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9.0 ENCLOSED ELECTRICAL/ELECTRONIC EQUIPMENT

9.1 PURPOSE

This section provides guidelines to

1. complement existing electrical codes and recommend industry standards,
2. improve electrical safety in the work environment for personnel within the DOE complex.
3. eliminate the ambiguity and misunderstanding in design, construction and implementation requirements for electrical/electronic equipment, and
4. assist the Authority Having Jurisdiction in providing information for acceptance of equipment within the scope of this document.

9.2 SCOPE

This section addresses enclosed electrical/electronic equipment electrical safety guidelines which are not specifically addressed elsewhere in the *Electrical Safety Handbook*.

These types of equipment include: instrumentation and test consoles; enclosed electrical/electronic equipment; other laboratory diagnostic electrical/electronic equipment (stationary or mobile) mounted in or on an enclosure or chassis; and special electrical/electronic equipment facility requirements.

9.3 GROUNDING AND BONDING

Many ground system types exist within electrical equipment. All metal parts of electrical equipment enclosures and chassis shall be bonded and grounded as per the NEC. The methods chosen to avoid ground loops and reduce noise shall meet the requirements of the NEC (See Section 4).

9.3.1 OBJECTIONAL CURRENT OVER GROUNDING CONDUCTORS

Enclosed Electrical/Electronic equipment has both power and signal conductors entering and leaving these enclosures. Objectional currents and noise may be the result of the design or installation of conductors and equipment and their grounding locations. NEC Section 250-21 addresses these objectional currents and noise (See Section 10.9.2.1).

NEC Section 250-21 must be used with care because it seems to give blanket authority to do whatever is necessary to stop objectionable currents from flowing in the grounding system. This is not the intent. This article specifically excludes modifying grounding systems in order to overcome noise that may be causing problems in sensitive electronic equipment.

This NEC Section principally deals with objectionable currents that can flow over grounding conductors due to severely unbalanced loads or improper installation practices. Because of the

complexity and number of interconnections of most grounding systems, the NEC allows modifications of the grounding system and connections in order to address such problems. Those permitted:

- 1) Arrangement to prevent objectionable current. Grounding of electric systems, circuit conductors, surge arresters, and conductive noncurrent-carrying materials and equipment shall be installed and arranged in a manner that will prevent an objectionable flow of current over the grounding conductors or grounding paths.

Use of a single-point grounding system, as well as meeting the other requirements of Article 250, will usually overcome problems.

- 2) Alterations to stop objectionable current. If the use of multiple grounding connections results in an objectionable flow of current, one or more of the following alterations are permitted to be made, provided that the requirements of NEC Section 250-51, are met. Such permitted alterations are:
 1. Discontinue one or more, but not all, of the grounding connections;
 2. Change the locations of the grounding connections;
 3. Interrupt the continuity of the conductor or conductive path interconnecting the grounding connections; and/or
 4. Take other suitable remedial action satisfactory to the authority having jurisdiction.
- 3) Temporary currents resulting from accidental conditions, such as ground-fault currents, that occur only while the grounding conductors are performing their intended protective functions shall not be classified as objectionable. This does not prohibit changes in the system to correct excessive current during a fault condition.
- 4) Limitations of permissible alterations. The intent of NEC Section 250-21 is not that of permitting electronic equipment to be operated on AC systems or branch circuits that are not grounded as required by Article 250. Currents that introduce noise or data errors in electronic equipment are not considered to be the objectionable currents addressed in this Section.

Voltage differences do exist because impedances to ground are not equal throughout a grounding system due to variations of the resistance of the earth, improper connections, or other problems.

Even though voltage differences allow unwanted currents to flow in the grounding conductors, and induced noise may travel over this path, it is not to be used as a reason to disconnect the grounding connections.

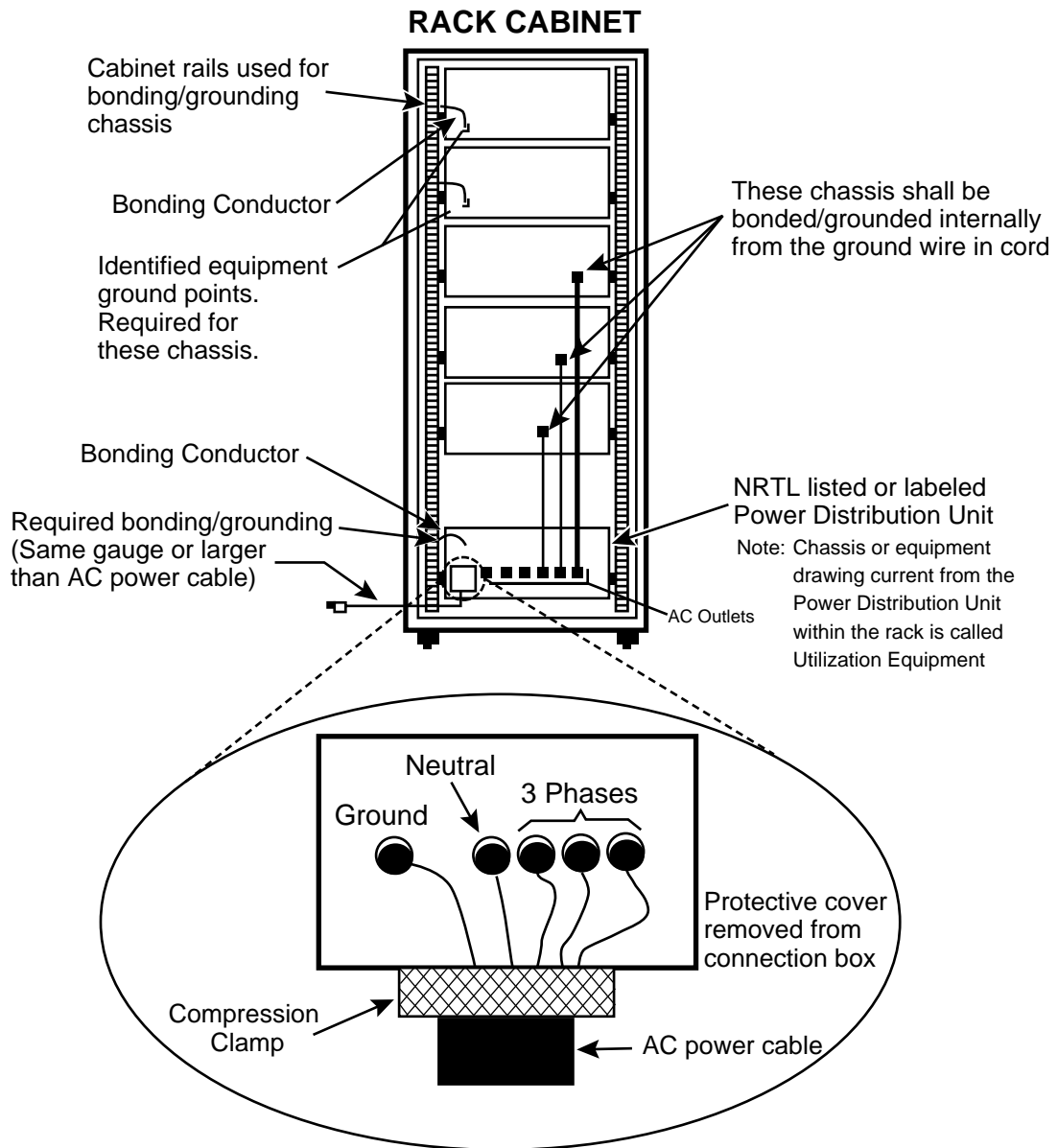
9.3.2 EQUIPMENT GROUNDING CONDUCTOR

The equipment grounding conductor of a power-supply cord or interconnecting cable should be at least the size of the largest circuit conductor in the power-supply cord or interconnecting cable. (ANSI/ISA-S82.01-1988 - Section 9.5.4.2)

9.3.3 ENCLOSURE GROUNDING AND BONDING

Enclosure grounding and bonding should comply with the following requirements: (See Figs. 9-1 thru 9-3)

- 1) Have a common grounding or bonding bus (normally a cabinet rail).



Note: This drawing represents typical 120/208 Volt, Three Phase Wye, 5 wire, ac power.

Figure 9-1

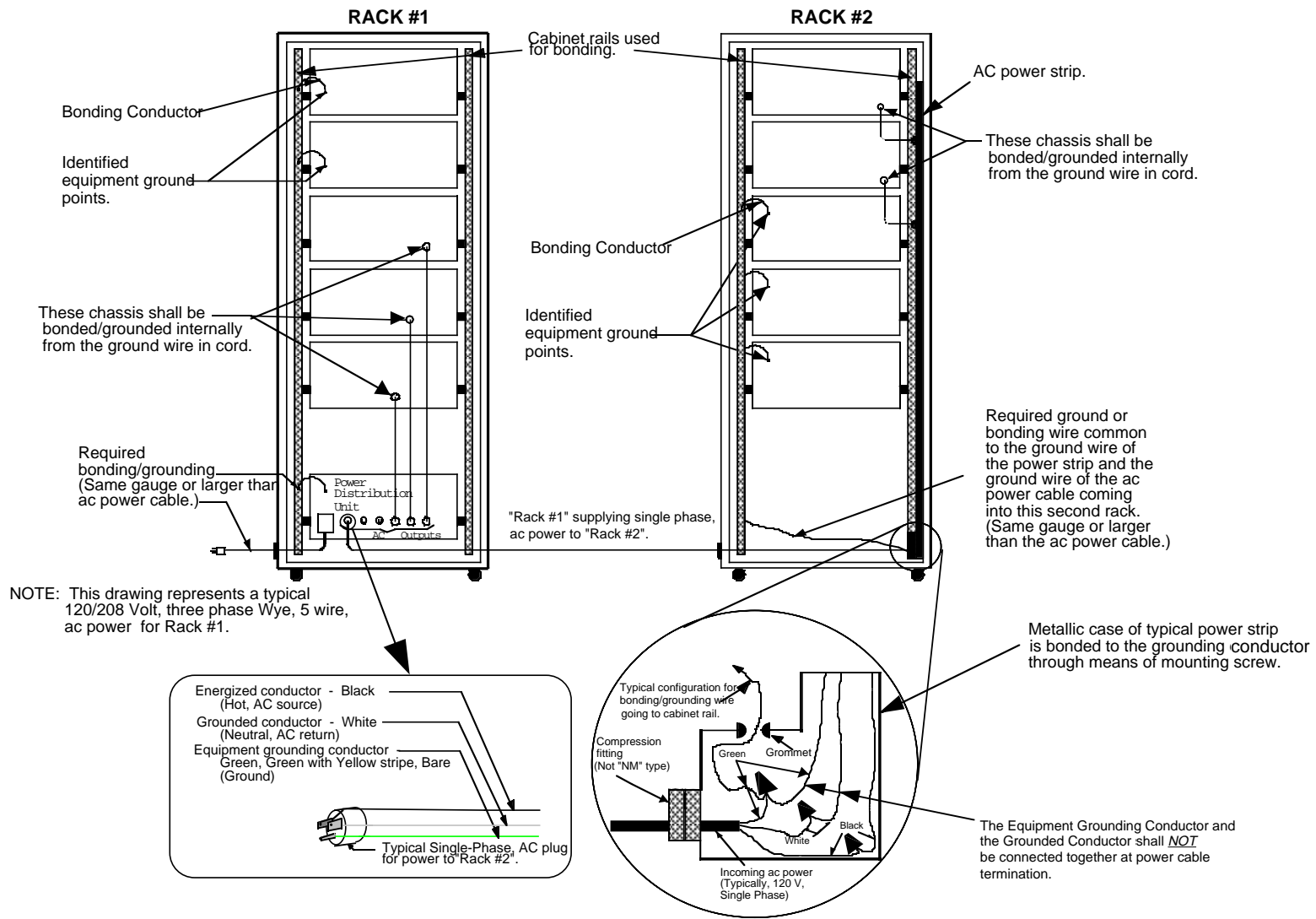
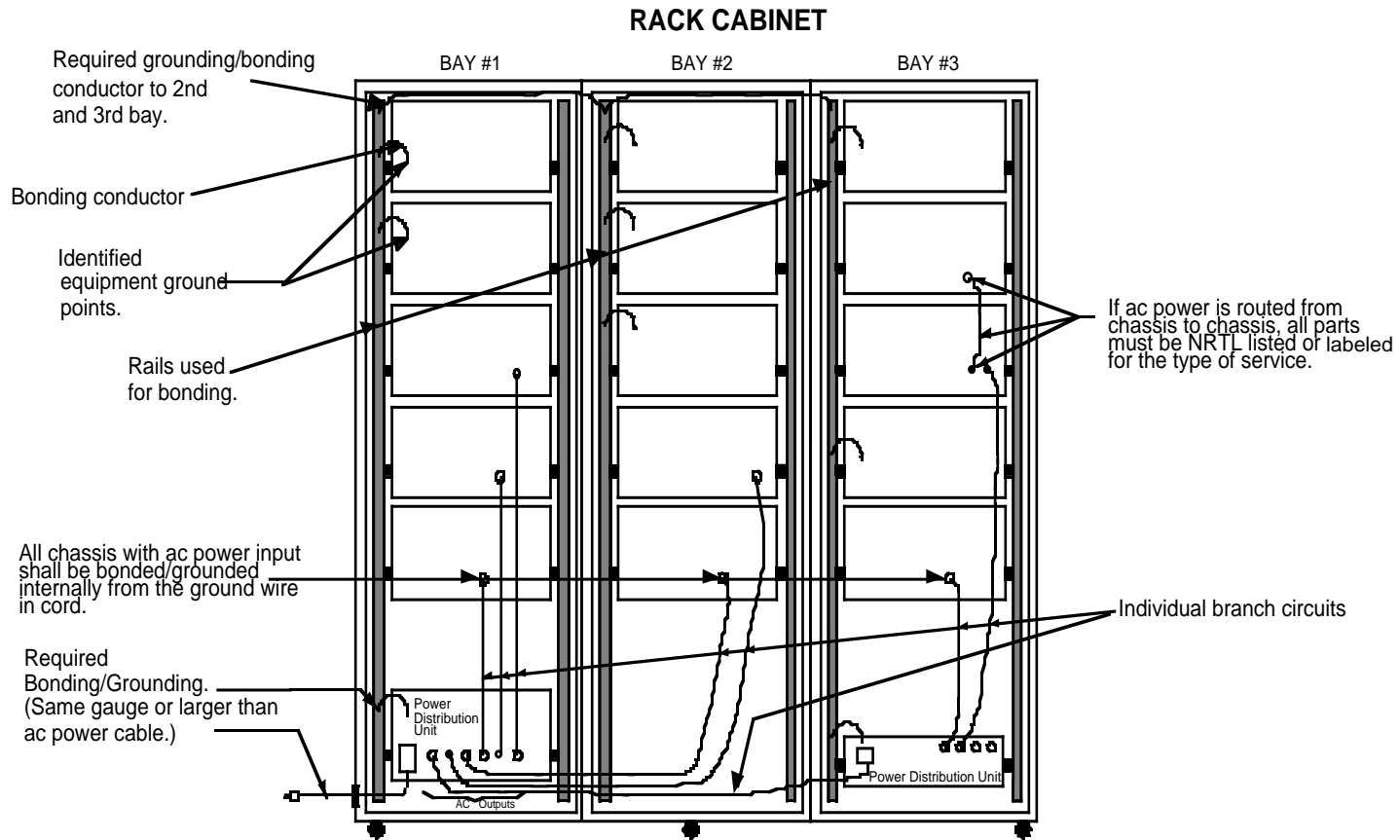


Figure 9-2



- NOTES: 1. This drawing represents typical 208/120-V, Three Phase Wye, 5 wire, ac power for Rack #1.
2. Multiple bays must be bonded together even if multiple Power Distribution Units are installed in separate bays.

Figure 9-3

- 2) When the enclosure contains more than one bay, bond all grounding or bonding busses together.
- 3) All mounted chassis within rack cabinets shall have a grounding or bonding conductor attached to the common grounding or bonding bus when the chassis is not grounded or bonded through the power cord.
- 4) The grounding or bonding conductor shall be permanent and continuous.
- 5) Subassemblies mounted in other types of enclosures should be bonded by adequate preparation of the mounting surfaces or by the use of a bonding conductor.
- 6) To provide protection against grounding or bonding conductor breakage, conductors between the common grounding or bonding bus and moveable chassis should be braided cable or stranded wire.

All grounding or bonding points should be tight for good continuity, identified by green color, permanently labeled, and properly prepared by cleaning metal surfaces to bare metal or by the use of serrated bushings. Anodized aluminum must be cleaned to bare metal.

The resistance across the bonding point should not be more than 0.1 ohm. If a measurement is required, the method of measurement is to be determined by the user. (See ANSI/ISA - S82.01 - 1988 - Section 9.5.2)

9.3.4 SPECIAL CONSIDERATIONS

Systems feeding power isolation transformers must continue the equipment grounding conductor to the equipment or the ungrounded equipment must be guarded and labeled.

For two-wire cord connected equipment, an equipment grounding connector should be installed according to the manufacturer's instructions.

9.4 RACK POWER DISTRIBUTION

The following guidelines will provide the necessary information to correctly install power distribution equipment within instrumentation racks containing electrical and electronic equipment.

9.4.1 GENERAL REQUIREMENTS APPLYING TO ALL AC POWER EQUIPMENT WITHIN OR ATTACHED TO INSTRUMENT RACKS

9.4.1.1 LOADS

Knowledge of the loads that will be connected within a rack cabinet is necessary before starting design of a rack power distribution system. All components must be sized correctly for the loads and should provide for expansion.

Equipment enclosures may or may not contain a power distribution unit. A rack power distribution unit contains a main overcurrent protection device and multiple branch circuits that are individually protected against overcurrent. Without a power distribution unit, the power wiring is considered part of one branch circuit.

Branch circuit loading shall meet the requirements of Article 210 of the NEC. (See NEC Sections 210-21 through 210-23).

External convenience outlets should be connected to a separate circuit breaker.

Where 3 phase 4 wire service is utilized, the loads should be evenly distributed on all phases and there should be consideration of sizing the neutral conductor for certain loads (such as computer equipment) due to the presence of harmonic currents. (See NEC Sections 210-4 and 310-10).

9.4.1.2 OTHER GENERAL EQUIPMENT REQUIREMENTS

Rack power distribution components or assemblies must be listed by a Nationally Recognized Testing Laboratory (NRTL), nationally recognized standards, or have the approval of the Authority Having Jurisdiction (See Section 2.5).

9.4.2 CONDUCTORS AND CABLES SPECIFIC REQUIREMENTS.

Each type of internal wiring for equipment or an accessory shall be acceptable for the particular application when considered with respect to (1) the current, ambient temperature, voltage, and other conditions of service to which the wiring can be subjected, and (2) exposure to oil or grease.

The term “cables” refers to groupings of wires typically used for control signals, data, or DC power. The term “cords” refers to AC power cords.

The basic insulation on each wire shall be rated for at least the maximum voltage to which the wire is connected, and for at least the temperature it attains. (ANSI/ISA-S82.01-1988 Section 9.4.3)

Insulating tubing, sleeving, and tape shall be rated for at least the maximum voltage against which it insulates, and for at least the temperature it attains. (ANSI/ISA-S82.01-1988 Section 9.4.4)

Power and signal wires should be routed separately within a chassis.

Wires shall be routed away from sharp edges, screw threads, burrs, moving parts, etc. Holes through which wires are routed shall have smooth, well-rounded surfaces, or shall have a bushing. Clamps for guides used for routing or wiring shall have smooth, well-rounded edges. Pressures exerted by such clamps should not cause cold-flow or otherwise deform the basic insulation. (ANSI/ISA-S82.01-1988 Section 9.4.2)

9.4.2.1 FLEXIBLE CABLES

Flexible cables may be used:

1. Where flexible cables and attachment plugs are furnished by the manufacturer as part of the equipment to be mounted in the rack.
2. For connection of stationary equipment to facilitate their frequent interchange.
3. To prevent the transmission of mechanical vibration.

4. Where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance and repair.
5. For data processing cables approved as part of the data processing system.
6. For temporary wiring.

Where breaking or loosening of a circuit connection would render an electric shock or could result in a fire, such connection shall be made mechanically secure. Mechanical security of connections may be provided by crimped, closed ring or flanged lug, or a wrapping that forms at least an open U or by cable clamps, or by cable lacing, insulating tubing, or similar means.

9.4.2.2 STRAIN RELIEF

Wiring, cords, or cables shall be provided with strain relief as required to prevent damage.

Additional insulation may be required when the construction of the strain relief may damage the insulation. The use of type NM (Romex) cable clamps on flexible cords and cables is not permitted. Use listed or labeled clamps. The use of any metal clamp or other means that may cause undue stress on the cables within or external to instrument racks is not allowed. Cord and cable support for AC power cable or other heavy duty or large diameter cables must distribute the load over a large area of the outer covering of the cable.

9.4.2.3 SEPARATION OF VOLTAGES

Insulated conductors of different circuits shall be separated or segregated from uninsulated live parts connected to different circuits unless provided with insulation suitable for the highest voltage involved.

Segregation of insulated conductors may be accomplished by clamping, routing, or equivalent means that provide permanent separation from insulated or uninsulated live parts of a different circuit.

Loose strands of stranded internal wiring, connected to a wire-binding screw, shall be prevented from contacting other uninsulated live parts not always of the same potential and from contacting noncurrent carrying metal parts. This may be accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, or soldering all strands of the wire together.

9.4.2.4 OTHER CONCERNS

Conductors shall not be bundled together in such a way that the temperature rating of the conductors is exceeded.

Flexible cord should be used only in continuous lengths without splice or tap when initially installed.

Repairs are permitted if the completed splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.

9.4.3 POWER SWITCHES AND INTERLOCK DEVICES SPECIFIC REQUIREMENTS

For all electrical/electronic enclosures utilizing power switches or interlocks, the following should apply:

1. Interlocks should be utilized where exposed voltages (50 volts or greater) are present in equipment and access to the exposed live parts is not controlled (See Section 9.6.4).
2. Ensure all line side unprotected contacts are guarded on interlocking contactors or other switching equipment.
3. Be suitable for the conditions, use, and location.
4. Circuit breakers used for the equipment power switch will be rated for switching under load.
5. Provide provisions for Lockout/Tagout requirements.

9.5 CHASSIS POWER DISTRIBUTION

Manufacturers are responsible for determining the safety of such chassis and/or enclosures and for providing documentation showing how that determination was made. Unlisted commercial equipment and in-house fabricated equipment shall be approved by the local Authority Having Jurisdiction.

9.5.1 AC POWER DISTRIBUTION

9.5.1.1 CHASSIS BONDING AND GROUNDING

Metal chassis shall be effectively bonded to a main grounding point in the rack cabinet where necessary to assure electrical continuity and shall have the capacity to conduct safely any fault current likely to be imposed on it. (NEC Section 250-75)

In a chassis with ac service connected to it, the grounding terminal of its receptacle shall be internally bonded to the chassis frame. (NEC Section 250-74)

If solder is used, the connection of the equipment grounding conductor shall not depend on solder alone. (ANSI/ISA-S82.01-1988 - Section 9.5.4.4 and NEC Section 250-115)

The leakage current of cord connected equipment should not be more than specified in Subclause 9.11 of ANSI/ISA-S82.01-1988.

9.5.1.2 CONNECTIONS, CONNECTORS, AND COUPLINGS

Input/output ac power connections to the chassis shall comply with NEC requirements.

The exposed, noncurrent carrying, metal parts of panel mount connectors operating at 50 volts or greater shall be bonded to the chassis.

Plugs and sockets for connecting any AC power source shall be NRTL approved for the application. (Ref. ISA-S82.01-1992, Section 6.10.3.a)

AC power plugs and sockets shall not be used for purposes other than the connection of AC power.

Connectors operating at 50 V or greater shall be rated or recommended for their intended use.

Any connector used to provide power at 50 V or greater shall not allow personnel to make inadvertent contact with the power source.

If plug pins of cord-connected equipment receive a charge from an internal capacitor, the pins shall not be capable of rendering an electric shock or electric burn in the normal or the single fault condition 5 seconds after disconnection of the supply. (Ref. ISA-S82.01-1992, Section 6.10.3.c)

Plug-in type connectors intended to be connected and disconnected by hand shall be designed so that the grounding conductor connection makes first and breaks last with respect to the other connections. [See ISA-S82.01-1992, Section 6.11.2.g and NEC Section 250-99(a)]

The following applies for all AC power connectors within or external to electrical/electronic enclosures:

1. There should be no exposed current-carrying parts except the prongs, blades, or pins.
2. The connector shall prohibit mating of different voltage or current rating than that for the device intended.
3. All connectors must be protected against overcurrent in accordance with their rated ampacity. (NEC Section 240-4)
4. Connectors must be NRTL approved for the application.
5. Use of MS, PT, or other non-approved connectors is not permitted except when justified to and approved by the AHJ.

If conditions require the use of a non-NRTL listed or labeled connector, such as a “MS”(military standard pin and socket type) or “PT” (similar to “MS” but smaller) type, for input/output ac power, a warning label should be affixed next to the connector stating: “WARNING - POWER MUST BE REMOVED BEFORE CONNECTING/DISCONNECTING.”

9.5.1.3 TERMINALS/LIVE PARTS

All terminals/live parts with a potential of 50 volts or greater shall be guarded to protect from accidental contact or bringing conductive objects in contact with them (NEC Section 110-17). Consult ANSI/ISA-S82.01-1988, Table 9-1 for spacing information regarding live parts.

All energized switching and control parts shall be enclosed in effectively grounded metal enclosures and shall be secured so that only authorized and qualified persons can have access.

9.5.2 DC POWER DISTRIBUTION

Guidelines for dc power distribution include:

1. The metal chassis or cabinet should not be used as a return path.
2. High-current analog or switching dc power supplies should use separate return paths from digital circuits.
3. All of the guidelines pertaining to ac power such as grounding, proper wire size, high voltage, etc. should apply to dc circuits as well.

An accessible terminal charged by an internal capacitor should be below 50 volts within 10 seconds after interruption of the supply. (ANSI/ISA-S82.01-1988 - Section 9.3.5.2)

As with ac power, avoid contacting dc parts when working on a live chassis. The use of the appropriate class gloves should be considered when performing this type of work.

9.6 PROTECTIVE DEVICES FOR ENCLOSED ELECTRICAL/ ELECTRONIC EQUIPMENT

This section deals with the various protective devices commonly found in electrical/electronic equipment not discussed elsewhere.

9.6.1 SURGE ARRESTERS

The more common types of surge arresters used with electronic equipment are the Metal oxide varistor (MOV), avalanche diodes, and spark gap arresters. The type and electrical rating of the surge arrester is generally determined by the requirements of the circuit being protected, and by the amplitude and duration of the expected surge. (See ANSI/IEEE C62.11-1986.)

Metal oxide varistors and avalanche diodes are voltage-dependent devices whose impedance changes from a near-open circuit to a highly conductive level when subjected to transient voltages above their rated voltages. A MOV is considered “sacrificial” in that a portion of its material is literally burned-off each time such a surge is encountered. The response time of a MOV is limited to approximately 500 picoseconds while avalanche diodes can respond in approximately 50 picoseconds. Lead lengths can greatly increase the response times of these devices. The normal failure mode of both devices is a short circuit although sustained voltages well beyond the rating of the MOV can cause the device to rupture and result in an open circuit. When used at a point on a circuit, a surge arrester should be connected between each ungrounded conductor and ground.

For power line applications, MOV manufacturers recommend a varistor be used with a fuse that limits the current below the level that MOV package damage could occur. In general, circuit breakers are not recommended for this application since circuit breaker tripping is too slow to prevent excessive fault energy.

Consult the manufacturer’s application data sheets for more information.

9.6.2 FUSES

Fuses are temperature-sensitive, current-sensing elements that are generally used as short circuit protective devices in individual electrical chassis. The fusing characteristic, or opening time versus current, must be within the safe time/temperature characteristic of the device being protected.

Designers must carefully consider the load requirements in the fuse selection process, particularly when high surge currents may be encountered during initial turn-on. Operating time/current characteristics of the various types available can usually be found in fuse manufacturers catalogs. A fuse's interrupting current capacity must also be considered when connected to a power distribution system having a significant fault current capacity.

The voltage rating on a fuse shall be equal to or greater than the device's operating voltage.

In general, cartridge fuses should have a disconnecting means on the supply side, (NEC Section 240-40), and shall not be connected in parallel unless factory assembled and listed as a unit (NEC Section 240-8).

9.6.3 CIRCUIT BREAKERS

A chassis or cabinet shall not employ circuit breakers as "on/off" switches unless rated for the application by the manufacturer.

9.6.4 POWER INTERLOCK DEVICES

Cabinets and equipment having potentially dangerous currents and/or voltages present should have a means of controlling access, or a power interlock device designed to interrupt the power to the cabinet. Provisions shall also be made to discharge any stored energy, such as in capacitors or inductors, to less than 50 volts within 10 seconds when the safety interlock is opened. Interlocks may not be used as a substitute for lockout/tagout. (29 CFR1910.333(c) and ANSI/ISA S82.01-1988, Section. 9.3.5.2)

9.7 DISCONNECTING MEANS

All enclosed electrical/electronic equipment shall be provided with a means for disconnecting it from each external or internal operating energy source. This disconnecting means shall disconnect all current carrying conductors.

9.7.1 GENERAL

Interlock systems are not a recommended disconnecting means for cabinets and equipment having potentially dangerous currents and/or voltages present. (See Section 9.6.4)

Permanently connected equipment and multi-phase equipment should employ a switch or circuit breaker as means for disconnection.

All cord-connected equipment should have one of the following as a disconnecting device:

1. A switch or circuit breaker,
2. Plug that can be disconnected without the use of a tool, or
3. A separable plug, without a locking device, to mate with a socket-outlet in the building.

Where equipment is connected to the source of supply by flexible cords having either an attachment or appliance plug, the attachment or appliance plug receptacle may serve as the disconnect (ANSI/ISA - S82.01 - 1988 - Section 13.10.1 and NEC Section 422-22).

Where a switch is not part of a motor, motor circuit or controller, the disconnecting means should be within 50 feet and in sight of the operator and marked as the disconnection device for the equipment.

Where a disconnecting means is not part of the equipment, the disconnecting means should be near the equipment, within easy reach of the operator during normal operation of the equipment, and marked as the disconnection device for the equipment.

If a disconnecting device is part of the equipment, locate it as close as practical to the input power source.

9.7.2 EMERGENCY SHUTDOWN

The emergency shutdown switch should be within arm's reach of the operator, be easily identifiable, deenergize all power to all equipment associated with the system, be separate from the routine on/off switch, and be located to protect the employee from moving parts. However, the emergency shutdown switch should not disconnect auxiliary circuits necessary for safety (such as cooling).

9.7.3 SPECIAL CONSIDERATIONS

The disconnecting means should interrupt the source voltage for thyristor controlled equipment. Do not rely on disconnecting the control voltage.

9.8 MARKING AND LABELING REQUIREMENTS

9.8.1 GENERAL MARKING REQUIREMENTS

For all chassis and rack cabinets (electrical, computer, power distribution, etc.), the manufacturer's name, trademark, or other descriptive marking of the organization responsible for the product should be identified.

Other markings for power requirements are:

1. Voltage.
2. Maximum rated current in amperes.
3. Wattage.
4. Frequency (computer only).
5. Other ratings as specified in the NEC.

(See ANSI/ISA-S82.01-1988 Section 5.3.4 and NEC Section 110-21)

9.8.2 HAZARD MARKING REQUIREMENTS

All enclosures containing exposed energized circuits over 600 volts nominal should be marked “Danger High Voltage Keep Out” with a label that is permanent. These areas shall be accessible to authorized personnel only. The label shall be placed in a noticeable location on the access panel to the enclosure. Mark all other hazards that are associated with the equipment.

9.8.3 OTHER REQUIREMENTS

All equipment markings shall be of sufficient durability to withstand the environment involved and should be large enough to read.

To obtain the correct chassis load requirements for marking and labeling, monitor individual chassis while under load. Many chassis have components that are not energized except under certain conditions.

A normal current draw may be a few amperes, but when the chassis is sourcing current to a load, the current draw may be much higher. Individual loads, internal and external, may be tabulated and added to determine the chassis current labeling requirements.

For rack cabinets with power distribution units, the outside of the rack cabinet should be labeled with the input parameters of the power distribution system installed within it.

For rack cabinets without power distribution units the outside of the rack cabinet should be labeled with the total current on the combined systems installed within it.

9.9 WORKING CLEARANCES

Clear working space and headroom shall meet the NEC requirements (see Figs. 9-4 and 9-5). The clear working space and passageways to this space should not be used for storage. At least one 24 inch wide (minimum) passageway should be provided for travel to and from the clear working space.

While maintenance, repair or calibration are being performed, personnel should identify clear working spaces via suitable means such as “Danger” or “Caution” barrier tape, or barricades to keep other personnel from entering the clear working spaces. (See Section 2.9.)

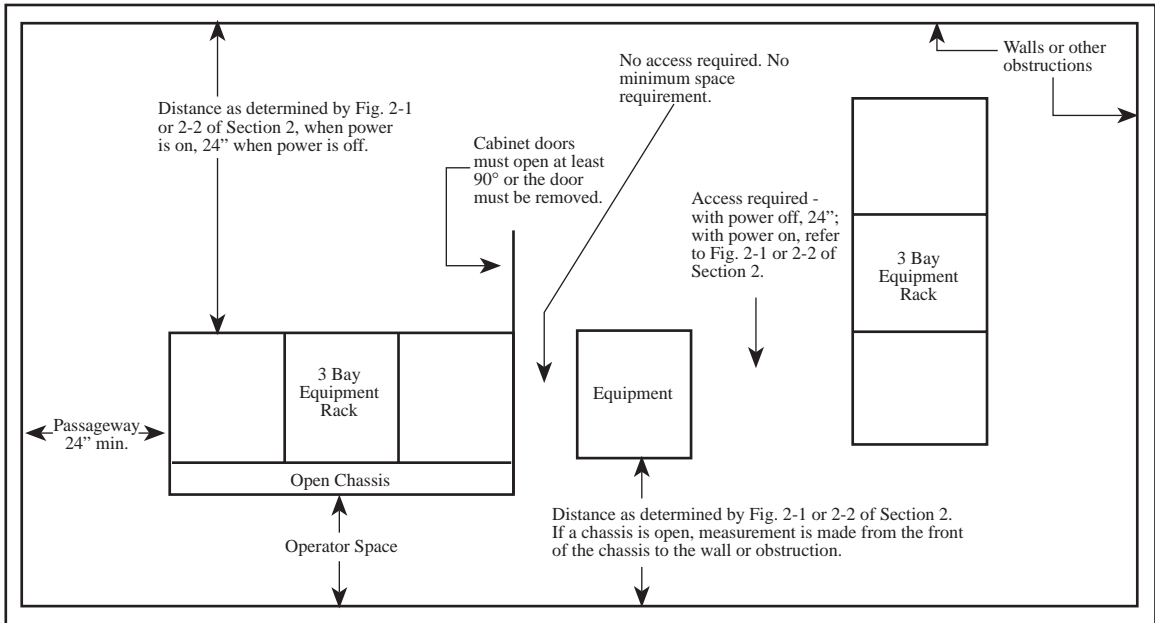


Fig. 9-4. Top View of Equipment Layout in a Room (Drawing is not to scale)

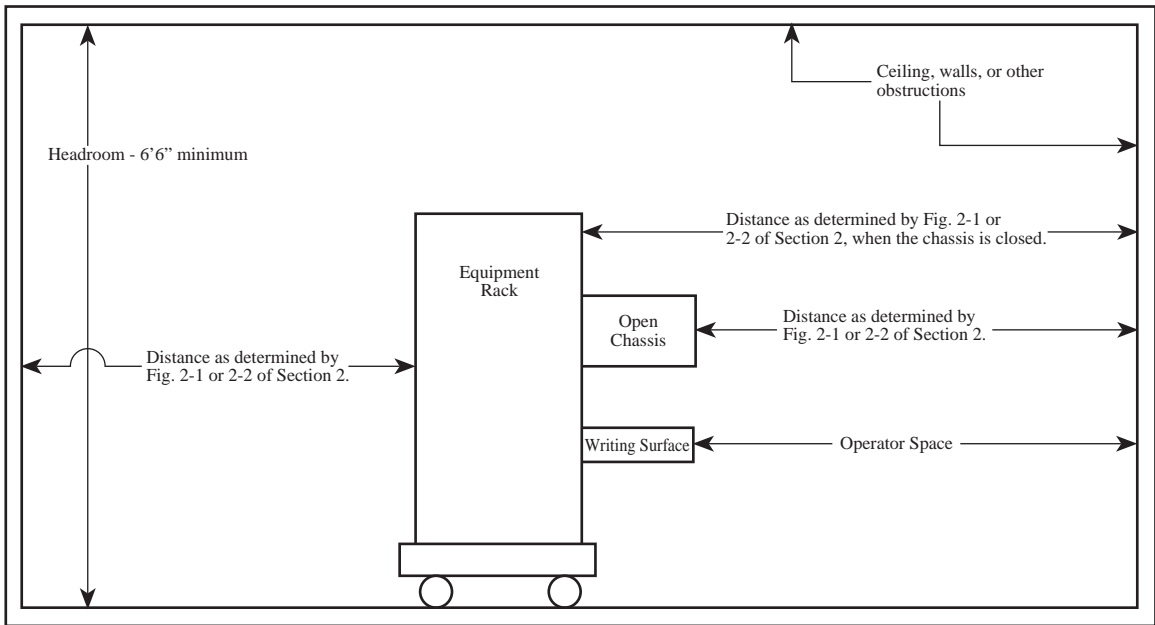


Fig. 9-5. Side View of Equipment Layout in a Room (Drawing is not to scale)

9.10 CABLE/UTILITY MANAGEMENT SYSTEM

Cable supports and/or cable enclosures are installed for dedicated usage with enclosed electrical/electronic equipment

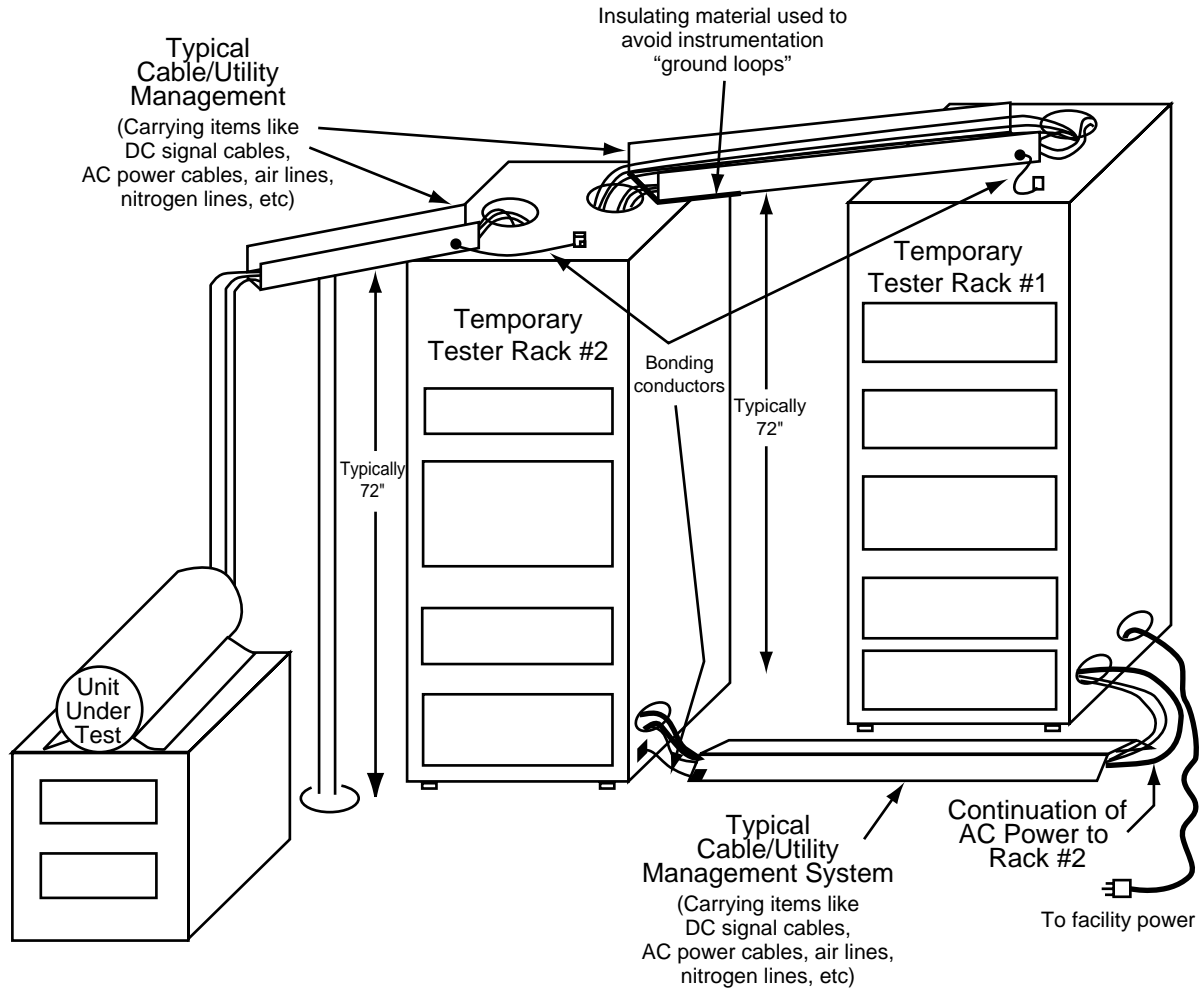


Figure 9-6

9.10.1 USAGE WITH ENCLOSED ELECTRICAL/ELECTRONIC EQUIPMENT

In certain locations cable supports and/or enclosures are installed for dedicated usage with enclosed electrical/electronic equipment. For these situations it is acceptable for these cable/utility management systems to be utilized for the required purposes of the equipment. This may include a bundle of cables, hoses, and tubing that is required to be run from the equipment console to the unit under test. In these situations the use of a cable/utility management system is considered to be a part of custom-made equipment consisting of enclosed electrical/electronic equipment, cabling, cable/utility management system, and unit under test with associated equipment (See Figure 9-6).

In cable/utility management systems where cables other than those of the equipment exist, the decision should be documented that any risk posed by the situation is acceptable for the operation to be performed and to the functions of the existing cables.

9.10.2 REQUIREMENTS

An assessment of any hazards identified with the equipment and the operation with which it is involved should be performed to assure safe operation of components in the cable/utility management system. Where any cable/utility runs include hazardous fluids or pressurized gases, the utilization of these utilities with the cables involved must be determined to be safe.

Metallic cable/utility management systems that support electrical conductors shall be grounded or bonded to the equipment. Where cable/utility management systems are installed exclusively for electrical/electronic equipment usage and where these trays are metallic and not grounded or bonded, approved documentation shall exist stating the reason for not grounding or bonding the system (See Section 9.3.1).

Equipment cable/utility runs installed in cable/utility management systems should be visually inspected. These inspections should be performed at the time of installation and any interval specified in the equipment documentation. Any inspection should, as a minimum, consist of:

1. A visual check for the integrity of cable jackets and visible shields;
2. A check for the integrity of all utility hoses by looking and listening for leaks;
3. A visual check on all securing devices used to hold the bundle on the tray to assure the bundle is positioned properly and no damage has occurred;
4. A visual inspection on all bends for signs of pinching, cutting, exceeding minimum cable bending radius, or other damage; and
5. Documentation of all results of any inspection.

Supports shall be provided to prevent stress and physical damage to cables where they enter or exit cable/utility management systems.

9.11 ELECTRICAL SAFETY REQUIREMENTS FOR TESTER FACILITIES

The following is not intended to encompass all of the electrical design requirements which must be considered in planning electrical systems for facilities intended to accommodate testers. The information provided should, however, provide a guide to understanding for personnel who would be tasked with specifying facility electrical safety necessary to the testing environment.

Provisions for an adequate number of receptacle outlets to accommodate cord and plug connected equipment, testers, etc., in a facility must also be considered in specifying the electrical requirements.

For equipment that cannot tolerate power interruption, consideration should be given to the use of a continuously operating or standby uninterruptable power supply (UPS) or a generator.

9.11.1 AMPACITY OF FACILITY WIRING AND DISTRIBUTION EQUIPMENT

Consideration must be given to accommodating the anticipated load demand which may occur as a result of power supplied to the various possible combinations of electrical equipment connected to a particular branch circuit (See Section 9.4).

9.11.2 FACILITY GROUNDING AT REMOTE SITES

Proper grounding is considered crucial to providing the safest possible electrical installation, from the standpoint of maximizing the safety of facility occupants and minimizing property damage and loss.

Designs for equipment to be used at remote sites must take into consideration the same grounding issues which may not be accommodated due to the lack of permanent facility power wiring (See Section 9.3).

9.11.3 FACILITY LIGHTNING PROTECTION

Lightning protection is required for facilities which will house enclosed electrical/ electronic equipment while such equipment is involved with radioactive, explosive, and similarly hazardous materials. (See Section 5.1)

9.11.4 SURGE PROTECTION

In addition to facility lightning protection, the effects of surges resulting from lightning strikes to power distribution systems may be lessened by the use of lightning arrestors and suppressors installed at strategic points in the supply system to the facility. An assessment is necessary, addressing the consequences of lightning-induced surges, in order to determine the degree to which protection should be provided.

For additional information see Section 9.6.1.

9.12 ENCLOSED POWER ELECTRONICS

Power electronics equipment is equipment that uses electronic components and subsystems to control significant amounts of electrical energy. Examples of power electronics systems include:

1. Power supplies and modulators for laser systems;
2. Accelerators, magnets, x-ray systems, and other research equipment;
3. Radio and radar transmitters;
4. Variable speed motor drives; and
5. Induction heating systems.

All applicable portions of this section should be addressed due to the hazards involved with this type of equipment.

9.12.1 ENCLOSURES

Power electronics equipment should be constructed in all-metal enclosures for containment of fire, high energy, and electromagnetic radiation hazards.

The enclosures should support the housed equipment, provide strength to brace conductors against short circuit forces, and protect housed equipment against physical damage.

It is usually easier to provide barriers to protect the electronics enclosure from collision and missile hazards rather than strengthening the enclosure itself.

9.12.2 COMPONENT CLEARANCES

Enclosures must provide adequate clearance from energized parts. The required clearances depend on the shape of the conductor, the surface characteristics of the conductor and enclosure, the voltage characteristics, environmental conditions, and creepage. The breakdown strength along the surface of supporting insulators may require larger clearances than breakdown in air.

All power electronics enclosures shall provide adequate room for access to parts and subsystems for expected maintenance and modification. Consideration should be given to handling provisions for heavy parts and subsystems, access to test points and calibration adjustments, and work clearances for safe access to enclosure interiors.

Safe work on high-voltage equipment requires installation of manual grounding devices on exposed high-voltage conductors. Enclosure size shall provide adequate room to safely apply and remove grounding devices, and permit grounding devices to remain in place without interfering with expected work.

Enclosures shall be sized to allow cables to be installed and routed without infringing on required clearances from high-voltage conductors.

Subassemblies, circuits, and related equipment should be segregated to the extent possible to minimize the possibility of a fault in one device damaging another.

9.12.3 INSTRUMENTATION

Power electronics systems can involve fast pulses, high frequencies and high currents and it is common for the voltage difference between ground in one circuit and ground in another circuit to differ substantially. This difference can be hundreds or thousands of volts. Wire and cable shall be insulated to withstand these potentials. Surge arrester and capacitor protection may be used to control these potentials. DC circuits connected to coils, solenoid valves and other inductive components should be tested for induced voltages and appropriate protection for circuits should be provided.

9.12.4 GENERAL

Test points needed for adjustment and diagnosis should be installed on the front panel or other appropriate location of power electronic systems to facilitate their use without exposure hazard to employees in the area.

Currents generated only during fault conditions or those introducing noise or data errors shall not be considered objectionable currents. Bonding and grounding connections shall not be altered to reduce the significance.

Conductors, busbars, and internal wiring should be insulated in the event objects are dropped into the equipment.

Automatic discharge devices are not a substitute for grounding devices used for personnel protection. Grounding points shall be located in the system and physically arranged to permit the attachment of adequate grounding devices for the protection of personnel working on the system.

These grounding points shall be capable of carrying the short-circuit current to which they may be subjected and applied using methods appropriate for the voltages or currents involved.

9.13 NON-IONIZING RADIATION

9.13.1 ELECTROMAGNETIC RADIATION

Human exposure to electromagnetic (EM) radiation at certain power-density levels can be hazardous. The hazards are generally regarded to be associated with the heating of biological tissue, which occurs when EM radiation is absorbed by a body. This heating is essentially similar to the cooking process in a microwave oven. Use caution where EM sources are being used with the shielding altered or removed.

When working with EM radiation, it is recommended that the emitted radiation levels be estimated by equations and measured by radiation hazard monitors.

EM radiation-safe levels have been established by the Institute of Electrical and Electronics Engineers and are documented in the IEEE standard - C95.1-1991.

Exposure to hazardous levels of EM radiation can be lessened by maintaining as much distance as possible from the source. Power density is reduced by a factor of four by doubling the distance from the source.

9.13.2 ELECTROMAGNETIC RADIATION THREAT TO ELECTROEXPLOSIVE DEVICES

Designers of enclosed electrical/electronic equipment must consider the possible effects on nearby electroexplosive devices (EED) of electromagnetic radiation (EMR), i.e., radio frequency (RF) energy, emitted by that equipment.

Energy induced into an EED by the electromagnetic field resulting from such emissions may be adequate to cause the device to detonate.

Factors which should be taken into account in assessing concerns for possible EMR emissions are:

1. Wiring, shielding, and sensitivity
2. Proximity
3. Frequency of the emissions causing coupling of electrical energy
4. Power density
5. Type of emission modulation

Possible measures to mitigate the threat of EMR emissions include:

1. Enclosure and signal line shielding and grounding to prevent leakage of EMR from the equipment.
2. Designed-in physical separation or barrier which would ensure that the power density of the electromagnetic field is inadequate to cause detonation of an EED at the closest possible distance to the emission source within the equipment.
3. Filter, or provide ferrite beads for, signal lines from the equipment which may conduct EMR emissions into EED circuitry or secondarily radiate EMR in the proximity of an EED thus causing a threat of detonation.
4. Ensure that the minimal power necessary is used to operate circuitry capable of producing EMR.
5. Label the equipment capable of emitting EMR to indicate the minimum separation distance to be maintained between the equipment and an EED(s).

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