are exposed to a wide variety of environmental service conditions, the determination of the appropriate service condition for each situation is a critical step in the cable system design.

Cables may be directly buried, laid in trenches, routed in tunnels, installed in duct banks and raceways below grade, or installed in cable trays, conduits, and wire-ways above ground both indoor and outdoor. Cable installed in any of these locations should be suitable for operation in wet/damp and dry conditions.

The use of MC or TC-ER type cables in exposed areas above ground is acceptable if properly supported and protected, and installed in accordance with the NEC and local governing codes.

Any cable anticipated to be installed in conditions such as underground ducts, vaults, manholes, trenches, tunnels, and other areas which are expected to be submerged in water for any part of their route should be designed to operate under submerged conditions over the expected design life of the cable. This can be achieved either by using semi-conductive shielding, insulation and jacketing compound materials designed to be resistant to water degradation or by the use of moisture barrier layers to protect the cable core, water-

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<sup>5</sup> Information on references can be found in Clause 2.

blocking, or other means to achieve a moisture impervious condition and prevent long term cable degradation due to submerged water conditions. See IEEE Std 1142<sup>TM</sup> [B30]<sup>6</sup> for selecting, testing, and installing cables with moisture barriers or water blocking features. Another installation design option is to re-route the cable so as to bypass the potentially submerged environmental condition. Depending on the cable type (shielded or unshielded), potential electrical degradation of cable electrical properties may be detected by one or a combination of the following tests: capacitance measurements, time domain reflectometry (TDR), and integrated measurement techniques such as computer-based electronic characterization and diagnostics trouble shooting and condition monitoring tools.

Cable operating temperatures in power generating stations are normally based on 40 °C ambient air or 20 °C to 30 °C (depending on location) ambient earth. Special consideration should be given to cable installed in areas where ambient temperatures are different from these values.

Cables should be suitable for all other environmental conditions (temperature, pressure, humidity, solar (ultra-violet) radiation, water submersion, chemicals, EMI/RFI, etc.) that occur in the areas where the cable is expected to be installed.

#### 4.4 Cable performance

Normally the service life of the cable should be at least equal to the design life of the power generating station to minimize cable replacement during the station service life.

The cable should maintain its insulating properties for its service life as required by operating conditions when subjected to maximum ambient temperature and the heat generated by the current within the cable and the heat from nearby cables or other heat sources.

Cables installed in open or enclosed cable trays, wire-ways, or in other raceway systems where flame propagation is of concern should pass the applicable flame test requirements of IEEE Std 1202<sup>TM</sup> [B33] or a comparable flame propagation test standard.

#### 4.5 Cable thermal limits

All power cables have thermal limitations, for example: cross linked polyethylene (XLPE) and ethylene propylene rubber (EPR) products are limited to 90 °C/105 °C steady state continuous operation, 130 °C/140 °C emergency, and 250 °C short circuit thermal limits per ICEA standards. Consult the cable manufacturer for the thermal limitations for other cable types such as: paper and lead, polyethylene, silicone rubber, etc., which may have different thermal limits than those given above.

These thermal limitations restrict the amount of current a power cable can carry, and are normally stated for cables routed indoors in free air. Thus, it is extremely important that all cable systems be properly rated, or de-rated, for the service environment. Any areas that have hot spots, have unusual heat buildup, restrict thermal heat release or restrict air flow, or are in direct sunlight must be thoroughly evaluated and understood for proper cable selection. Otherwise, thermal runaway can occur. Thermal runaway can cause cable system destruction, damage to associated hardware, raceways, and fixtures. It can cause damage to the generating station or even cause personal injury.

Since thermal runaway of a power cable is a dangerous problem for a generating station, the cable raceway system designer should review the areas listed below.

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<sup>6</sup> The numbers in brackets correspond to those of the bibliography in Annex A.

#### 4.5.1 Raceways

- a) The number of cables in a raceway,
- b) Cable locations and proximity to each other,
- c) Location of any environmental heat source near the raceway,
- d) Environmental (ambient) temperature,
- e) Air movement, or lack of air movement, to carry away heat and avoid heat buildups.

#### 4.5.2 Circulating currents

- a) Electrically balancing of cables,
- b) Circulating currents in the grounding paths or cable sheaths that can increase thermal loss and reduce current carrying capacity,
- c) Shields type used for grounding on the cables: tape, stranded wire, etc.

#### 4.5.3 Tunnels and enclosed zones

- a) Check all the cable racks, or raceways, against the requirements stated in 4.5.1,
- b) Proper air movement to carry away the heat being generated by the cable systems either naturally or by forced cooling,
- c) Locations in the tunnel that restricts air flow or narrows that can cause heat buildup,
- d) Coordinate cable ratings with air movements and cable current loads that vary due to time of day, changing environmental conditions, or temporary work,
- e) Thermal insulating wraps or coatings typically used for fire protection trapping air and possibly leading to higher temperatures (reduced ampacity).

#### 4.5.4 Hardware connections, splices, and equipment attachment points

- a) Check all hardware connections, clamps, and splices for potential hot spots, which are usually due to loose or dirty electrical connections.
- b) Check current de-rating of splices that may often be hotter than a cable without a splice.
- c) Be aware of transition locations where cable systems are changing their arrangements in order to be attached to other devices. These are prime locations for thermal hot spots, which can occur while trying to force a cable into a thermally restricted area, coming into close proximity to heat producing equipment, or connecting the cables to heat producing equipment such as transformers, generators, etc.

Cable network systems should be carefully analyzed on a thermal limiting current capacity basis. Always check it thoroughly, or have the cable supplier provide expert advice as it pertains to the locations and operational restrictions of their cable in the exact locations or situations in which they are being applied.

### 5. Cable conductor sizing and voltage levels

The proper design of power cable systems requires the consideration of many factors. These factors include ambient temperature, normal and emergency loading, system fault levels, voltage drops, and system nominal voltage, service factor, power factor, grounding, etc.

The type of load (resistive, capacitive, inductive, or combination thereof) and ambient temperature are important design parameters because they determine the continuous current-carrying capability (ampacity) of a cable for a given size in a particular type of installation. In areas where temperatures exceed stated ambient, cables require ampacity de-rating or special types of insulation and jacket materials to be used.

The ampacity of low and medium voltage power conductors may be determined from tables provided in NEC Articles 310.15(B) or 310.60(C) or under engineering supervision as provided in NEC Articles 310.15(C) or 310.60(D).

The ampacity of medium voltage power cables in cable trays with single layer or maintained spacing should be in accordance with NEC Articles 392.22(C) and 392.80(B).

Power cables should be designed to carry normal and emergency load currents. IEEE Std 835<sup>TM</sup> [B25] provides cable ampacity tables for various cable constructions and methods of installation. These tables are based on 40 °C ambient air and 25 °C ambient earth and include data for various conductor temperatures. The ampacity ratings for the cable shown in the tables of IEEE Std 835 [B25] will require adjustment if the site ambient air or earth temperatures are different. Appropriate factors for cable and conduit grouping are also given, as well as an adjustment formula for change in parameters. Ampacity for cable in an underground duct bank is based on all power cable ducts being peripherally located and having the cable shields of single-conductor, non-triplexed, medium voltage cables grounded at one point.

Ampacities for non-spaced, random filled cables in open top trays should be determined from ICEA P-54-440/NEMA WC51 [B11], unless the circuit is routed in both underground and open top trays. For this case, the most conservative ampacity should be used. However, normally the ampacity tables listed in IEEE Std 835 [B25] are not applicable for the non-spaced, random filled cables in open top tray applications. The publications listed in Annex A also provide guidance for de-rating the cable ampacity. There is an ampacity difference for the same size cable between the NEC (NFPA 70) and ICEA P-54-440 [B11] where a single layer with no spacing is used. IEC 60287-1-1 [B16] provides a simplified formula for the ampacity of cables in a trench. Trenches are complicated from the heat transfer perspective, and more sophisticated calculation techniques may be required.

Where cables are routed through several types of installation conditions (buried, outdoors exposed to sunlight, exposed conduit, covered cable trays, wireways, near hot steam lines, etc.), the conductor size should be selected for the most severe thermal condition. The application of fire-retardant coverings, penetration fire stops, etc. may also affect cable ampacity and may require further de-rating.

Guidance for fault current and short circuit characteristics of insulated conductors is provided in ICEA P-32-382 [B9]. Fault current capabilities of metallic shields and sheaths are provided in ICEA P45-482 [B10].

Voltage regulation requirements should be considered when selecting the conductor size. Motor feeder voltage drop under starting and running conditions should be limited to allow the motor to operate within its design specifications.

System nominal voltage level and the type of grounding (solidly grounded, resistance grounded, or ungrounded) determine the rating and insulation level (i.e., 100%, 133%, or 173%) of medium voltage cable. AEIC specification CS8-07 [B1] and ICEA S-73-532 [B12], ICEA S-93-639 [B13], ICEA S-95-658 [B14], and ICEA S-97-682 [B15] provide guidelines for the proper selection of cable rating and insulation level as well as the overvoltage capabilities associated with cable voltage ratings.

## 6. Electrical segregation of cable systems

### 6.1 General

Cable systems should have electrical segregation according to voltage levels, signal levels, and vulnerability to electrical noise pickup.

### 6.2 Segregation

#### 6.2.1 General

Cables installed in stacked cable trays generally should be arranged by descending voltage levels with the higher voltages at the top. Distance between tray voltage levels should be a minimum of 30 cm (12 in) measured from the bottom of the upper tray to the top of the lower tray. A larger spacing may be desirable for ease of cable installation.

#### 6.2.2 Medium voltage power cables

These cables should be installed so that the medium voltage cannot be impressed on any lower voltage system. Methods for achieving this segregation are:

- a) Installation of medium voltage cables in raceways that are separated by either a minimum of 30 cm (12 in) or a solid metal barrier from low voltage power, control, and instrumentation cables. Installation of different classes of medium voltage power cables in separate raceways is recommended.
- b) Utilization of shielded cables helps to contain the magnetic and electric fields within the insulated conductor of the cable. Induced current in the shield acts to reduce the magnetic field if the shield is grounded at both ends because the current in the shield flows in the opposite direction from the conductor current. However, the shield current is normally limited to reduce the losses in the cable. Since the shield is not normally made from ferromagnetic materials, there is little magnetic shielding without shield current. If the shield is single point grounded, there is no electromagnetic shielding.
- c) Utilization of armored cables may help to contain the magnetic and electric fields within the cable depending on the type of armor material and the grounding scheme. Even when armored cable is used, separation of raceways is desirable to reduce propagation of heat from the medium voltage cable and to minimize physical damage in the event of high magnitude faults internal to the medium voltage cable.

The segregation of medium voltage cables in trays is mandatory in areas that are subject to the requirements of the National Electrical Code (NFPA 70).

In the past, cables rated up to 5000 V have been made without insulation shields (commonly referred to as “unshielded” or “non-shielded” cables), and these cables were used extensively in systems which had a nominal system voltage of 4160 V. However, since the 2005 Edition of the NEC, cable used on a system with a nominal voltage rated above 2400 V is required to be provided with a semiconducting shield except for special applications. A semiconducting polymer shielded cable design confines the electric field to symmetrical configurations around the cable, provides a uniform ground plane to facilitate cable testing, and allows monitoring or testing cable installations for damage. Nonmetallic shielded medium voltage cables for systems with a nominal voltage higher than 2400 V (line-to-line) have also been used in the past.

However, their use is now limited to designs that are not subject to NEC. In addition, the limited availability of non-shielded medium voltage power cable further restricts their use to replacement applications or special designs such as internal generator leads. Rule 124 of the NESC requires these cables to be guarded and requires that all such unshielded cables be installed in completely enclosed raceways such as a conduit. However, the 2011 revision to the NEC has relaxed the restrictions imposed by 2005 NEC Edition and allows an expanded use of non-shielded 5 kV cable for such activities as retrofit work and other special applications.

### **6.2.3 Low voltage power and control cables**

Low voltage power and control cable classifications may be mixed if they have compatible operating temperatures and voltage (600 V or less) ratings. The objective is to prevent physical damage to the cable due to size difference or physical construction of the cable. It is generally possible to have 120 V control and 480 V power cables in close proximity, as the characteristics of the insulated conductors of both types of cables are similar. The heat generation of the power cables should be small enough to avoid excessive temperatures in the installation. The size of the power cables should be compatible so as not to present a risk of physical damage to the control cables during installation and service. In case of doubt, the cable manufacturer should be consulted.

NEC Article 725 imposes additional requirements for segregation in locations such as remote-control, signaling, and power-limited circuits.

### **6.2.4 Instrumentation cables**

These cables should be installed to minimize noise pickup from adjacent circuits and equipment. Methods for achieving segregation are:

- a) Provide physical separation between the instrumentation cables and any electrical noise source;
- b) Install instrumentation cables in separate enclosed raceways made of magnetic materials;
- c) Use cable construction configurations such as twisted conductors and shielded pairs with overall shielding;
- d) Install analog signal cables separate from all power and control cables and from unshielded cables carrying digital or pulse-type signals. Shielded voice communication cable (without power supply conductors) may be included in raceways with analog signal cables.

### **6.2.5 Fiber optic cables**

Fiber optic cables are not affected by electrical interference from other cables, nor do they create any electrical interference issue with other cables. Since most fiber optic cables are relatively small, compared to most power plant cables, fiber optic cables should be segregated from larger cables to prevent damage to the fiber optic cables during installation and maintenance. This segregation can be obtained by using a separate raceway for small cables or a barrier to separate the fiber optic cable from other cables.

### **6.2.6 Adjustable speed drives and other non-linear loads**

Several different technologies are used for adjustable speed drives (a.k.a. variable frequency drives, etc.) and other non-linear loads which often create high frequency components in their load currents. These higher frequency currents are more easily coupled to nearby conductors compared to power frequency (50 Hz-60 Hz) currents. The use of adjustable speed drives requires special conductor size considerations,

thicker insulation walls, and special cable shielding/grounding considerations to contain the EMI/RFI emissions generated by the drive circuitry.

Therefore, it is important that the cables associated with these loads be segregated from low voltage power, control, and instrument cables. Segregation may be accomplished by the use of armored cable, use of conduit, or by the use of special cables between the inverter source and the load. When possible, the cable length between the inverter source and the motor load should be minimized to reduce the potential for unwanted effects of EMI/RFI coupling.

In addition, the modern solid state devices used in adjustable speed drives are capable of producing waveforms with fast rise times. Under some conditions, this can be a source of transient over-voltages in power circuits and noise in nearby instrumentation circuits. Therefore, it is important that power cables from the adjustable speed (variable frequency) drive to the motor load be carefully selected. Power cables for these applications are specially designed and may have increased insulation thickness, three conductor configurations with ground wires under common jacket, extra ground wire configurations, braided sheaths, armored sheaths, or other features to mitigate voltage spikes produced by variable frequency drives.

## 7. Separation of redundant cable systems

### 7.1 General

This clause provides guidance for the separation of redundant cable systems. Redundant cable systems are two or more systems serving the same objective. They may be systems where personnel or public safety is involved, such as fire pumps, or systems provided with redundancy because of the severity of economic consequences of equipment damage. Turbine-generator ac- and dc-bearing oil pumps are examples of redundant equipment under this definition. Partially redundant systems, such as a system consisting of three 50% feedwater pumps provided so that maintenance on any one pump can be performed without loss of operating capability, are another example of design redundancy which require redundant cable systems.

### 7.2 Design considerations

Redundant cable systems should be separated to assure that no single credible event (fire, seismic, flood, etc.) will prevent the operation of a required plant function.

Separation should also be applied to partial capacity systems, such as three 50% systems, to improve service reliability.

The degree of separation required varies with the potential hazard to the cable systems and the specific power generating station area. Where transient fire loads are possible and need to be accounted for, administrative controls such as procedures, security measures, or fire watch patrol could constitute acceptable measures of protection.

These areas may be classified as follows:

a) Mechanical damage area:

Physical arrangement, or protective barriers, or both should be incorporated into the design so that no credible event such as missile, pipe whip, or jet impingement can cause the destruction of both the main and the redundant cable systems. Possible event sources include:

1) Large rotating equipment,

- 2) High-pressure/high temperature piping and pressure vessels,
- 3) Transformers and switchgear,
- 4) Overhead cranes,
- 5) Temporary power or equipment installations.

b) Fire hazard area:

Cables should be selected that have passed an appropriate vertical tray flame propagation test, and cable systems should be arranged to assure that a postulated fire does not:

- 1) Damage more than one system. Even though separation and routing of redundant cable systems is not a substitute for a fire-rated cable or fire-rated barrier, cables should not be routed through an area where there is potential for accumulation of large quantities of oil or other combustible material (including coal dust, grain dust, natural gas, etc.). Where avoidance is not possible, cable should be routed in the appropriate hazardous duty rated raceway and equipment, and fire-rated cables should be considered.
- 2) Propagate from one system to another. Cables of redundant systems should have sufficient horizontal (minimum of 3 m [10 feet]) and vertical (minimum of 6 m [20 feet]) separation to prevent ignition of the cables in one system by a fire in the other. If this separation is not attainable, a fire-resistant barrier should be installed or one system should be wrapped with a minimum of a 1-hour fire rated cocoon, and fire-rated cables should be considered.

c) Cable spreading area:

The cable spreading area is normally adjacent to, above or below, the control room where cables leaving the panels are dispersed into various cable trays for routing to all parts of the plant.

- 1) Where cables of redundant systems are located such that there is no adequate assurance that a postulated fire in one system will not ignite the cable in the redundant system, barriers should be installed between the redundant cable systems. Enclosing both systems in metallic raceways and enclosing one system by cocoon are examples of acceptable barriers, providing the barriers are fire-rated. The NEC now requires fire barriers to be a minimum 2-hour rating. Where cocoons are used, cable ampacity de-rating should be taken into account during the design of the cable system.
- 2) The cable spreading area should not contain high energy equipment such as switchgear, transformers, rotating equipment, or potential sources of hot or combustible fluids, missiles, or piping and should not be used for material storage, especially flammable or toxic chemicals. Circuits in the cable spreading area should be limited to control and instrument functions and those power supply circuits and facilities serving the control room and instrument systems. Power supply feeders to instrument and control room distribution panels should be installed in enclosed metallic raceways.
- 3) The cable spreading area should not contain station batteries due to the off gassing of flammable or toxic fumes.
- 4) High pressure or high temperature piping should not be routed through or traverse the cable spreading area.
- 5) When redundant cable systems cannot be sufficiently separated by means identified above, consideration should be given to providing two cable spreading rooms, one above and one below the control room, with separate chases providing segregated paths to each from the plant, which allows cable to enter the control room from the top or bottom.
- 6) When low voltage power circuits are required to traverse this area, they should be assigned to a minimum number of routes consistent with their separation requirements and allocated solely for these power circuits. Such power circuits should be separated from other circuits in this area in accordance with 6.2. An acceptable alternative routing for such traversing power circuits would be to route them in embedded conduit or in a separate raceway (e.g., a conduit

or dedicated wireway), which in effect removes them from the cable spreading area. Medium voltage and high voltage power circuits should not be routed in the cable spreading area.

d) Cable penetrations:

Penetrations exist where cables are required to pass through barriers such as walls, floors, ceilings, fire stops, etc. Redundant cable systems passing through a barrier should be installed where either:

- 1) Cables are in separate penetrations that provide physical separation
- 2) Cables are sufficiently separated by physical arrangement, protective barriers, or both inside a single penetration such that no credible event can cause the destruction of the redundant cable systems
- 3) When cables pass through fire-rated walls, ceilings, and/or floors; these penetrations shall be sealed with a fire stop material of equal fire rating to the fire rating of the wall, ceiling, or floor being penetrated

## 8. Shielding and shield grounding

### 8.1 General

This clause provides guidance for shielding and grounding of the metallic shield of medium voltage power and instrumentation cable systems.

### 8.2 Medium voltage power cable

#### 8.2.1 General

The use of metallic shielding and grounding of the shield of a medium voltage power cable is a common practice to reduce the hazard of shock to personnel, to confine the electric field within the cable, and to minimize deterioration of cable insulation and jackets caused by surface discharges. The selection of the shield grounding locations and the effects of single and multiple point grounds are design considerations for the proper installation of shielded cable.

The conductor (strand) shield consists of a layer of semi-conductive polymer or a material with a high dielectric constant that is extruded over the conductor. The insulation is then extruded over the conductor shield. The strand shield reduces the dielectric stress at the inside surface of the insulation and prevents partial discharges by filling in the voids and irregularities of the conductor surface and by providing a smooth, equi-potential surface at the inside surface of the insulation.

The semiconducting insulation shield on an extruded dielectric cable consists of a partially conductive (semi-conductive) polymer, or a material with a high dielectric constant, extruded over the insulation. This polymeric material collects leakage currents and provides a uniform electric field around the cable core. A semiconducting insulation shield is a separate layer in most cable designs, but there is one cable design that uses a semiconducting jacket with embedded drain wires as a combination insulation shield and jacket.

The core of the cable is then surrounded by metallic tapes, or wires, or straps concentrically applied over, or embedded in, the semi-conductive layer. These metallic shields collect the leakage currents from the semiconducting insulation shield by contact and provide a path for them to ground at the grounding points for the metallic shields. In addition, the grounding points of the shield provide a path for fault and short circuit currents to ground. The metallic shield is normally grounded at one or more points depending on

circuit length. The length between grounds is chosen to reduce the shock hazard from high voltages appearing at the surface of the cable. In addition, the grounding points of the shield provide a path for fault and short circuit currents to ground.

### 8.2.2 Shielding practices

All medium voltage cables above 2400 V should be shielded with metallic components.

Cables without metallic shielding typically result in a shorter cable life when exposed to the conditions listed below; therefore, metallic cable shielding is necessary where any of the following conditions exist:

- a) Transition from a conducting to a non-conducting environment
- b) Transition from moist to dry earth
- c) Dry soil, such as in a desert
- d) Damp or wet conditions such as underground conduits
- e) Connections to overhead lines
- f) Locations where the cable surface collects conducting materials, containments such as soot or salt deposits
- g) Locations where electrostatic discharges are sufficient in magnitude to interfere with control and instrumentation circuit functions
- h) Locations where safety to personnel is involved
- i) Long underground cable routes
- j) Single-conductor cables in trays

### 8.2.3 Power cable shield termination practices

The insulation shield system should be removed carefully and completely, and proper stress control materials or devices used to avoid severe dielectric stress in the area of the termination. Manufacturer's instructions and recommendations as to termination of cables should be followed. If all elements of the insulation shield are not removed, excessive leakage current with tracking or flashover may result.

### 8.2.4 Power cable shield grounding practices

Metallic cable shields and sheath/armor should be solidly grounded at one or more points so that they operate at or near ground potential at all times. The length of cable run should be limited by the acceptable voltage rise of the shield (typically 25 V for steady state voltage) if the shield is grounded at only one point. The shield voltage is usually reasonable in the following cases for all but very long three-phase circuits:

- a) Three-conductor cables encased by a common metallic shield or sheath
- b) Single-conductor metallic shielded cables 500 kcmil conductor or smaller installed together in a common duct
- c) Triplexed or three-conductor individually metallic shielded cables 500 kcmil conductor or smaller
- d) Single-conductor lead-sheathed cables 250 kcmil conductor or smaller installed together in a common duct

Where the sheath voltage reaches higher than acceptable values on long cable runs, the shields can be broken into shorter sections, each of which is grounded, or the sections of shield can be cross bonded to

cause cancellation of the induced voltage. CIGRÉ Technical Bulletin 283 [B4] provides guidance in such situations.

Because of the frequent use of window-type or zero-sequence current transformers for ground-over-current protection, care should be taken in the termination of cable shields at the source. If the shield wire is passed through the window-type current transformer, it should be brought back through this current transformer before connecting to ground in order to allow the correct operation of relays.

### **8.2.5 Shield losses that affect ampacity**

Metallic shields or sheaths that are grounded at more than one point carry induced circulating currents. The magnitude of the circulating currents in shields grounded at more than one point depends on the mutual inductance between the cable shielding and the cable conductors and the mutual inductance to the conductors in other cables, the current in these conductors, and the impedance of the shield. Circulating currents heat the shield and reduce the effective ampacity of the cable.

If a single-point metallic shield grounding scheme is used, the cable jacket should be a non-conducting or insulating material. The use of a semi-conducting jacket with a single-point grounded metallic shield may cause premature cable failure and may cause safety issues (the induced voltage on the shield will cause arcing and/or tracking at locations where the semi-conductive jacket contacts any grounded surface).

IEC Standard 60287-1-1 [B16] describes the method for calculating the shield loss for ampacity calculations. Volume 4 of the EPRI Power Plant Electrical Reference Series [B46] provides additional information.

Shielded power cable ampacity tables that are based on IEEE Std 835 [B25] include the effects of cable shield losses.

### **8.2.6 Effect of shield grounding on switching over voltages**

The propagation and reflection of switching and other transients is affected by the shield grounding arrangement selected. The effects of the shield grounding technique on the exposure to transient over voltages should be considered for loads with low tolerances against transient over voltages, such as rotating machines. IEEE Std C62.21 [B35] provides additional information on this topic.

## **8.3 Instrumentation cable shielding**

Instrumentation cable shielding and grounding is used to prevent the coupling of interfering signals and noise into circuits carrying instrument signals, many of which are of low magnitude. The cables used for instrumentation have construction features to make the instrument circuits more immune to external interfering electric and magnetic fields. Typical features include using twisted pairs for balanced circuits along with a shield that is typically grounded at a single point. Cables for use in high lightning environments, or where fault currents may be a concern, have an overall, relatively thick, metallic shield grounded at both ends while the twisted conductor pairs inside the overall shield have foil shields grounded at one end. The construction of these cables is described in IEEE Std 1143 [B31]. Grounding and shielding techniques are described in IEEE Std 1050 [B28].

Because of the high frequencies associated with computer equipment, the length of typical cables becomes significant compared to the wavelength associated with the signal being transmitted by the cable. In this case, classical single-point instrument system grounding can no longer be used, and a system of multiple ground connections is more suitable. This method of grounding is described in IEEE Std 1100 [B29].

## 9. Raceway

### 9.1 General

This clause provides guidance for raceway grounding, for assuring grounding/bonding continuity of metallic raceway sections, for a means of supporting cable runs between electrical equipment, and for physical protection to the cables. Raceway systems consist primarily of cable tray and conduit.

Raceways should be adequately sized as determined by the maximum recommended percentage fill of the raceway area.

Guidance for the maximum fill of cable trays is provided in Article 392 of the NEC.

Guidance for the maximum fill of conduit is given in Chapter 9 of the NEC.

### 9.2 Conduit

#### 9.2.1 Conduit application

NEC Articles 342, 344, 348, 350, 352, 353, 355, 356, and 358 provide criteria that can be used for conduit design and installation, including uses permitted and uses not permitted.

#### 9.2.2 Conduit system design

Flexible conduit should be used between rigid conduit and equipment connection boxes where vibration or settling is anticipated or where the use of rigid conduit is not practical. A water impervious sealed flexible conduit is commonly used for this application. Flexible conduit length should be as short as practical, but consistent with its own minimum bending radius, consistent with the minimum bending radius of the cable to be installed, and be installed for any relative motion expected between connection points. Under certain circumstances a separate ground wire may be required around the flexible conduit. See Article 250.134(B) and Article 250.102 of the NEC for additional guidance.

Where it is possible for water or other liquids to enter conduits, conduits should be sloped and low point drainage provided.

Electrical equipment enclosures installed outdoors should have the conduit installed in a manner to prevent the entrance of water and condensation. Drain fittings and air vents in the equipment enclosure should also be considered. Expansion couplings should be installed in the conduit run or at the enclosure to prevent damage caused by frost heaving or expansion.

The entire metallic conduit system, whether rigid or flexible, should be electrically continuous and grounded.

When cable is installed in conduit made of a magnetic material, all phases of a three-phase ac circuit and both legs of single-phase ac/dc circuits should be installed in the same conduit or sleeve. If all phases of a three-phase ac circuit or both legs of single-phase ac/dc circuit are not installed in the same conduit, the cable may require de-rating.

All conduit systems should have suitable pull points (pull boxes, manholes, handholes, etc.) to avoid over tensioning the cable during installation.

Care should be taken in routing above-grade systems to minimize interference with traffic and equipment access.

### 9.2.3 Embedded conduits and manholes

Spacing of embedded conduits should permit fittings to be installed. The spacing may vary in accordance with the class of concrete being used around the conduits.

Conduits in duct runs containing one phase of a three-phase power circuit or one leg of a single-phase power circuit should not be supported by reinforcing steel forming closed magnetic paths around individual conduits. Reinforcing steel in the manhole walls should not form closed loops around individual nonmetallic conduit entering the manhole. Nonmetallic spacers should be used.

Concrete curbs or other means of mechanical protection should be provided where other than rigid metal conduit (RMC) turn upward out of floor slabs.

The lower surface of concrete-encased duct banks should be located below the frost line. When this is not practical, lean concrete or porous fill can be used between the frost line and the duct bank. Concrete-encased duct banks should be adequately reinforced under roads and in areas where heavy equipment may be moved over the duct bank.

Direct buried nonmetallic conduits should not be installed under roadways or in areas where heavy equipment may be moved over them unless the conduits are made from resilient compounds suitable for this service or are protected structurally.

Conduits in duct banks should be sloped downward toward manholes or drain points.

Duct lengths should not exceed those which will develop pulling tensions or sidewall pressures in excess of those allowed by the cable manufacturer's recommendations. Bends in conduit should be greater than the cable minimum pulling bend radius.

Manholes and vaults should be oriented to minimize bends in duct banks.

Manholes and pits should have a sump to facilitate the use of a pump.

Manholes and vaults should be provided with the means for attachment of cable-pulling devices to facilitate pulling cables out of conduits in a straight line. Provisions should be made to facilitate racking of cables along the walls of the manhole or vault. Exposed metal in manholes and vaults, such as conduits, racks, and ladders, shall be grounded. End bells to provide a smooth surface for cable entry should be provided where conduits enter manholes, vaults, or building walls. Manholes and manhole openings should be sized so that the cable manufacturer's minimum allowable cable bending radii are not violated. Alternately, the entire top of the manhole may be removed to facilitate cable pulling activities.

### 9.2.4 Conduit installation

Supports of exposed conduits should follow industry standards. See the NEC Section 250 and NESC Section 32 for additional information on conduit systems.

Conduits and ducts embedded in concrete, installed indoors in wet areas, or located outdoors, should have threaded conduit joints and connections and be made watertight and rustproof by means of the application of a conductive thread compound which will not insulate the joint. Each threaded joint should be cleaned to remove all of the cutting oil before the compound is applied. The compound should be applied only to the male conduit threads to prevent obstruction.

Running threads should not be utilized, and welding of conduits should not be done.

Field bends should show no appreciable flattening of the conduit. The total number of bends should not exceed an amount that would prevent pulling cable through the conduit without exceeding permissible pulling tensions or sidewall pressures. The NEC Articles 342, 344, 348, 350, 352, 353, 355, 356, and 358 provide guidance for the maximum number of bends between pull points permitted in a run of conduit. Large radius bends should be used to reduce the cable sidewall pressure during cable installation and in conduit runs when the bending radius of the cable to be contained in the conduit exceeds the radius of standard bends. The conduit bend radius should not be less than the minimum pulling bend radius of the cable as allowed by the cable manufacturer.

Conduits installed in concrete should have their ends plugged or capped before the concrete is poured.

All conduit interiors should be free of burrs and should be cleaned after installation.

Exposed conduit should be marked in a distinct permanent manner at each end and at points of entry to, and exit from, enclosed areas such as manholes and vaults.

Flexible conduit connections should be used for all motor terminal boxes and other equipment which is subject to vibration. The connections should be of minimum lengths and should comply with the minimum trained bending radii established by the cable manufacturer. Since the cross-sectional area of the ground return path is small in flexible conduit, adequate provisions should be made to maintain the continuity of the ground return path through the flexible section. In some cases, the flexible conduit may be supplemented with a ground jumper or similar device.

Conduit should not be installed within 30 cm (12 in) of hot pipes or other heat sources. This recommendation assumes that the hot pipe is insulated and allows for insulation removal in the event of any future pipe maintenance or modification work. This minimum distance also allows for some air flow around the conduit.

Proper fittings should be used at conduit ends to prevent cable damage.

Conduit building entrances should be provided with barriers or conduit seals to protect against rodents, fire, and weather.

## **9.3 Cable tray**

### **9.3.1 Tray construction**

Cable tray design should be based upon the required loading and the maximum spacing between supports. Loading calculations should include the static weight of cables and a concentrated load of 890 N (200 lbf) at mid-span. The tray loading factor (safety factor) should be at least 1.5 based on collapse of the tray when supported as a simple beam. Refer to NEMA VE 1 [B43] for metallic tray or NEMA FG 1 [B39] for fiberglass tray, and NEMA VE 2 [B44] for cable tray installation guidelines.

When the ladder-type tray is specified, rung spacing should be a nominal 23 cm (9 in). For horizontal elbows, rung spacing should be maintained at the center line.

Cable tray covers should be provided on the top tray to minimize the accumulation of fluids and debris in the trays. Raised covers may be used to avoid additional de-rating of the cable.

### 9.3.2 Tray system layout

The optimal vertical spacing for cable trays is a minimum of 30 cm (12 in), measured from the bottom of the upper tray to the top of the lower tray. A minimum clearance of 23 cm (9 in) should be maintained between the top of a tray and beams, piping, etc., to facilitate installation of cables in the tray.

Cables installed in stacked cable trays should be arranged by descending voltage levels, with the higher voltage at the top.

For stacked trays, the structural integrity of components and the pullout values of support anchors and attachments should be verified.

Trays should not be installed within 30 cm (12 in) of hot pipes and other heat sources. This recommendation assumes that the hot pipe is insulated and allows for insulation removal in the event of any future pipe maintenance or modification work. This minimum distance also allows for some air flow around the tray.

### 9.3.3 Tray application

The materials from which the trays are fabricated include aluminum, galvanized steel, stainless steel, and fiberglass. In selecting material for trays, the following should be considered.

A galvanized tray installed outdoors will corrode in locations such as near the ocean due to the humid salt air, or immediately adjacent to a cooling tower where the tray may be continuously wetted by chemically treated water. If an aluminum tray is used for such applications, a type resistant to corrosion should be specified. Special coatings for a steel tray may also serve as satisfactory protection against corrosion. The use of a nonmetallic tray should also be considered for such corrosive applications.

When comparing aluminum and steel trays, there are many properties that are different between these metals. Below are a few that may help when choosing between an aluminum tray and a galvanized steel tray. Note that differences in alloys and coatings can affect the choice as well.

- a) Corrosion—Aluminum tray may be better in some wet or corrosive areas. Whether aluminum is better than steel is dependent on the coating materials used on steel for corrosion protection. In highly corrosive areas, a nonmetallic tray or a stainless steel tray may be more suitable. Consult the tray manufacturer for more information or further guidance.
- b) Physical properties—Aluminum is lighter than steel and depending upon the tray design, it may be easier to install. Depending upon the alloy and temper used, steel may be able to carry a greater load.
- c) Expansion coefficient—The expansion characteristics as well as the change in load bearing properties with temperature are different between aluminum and steel. The rate of expansion needs to be considered when grounding the tray.
- d) Fire resistance (melt point)—Aluminum tray is generally not recommended where the tray is expected to be used as a support in a fire because of the much lower melting temperature of aluminum than steel.
- e) Grounding (conductivity)—Aluminum conductivity varies with the alloy, but aluminum is generally much more conductive than a steel tray. Appropriate precautions with dissimilar metals and expansion coefficients should be considered at ground connections.
- f) Other electrical effects—Aluminum is not magnetic, but mild steel that is used for galvanized steel trays is magnetic. In general, no de-rating of the cables in the tray is required based on magnetic properties of the tray.

For cable trays and tray supports located outdoors, the effect of the elements on both the structure and the trays should be considered. Ice, snow, and wind loadings should be added to tray and cable loads. Aluminum alloys 6061-T6, 6063-T6, and 5052-M34 are typically used, with careful recognition of the differences in strength. Steel tray that is mill-galvanized should normally be used for indoor applications in non-corrosive environments. Steel tray that is hot-dipped galvanized after fabrication should be used for outdoor and damp locations.

When the galvanized surface on the steel tray is broken (i.e., nicked, cut, damaged, scraped, etc.), the area should be recoated to protect against corrosion. The layer of galvanize is designed to sacrificially corrode to protect the steel when it has dissipated in the damaged area, then corrosion of the underlying steel may occur. Recoating should help to prevent the corrosion from progressing.

### **9.3.4 Tray loading capacity**

The quantity of cable installed in any tray may be limited by the structural capacity of the tray and its supports. Tray loading capacity is defined as the allowable weight of wires and cables carried by the tray. This value is independent of the dead load of the tray system. In addition to, and concurrent with, the tray loading capacity and the dead weight load of the tray system, a tray should neither fail nor be permanently distorted by a concentrated load of 890 N (200 lb) at mid-span whether the load is at the center line of the tray or on either side rail.

### **9.3.5 Cable tray installation**

Drop-out fittings should be provided when they are required to maintain the minimum cable training radius.

Where conduit is attached to the tray to carry an exiting cable, the conduit should be rigidly clamped to the side rail. When conduit is rigidly clamped, consideration should be given to the forces at the connection during dynamic (seismic) loading of the tray and conduit system. Conduit connections through the tray bottom or side rail should be avoided.

Covers should be provided on exposed vertical tray risers at floor levels and other locations where potential physical damage to the cables could occur.

### **9.3.6 Tray grounding**

Cable tray systems should be electrically continuous and solidly grounded. When cable trays are used as raceways for solidly grounded or low-impedance grounded power systems, consideration should be given to the tray system ampacity as a conductor. Inadequate ampacity or discontinuities in the tray system may require that a ground conductor be attached to, and run parallel with the tray, or that a ground strap be added across the discontinuities or expansion fittings. The ground conductor may be bare, coated, or insulated, depending upon metallic compatibility.

### **9.3.7 Identification**

Cable tray sections should be permanently identified with the tray section number as required by the drawings or construction specifications.

### 9.3.8 Supports

The type and spacing of cable tray supports generally depends on the loads. Tray sections should be supported near section ends and at fittings such as tees, crosses, and elbows. Refer to NEMA VE-1 [B43] or NEMA VE-2 [B44] for more information.

## 9.4 Wireways

Wireways are sheet metal troughs with hinged or removable covers for housing and protecting wires and cables. Wireways are used for exposed installations only and should not be used in hazardous areas. Guidance in the determination of hazardous areas is given in the NEC. Consideration should be given to the wireway material where corrosive vapors exist. In outdoor locations, wireways should be of rain-tight construction. The sum of the cross-sectional areas of all conductors should not exceed 40% of the interior cross-sectional area of the wireway. Taps from wireways should be made with rigid, intermediate metal, electrical metallic tubing, flexible-metal conduit, or armored cable.

## 9.5 Direct burial, tunnels, and trenches

### 9.5.1 Direct burial

Direct burial of cables is a method whereby cables are laid in an earth excavation with cables branching off to various pieces of equipment. The excavation is then backfilled. A layer of sand or cement stabilized sand is usually installed below and above the cables to prevent mechanical damage. Care should be exercised in backfilling to avoid large or sharp rocks, cinders, slag, or other sharp materials. A warning system to prevent accidental damage during excavation is advisable. Several methods may be used including treated wood planks, a thin layer of colored lean concrete, a layer of cement stabilized sand, a layer of sand, strips of plastic, and above ground markers. Untreated wood planks may attract termites, and overtreatment may result in leaching of chemicals harmful to the cables. Spare cables or ducts may be installed before backfilling. This system has low initial cost but does not lend itself to changes or additions and provides limited protection against the environment unless moisture barrier sheaths are used. For more information, see references [B3] and [B30]. Damage to cables in a direct burial system requires excavation at the point of damage to make a repair. For more information on direct burial systems, see NESC Section 35 and NEC Section 300.5.

### 9.5.2 Cable tunnels

Walk-through cable tunnels may be used where there are a large number of cables to be run. This system has the advantages of minimum interference to traffic and drainage, good physical protection, ease of adding cables, shielding effect of the ground mat, and the capacity for a large number of cables. Disadvantages include high initial cost and danger that fire could propagate between cable trays and along the length of the tunnel. Fire hazards may be reduced by providing fire stops; however, if fire stops are applied, the effect on the cable ampacity should be evaluated. Cables with ratings for limited fire propagation [B33] may also reduce the fire hazard, while cables with ratings for reduced flame propagation and low smoke properties should further reduce both the fire propagation and safety hazards.

### 9.5.3 Permanent trenches

Trench systems, also called troughs, consist of large groups of cables, usually main runs, through the centers of equipment groups, with short runs of conduit, smaller trenches, or direct-burial cable branching off to individual pieces of equipment.

Duct entrances may be made at the bottom of open-bottom trenches or through knockouts in the sides of solid trenches.

Trenches may be made of cast-in-place concrete, fiber pipes coated with mastic, usually of a bituminous nature, or precast concrete.

Where trenches interfere with traffic, vehicle crossovers, permanent or temporary, may be provided as needed. Warning posts or signs should be used to warn vehicular traffic of the presence of trenches.

The trenches may interfere with surface drainage and should be sloped to storm sewers, sump pits, or French drains. Open-bottom trenches may dissipate drainage water but are vulnerable to rodents. A layer of light concrete or cement stabilized sand applied around the cables in the trench may protect the cables from damage by rodents. Trenches at cable entrances into buildings should be sloped away from the building for drainage purposes. The trenches also should have a barrier to prevent fire or rodents from entering the building.

The tops of the trench walls may be used to support hangers for grounded shield conductors. The covers of trenches may be used for walkways. Consideration should be given to grounding metal walkways and to providing clearance above raised walkways for safe passage. Caution should be given to the use of wood for walkways and structural components of the trench due to the potential flammability of wood.

### 9.6 Floor trenches

Trenches cast into concrete floors may be extensive, with trenches run wherever required; or a few trenches may be run under the electrical equipment with conduits branching to various pieces of equipment.

Removable covers may be made of metal, plywood, or other materials. Nonmetallic cover materials should be fire retardant. Trenches cast into concrete floors should be covered.

Where cables pass through holes cut in covers (i.e., in rear or inside of switchboards) the edges should be covered to prevent cable damage from contact with the sharp edges.

### 9.7 Raised floors

Raised floors, often used in computer rooms, provide maximum flexibility for additions or changes. Entrance from the outside into the raised floor system may be made at any point along a wall. A tray system under a raised floor should be considered whenever the number of cables to be installed is large or when different cable types (i.e., instrument, control, LV power, fiber optic, data transmission, etc.) are anticipated. Use of a fire protection system under the floor should also be considered.

## Annex A

(informative)

### Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

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[B2] ASTM E119-12, Standard Test Methods for Fire Tests of Building Construction and Materials.<sup>8</sup>

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[B15] ICEA S-97-682-2007, Standard for Utility Shielded Power Cables Rated 5 through 46 kV.

[B16] IEC 60287-1-1 (2006) Electric cables—Calculation of the current rating—Part 1-1: Current rating equations (100% load factor) and calculation of losses—General.<sup>10</sup>

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<sup>7</sup> AEIC publications are available from the Association of Edison Illuminating Companies, 600 N. 18th Street, P. O. Box 2641, Birmingham, AL 35291-0992, USA (<http://www.aeic.org/>). AEIC publications are also available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112-5704, USA (<http://global.ihs.com/>).

<sup>8</sup> ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

<sup>9</sup> ICEA publications are available from the Insulated Cable Engineers Association, ICEA P.O. Box 1568 Carrollton, GA 30112, USA (<http://www.icea.net/>).

- [B17] IEEE Std 400-2012, IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above.<sup>11</sup>
- [B18] IEEE Std 400.1-2007, IEEE Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage.
- [B19] IEEE Std 400.2-2004, IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF).
- [B20] IEEE Std 400.3-2006, IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment.
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<sup>10</sup> IEC publications are available from the Sales Department of the International Electrotechnical Commission, 3 rue de Varembe, PO Box 131, CH-1211, Geneva 20, Switzerland (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org>).

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