DEPARTMENT OF THE ARMY
SOUTH PACIFIC DIVISION, CORPS OF ENGINEERS
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DIVISION TECHNICAL
LETTER 1110-4-43 28 December 1990

Expires 19 December 1991
Engineering and Design
ENGINEERING TECHNICAL LETTER (ETL) 90-6: ELECTRICAL SYSTEM GROUNDING, STATIC GROUNDING AND LIGHTNING PROTECTION - AIR FORCE

1. Purpose. Enclosed ETL 90-6:

a. Specifies and clarifies basic requirements for electrical grounding, static grounding and lightning protection criteria for the design of safe and effective protections systems for Air Force facilities;

b. Supersedes those portions of referenced publications only as specifically stated; and

c. Is authorized in accordance with AFR 8-7, Air Force Engineering Technical Letters (ETLs), and is to be implemented accordingly. Waivers for explosives facilities will be processed in accordance with AFR 127-100. All other waivers will be processed in accordance with the procedures established by the Model Installation Program.

2. Applicability. It is applicable to Los Angeles and Sacramento Districts.

3. Reference. TM5-811-1/AFM 88-9 Chapter 1, paragraphs 9-1 through 9-4, and TM 5-811-2/AFM 88-9 Chapter 2, paragraph 2-5, and TM 5-811-3/AFM 88-9 Chapter 3.

4. Action to be Taken. Use ETL 90-6 for all projects which have not reached the 35 percent preliminary design stage as of the date of this letter, and for projects, regardless of their design stage, with proposed systems which are unsafe or inadequate for acceptable equipment operation as determined by the Major Command (MAJCOM).

5. Implementation. This criteria shall have special application as described in paragraph 6c(1) of ER 1110-345-100.

FOR THE COMMANDER:

<signed>

Encl — JAY K. SOPER

Air Force ETL 90-6 — Director, Engineering

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON DC 20330-5000

LEED

Engineering Technical Letter (ETL) 90-6 : Electrical Grounding, Static and Lightning Protection.

See Distribution List

1. Attached for your information and action are criteria for the design of electrical grounding and static and lightning protection systems for Air Force facilities.

2. Purpose. This ETL:

a. Specifies and clarifies basic requirements for electrical grounding, static and lightning protection criteria for the design of safe and effective protection systems for Air Force facilities.

b. Supercedes those portions of referenced publications only as specifically stated.

c. Is authorized in accordance with AFR 8-7, Air Force Engineering Technical Letters (ETL), and is to be implemented accordingly. Waivers for explosives facilities will be processed in accordance with AFR 127-100. All other waivers will be processed in accordance with the procedures established by the Model Installation Program.

3. Effective Date. This ETL is effective:

a. For all projects which have not reached the 30 percent preliminary design stage as of the date of this letter.

b. For projects, regardless of their design stage, with proposed systems which are unsafe or inadequate for acceptable equipment operation as determined by the requiring Major Command (MAJCOM).

4. This is a coordinated HQ USAF/LEED and HQ AFESC/DEM letter.

CHARLES L. PEARCE, Colonel, USAF
Chief Installation Development Div.
Directorate of Engineering & Services

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ETL 90-6

3 OCTOBER 1990

ENGINEERING TECHNICAL LETTER

ELECTRICAL SYSTEM GROUNDING, STATIC GROUNDING AND LIGHTNING PROTECTION

DIRECTORATE of ENGINEERING AND SERVICES
INSTALLATION DEVELOPMENT DIVISION
ENGINEERING BRANCH

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Part 1 - General

1. Introduction. This document specifies and clarifies basic electrical grounding, static and lightning protection criteria for the most common Air Force applications. Refer to the list of publication in the appendix for additional information and for applications not covered.

2. Referenced Documentation: Applicable referenced publications are as follows:

a. AFR 88-4, Chapter 11, Criteria for Data Processing Facility

Design and Construction.

b. AFR 88-15, Criteria and Standards for Air Force Construction (Draft Version, Jan 86).

c. AFM 88-9, Chapter 3, Electrical Design, Lightning and Static Electricity Protection.

d. AFR 91-38, Maintenance of Electrical Grounding Systems.

e. AFP 91-43, Maintenance Responsibilities for Air Force Grounding Systems.

f. AFR 127-100, Explosives Safety Standards.

g. DOD 6055.9-STD, Ammunition and Explosives Safety Standards.

h. Engineering Technical Letter (ETL) 86-17, Power Conditioning and Continuation Interfacing Equipment (PCCIE).

i. Federal Information Processing Standards (FIPS) Publication 94, Guideline on Electrical Power for ADP Installations.

j. Institute of Electrical and Electronic Engineers (IEEE) Standard 141, Recommended Practice for Electrical Power Distribution for Industrial Plants.

k. IEEE Standard 142, Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book).

l. IEEE Standard 446, Recommended Practice for Emergency and Standby Power (Orange Book).

m. Military Standard (MIL-STD) 188-124A, Grounding, Bonding and Shielding for Common Long Haul/Tactical Communication Systems.

n. Military Handbook (MIL-HDBK) 419A, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities.

o. National Fire Protection Association (NFPA) 70, National Electrical Code.

p. NFPA 77, Recommended Practice on Static Electricity.

q. NFPA 78, Lightning Protection Code.

3. Definitions.

a. System Grounding. The intentional connection of a circuit conductor, such as the neutral of a generator, transformer or building service, to earth either directly (solid grounding) or through a resistance or reactance. Reference Figure 1 for details.

Figure 1. Typical system grounding schematic.

b. Equipment Grounding. The connection to earth of all noncurrent carrying metal parts of an electrical wiring system. Reference Figure 2 for a typical equipment grounding schematic.

Figure 2. Typical equipment grounding schematic.

c. Isolated Grounding. An insulated equipment grounding conductor which runs with the circuit conductors (including the "green" wire) and permitted to pass through one or more panelboards without connection to the panelboard grounding terminal and connected at the equipment grounding conductor terminal of the applicable derived system or service entrance transformer. This is not a "separate" or "dedicated" grounding which is unsafe and not permitted by the NEC. This type of grounding is sometimes used to reduce electromagnetic interference or "noise" on the ground circuit. Reference Figure 3 for a typical isolated grounding schematic.

Figure 3. Typical isolated ground schematic. (Figure taken from AFR91-38, Figure 3-2)

d. Lightning Protection Grounding. Additional protection against overvoltages and surges involves the dissipation to earth of lightning induced overvoltages through arrestor type devices installed at various locations within the system. Reference Figure 4 for lightning protection of various types of roof structures. Reference NFPA 78, Lightning Protection Code for further details.

Figure 4. Lightning protection for various types of roof types. (Figure taken from NFPA 78, Figure 3-1.1(a).)

e. Static Grounding. Conductive paths between the objects (bonding) and to earth (grounding) which will equalize any potential differences between them and dissipate any electrical charge. Reference Figure 5 for diagrams on bonding/grounding of equipment or bodies with static charge. Refer to IEEE Std 142-1982 for further details on static grounding.

(a) Static charged & uncharged equipment/bodies are insulated from ground.

(b) Both insulated equipment/bodies share the same static charge.

(c) Both equipment/bodies are grounded and have no static charge.

Figure 5. Static grounding of charged equipment or bodies. (Diagrams taken from ANSI/IEEE Std 142-1982, pg 94)

f. Signal Reference Grid Grounding. Metal grid to control static charge and provide an equipotential conducting plane to which high frequency signal circuits are referenced, thereby minimizing interference and noise. Reference Figure 6 for a typical schematic.

Figure 6. Typical schematic of an equipotential plane. Optional ground strap is recommended to reduce impulse noise currents in ADP system ground conductors. (Diagram taken from FIPS Pub 94, Fig 23.)

Part 2 - Requirements

4. General Requirements. Proper electrical grounding is essential for personnel and equipment safety, as well as for satisfactory equipment operation. Improper methods and techniques can create extreme safety and fire hazards and result in personnel injury or death and/or costly damage to the facility and its contents.

a. Facility Grounding System Functions. A safe and effective grounding system for a facility must perform a number of functions to include:

(1) System Grounding. System grounding is required for all facilities. It provides a stable system voltage reference for equipment operation; limits overvoltages caused by lightning, switching surges, ground faults and other conditions; and enables proper operation of circuit protective devices by providing a low impedance path for fault current.

(2) Equipment Grounding. Equipment grounding is required for all facilities. It eliminates the voltage shock hazard to personnel caused by unintentional contact of an energized circuit conductor with its metal frame or enclosure, and also provides a nondestructive current carrying path for fault current until it can be interrupted by a protective device.

(3) Isolated Grounding. Connections to "separate" or "dedicated" grounding electrodes which are not bonded to the facility grounding electrode system are prohibited by the NEC.

(4) Lightning Protection Grounding. Direct stroke protection involves installing one or more air terminals (lightning rods, masts or elevated/catenary wires) designed to intercept lightning strokes, and connecting them to earth by down conductors and/or the metal building frame or skin. Reference Figure 4. Protection of explosives facilities require the protection contained in AFR 127-100 and AFR 91-43.

(5) Static Grounding. Static protection is required in facilities as described in subsequent paragraphs, typically where flammable or explosive materials are handled or processed. It prevents static electrical charges on objects such as equipment, materials and operating personnel from accumulating to a potential which can discharge from them to ground or to another charged object of different potential, creating a fire or explosion.

(6) Signal Reference Grid Grounding. Signal reference grids, which are discussed in more detail later, should generally be provided in data processing/computer room installations and

other areas where sensitive electronic equipment are installed and interconnected by high frequency signal cables. These grids must be grounded for safety, just as all other conducting members near energized electrical conductors must be grounded. At the same time, they must minimize the adverse effects of any currents which may be present on the grounding system.

b. Single System Requirement. The equipment or subsystems used to perform these functions must be integrated into a single grounding system for the facility. So-called "separate" and "dedicated" grounds are unsafe for both personnel and equipment, and their intended purpose (typically acceptable equipment operation) can be achieved by methods which are both safe and effective.

(1) As a minimum, all grounding electrodes, ground terminals and loop conductor/counterpoise for a facility including those used for lightning and static protection, system and equipment grounding, telephone and antenna systems, as well as the metal frame of the building and underground metal water piping, shall be bonded together in accordance with National Electrical Code (NEC) Art 250-81 to form the grounding electrode system for the facility. Note that underground metal gas piping must not be used as a grounding electrode.

(2) Bonding between other grounding media in the facility will be provided as specified by other paragraphs of this ETL and as permitted in the referenced documents. This is necessary to minimize the potential differences between noncurrent carrying metal objects within the facility which can result from lightning, ground fault and other conditions. Such differences create shock hazards and can also result in destructive side flashes and improper operation of and damage to equipment.

c. Compliance with Referenced Documents. All grounding, static and lightning protection features for a facility shall comply with the applicable provisions of the references listed in the Appendix to this ETL except as specifically noted.

d. Grounding and Overall Electrical System Performance. A safe and effective grounding system will preclude many electrical system performance problems, but it is not a panacea. Improper or inadequate design or installation of many other aspects of the facility's electric system can result in unacceptable equipment operation and/or hazardous conditions. Failure to provide or improper installation or application of surge arrestors, power conditioning equipment, and dedicated feeders for technical loads are just some examples of deficiencies which can cause problems often attributed to "inadequate grounding". The design or investigation/evaluation of a facility's electrical system must, therefore, concentrate on many features of the electrical system, not just the grounding system.

5. System Grounding Requirements. The following paragraphs contain general system grounding requirements and clarifications of some specific requirements which are commonly misunderstood and violated.

a. General. Electrical systems for all facilities must be grounded in accordance with the requirements of the National Electrical Code (NEC) and IEEE Standard 142 (Green Book). Solid grounding is the preferred method for low voltage (1000V or less) systems. Resistance grounding may be considered for medium voltage systems and for installations with multiple generators, where it may be necessary to limit fault current to prevent equipment damage.

b. Neutral and Ground Connections. NEC Art 250-23 requires that the grounded circuit conductor such as the neutral of a 480/277V or 208/120V electrical system must be connected to the grounding electrode system at the transformer supplying the service and/or at the service entrance on the supply side of the service disconnecting means. It also requires that no other grounding connection be made on the load side of the service disconnecting means except in the case of a separately derived system. This includes avoiding connections between the neutral and any grounding electrodes, equipment grounding conductors or noncurrent carrying metal parts of the wiring system. Failure to maintain this separation between neutral and "ground" throughout the facility can result in unwanted neutral return current flowing on the grounding system. This is a shock and fire hazard and can also lead to inadvertent operation of ground fault circuit interruption equipment, and improper operation or damage to other equipment.

c. Separately Derived Systems. A separately derived system is defined by the NEC (Art 250-5) as a premises wiring system whose power is derived from a generator, transformer, or converter windings and has no direct connection, including a solidly connected grounded circuit conductor, to supply conductors in another system. The neutral of a separately derived system must be connected to a nearby grounding electrode, preferably structural metal (Art 250-26). Additionally, a bonding jumper is required between the grounded circuit conductor (neutral) and the equipment grounding conductors (metal enclosures, conduit and "green wire") of the separately derived system.

(1) Dry type transformers (isolation and non-isolation types) are common sources of separately derived systems in a facility. They are generally connected in a delta-wye configuration. To comply with the NEC and to minimize the impedance to ground, the neutral of the transformer secondary must be connected to the nearest practical grounding electrode. Effectively grounded structural steel or metal water pipe must be used if available. Only when neither is available can any other grounding electrode (ground rod, counterpoise, etc) be used. This prohibits the grounding of the secondary of an isolation transformer to a separate ground rod, or running the grounding electrode conductor back to the service entrance, practices commonly (and wrongly) believed to reduce electrical noise on computer systems. This will be discussed in more detail in subsequent paragraphs on signal reference grid grounding.

(2) Standby or emergency generators are also common sources of separately derived systems. However, a generator connected to a facility through a transfer switch is not a separately derived system if the neutral conductor remains connected to the normal commercial power source neutral after transfer (i.e., the neutral is not switched along with the phase conductors). In this case, the required connection of the neutral to the facility's grounding electrode system for both the commercial power source and the generator is made only on the supply side of the commercial

power service disconnecting means as described in paragraph 3b above. Providing an additional connection between the generator neutral and a grounding electrode at the generator would be a grounding connection on the load side of the service disconnecting means and a violation of the NEC. Refer to IEEE Standard 446 for additional information and requirements on grounding emergency and standby generators.

(3) Grounding Electrode System Resistance. Essentially, the resistance of the grounding electrode system must be low enough to ensure ground fault current can be returned to its source without creating an unacceptable overvoltages on the noncurrent carrying parts of the wiring system, and the fault current will also be of sufficient magnitude (particularly at locations remote from the source) to operate overcurrent devices.

(a) Low Resistance. Low grounding electrode system resistance is desirable but not essential for a safe and effective grounding system. In most facilities, a grounding system with a grounding electrode system of relatively high resistance can still be safe and effective if potential differences between the various non-current carrying metal objects in the facility are minimized using proper bonding techniques. Likewise, a system with a grounding electrode system of very low resistance may still be very unsafe and ineffective if other aspects of the grounding system are improperly designed or installed.

(b) Basewide Applications. For standard commercial and industrial systems, IEEE Standard 142 defines an effectively grounded system (one which is adequately free from transient overvoltages) as one which is grounded through a low enough impedance such that for all system conditions, the ratio of zero sequence reactance to positive sequence reactance (X0/X1) is positive and less than 3, and the ratio of zero sequence resistance to positive sequence reactance (R0/X1) is positive and less than 1. This ensures that line-to-ground transient voltages will be limited to 1.5 times the system (per unit) voltage. Note that proper application of this criteria requires an analysis which considers the total system reactance including that of any generators, transformers and rotating machines. It is, therefore, more appropriate for basewide systems and large industrial complexes, rather than for individual facilities. Similar criteria

are also provided for resistance grounded systems.

(c) Commercial and Industrial Applications. For most commercial and industrial facilities, the required resistance for the grounding electrode system is derived from the NEC. Art 250-84 states that a single grounding electrode consisting of a rod, pipe, or plate which does not have a resistance to ground of 25 ohms or less shall be augmented by one additional electrode. This 25 ohm value is often interpreted as the requirement for the grounding electrode system and represents a target which is easily achievable at most facilities (depending on soil conditions), particularly if other requirements for bonding together of all available grounding electrodes (Art 250-81) are met. Where 25 ohms or less is not achievable after all NEC requirements have been met, an analysis (including soil resistivity measurements) of the various methods for obtaining lower resistance such as deeper rod penetration, parallel rods, loop conductor/counterpoise, soil replacement and concrete encapsulation must be performed. The most practical and cost effective methods which will ensure an adequate level of safety and acceptable equipment performance must be implemented.

(d) Communication-Electronics Applications. Grounding electrode systems for communications-electronics (C-E) facilities covered by MIL-STD 188-124A and MIL-HDBK-419A must have a maximum resistance of 10 ohms. However, this should not be interpreted as the requirement for all facilities containing electronic data processing and other electronic equipment. Design of these facilities must comply with AFR 88-4, Chapter 11 (and FIPS Pub 94) as discussed in subsequent paragraphs.

(e) Hazardous Explosives Applications. AFR 127-100 contains grounding requirements for hazardous explosives facilities. To ensure adequate lightning protection, the target maximum grounding electrode system resistance is 10 ohms. The regulation specifies analyses and procedures for providing an optimum system resistance when 10 ohms or less is not achievable due to soil conditions.

(f) Other Applications. AFR 91-43 contains a table summarizing resistance requirements for grounding electrode systems at other facilities (electrical substations, aircraft parking aprons, etc).

(4) Ground Fault Protection. NEC Art 230-95 requires ground fault protection of equipment for solidly grounded wye electrical services of more than 150V to ground, but not exceeding 600V phase to phase for each service disconnecting means rated 1000A or more. This is necessary to prevent equipment damage from high impedance (arcing) ground faults which may have sufficient energy to cause equipment heating and burn down, but not enough current flow to activate protective devices. However, to prevent shut down of the entire facility due to ground faults on feeders, ground fault protection with "zone isolation" features must be

provided on all feeder circuits to coordinate the protection and limit the portion of the system affected.

6. Equipment Grounding Requirements. As previously stated, equipment grounding is necessary to eliminate the voltage shock hazard to personnel caused by unintentional contact of an energized circuit conductor with its metal frame or enclosure, and also provides a nondestructive current carrying path for fault current until it can be interrupted by a protective device. The NEC requirements in Art 250 must be met with the following exceptions and clarifications.

a. No Substitutes for Equipment Grounding Conductors. The noncurrent carrying metal parts of all equipment must be connected to an equipment grounding conductor system which provides an electrically continuous path for fault current to return directly to the source of the system supplying the equipment (building service or separately derived system, whichever is applicable). The earth, which is a relatively poor conductor, is not an acceptable equipment grounding conductor. Therefore, connections to nearby parts of the grounding electrode system such as structural steel or counterpoise/ground loop conductor which may be desirable for lightning protection or other purposes, are permitted but are not a substitute for an equipment grounding conductor to the system source.

b. No Separate Grounds. Connections to "separate" or "dedicated" grounding electrodes which are not bonded to the facility grounding electrode system are prohibited. This is necessary to prevent dangerous potential differences from developing during lightning and fault conditions between the metal enclosure or frame of equipment "grounded" in this manner and nearby noncurrent carrying metal objects connected to other grounding electrodes. Additional information on this restriction and on the proper application and installation of "isolated" grounds is covered in the paragraphs on electronic data processing and signal reference grids.

b. Equipment Grounding Conductors. A separate, appropriately sized, "green (or bare) wire" equipment grounding conductor is required for all feeder and branch circuits in all facilities. Metallic conduit may not be used to satisfy the requirement.

7. Lightning Protection. Lightning protection systems provide for the safe dissipation of lightning strokes and surges into the earth and limit the transient overvoltages induced on the electrical system to acceptable levels. The requirements of AFM 88-9, Chapter 3 and NFPA 78 apply with the following clarifications and exceptions.

a. Nonconventional Systems. Only lightning protection systems recognized by the NFPA and Underwriters Laboratories may be used. Nonconventional systems such as dissipation arrays and those using radioactive lightning rods are not acceptable.

b. Manual Changes and Additions. The following additions and changes to AFM 88-9, Chapter 3 apply:

(1) Air Terminal Types. In addition to the traditional integral system of air terminals (commonly known as lightning rods), systems using overhead wires (catenaries), masts or faraday cage in accordance with NFPA 78 are acceptable.

(2) Hazardous Locations. Lightning protection systems for hazardous explosives facilities must comply with AFR 127-100.

(3) Terminal Tips. Integral type air terminals must have pointed tips; capped terminals are no longer permitted. Terminals must be copper (preferred) or aluminum in accordance with NFPA 78.

(4) Stainless steel ground rods are subject to corrosion underground and are no longer permitted.

(5) Connections to Air Terminals. In addition to spot

weld and exothermic weld type connections, high compression connections are also acceptable for grounding and bonding.

c. Bonding. Adequate bonding of metal objects and bodies in, on and near a facility to the lightning protection system is one of the most critical aspects of effective lightning protection. This ensures potential equalization and freedom from dangerous side-flashes. Chapter 3 of NFPA 78 contains details on minimum bonding requirements for ordinary facilities.

d. Ground Terminal Subsystem Resistance. NFPA 78 does not specify a maximum resistance for the ground terminal subsystem (connection of the lightning protection system to earth) for ordinary structures. However, it does require application of specific techniques such as longer and multiple ground rods and loop conductor/counterpoise to reduce the resistance in high resistivity soil conditions (sandy, gravelly or "shallow" soil). It also requires bonding of the ground terminal subsystem to other grounding media, consistent with the NEC requirement for the facility's grounding electrode system.

e. Application of Surge/Lightning Arrestors. Transient over-voltages and surges on a facility's electrical system can be produced by lightning, switching, ground faults and other conditions. Limiting these surges to an acceptable level requires proper application of surge arrestors at all levels of the electrical system, including both the interior and exterior distribu-

tion system. Arresters installed within a facility may be overwhelmed and destroyed by surges induced on incoming distribution lines if that portion of the system has not been adequately protected. As a minimum, appropriate class surge arrestors must be provided at the power transformer supplying the facility and in the facility's main distribution panel or switchgear. Additional surge protection and power conditioning may be provided by the user for his individual equipment items in accordance with ETL 86-17.

8. Grounding and Bonding for Static Protection. Static protection requirements in AFM 88-9, Chapter 3 and NFPA 77 apply with the exceptions and clarifications below. AFR 127-100 specifies additional requirements for hazardous explosives facilities.

a. System Integration. Bonding and grounding are common techniques for static protection. Bonding or electrically connecting two or more conductive objects equalizes the potential between the objects. Grounding minimizes the potential differences between the objects and the ground by providing a connection between them and the earth to drain off static charges before they reach a sparking potential. Although static grounds are not part of the facility's electrical power system, they must be properly integrated into the overall facility grounding system and not applied in isolation.

b. Static Ground Resistance. All grounds used for static protection in Air Force facilities including those for aircraft and fuel tanks must have a maximum resistance of 10,000 ohms. This is in contrast to AFM 88-9, Chapter 3 which recommends maintaining an average range of between 25,000 to 100,000 ohms (resistances as high as a megohm can often provide an adequate leakage path for static electricity) to limit fault current and avoid shock hazard to personnel. Any danger of electrical shock hazard caused by the 10,000 ohm value can be eliminated by proper bonding to other grounding media (equipment grounding conductors, lightning protection system components, grounding electrode system).

c. Exception. A specific exception to the bonding requirement of the previous paragraph involves static bus bars in hazardous explosives facilities per AFR 127-100. These static bus bars must be used only for static grounding and must not be connected to telephone grounds, electrical conduit or other grounding media. However, the grounding electrodes for these bars must be bonded to the facility's grounding electrode system.

d. Conductor Size. The size of bonding conductors used solely for static protection is determined by the need for mechanical strength since static electrical currents are very small (microamps). Any grounding conductor adequate for power circuits (sized in accordance with the NEC) or lightning protection is adequate for protection from static electricity.

9. Electronic Data Processing Equipment. Standard grounding techniques which are adequate for equipment operating at 60 HZ may be totally inadequate for electronic data processing equipment which may operate at clock and signal frequencies well above 10 MHZ. The underlying reason for this is the inherently high impedance of standard conductors/wires at these frequencies. In lengths greater than 1/20 of a wavelength (about 4 feet at 10 MHZ), they are very ineffective at equalizing potential and can lead to resonance conditions and electromagnetic and capacitive coupling of noise and interference onto signal circuits. Special techniques are therefore required to provide a safe and effective grounding and signal referencing system for this equipment.

a. Safety First. Acceptable performance of electronic equipment has often been used as an excuse to violate applicable safety requirements in governing codes such as the NEC and NFPA 78. This is not acceptable. The 1990 NEC contains revisions and clarifications to specifically prohibit this.

(1) Art 100 contains a revised definition of "premises wiring". Such wiring (which is subject to NEC requirements) includes all interior and exterior wiring and interconnected equipment on the load side of the service and the output of any separately derived system (such as a transformer, generator, computer power distribution unit, or uninterruptible power supply).

(2) Art 250-21 now states that currents which introduce noise or data errors in electronic equipment are not considered to be objectionable currents that allow modification of grounding requirements.

b. Design and Construction Requirements. AFM 88-4, Chapter 11 contains design and construction requirements for electronic data processing facilities. By reference, it incorporates the guidelines of FIPS Pub 94 which addresses safe and effective grounding and signal referencing techniques. Communications-electronic facilities and facilities where TEMPEST and HEMP are considerations must be designed in accordance with USAF Handbook for the Design and Construction of HEMP and TEMPEST Shielded Facilities.

c. Zero Signal Reference Grid (ZSRG). As previously stated, ZSRGs are provided in computer rooms and other facilities where electronic equipment items are interconnected by high frequency data and signal cables. They are used to control static charge and provide an equipotential conducting plane to which high frequency signal circuits are referenced, thereby minimizing interference and noise.

(1) The ideal ZSRG would be a continuous sheet of material with good surface conductivity (copper, aluminum, zinc plated steel) to which all data/signal cable shields and equipment enclosures

could be bonded (referenced) by very short connections. However, this is not practical from a cost and installation standpoint. Alternatives to this which exhibit acceptably low impedance at high frequencies are grids of copper wire or straps which are installed under the raised floor typically found in electronic data processing rooms. One disadvantage of these options is the increase in length of the connections from the equipment to the grid due to the height of the raised floor. This disadvantage can be overcome and costs reduced by using the raised floor itself as the ZSRG. These floors will have acceptably low impedance if they employ carefully installed bolted-down stringers and they are suitably plated with tin or zinc to permit low resistance pressure connections.

(2) ZSRGs must be grounded for safety, just as all other conducting members near energized electrical conductors must be grounded. The conductor which grounds the grid at some convenient point to the equipment ground bus in a branch circuit distribution circuit breaker panel should be a green wire enclosed in conduit and of a conductor size appropriate (per the NEC) to the largest phase conductor ampacity brought into the computer room.

(3) To provide adequate protection from lightning induced overvoltages, any metal objects (structural steel, electrical and communication conduits, water pipes, air conditioning ducts, etc) passing through or near the ZSRG must be bonded to it. Also, if building structural steel is not available, multiple connections should be made, if practical, between the ZSRG and the facility's grounding electrode system.

d. Isolated Ground Equipment. Certain isolated grounding techniques are permitted by the NEC. However, they should not be confused with "separate" or "dedicated" grounds which are unsafe and not permitted. Additionally, since they are of questionable value for high frequency grounding and may, during lightning conditions, exhibit potential differences between the "isolated" equipment ground and other parts (such as metal conduit and enclosures) of the facility's equipment grounding conductor system, they should be used only when required by governing codes (hospital applications) or when satisfactory equipment operation cannot be achieved by any other approved method.

(1) (IG) Receptacles. In IG receptacles, the grounding pin is insulated from the receptacle body and mounting yoke. Per NEC Art 250-74, this grounding pin must not be connected to any separate or dedicated ground, but must be connected (by an insulated conductor run with the circuit conductors) to the equipment grounding conductor terminal of the electrical source supplying the equipment (building service or first separately derived system, whichever is applicable). Additionally, the body of the receptacle (and metal outlet box and conduit) must be connec-

ted to the "green wire" facility equipment grounding conductor.

(2) Hardwired Equipment. The 1990 NEC (Art 250-75) permits the installation of an insulating spacer or fitting to interrupt the electrical continuity of a metallic raceway system at the point of connection to a metal enclosure if the metal conduit is grounded at its supply end and an equipment grounding conductor is run through the conduit into the metal enclosure and is connected to the equipment grounding terminal of the enclosure. As in the case of IG receptacles, this equipment grounding conductor must not be connected to a separate or dedicated ground, but to the equipment grounding terminal of the source supplying the equipment.

(3) Isolation Transformers. Isolation transformer must comply with the NEC requirements for separately derived systems and must not be used to establish separate or dedicated grounds for equipment. As discussed in paragraph 3c above, the neutral, enclosure (and equipment grounding conductor of the transformer's source), shield and equipment grounding conductor system of the isolation transformer must be connected to the nearest effectively grounded steel or metal water pipe to minimize the impedance to ground. Any other type of grounding electrode must not be used if either is available. Separate or dedicated grounding electrodes are unsafe and prohibited by NEC Art 250-81.