b. AC Power. Providing AC power is the responsibility of the host activity. However, should installation scheduling preclude AIA from providing power in a timely manner, IMD may make AC power runs after coordination with AIA and AF field

units. The following criteria applies.

- AC power will be run by IMD using AF provided materials.

- AC duct will not be installed in AF facilities. AC wire to the equipment will be in a continuous run of flex conduit.

- The flex conduit may not be run diagonally across rooms or haphazardly.

- Only 90° bends are permitted and it is expected that these will be minimized.

- Equipment, outlet boxes (Walker boxes), and electrical connections/splices are not permitted under the raised floor.

c. Cabinet Installation. Equipment cabinet/rack installation at AF host sites will be the same as for Navy sites with the following exception:

- In areas with raised floors, the continuously threaded rod securing the wooden foundation (sleeper) to the true floor will always be connected to a unistrut rather than into an anchor in the slab.

- When sleepers are installed on raised floors which serve as an air plenum, AIA recommends placing sleepers under all the edges of the cabinets to make louvered vents controlling the volume of air flow more effective.

d. Equipment Grounding. The existing AF equipment ground will be used. Modifications to the existing ground system or separate grounding systems will not be employed. Under raised floors, the equipment ground is provided by a solid copper wire attached to the unistrut lattice by split bolts. The ground conductor from equipment cabinets will be a solid copper #6 wire. The use of AF grounds is entirely acceptable as long as excessive ground currents are not injected into Navy equipment.

CHAPTER 6
ELECTRICAL POWER

1. General. NAVSECGRU Elements require a reliable source of electrical power to support the operation of sensitive electronic equipment. Power system reliability is obtained through the installation of various combinations of primary, emergency, standby, and UPS. These power sources and distribution systems are planned and designed by NAVFAC to meet NAVSECGRU requirements and must conform to the criteria listed in Table 6-1. This chapter will discuss various categories of electrical loads within NAVSECGRU facilities and outline the criteria which will be used for the electrical power that supplies those loads. This chapter addresses only mission operational loads and is not applicable to non-operational electrical requirements (e.g., ball field lighting, barracks, etc.) even if these non-operational loads derive their power from the main operations facility.

2. Power Class Definitions

a. Primary power (Class "A"). The normal source of power which serves the station load. The primary power should be supplied to the operational site from a commercial utility or government owned power source through two separate feeders entering the site from different directions and will conform to the stability criteria of Table 6-1.

b. Primary power (Class "B"). An independent auxiliary power source capable of providing electrical service during an extended (several days) outage of the primary power (Class "A") source.

c. Emergency power (Class "C"). An auxiliary source of power whose function is to rapidly restore electrical service to the technical load during primary power source failures. Emergency generators should be equipped with automatic start and depending upon local conditions, assumption features, which will enable the technical load to be powered within one minute (nominally 10-20 seconds) of loss of the primary power source. These generators will be installed with features which allow uninterrupted synchronous transfer between the emergency generators and primary power source (or vice-versa).

d. UPS (Class "D"). An electronic or electromechanical system using stored energy to provide precise, continuous power to the critical technical load.

3. Load categories. The NAVSECGRU electrical power load requirements are categorized according to operational importance, mission degradation resulting from power outages, and occasionally for isolation purposes. The following categories are used to describe the NAVSECGRU load hierarchy and are depicted in Figure 6-1.

a. Operational load. That portion of the total station load which supports the communications and NAVSECGRU operations functions. The operational load is the sum of the nontechnical and technical loads. All NAVSECGRU operational loads require emergency power.

b. Nontechnical load (Utility). That portion of the operational load which includes general lighting, air conditioning (not essential for equipment cooling), convenience outlets for tools and cleaning equipment, and habitable items. Nontechnical loads are provided emergency power but may be served by an emergency generator using manual, vice automatic, start-up and assumption controls.

c. Technical load. That portion of the operational load required to maintain continuity of communications and NAVSECGRU operations. The load is the sum of the non-critical technical and critical technical loads.

d. Non-critical technical load. That portion of the technical load necessary for essential communications and NAVSECGRU operations. The non-critical technical load is protected from extended primary power outages (greater than two minutes in length) by automatic startup emergency generators.

e. Critical technical load. That portion of the technical load supporting equipment which is unable to tolerate even momentary power outages. Critical technical loads require UPS. This category includes any unit of equipment, whether individual or part of a system, that will malfunction during a momentary power drop-out and cause:

(1) The need to resynchronize equipment, after restoration of power, which causes dependent systems and/or sites additional mission outages of one minute or more.

(2) Loss of real time count by master time source with attendant loss caused by resynchronization with distant time source.

(3) The loss of buffered data in automatic control and processing systems

	UTILITY	TECHNICAL	UPS
VOLTAGE SUPPLY	120/208	(Nominal) 120/208	120/208
VOLTAGE RANGE	+04% -12%	(Percent - 24 Hr Period) +04% -12%	+01% -05%
VOLTAGE REGULATION	+05% -05%	(Percent - 24 Hr Period) +02% -02%	+01% -01%
HARMONIC CONTENT TOTAL VOLTAGE	12%	(Percent) 06%	04%
HARMONIC LARGEST UNGLE VOLTAGE	06%	(Percent) 04%	03%
FREQUENCY	60.0	(Hertz) 60.0	60.0
FREQUENCY STABILITY Under Full Load	+0.5 -0.5	(Hertz - 24 Hr Period) +0.5 -0.5	+0.3 -0.3
PHASE DISPLACEMENT Under Full Load		(Degrees - 24 Hr Period)	
Balanced 120	+2.0 -2.0	+2.0 -2.0	+1.0 -1.0
Unbalanced 120	+5.0 -5.0	+5.0 -5.0	+3.0 -3.0
LOAD BUS AUTO CUTOUT		(Any Bus Greater Than 15 Seconds)	
Over Voltage	140.0 Volts		
Under Voltage	100.0 Volts		
Over Frequency	64.0 Hz		
Under Frequency	56.0 Hz		
Phase Lees	Any Phase		
TRANSIENT SUPPRESSION		(0.1 Seconds Duration)	
Voltage Surge Max	+10%	+10%	+01%
Voltage Sag Max	-15%	-15%	-05%
AUTO START UP TIME Less Than	15	(Seconds Duration) 15	0

TABLE 6-1
POWER SPECIFICATIONS

(4) The loss of an on-line operational program where the program reload must be made from an off-line medium (tape, disk, card-deck, etc.) and the reload requires more than fifteen minutes.

Note: NAVSECGRUINST 11310.1D provides specific guidance on loading criteria, UPS connectivity, and power system testing procedures.

4. Load requirements. Electrical equipment and systems installed prior to 1968 present basically linear loads (resistive and reactive) to the power distribution bus. The majority of electrical equipment and systems installed after 1978 utilize switching power supplies which present nonlinear loads to the distribution bus.

a. The rapid expansion of nonlinear loads has led to serious and unexpected problems, such as failure of transformers and generators loaded well below their maximum ratings, and severe overheating of full sized neutral conductors. Equipment and system application, as well as past and future equipment installation designs must take into consideration this increase in nonlinear loads.

b. A nonlinear load occurs when the load current is not proportional to the instantaneous voltage. The major consequence of nonlinear loads is considerable harmonic distortion on the power distribution system. One example of a non-linear source of harmonic current is a high-powered UPS. Considering the harmonics generated by nonlinear loads, odd harmonics become additive in the neutral conductors of the power distribution system and the pulsed currents in the neutral are not self canceling. This phenomenon occurs even in three phase power systems which have been carefully balanced. Equipment which presents a transient load, either at start-up or any other time and causes the line voltage to drop more than 10 percent, will not be installed on the technical power bus.

c. Bulk RFI filters were previously installed at NAVSECGRU sites to reduce TEMPEST emissions conducted through the power distribution system. At the time the filters were installed, site equipment loads were linear. Today's equipment produces non-linear load currents that the filters were not designed to handle. The result is that the filters generate excessive heat from the flow of harmonic current. Bulk filters are no longer required and should be removed.

5. Redundancy. The high voltage electrical power service to a NAVSECGRU facility must include at least two separate service feeders coming to the operations facility transformer. To prevent accidental or intentional damage to one of the feeders from affecting the operability of the other, they should be routed so as to approach the operations facility from different directions. In order to reduce the possibility of electromagnetic interference to the station's mission, the high voltage feeders must be buried in accordance with the criteria outlined in Chapters 3 and 5.

a. In addition to the UPS, NAVSECGRU facilities must have diesel (or other prime motor driven) emergency generator systems to provide backup power to the utility and technical distribution buses. These units must have a generating capacity sufficient to supply the operational facility design load for an indefinite time with at least a 30 percent reserve, with any one generator off line. This is to ensure that, even with one generator off line whether for corrective or preventive maintenance, sufficient generating capacity exists to carry on continuous operations. Fuel tank capacity will be sufficient to provide for a minimum of thirty days continuous operation. Figure 6-2 illustrates accepted standard redundancy configurations for NAVSECGRU sites.

6. Building main service and distribution. The building main service panel, which contains the main over-current protective devices (circuit breakers), terminates the electric service entering the facility. Beginning from the building/facility supply transformer, if any service conductor is grounded, a separate grounded conductor (neutral conductor) must be run with the service phase conductors. NEC Article 250-23(b) applies in order to provide a low impedance path for fault current to return from the building service to the transformer neutral point. Within the main service panel, a connection from the neutral bus to the earth electrode subsystem is required to establish a "zero voltage" reference point for the system. This connection is also required to provide a path to earth for static and lightning protection. Also required by the NEC, within the main service panel, is a main bonding jumper which physically connects the equipment ground bus to the neutral ground bus. This connection extends the "zero voltage" reference point to the ground bus where all equipment grounding conductors (green wire safety grounds) are terminated.

NOTE: Both the connection to the earth electrode subsystem and the connection of equipment grounds to neutral must only be made within the main service panel. The only exception to this requirement is where a new electrical system is derived through a down stream transformer.

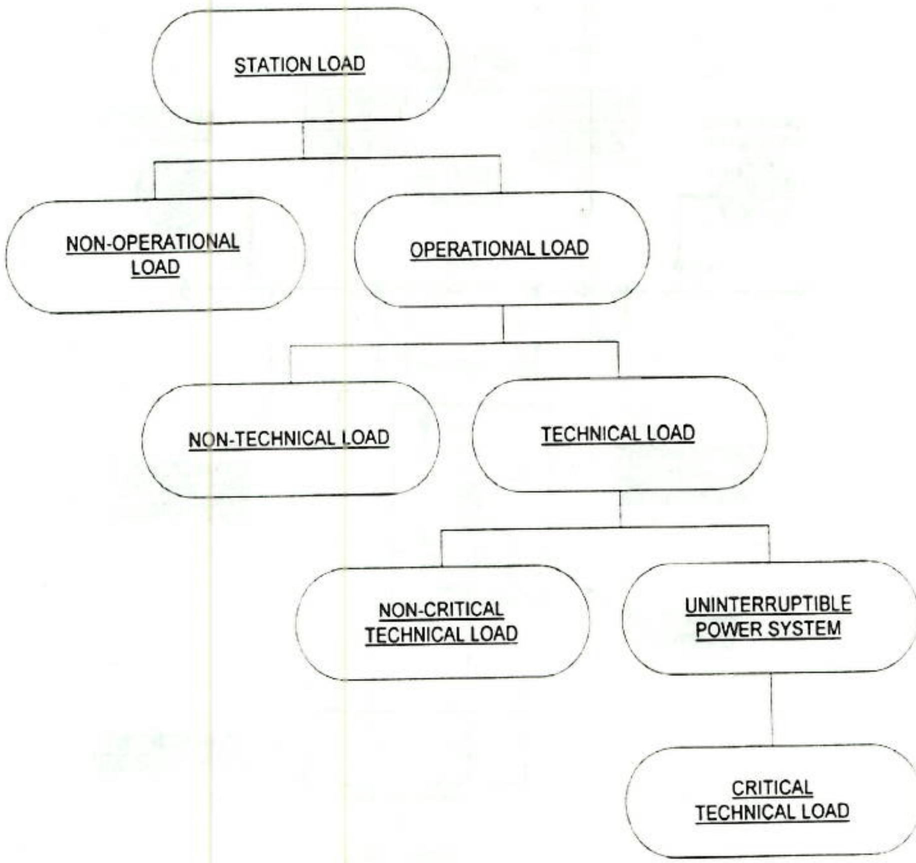

FIGURE 6-1

ELECTRICAL LOAD HIERARCHY

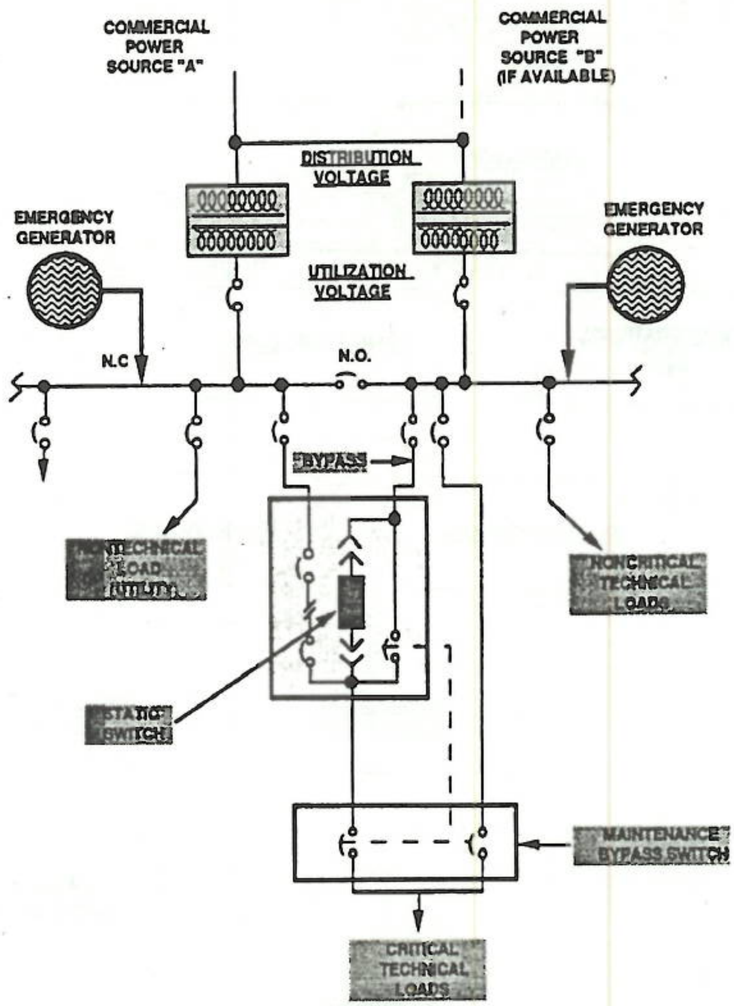

FIGURE 6-2

REDUNDANCY REQUIREMENTS

7. Electrical distribution wiring. Interior building wiring for all NAVSECGRU operational facilities will be accomplished per MILHDBK 1004, MILHDBK 419A and the NEC. Specific wiring criteria for NAVSECGRU sites are as follows:

a. Electric power service and feeders will be placed in rigid steel conduit or steel bus ways.

b. Interior electric power and lighting wiring will be placed in rigid steel conduit, EMT, or for lengths of 6' or less, flexible steel conduit. Rigid non-metallic conduit, armor cable, aluminum conduit, PVC conduit, intermediate metal conduits, open wireways, and electrified floor system (Q cells), will not be used.

c. All electrical wiring will have a full-sized equipment grounding conductor (safety ground) run within the conduit or bus way. The conduit shell or steel bus way case will not be used as the main equipment grounding conductor.

d. All electrical wiring within NAVSECGRU operational facilities will have copper conductors. In no case will aluminum wire or bus ways be used.

e. The grounded conductor (neutral) will be bonded to the equipment grounding conductor (safety ground) only at the premises wiring system. See NEC 250-23.

f. The grounded conductor (neutral) will be full-size or when used for 3 phase power (and nonlinear loads) will be 200 percent size. For wire sizes smaller than 1/0 AWG, the grounded conductor will be run as a single conductor per NEC.

8. Power conditioning and installation. Since NAVSECGRU elements electronically process classified information, the possibility exists that information from processing devices may be conducted along power lines. Consequently, the power conductor connected to the processing devices must be installed and conditioned not only to the latest edition of the NEC and the MILHDBK 1004, but also the criteria contained in MILHDBK 232A. To alleviate the possibility of conducting classified information along power lines, power distribution will always be routed separately from signal cables.

a. Power conditioning

(1) Transient protection. MOV, voltage dependent zinc-

oxide varistors, when exposed to high energy voltage transients (spikes) temporarily convert to a conducting mode, safely shunting the transient to ground. Previously MOVs were required in power distribution circuitry per NAVSECGRUINST 11310.1. Although MOVs have the potential for significantly reducing problems associated with transient overvoltages on communication and electronic equipment, under certain conditions MOVs allow high voltages to exist on the ground at the equipment and may cause damage to the equipment. MOVs should not be used; more problems are caused then are cured.

(2) LVRs compensate for long term power line voltage drift. Effective for "brown out" protection. Solid state LVRs are the fastest type, but still do not achieve regulation until about 10 cycles, and therefore provide little protection from the most common voltage disturbance, the sag. An incorrect voltage level is generally indicative of other power distribution problems, e.g., wrong transformer tap, overloaded transformer or undersized feeder. Therefore, the entire power distribution system should be thoroughly studied before resorting to using LVRs.

(3) Ride through MG. MGs are used for frequency conversion and/or voltage disturbance protection. A MG will provide energy to the load during sags and very short power outages. The rotating mass of the MG unit provides a ride-through for outages of up to approximately one-third of a second. The unit also affords sag protection, noise and transient isolation, and voltage regulation nearly equivalent to an UPS.

b. Power system installation. From an installation standpoint, the primary power distribution panels, circuit breakers, etc., must be accessible from either outside of the operational spaces or from unclassified areas within the building. Standby, emergency, and UPS power sources will be located so as to minimize physical and electrical interference, and allow ready access to maintenance personnel for periodic check-out and routine maintenance.

9. <u>Lightning protection</u>. Electrical power generating and distribution systems are to be protected in accordance with MILHDBK 1004 and MILHDBK 419A.

CHAPTER 7
GROUNDING AND BONDING

1. General. This chapter addresses the practical considerations of grounding systems, subsystems, and other component networks within NAVSECGRU operational activities. Grounding, bonding and shielding of fixed plant telecommunications/electronics facilities are the primary concern of this chapter.

2. Purpose of Grounding. All telecommunications and electronic facilities are inherently related to earth either by capacitive coupling, accidental contact, and/or intentional connection. Therefore, grounding must be looked at from a total system viewpoint with various subsystems comprising the total facility ground system. The facility ground system forms a direct path of known low impedance at low frequencies (< 100kHz) between earth and the various power, communications, and other electronic equipment. This path effectively extends an approximation of a ground reference throughout the facility for low frequencies only. The total facility ground system serves two primary functions:

a. Personnel safety. Personnel safety is provided by low impedance grounding and bonding between equipment, metallic objects, piping, and other conductive materials, so that currents due to faults or lightning do not result in voltages sufficient to cause a shock hazard.

NOTE: SAFETY OF PERSONNEL is the most important reason for grounding!

b. Equipment and facility protection. Equipment and facility protection is provided by low-impedance grounding and bonding between electrical services, protective devices, equipment, and other conductive objects, so that fault or lightning current does not result in hazardous voltages within the facility. Also, the proper operation of overcurrent protective devices is dependent upon low-impedance fault current paths.

c. In order to maintain a good effective ground system, periodic inspection and routine maintenance are of the utmost importance. Continued or periodic maintenance is aided through adequate ground system design, choice of materials, and proper installation techniques. This ensures ground networks resist deterioration or inadvertent destruction and thus require minimal repair to retain their effectiveness throughout the life of the facility.

3. Ground. Grounding is one of the most important and least understood aspects of the facility electrical system. The NEC defines "GROUND" as:

a. Ground, a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and earth, or some conducting body that serves in place of earth.

NOTE: All currents to ground, that are not dissipated as heat or radiation, are returned to the source via some other path (Kirchhoff's Law).

b. To clearly understand the purpose and function of grounding electrical systems and equipment, grounding must be subdivided into two categories, EARTH GROUND and EQUIPMENT GROUND. These two categories are often interchanged and the resultant misapplication of earth and equipment grounding practices can lead to a system that is expensive, inefficient and often unsafe. Also keep in mind that grounding principles apply only to low frequency sources. At higher frequencies, grounds become transmission lines whose characteristic impedance varies widely over frequency and is unpredictable.

c. Earth ground (Earthing). The basic purpose of earthing is to protect the electrical system and equipment from super-imposed voltages caused by lightning and accidental contact with higher voltage systems. Earthing also prevents the build-up of static charges on equipment and materials. Additionally, earthing is used to establish a "zero voltage" reference point at power frequencies for the facility. This purpose of earthing is one that is important to insure proper equipment performance, as well as provide a limitation on the maximum phase to ground voltage at power frequencies that will appear on the system. The only purpose of the earth ground is to satisfy NEC with only one neutral to ground bond at the entrance of power to a facility. The earth ground does not control EMI or have any impact on EMI. It does not provide a zero-potential EMI reference. The earth ground or any other ground does not allow EMI to be conducted or absorbed into the earth.

d. Equipment ground. Equipment ground is to provide assurance that all exposed non-current carrying conductive surfaces (i.e. equipment enclosures, conduits, ducts, etc.) are effectively interconnected and tied to earth. The objectives obtained by effective equipment grounding are:

- To minimize to the greatest extent possible the appearance of any voltages on equipment enclosures. This will provide protection from serious shock hazard and/or electrocution to personnel in contact with the enclosure.

- To provide an intentional path of ample current carrying capacity and LOW IMPEDANCE (less than 0.5 W) that will carry sufficient fault current to insure rapid operation of the circuit overcurrent protective device under ground fault conditions.

- To establish and maintain a "ZERO VOLTAGE" reference point for power frequencies.

e. Current limits. It is necessary to place additional requirements on equipment grounds in order to control the conduction of RFI/EMI current between systems. These requirements are placed on all equipment grounding conductors and other conductors electrically connected to ground, whether intentionally or unintentionally connected. This includes conduits, cable trays, cable ducts, pipes, air conditioning ducts, power conductors, telephone wires, cable shields, communication cables, and building structural materials (such as reinforcing rod, steel beams, concrete walls and floors, etc.) Modern digital systems have the potential to inject RFI/EMI current onto grounds and other conductors with levels sufficiently high enough to interfere with RF signal reception. Therefore, the following maximum levels are recommended:

- 2 mA of RFI/EMI current at any frequency from 10 Hz to 10 kHz

- 10 mA of RFI/EMI current at any frequency from 100 kHz to 100 MHz

- For frequencies between 10 kHz and 100 kHz,a straight line can be used to extrapolate the correct level.

These limits were derived from the following practical considerations:

- RFI/EMI current flowing on intentional or unintentional conductors must be significantly low so that RF signals are not contaminated by coupling.

- In-band RFI/EMI current flowing on the antenna ground screen appears as normal radio signals to the antenna elements. This current must be below a detectable level in order to maintain interference free reception.

4. Grounding methods and practices

a. The following publications discuss in detail the methods and practices used to establish satisfactory grounds and ground systems:

- National Electric Code

- MILHDBK 419A

- MILHDBK 232A

- NACSIM 5203

- NAVFAC DM-12.02

b. Typical subject matter discussed in these publications:

- Type and characteristics of ground electrodes

- Earth ground point testing

- Methods to improve earth ground point efficiency

- Soil resistivity and measurement techniques

- Current loading capacity

- Electrode corrosion prevention techniques

- Equipment ground connection termination

c. The primary reference document that governs grounding, bonding and shielding for NAVSECGRU sites is the NEC. Specific additional guidance for the grounding of electronic equipment processing classified information may be found in MILHDBK 232A and NACSIM 5203. In addition to the preceding references, additional requirements to mitigate electromagnetic interference at NAVSECGRU sites have been incorporated in this instruction.

5. Facility ground system. The facility ground system forms a direct path of known low impedance between earth and various

power and communications equipment. The facility ground system consists of the following electrically interconnected subsystems:

a. Earth electrode subsystem. An earth electrode subsystem will be installed at each NAVSECGRU facility to provide a low resistance path to earth for lightning and power fault currents

and ensure that hazardous voltages do not occur within the facility. The subsystem will be capable of dissipating to earth the energy of direct lightning strokes with no ensuing degradation to itself. This system will also interconnect all driven earth electrodes and underground metal objects of the NAVSECGRU facility. The earth electrode subsystem will not degrade the quality of signals in the signal circuits connected to it. Installation practices for installing the facility earth electrode subsystem are contained in MILHDBK 419A.

(1) Earth resistivity survey. A earth resistivity survey is required for each new facility construction. The design agency will conduct the resistivity survey at the site before construction is commenced, and the values of earth resistivities characterizing the site will be measured and recorded. Natural features, such as rock formations and underground streams as well as man-made features will be indicated.

(2) Minimum configuration. The basic earth electrode subsystem configuration will consist of driven ground rods uniformly spaced around the facility and placed 0.6m (2’) to 1.8m (6’) outside the drip line of the structure. The rods will be interconnected with a minimum of 1/0 AWG bare copper wire buried at least .45m (1.5’) below grade level. The interconnecting cable will be bolted to each ground rod and will close on itself to form a complete loop with the ends brazed or welded together. Where ground wells are used, acceptable compression type connectors will be used to bond the cable to the ground rods. Coverage of the earth electrode subsystem by asphalt, concrete etc. should be kept to a minimum in an effort to maintain the effectiveness of the system and to allow for periodic required inspection/maintenance.

(3) Resistance to earth. The resistance to earth of the earth electrode subsystem should not exceed 10 ohms. Where 10 ohms cannot be obtained with the basic electrode configuration due to high soil resistivity, rock formations, or other terrain features, alternate methods for reducing the resistance to earth will be considered. See MILHDBK 419A for further information.

(4) Ground rods and connecting risers. Ground rods will be copper-clad steel, a minimum of 3m (10’) in length, spaced not

less than twice the rod length apart, and will not be less than 1.9cm (3/4") in diameter. The thickness of the copper jacket will be not less than 0.3mm (0.012"). Provisions will be made for bonding the lightning down conductors, the connecting cables

required by the signal reference, and fault protection subsystems to the risers of the earth electrode subsystem.

b. Fault protection subsystem. The fault protection subsystem consists of a separate equipment grounding conductor (green wire) to provide personnel and equipment protection against power fault currents and static charge build-up. Protection from lightning flashover will be provided by grounding all major noncurrent-carrying metal objects, including main structural steel support members. An approved ground bus will be provided in all switchboards and panelboards and a <u>separate</u> connecting equipment grounding (green) conductor <u>will be carried within the same raceway or cable</u> with the A/C power conductors. The A/C power busway/conduit shell <u>will not</u> be used in place of an independent (green wire) equipment grounding conductor!

(1) Building structural steel. All building metallic structural components such as building columns, wall frames, and roof trusses of metallic frame buildings should be made electrically continuous and grounded to the facility ground. Whenever rebar is used it will be made electrically continuous and grounded.

(2) Pipes, tubes and conduits. All metallic piping/ tubing and conduit and the supports thereof should be electrically continuous and will be grounded to the facility ground system through the fault protection subsystem (see Figure 7-1). All conduit, whether used for power distribution, signal, or control wiring, will be electrically continuous and grounded in accordance with the following:

(a) All joints between sections of conduit, fittings, and buses will be treated with a conductive lubricant and firmly tightened. Gouging locknuts will positively penetrate all paint or other finishes.

(b) All pull, junction and outlet boxes will be grounded with an equipment grounding conductor (green wire).

(c) Conduit brackets and hangers will be electrically continuous to the conduit and to any metal structure to which they are attached.

(3) Cable trays, raceways and ducts (conductive). Individual sections of all cable tray systems will be bonded to each other and to the raceways which they support.

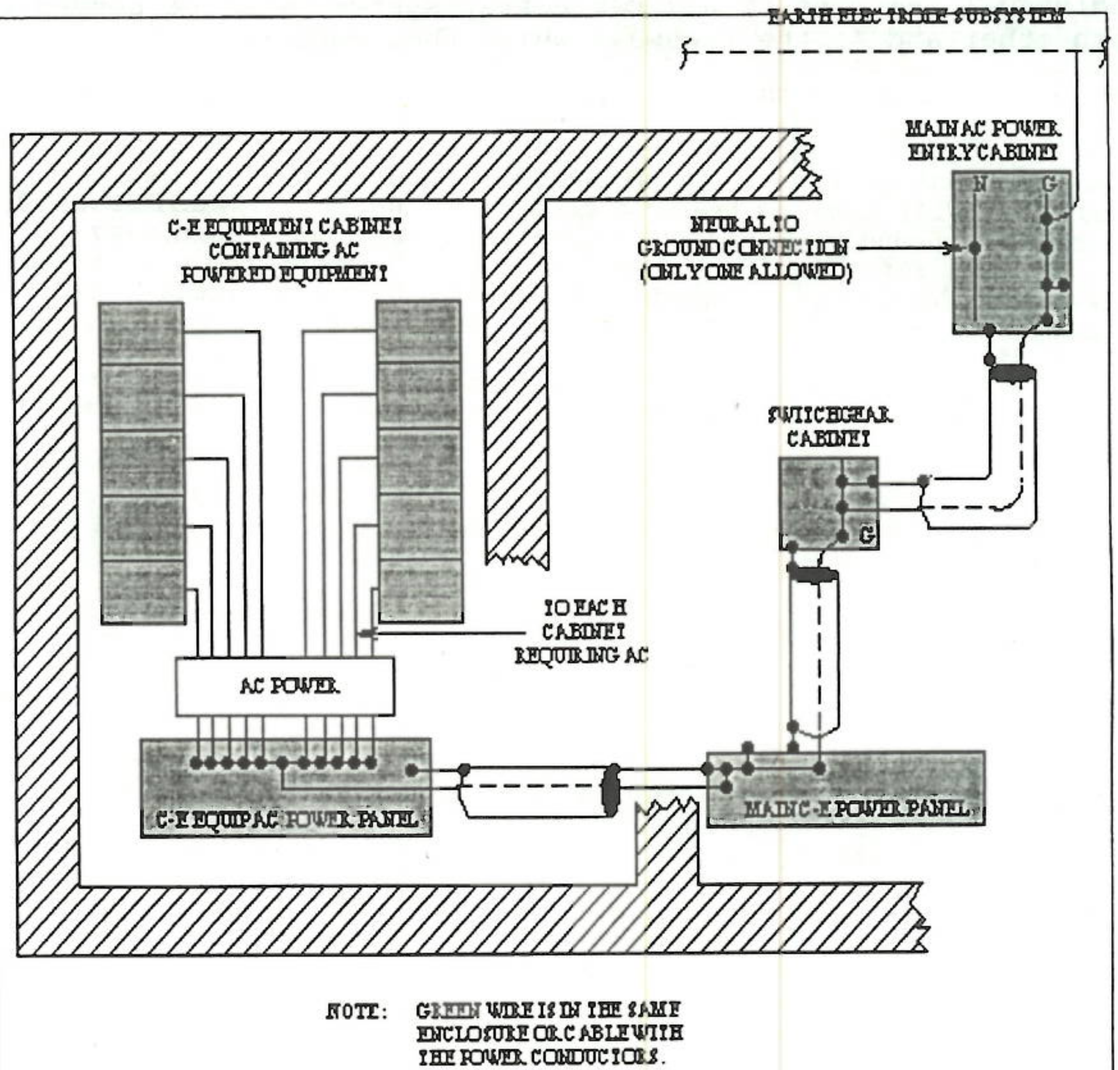

Figure 7-1

Metallic Piping/Tubing Ground

NOTE: The welding of galvanized metal is not permitted. All cable tray/duct assemblies will be connected to ground within 0.6m (2') of each end of the run and at intervals not to exceed 15m (50') along each run.

(4) System Enclosures. All electrical and electronic wiring and distribution equipment enclosures, not otherwise specifically covered herein, will be grounded. The equipment grounding conductor must not penetrate equipment cabinets or cases but rather will be terminated on a ground stud peripherally attached (welded, threaded, etc.) to the metal barrier. (See paragraph 6 for Topological Barrier Grounding).

(5) Metallic power cable sheaths. Metallic cable sheaths on electrical power cables will be connected to ground at both ends.

(6) Electrical power systems. All electrical power distribution systems will be grounded in accordance with the following:

(a) A/C distribution systems. A/C power distribution systems will have the neutral conductor grounded only at the distribution transformer and to the earth electrode subsystem of the facility.

NOTE: Neutral and ground conductors (green wire) will never be connected at any other point in the distribution system.

(b) For ground conductor sizing see MILHDBK 419A Table 1-20 or Table 250-94 of the NEC. Each facility served by a common distribution transformer will have the neutral directly connected to the nearest point of the earth electrode subsystem. Where delta-wye system conversion is employed, the service entrance will be a five wire system consisting of three phase conductors, a grounded (neutral) conductor and a equipment grounding (green) conductor. Pure delta systems will employ four wires from the source, consisting of three phase conductors and a equipment grounding conductor. The fault protection subsystem equipment grounding (green) conductor will be installed in accordance with the NEC for all C-E equipment. Conduit will not be used in lieu of the separate equipment grounding (green) conductor.

c. Lightning protection subsystem. Lightning protection will be provided as required for buildings and structures in accordance with NFPA No. 78. This protection will be extended to all electrical, electronic, or other elements which are part of, or are in support of all NAVSECGRU facilities. Elements will include, but not be limited to, substations (to the extent that additional protection beyond that provided by the electric utility is necessary), power poles, towers, antennas, masts, etc.

(1) Down conductors. Either copper-clad steel (not less than No. 4 AWG) or solid copper (No. 6 AWG) may be used for down conductors. If copper-clad steel is used, the copper covering will be permanently and effectively welded to the steel core. The conductivity of the copper-clad conductors will not be less than 30 percent of a solid copper conductor of equivalent cross-sectional area. Where copper-clad conductors are used on structures less than 23m (75') in height, the D/C resistance of solid wires or stranded cables will not be greater than 0.176 ohms per 305m (1000'). On structures greater than 23m (75') in height, the D/C resistance of the wire or cable will not be more than 0.088 ohms per 305m (1000'). Down conductor bends should not have a bend radius of less than 20cm (8") or greater than 90°.

(a) Any metallic object within 1.8m (6') of a lightning downlead will be bonded to the down conductor (NEC Article 250). On structures higher than 18m (60') there will be at least one additional down conductor for each additional 18m (60') or fraction thereof. Regardless of structure height, the interval between down conductors will not be less than 15m (50') nor more than 30m (100'). Down conductors will be bonded to the earth electrode subsystem.

(2) Air terminals (Lightning Rods). Non-metallic objects, extensions, or protrusions requiring protection will have the air terminals designed and installed per NFPA No. 78.

(3) Structural steel. Substantial metal structural elements of buildings and towers (including overall building shield) are acceptable substitutes for lightning down conductors provided they are permanently bonded to the earth electrode subsystem.

(4) Bonding. All bonds between elements of the lightning protection subsystems will be made by welding or brazing or UL approved high compression clamping devices. Welding or brazing will be used for all bonds not readily accessible for inspection and maintenance. Soft solder will not be used for bonding any conductor within the lightning protection subsystems.

NOTE: The welding of galvanized metal is not permitted.

(5) Supporting Structures. Lightning protection will be provided for NAVSECGRU antenna towers/systems, communication, navigational aid towers, and all other supporting structures as indicated below. For CDAA lightning protection see Appendix C Reference II3.

(a) Earth electrode subsystem. An earth electrode subsystem conforming to the requirements of paragraph 3c will be provided for all supporting structures. Towers adjacent to other structures such that the minimum distance between the tower and the structure is 6m (20') or less, one earth electrode subsystem may serve both. For separation distances greater than 6m (20'), separate earth electrode subsystems will be installed. A minimum of two bare 1/0 AWG copper cables, run by independent routes, will be used to bond the earth electrode subsystem of the antenna/tower to the earth subsystem of buildings and structures having signal, control, or power interfaces with the antenna/ tower.

(b) There is the common belief that RFI/EMI current can be dissipated in earth ground. A careful examination of the situation shows that RFI/EMI current flows from a source through a complex maze of conductors and returns back to that source in accord with Kirkoff's laws of current flow. The total current flow is not decreased or attenuated while flowing over these paths. Current cannot be diverted to some magical absorbing region. The RFI/EMI current paths in a complex site can include both conductive paths and near-zone induction paths. Since the resistive and reactive impedance components of RFI/EMI current paths that include earth-ground are always higher than paths through the complex maze of ground wires and other conductors, little or no RFI/EMI current will flow into an earth ground. This has been verified by measurement. Thus the quality and number of earth grounds is not significant in the control of RFI/EMI at a receiving or data processing site. A good earth ground is required for power-safety reasons and the control of lightning-caused current.

(c) Air terminals. An air terminal will be installed on the tower/pole as specified in 5(c)5(a). A minimum of two conductive paths will be provided between any two air terminals (on the same structure) and between any air terminal and the earth electrode subsystem.

(d) Down conductors. Down conductors will meet the provisions of paragraph 5(c)(1) as a minimum. For metal towers, where the structural elements are not used as down conductors, independent down conductors will be provided and will be bonded to the tower legs at the tower base.

(6) Additional lightning protection considerations. Requirements for the following systems/structures with regard to lightning protection and grounding may be found in MILHDBK 419A.

- Waveguide grounding

- Exterior nonstructural metal elements (handrails, ladders, antenna pedestals, etc.)

- Exterior wires and cables

- Security perimeter fences

d. Those other grounds. There is no technical conflict between the NEC grounding requirements for safety and the need to control RFI/EMI in receiving and data processing sites. It is necessary to place additional requirements on the NEC green-wire power-safety ground in order to control the conduction of RFI/EMI current from one system to another and from one location in a site to another. The additional RFI/EMI requirements must also be placed on all electrical ground conductors in a site, and on <u>all other conductors that are intentionally or unintentionally electrically connected to ground conductors</u>. The term "<u>other conductors</u>" includes conduits, cable trays, cable ducts, pipes, air conditioning ducts, power conductors, telephone wire, cable shields, communication cables, coaxial-cable shields, security system conductors and building structural materials (such as reinforcing rod, steel beams concrete walls and floors, etc.).

e. RFI/EMI Ground Current Limits. The additional RFI/EMI requirement (paragraph 3e) is necessary because many modern digital systems inject levels of RFI/EMI current into grounds and other conductors with levels sufficiently high enough to interfere with the reception of SOI. Maximum levels of RFI/EMI currents in grounds and other conductors at CDAA sites are based on two practical considerations. First, RFI/EMI current flowing in cable shields, cable trays and other conductors in close proximity to antenna and RF signal cables must be sufficiently low that it is not coupled into the cables by cable-shield leakage and by the cable terminations. The use of double-shielded coaxial cables for all RF signals is necessary to avoid a requirement for unreasonably low levels of RFI/EMI current in cable shields and other nearby conductors. Second, in-band RFI/EMI current flowing on the antenna ground screen appears as