

PROTECTIVE GROUNDING SYSTEMS
GENERAL EQUIPMENT GROUND REQUIREMENTS FOR
AC SERVICE DISTRIBUTION SYSTEMS
IN BUILDINGS HOUSING COMMUNICATION SYSTEMS
POWER SYSTEMS

CONTENTS	PAGE	CONTENTS	PAGE
1. SCOPE	2	A. Standard Circuit Schematic Drawings	13
2. GENERAL	2	B. Manufacturing Drawings	14
A. AC Service Grounding System	2	C. Job Drawings, Architectural	14
Separately Derived System	3	D. Job Drawings, Communication System AC Distribution	15
B. AC Equipment Grounding System	3	E. AC EG Conductor Identification on Drawings	15
Overcurrent Devices	4		
NEC Requirements	4		
3. BELL SYSTEM AC EQUIPMENT GROUND REQUIREMENTS	4	Figures	
4. AC EQUIPMENT GROUND CONDUCTOR	6	1—Table of AC Equipment Ground Conductors	16
A. Engine Alternator Sets	9	2—Typical Calculation of Phase, Neutral, AC EG Conductors and Conduit	17
B. Busduct System	9	3—Single AC EG Conductor Serving Multiple AC Circuits in a Common Conduit Run	18
C. AC Power Distribution Service Cabinets	10	4—Requirement for Grounding Frames Mounting AC Operated Equipment Units	19
D. Lighting Distribution Systems	11	5—Typical Arrangement of AC EG Conductors at Service Entrance and Emergency Equipment	20
E. Cord Connected AC Operated Equipment	11	6—Typical Busduct System Equipment Grounding Arrangement	21
F. Frame Base Appliance Outlets	12		
G. KS-20085 Trolley Type Busduct	12		
5. DOCUMENTATION OF AC EG REQUIREMENTS	13		

CONTENTS	PAGE
7—Typical Power Distribution Cabinet Equipment Grounding Arrangement	22
8—Typical Conduit and AC EG Conductor Terminations at Equipment Enclosures	23

1. SCOPE

1.01 This section provides equipment requirements and engineering information pertaining to the provision of effective equipment grounding in AC distribution networks. It defines the function of the AC service neutral conductor and the method of providing ground reference to the neutral. Additionally, the requirement for, function of, and method of design and assembly of an equipment grounding system that supplements the ground paths formed by adjoinment of metallic raceways and electrical equipment are covered herein.

1.02 This section supplements Section 802-001-180, General Grounding Requirements for Communication Systems in Central Offices, Radio Stations and other Structures. Other Protective Grounding Systems sections supplementary to this section are:

802-001-190—Ground System Material

802-001-191—Office Ground Electrodes.

2. GENERAL

2.01 AC service distribution systems used in Central Office installations are usually single or three-phase 120/208 or 277/480 volt grounded systems. Two distinctly different grounding systems are employed concurrently in these installations. They are:

- (a) A service ground system
- (b) An equipment grounding system.

A. AC Service Grounding System

2.02 Three-phase AC service systems, which are most commonly used, allow the use of both single or three-phase load units. Three-phase service is distributed to load units by means of three

conductors (phase legs), each served by a different secondary winding of the station service transformer. Single phase service is obtained by extending conductors from any two of the three phase legs. The voltage induced in these secondary windings is referred to as the *secondary service* voltage.

2.03 Generally, the transformer secondary windings are arranged in a Wye configuration, consisting of three windings commonly connected together at one end, with phase leg conductors extended from the other ends to facilitate distribution of power. The voltage appearing across any two of the three conductors is equal in magnitude but 120 degrees out of phase from that of the voltage across the other conductors. The (60 Hz) voltage is expressed in terms of the greatest root-mean-square (ie, effective) difference of potential impressed across any two conductors of the secondary service circuit. In central office AC distribution systems the secondary service voltage is usually 208 or 480 volts (3-phase systems) or 240 volts (1-phase systems).

2.04 A utilization voltage lower than the secondary voltage is available from Wye wound transformers, as well. This voltage is made available by extending a fourth conductor from the common connecting (neutral) point of the transformer windings. This conductor is referred to as the *Neutral*. Voltage between the neutral and any phase lead is 120 volts in a 208-volt secondary system and 277 volts in a 480-volt system. The neutral is always extended from the transformer to the building main AC service distribution switchboard and terminated on a neutral bus bar therein. It is extended therefrom (with phase leg conductors) only to load units that require the lower voltage obtainable from connection between the neutral and a phase conductor. The 120 volts is used extensively to power building lighting systems and relatively small AC operated load units: Motors, rectifiers, appliances, etc. The 277 volts is used principally for lighting. The 120-volt load units are generally powered via a 480V:120/208V step-down transformer (a separately derived system) when the secondary voltage is 480 volts.

2.05 Use of a neutral in an AC system affords the opportunity to stabilize voltage on phase legs to a limited differential from that of conductive metal in proximity to but insulated from the phase legs. This is accomplished by connecting the neutral to earth. In effect, this provides earth potential

reference to the commonly connected ends of the transformer winding. Therefore, the potential on phase legs is stabilized with earth to no greater than that induced in the windings. When so arranged, the AC system is referred to as a grounded system.

2.06 The neutral conductor may be connected to ground electrodes or to grounded metallic objects at different points between the secondary service transformer neutral and the neutral bus bar in the main distribution switchboard (location of main disconnect device) without restriction. A neutral conductor shall not under any circumstance be connected to a grounded object on the load side of the main disconnect device. Neutral conductors are insulated current carrying leads and connection to a grounded object would create a load current path through grounded objects in parallel to the neutral conductor. A neutral conductor should never be used as a source of ground reference for the same reason.

2.07 The conductor provided to bond the neutral to earth is referred to as the ***Grounding Electrode Conductor***. It is connected to the neutral at a point between the transformer neutral connection point and the neutral bus bar in the main distribution switchboard. From this point it is extended to the office principal grounding point or to a driven (or other type) ground electrode provided exclusively for this purpose.

2.08 The grounding electrode conductor also serves as a current path for lightning discharges and as a fault current return path to energy sources located outside the building and not connected with a neutral conductor. It does not, and should not, have any function in providing a current path for faults occurring within the building when a neutral is provided to the transformer (energy source). That current path is provided by the ***AC Equipment Grounding System***.

AC Service Grounding of Separately Derived AC Systems

2.09 AC distribution systems that receive power through a step-down transformer, or from a DC powered motor-alternator set, inverter or by means other than by direct connection to a secondary system are commonly found in Control Offices. These systems normally employ a neutral conductor and require ground reference. Since the neutral conductor of the secondary system is prohibited

from connection to grounded objects on the load side of the main disconnect device, it cannot be extended to provide ground reference to separately derived systems. Therefore, a separate grounding electrode conductor must be extended from the neutral of each such separately derived system to a source of ground reference. In offices equipped with a CO GRD system, a floor CO GRD bus is an optimal point for obtaining ground reference. In other offices, a connection of the grounding electrode conductor to building steel or cold water piping known to have low impedance continuity to earth is acceptable as an alternative to running the grounding electrode conductor to the office principal ground point or a service grounding electrode.

2.10 Engine-alternator and inverter-derived AC supplies provided for emergency service in case of commercial power failure are normally controlled through automatic or manual switching so that the emergency supply is never adjoined to the commercial supply. The neutral conductor of the emergency supply, when required, is permanently connected to the neutral of the commercial secondary service. The grounding electrode conductor of the secondary service system, therefore, suffices as a single point ground reference for both the emergency and commercial systems and such separately derived systems do not require a separate grounding electrode conductor. One exception applies: When an engine-alternator set is located in a separate building having its own ground electrode, the emergency system neutral shall also be connected to that ground electrode.

2.11 A summary of AC service grounding requirements and methods of providing and connecting grounding electrode conductors is contained in Section 802-001-180 Part 5. The summary describes basic National Electrical Code (NEC) requirements pertaining to grounding of neutral conductors for service of 600 volts or less. Individual installations must conform with all requirements expressed in the NE Code and local codes that pertain to the service furnished.

B. AC Equipment Grounding System

2.12 Protection of personnel from shock hazard and of equipment from damage is dependent on:

- (a) Properly sized and co-ordinated overcurrent devices

SECTION 802-001-198

- (b) Reliable shielding of AC circuit components with grounded metallic coverings.

Overcurrent Devices

2.13 Overcurrent devices with operating characteristics suitable to protect downstream components from overheating or damage from electromagnetic forces generated by fault current are installed in the phase leads of service, feeder and branch circuits. These devices are intended to break the circuit quickly so that excessive current flow is interrupted before heating or stress reaches a level that results in combustion, melting, mechanical distortion or other damage to circuit components.

2.14 Fusible element devices (NEC standard, time delay and current limiting fuses) operate solely on heat generation. Circuit breakers generally operate on heat or magnetization, utilizing a bimetal (heat sensitive) trip device for moderate overloads and an instantaneous or time delay magnetic trip coil for heavy overloads. Interrupting time therefore depends on the amount of fault current delivered to the overcurrent device intended to protect the phase conductor in which the fault occurs. Quick action is assured only when a low impedance current path exists from the point of fault to the neutral point of the transformer windings.

2.15 In a phase-to-phase fault, a low impedance path exists through phase conductors, assuring a maximum flow of current through the overcurrent devices. In a phase-to-neutral fault, a similar path occurs via the neutral conductor. In a phase-to-ground fault, a low impedance path must be provided by means other than the circuit conductors.

NEC Requirements for Shielding and Grounding

2.16 In order to protect personnel from shock hazard, AC circuit components are normally required to be enclosed in grounded metallic enclosures or nonconductive material. When metallic enclosures are used, every part of the shielding system for a secondary service or separately derived AC distribution system must be joined together to form a common ground plane connected to the ground electrode conductor serving that system. When metallic conduit, armored cable or other forms of raceway approved by the NE Code or local codes as a grounding medium is used to enclose AC conductors, an equipment grounding plane is formed throughout the AC distribution system.

When nonmetallic conduit or other nonconductive or unapproved raceway is used or when phase leads are run in free air, an AC equipment ground conductor must be run with phase leads and connected to cabinets, frames, chassis to form metallic units of the AC distribution system into a common ground plane. The system employed to form metallic enclosures into a common ground plane is referred to as the **AC Equipment Ground System**.

2.17 The requirement to bond the AC equipment ground system to the grounding electrode conductor, which in turn is connected to the AC system neutral conductor, provides a direct path to the transformer windings for fault current imposed at any point on the AC equipment ground plane. In practice, raceways or equipment ground conductors terminating at the main AC distribution panel are usually bonded or extended to an equipment ground bus mounted in the panelboard near the neutral bus provided therein. The equipment ground and neutral buses are connected together with a strap or wire. The grounding electrode conductor, which is terminated on the neutral bus, is thereby connected to the AC equipment ground system and provides ground reference to it.

2.18 The AC equipment ground system for a separately derived AC system requires connection to the grounding electrode conductor and the neutral. This is generally accomplished by extending the grounding electrode conductor to the neutral and to a point on the equipment ground plane at the location of the energy source (transformer, inverter, etc.) It may, however, be connected at any point between the energy source and main disconnect device, if expedient.

3. BELL SYSTEM AC EQUIPMENT GROUND REQUIREMENTS

3.01 Minimum safety requirements specified in the National Electrical Code are met by forming the equipment ground system by means of either metallic raceway or equipment grounding (wire) conductors. It has been recognized, however, that these forms of grounding are not always effective in shielding communication circuits from noise generated in AC systems. Supplementary requirements for a more effective AC equipment grounding system to be used in Bell System buildings housing communication equipment are listed below.

3.02 Supplementary Bell System requirements are as follows:

(a) AC conductors shall be run in metallic raceway (NEC approved as an equipment grounding conductor) exclusively, except for short runs. Short runs not in metallic raceway shall be provided only for reasons of physical limitation and must employ an equipment ground conductor to maintain continuity of the equipment ground plane.

(b) An AC equipment ground conductor shall be provided in metallic raceway, bonded to equipment enclosures so as to provide continuity between enclosures independent of raceway continuity, except for short run and low current branch circuits.

3.03 Installation of metallic raceways shall be in conformance with requirements outlined in the National Electrical Code and local codes.

3.04 The requirement to provide AC equipment ground conductors in metallic conduit exceeds NEC and known local code requirements. In general, installation requirements are identical to those outlined in NEC Article 250 for equipment ground conductors required with AC conductors run in other than metallic raceways. Certain exceptions to those requirements are allowed, as outlined in following parts of this section. The exceptions are predicated on the theory that the use of an equipment ground conductor in parallel with metallic raceway is desirable when it significantly increases reliability of the equipment ground system but that portions may be omitted where the raceway dependability is not significantly improved. Generally, these exceptions are restricted to:

(a) **Short Raceway Runs:** Generally, short runs have relatively few fittings that may become corroded or otherwise introduce impedance. Also, impedance of conduit metal, which may be significant in retarding fault current flow in long runs, is not significant in short runs.

(b) **Low Current Branch Circuits:** For circuits having overcurrent devices of 20 ampere or less rating, the raceway metal provides an adequate fault current path. Provision of an AC equipment ground conductor in parallel with raceway metal generally does not result in a

significant improvement in protection except for unusually long runs.

3.05 Principal advantages of the use of an equipment ground conductor in parallel with metallic raceway are:

(a) The conductor provides a path in parallel to inadvertent disconnections or impedances in the raceway current path. Raceway continuity depends on the integrity of a number of series joints. These joints are known to be prone to corrosion or relaxation that in time may result in discontinuity or increased impedance.

(b) The conductor decreases ground path impedance in long conduit runs. The resistivity of raceway metal becomes a significant factor in long runs, reducing the amount of fault current flow to overcurrent devices, which can radically affect the disconnect time. Generally, resistivity of raceway is dependent on its length, conductivity of the metal and the available cross-sectional area. For example, rigid steel conduit enclosing 120-volt leads, is effective for run lengths of from about 100 to 150 feet, dependent on conduit size and overcurrent device rating, for disconnect time of 1-1/2 seconds or less. If run length were doubled, disconnect time could increase ten-fold. Addition of an equipment ground conductor, sized for NEC Article 250-95, would allow an increase in the run length to greater than 150 percent without increasing disconnect time.

(c) Shielding of AC generated noise from imposition on communication circuits is improved by provision of a shunt path around impedance points in the equipment ground plane and by ensuring that AC conductors are enclosed in grounded metallic raceway.

3.06 AC equipment ground conductors shall be provided in:

(a) New buildings housing communication equipment:

(1) In AC service, feeder and branch circuit raceways serving:

(a) Communication equipment.

SECTION 802-001-198

(b) Building service equipment (at option of owner).

(b) Existing buildings housing communication equipment:

(1) In new extensions of the existing AC network serving:

(a) Communication equipment.

(b) Building service equipment (at option of owner).

(2) In existing AC circuit runs only if:

(a) Existing AC generated noise on communication circuits cannot be eliminated by improvement of continuity of the raceway.

3.07 Generally, retrofitting of in-service circuits with AC EG conductors is not economically justified; therefore it is not recommended unless proven that reduction of noise in the communication system will result. Noise generated by an AC circuit which may be reduced by addition of an AC EG conductor is often produced by a loose or corroded joint in the raceway ground path. Every effort should be made to eliminate such impedances, rather than attempting to short them out with an AC EG conductor, since they constitute a potentially dangerous condition that requires correction.

4. AC EQUIPMENT GROUND CONDUCTOR

4.01 This part covers requirements for provision of an AC Equipment Ground (AC EG) conductor in metallic raceways of AC distribution systems. It does not cover installation of raceways, which shall be installed in accordance with NEC Article 250 and local code requirements. The instructions are not identical to NEC requirements for use of equipment grounding conductors in AC systems using other than metallic raceways; therefore engineering of such nonstandard systems from these instructions should not be attempted.

4.02 The main purposes of the AC service equipment ground system described herein are:

(a) To maintain low potential between cabinets, conduits and other metallic enclosures of the AC service system and nearby metallic

members, so as to minimize possibility of electrical shock hazard.

(b) To provide an adequate conductive path for current flow in ground faults, so as to cause overcurrent devices to interrupt current quickly, thereby minimizing fire hazard and equipment damage.

(c) To assist in the reduction of noise in communication circuits by provision of a low impedance grounded shield throughout the AC service system.

4.03 The AC equipment ground conductor supplements the ground path inherent in metallic raceways and associated equipment enclosures to ensure that an adequate conductive path exists independent of the condition of connective joints between raceways and enclosures.

4.04 In the past it was generally believed that adequate equipment grounding could be obtained by grounding the electrical apparatus (fixed cabinets, motors, rectifiers, etc) to steel building structures or by having the equipment served by grounded metallic raceways. Conduits and raceways carrying ac service were assumed to be adequately grounded by their mechanical connections to house service cabinets and incidentally grounded by being clamped to framing bars, superstructures, cable racks, etc. In many instances, the frequent bolting of conduits to various racks and pieces of equipment throughout the office does not necessarily ensure that an adequate ground fault path has been provided and all shock hazard eliminated. The use of nonconductive finishes in many cases decreases the probability of dependable grounding through auxiliary framing and cable rack structure. The external bonding of conduits to various grounds may also prove to be ineffective at times.

4.05 In AC circuits, the division of current in parallel paths will depend on the inductive reactance as well as the resistance of these paths. The reactance increases as the spacing between the outgoing and return path increases. The reactance may become the major controlling factor and may force the ground-return current to flow largely on the path close to the outgoing conductor regardless of the lower resistance paths more distant from the outgoing conductor. The presence of magnetic material in the power conductor

enclosures introduces additional inductive effects tending to confine the return ground currents within the magnetic enclosure. Excessive voltages can exist if the impedance of the ground path (enclosure) is high. The potential can be great enough to be injurious to a person stepping or reaching from one point to another. Failure to pass sufficient current to operate the protective device can cause fires due to the heat generated by the short-circuit current.

4.06 Attempting to relieve the conductor enclosure by installation of an external grounding conductor is sometimes ineffective. It should be realized that most of the total ground-fault current will flow through the enclosure. For example, when conduits are grounded with a conductor outside of the enclosure whose impedance is approximately equal to that of the conduit, the ground fault current divides with ratios, such as, 20 parts in the conduit to 1 in the conductor at low currents and 10 parts in the conduit to 1 in the conductor at high currents. With a separate grounding conductor of equal impedance inside the conduit, the current tends to divide equally between the conductor and the conduit. It may be concluded that when the circuit conductors are enclosed in, and the grounding conductor is external to a metallic enclosure, the enclosure will carry a major portion of the return fault current. Failure to provide a continuous path in the enclosure may result in arcing and heating which may cause fires.

4.07 An AC equipment ground (AC EG) conductor provided in the same raceway with phase conductors ensures that minimal impedance to the flow of fault current will be encountered. The following requirement shall therefore be applied to the design of AC distribution systems in Bell System buildings:

An AC equipment ground (AC EG) conductor, enclosed in the same raceway with phase conductors, shall be provided for circuits distributing AC power from a commercial or locally derived power source, with exceptions as follows:

Exception 1: An AC EG conductor is not required when a branch circuit overcurrent protection device rating does not exceed 20 amperes and the conductors are run in continuous metallic raceway approved as a grounding conductor.

Exception 2: An AC EG conductor is not required when branch circuit phase conductors are run in continuous metallic raceway approved as a grounding conductor that does not exceed 25 feet in length from the enclosure of the unit containing the circuit overcurrent device to the enclosure of the unit served by the branch circuit.

Note 1: Exceptions 1 and 2 are based on the assumption that the metallic raceway provides adequate grounding for low amperage circuits, and for short conduit runs regardless of amperage rating of the circuit. The exceptions are included to simplify the installation of an adequate equipment grounding system.

Note 2: Where metallic raceway may be subject to unusual corrosion (i.e., run outdoors or buried) or is not approved as a grounding conductor, exceptions 1 and 2 do not apply.

Note 3: Where branch circuit raceway runs covered under exception 1 are exceptionally long (greater than 250 feet), the raceway may constitute sufficient impedance that disconnect time of overcurrent devices will be increased to an undesirable interval. It is recommended (not mandatory) that these runs be equipped with an AC EG conductor.

Note 4: Exception 1 shall not apply to branch circuits serving frame and aisle fluorescent lighting units. The AC EG conductor shall be extended to ballasts within units so as to provide a parallel grounding path to that afforded by the interconnection of lighting unit enclosures and conduit of the branch circuit.

4.08 The inclusion of an AC EG conductor in a raceway shall not be counted in determining the ampacity of conductors in accordance with Note 8 associated with Tables 310-12 and 310-14 of Article 310 of the National Electrical Code. The AC EG conductor is not a current carrying conductor. In a three phase grounded circuit, as defined in Note 11 of the NEC Article 310, the neutral is not counted as well. Therefore a conduit containing three phase wires, a neutral and an AC EG conductor may be, within the limitations defined in Note 11, considered as not more than three conductors and need not be derated. The AC EG conductor shall

SECTION 802-001-198

be included in calculations of allowable percentage of conduit fill defined in Chapter 9, Table 1 of the National Electrical Code.

4.09 AC service phase conductors in sizes 1/0 and larger may be run in multiple provided the arrangement is such to assure equal division of total current among all conductors involved. When run in multiple raceways, separate equipment ground conductors shall be run in each raceway. All of the multiple equipment ground conductors shall be of the same length and size and terminated in the same manner. Size of the equipment ground conductors shall be determined as follows:

- (a) Determine number and size of phase and neutral conductors required for load.
- (b) Determine number of raceways required to accommodate phase and neutral conductors. Each raceway shall contain an equal number of conductors of each phase, a neutral conductor (if grounded service is provided), and an equipment ground conductor.
- (c) Determine ampacity rating (fuse or nonadjustable circuit breaker) or setting (adjustable circuit breaker) of overcurrent device protecting phase conductors.
- (d) Determine size of individual equipment ground conductors: Consult Fig. 1. Wire size is denoted at intersection of column representing number of raceways and line representing overcurrent device rating or setting. Number of wires to be provided is indicated on top of column.

EXAMPLE: Figure 2 outlines a typical procedure for determining the number and size of phase, neutral and AC EG conductors, and number and size of conduits required for a multiconduit AC circuit. Typical calculations shown equate to the requirements of a 750KW, 120/208V, 3 phase, 4 wire, gas turbine alternator set. Other 1 or 3 phase, grounded or ungrounded AC circuit applications may be calculated by modification of the procedure per Note 1 of Figure 2.

4.10 The AC equipment ground conductor may be NEC standard green insulated or bare stranded (8 AWG or larger) or solid wire. Insulation

may be type RH, RHW, TW, THW or other NEC coded types.

4.11 When other than KS-20785 (ie, KS-5497-01, etc) armored cable is used for AC service, the equipment ground conductor shall be the same size as phase leads. The entire exposed portion of the EG conductor shall be painted or otherwise colored green or made bare for purpose of identification. KS-20785 may be ordered with an appropriately sized AC EG wire.

4.12 When multiple AC circuits are run in a common raceway (see Fig. 3), the AC EG conductor may be a single conductor of size required by the ampacity rating or setting of the largest overcurrent device of the associated circuits. The single AC EG conductor shall be tapped and branched, reduced and extended with each branch circuit emanating from the common raceway to each unit in which phase leads terminate. Reduction of the branch AC EG conductors shall be in accordance with requirements of the branch circuit overcurrent device ampacity or setting. When the branch circuit is a low ampacity (20 amp or less) circuit or a run of less than 25 feet, and enclosed in conductive raceway, the AC EG conductor may be omitted from the branch circuit. The main AC EG conductor shall be connected to the raceway at every point of emission of any branch circuit, regardless of whether or not the branch circuit contains an AC EG conductor.

4.13 The AC EG conductors provide continuity in parallel with enclosing raceway, therefore each end of an AC EG conductor shall be terminated within the cabinet or other enclosure to which the raceway is electrically joined so that continuity exists between the raceway termination and the AC EG conductor termination. Facilities for terminating AC EG conductors are furnished with some electrical equipment. They may consist of a bus bar equipped with or designed to accept connectors, mounted or bonded to the interior of the enclosure to which the raceway is terminated. They may consist of studs welded or bolted to the interior which will accept connectors or they may consist of connectors bolted directly to the interior of the unit frame or sheet metal. When no such facility is provided, equivalent facility shall be provided on a job basis. Location of such facility as close as practicable to the raceway entry point is preferred. Continuity between raceway and AC EG conductor terminations is dependent on the

metal of the enclosure. AC EG conductors routed through pullboxes and other structures that interrupt the raceway run, other than normal raceway fittings (i.e., elbows, couplings, etc.) shall be bonded to the structure interior.

4.14 AC EG conductors routed in metallic raceways and other components comprising the equipment ground plane shall be bonded to such components at intervals not exceeding 100 feet between bond points.

4.15 It is imperative that a continuous conductive path exists throughout both the AC EG conductor and any enclosing metallic material. Therefore, when the AC EG and phase leads emit from a conduit or other raceway into free air or a nonconductive fitting, the AC EG conductor and conduit must be bonded together so that the conduit maintains continuity to the termination point of the AC EG conductor. Similarly, any breaks in conduit or enclosure continuity must be bonded. Generally, the connection provisions of standard electrical fittings and enclosures utilizing bolts, screws, threads, pressure fittings and similar devices are considered adequate for electrical continuity. Certain other joining devices such as wireduct telescopic fittings are not, and should be bonded.

4.16 Generally, a floor mounted frame, cabinet or similar metallic structure provided for the support of an AC operated equipment unit served by an AC equipment ground system that conforms to Bell System requirements (see 3.02) is considered to be adequately grounded via the AC equipment ground system. When such frames are mounted in floor areas also occupied by communication equipment grounded to a CO GRD system, it is recommended that these frames be grounded to the CO GRD system also, by extending a No. 6 AWG framework ground bond from the frame to a suitable point on the CO GRD system. When the AC operated equipment is served from an AC service cabinet located on other than the same or an adjacent floor, a framework ground bond must be provided (Fig. 4). Provision of framework ground bonds ensures that low impedance exists between grounded objects in close proximity, which reduces the probability that a dangerous difference in potential can develop between components grounded by different systems.

4.17 AC EG conductors shall never be connected to the AC neutral termination point in any

equipment enclosure, except as covered in 2.17 and 2.18.

A. Engine Alternator Sets

4.18 Engine alternator sets always require an equipment ground conductor in the conduit or the metallic or nonmetallic raceways that contain phase leads from the alternator. The equipment ground conductor(s) shall be furnished in accordance with requirements per 4.09.

4.19 The equipment ground conductor(s) shall terminate within the engine alternator cabinet provided for termination of phase leads. Termination may be made on a bus bar or ground stud electrically bonded to the cabinet or directly to the cabinet interior with terminal lugs. The cabinet must be electrically connected to the set frame by bolting thereon or by a bonding strap or equivalent means to provide ground continuity between the entire set and the equipment ground conductors.

4.20 If phase and equipment ground conductors are not continuously enclosed in raceway so that electrical continuity is not maintained through raceway metal between the cabinet and the unit to which phase leads are run, the equipment ground leads must be bonded to the raceway at the point(s) of discontinuity. (See Fig. 5.)

4.21 The neutral of the alternator shall not be bonded to the AC EG conductor or set frame when the set is located in the same building as the main AC service board. The neutral shall be bonded to the AC EG conductor only when the set is located in a separate building equipped with its own ground electrode.

B. Busduct System

4.22 Busduct components used to supply floor mounted DC rectifiers in Central Office power plant installations are manufactured by outside suppliers in accordance with Bell System KS specification requirements. Equipment ground continuity is required throughout the busduct system. KS-15696 and KS-15698 busducts are not arranged for equipment ground and must be modified in accordance with requirements specified hereunder.

4.23 Each busduct section must have a connection between case and equipment ground conductor. To provide for the connection a three phase, four

SECTION 802-001-198

wire duct (50% neutral) modified to provide the bond between neutral and case may be ordered from the manufacturer for three phase, three wire AC service application. In this application the neutral bar serves as the equipment ground conductor. Three phase, four wire plug-in units may be used with this system *only* to extend equipment ground continuity to load units when required and shall *never* be used to obtain a supply requiring neutral connection, such as 120/208V service.

4.24 Section 802-004-151 (J86735), *Power Service Equipment*, and PEL 6132 notes cover equipment design and application requirements for AC service equipment in telephone central offices. Both publications specify that AC service cabinets serving single phase grounded circuits shall be fed from the house service board. In view of the possibility of creating a hazardous or noisy condition by inadvertent misconnection of plug-in units to neutral and equipment grounds, modifications of busduct to provide five conductors (phase A, B, C, 50% neutral, 50% AC EG) shall not be provided for the purpose of furnishing three phase, four wire service to AC service cabinets.

4.25 Continuity of the equipment ground conductor from busduct to the load unit is not required when the length of the conduit or armor between the case of the plug-in unit and point of connection at the load unit is not more than 25 feet and the conduit or armor is electrically continuous, or if electrically continuous and the overcurrent device rating is not more than 20 amperes regardless of length of run. These exceptions are predicated on the expectation that the conductivity of the conduit or armor will provide adequate protection for relatively short runs or low amperage circuits. Normally, the load units fed from busduct systems, principally rectifiers associated with the DC power plants, will be within 25 feet of the duct and extension of equipment ground conductor will not be required.

4.26 Feeder tap boxes and plug-in units are considered to be adequately bonded through mechanical interconnection to busduct sections, and will not require internal bonding to equipment ground conductor.

4.27 The equipment ground conductor(s) associated with busduct feeder and distribution circuits

shall be furnished in accordance with requirements per 4.09.

4.28 Figure 6 illustrates a typical method of extending AC EG continuity to a busduct system serving a typical four pack rectifier bay.

C. AC Power Distribution Service Cabinets

4.29 AC distribution cabinets always require an AC EG conductor in conduit or other metallic raceway(s) that contain phase feeder leads to the cabinet. The AC EG conductor shall be provided in accordance with requirements per 4.09.

4.30 The AC EG conductor provided with the feeder circuit is considered adequate for providing framework grounding for the AC distribution cabinet and connected AC operated equipment only when the AC EG conductor obtains ground reference (CO GRD or grounding electrode) on the same or adjacent floor to that on which the AC service cabinet is located. Otherwise, the cabinet shall be framework grounded to the floor CO GRD system, using a No. 6 AWG wire (see Fig. 4).

4.31 AC EG conductors shall terminate in the interior of the cabinet enclosure on an equipment ground bus bar electrically connected to the cabinet enclosure, if provided. Otherwise, each AC EG conductor shall terminate, using terminal lugs bolted to the cabinet enclosure, near the raceway entry point.

4.32 Continuity of AC EG leads from the AC distribution cabinet to branch circuit load units is not required when the circuit conforms with conditions outlined in exceptions 1 or 2 in 4.09.

4.33 The neutral bar provided in AC distribution cabinets must be insulated from the enclosure and the equipment ground bar. Extreme care must be exercised to insure that the neutral does not have electrical continuity through mounting apparatus, terminal mounting bolts, or otherwise to the cabinet enclosure.

4.34 Figure 7 illustrates typical AC circuits that terminate in an AC distribution cabinet and defines those circuits that require an AC EG conductor. The illustration is based on the assumption that all raceway is metallic conduit that is electrically continuous between the AC distribution

cabinet and load unit enclosures. It should be noted that the AC EG conductors would terminate on the cabinet enclosure metal if an AC EG bus is not provided in the cabinet.

D. Lighting Distribution Systems

4.35 AC feeder circuits serving AC distribution panels provided for branch circuit distribution of AC service to lighting fixtures and AC appliance outlets shall include an AC EG conductor. An AC EG conductor shall be provided as described in 4.12 in each raceway emanating from such panels that contains branch circuits serving switchroom fluorescent lighting fixtures. The AC EG conductor shall be branched and extended so as to terminate at one of the screws that secure the lamp ballast on the interior of every fluorescent lighting fixture. This ballast grounding system is recommended to ensure a reliable ground path from ballasts for the purpose of suppressing transient voltages emanating from ballast and other components of the lighting system. The exceptions noted in 4.09 therefore do not apply to this application.

4.36 General Electric type DH busway (M.D.) has been used in No. 1 ESS and other electronic systems lighting distribution circuits, in place of panel boards. There is no practical way to extend an AC EG conductor within the busway. The busway enclosure metal must therefore be depended on to provide continuity from the AC EG conductor furnished with busway feeders to plug-in circuit breaker units mounted thereon. It is expected that some DH busway installations will be replaced with the standard distribution system for ESS installations that utilizes "Wiremold" raceway. When replacement occurs, AC EG conductors shall be added.

E. Cord Connected AC Operated Equipment

4.37 Parallel polarized U ground slot receptacles are standard for frame base appliance outlet and other miscellaneous 15 Amp 120V AC branch circuit applications serving cord connected equipment. Such equipment, whether portable or permanently mounted, shall be equipped with a three wire cord and a three wire grounding attachment plug (cap). Two wires of the cord shall serve as circuit members. The third wire shall serve as a grounding member, connected at the cap to the U blade, and to the equipment structural metal, so that ground continuity

is established from the receptacle to the equipment structure.

4.38 The U ground slots of such receptacles are permanently bonded to the metallic parts utilized for mounting the receptacle to a box or frame, and mounting thereto establishes a ground path to the box or frame metal (a bonding jumper per NEC 250-74 is normally not required). Armored cable, conduit or other raceway metal utilized as enclosures for branch circuit conductors serving the receptacle must be electrically connected (conduit locknuts or equivalent) to the box or frame to serve as an extension of the ground path to the panelboard or other unit containing the branch circuit overcurrent protection device.

4.39 When branch circuit conductors are not run in electrically continuous metallic raceway an AC EG conductor must be provided from the panelboard to the receptacle, and may be provided as additional protection when such circuits are in electrically continuous raceway. The AC EG conductor shall terminate on the metal outlet box or other enclosure mounting the receptacle, not on the EG (green) terminal screw of the receptacle. Ground continuity is provided to the U ground slot via the receptacle mounting members (NEC 250-114). Bonding jumpers (NEC 250-74) are ordinarily not required, except for flush receptacle boxes in masonry walls when the receptacle is not equipped with a mounting screw positive contact device.

4.40 For branch circuits of other than 120V and/or 15 Amp maximum, suitable receptacles, cords and caps for the required service shall be provided to furnish equivalent grounding facility.

4.41 Older central office installations may be equipped with 2-pole, 3-wire grounded receptacles of other design: Crowfoot, "T" slot or other. These receptacles may be used with parallel polarized U ground caps equipped with suitable plug adapters. Some offices may employ 2-pole parallel ungrounded receptacles. Adapters equipped with a ground wire and terminal for attachment under receptacle mounting screw head or to other suitable ground point must be employed for use with 2-pole 3-wire grounded caps.

4.42 Certain portable equipments now in use may be equipped with 2-pole ungrounded caps and 2 wire cords. Unless protected by an approved system of double insulation, such units are potentially

hazardous. Where practical, such cord and caps shall be replaced with 3-wire cords and 2-pole, 3-wire grounded caps. If not grounded or double insulated, the equipment may be in violation of the Occupational Safety and Health Act, which adopts NEC Article 250-45, retroactively. Where units suitably arranged for grounding are used in offices with 2-pole ungrounded receptacles, the cap shall be equipped with a ground wire type adapter to ensure that grounding facility is available. Makeshift grounding arrangements, such as taping a ground conductor to the exterior of a 2-wire cord is undesirable since such a wire is susceptible to damage.

4.43 Frame mounted AC operated equipment now in service that are served with 2-wire cord and ungrounded caps need not be modified for a grounded system where it can be ascertained that these permanently mounted units have continuity through the frame to the branch circuit enclosing raceway. Such a path constitutes adequate grounding protection.

4.44 Generally, all new manufacture AC operated portable or permanently mounted equipment units utilizing cord and cap for AC supply shall be supplied with 3-wire cords and 2-pole, 3-wire grounded caps that function to ground the unit structure. The only exceptions shall be for tools such as soldering irons that must be employed on or near circuit connection points that may have DC potential, where contact with the tool would constitute a short to ground, or for other specialized requirements of similar nature. Electrical protection requirements covered in Section 010-111-010 shall be applied when portable electrically operated tools are used.

F. Frame Base Appliance Outlets

4.45 Convenient appliance outlets are provided throughout a communication equipment area to make 120V single phase grounded AC service available to operate cord connected appliances: Test sets, soldering irons, floor maintenance equipment, etc. Appliance outlets are established by mounting duplex parallel polarized U ground slot receptacle units in the base of communication equipment frames, with the U ground slot in contact with the frame metal. Generally, two circuits are used to serve the receptacles located in frame lines comprising an equipment block (group of contiguous frame lines). In each block, the two circuits are

alternated so that each serves receptacles in alternate frame lines.

4.46 The AC circuits are generally extended to the frame area by means of metallic raceway (ie., conduit, armored cable, wiremold). They are alternatively tapped and extended to the ends of frame lines in armored cable or conduit. The metallic raceway is usually terminated in a conduit hole provided in an end guard mounted on an end frame of the frame line, with a fitting (ie, Kondu K0-2, KS-20785 L-33, etc) approved for use as an equipment grounding fitting (NEC Article 250-91(b)). When so arranged, equipment ground continuity exists between the unit containing the circuit overcurrent device (usually a 20-ampere circuit breaker mounted in a lighting and appliance branch circuit panelboard) and the frame end guard via the raceway metal. An AC EG conductor may be provided in the raceway and terminated on the end guard, but it is not a requirement (4.07, Exc. 1).

4.47 For the purpose of providing continuity between the U ground slots of the several receptacles and the terminal point of the raceway in the end guard of a frame line, the frame line is considered to be one continuous metal frame. It provides a ground current path for faults occurring in a portable appliance or cord plugged into the receptacle, or in the AC conductors extended through the frames to the receptacles. Generally, in addition to ground paths formed by bolting between frames, ground bus bars and/or framework ground conductors provided as part of the discharge ground or CO GRD systems ensure dependable bonding between frames.

4.48 Usually, the circuit conductors are extended from the raceway terminal point as loose wires run in end guard and frame bases. They may, however, be extended in raceway if protection from physical damage or shielding from personnel is desirable. Where gaps occur in the frame line, the portion of the circuit run that bridges the gap must be run in raceway terminated at frames with fittings that provide equipment grounding continuity via the raceway between the separated frames.

G. KS-20085 Trolley Type Busduct

4.49 Trolley type busduct provides 15 ampere 120V AC power for portable appliances. Generally, installations are made at distributing frames where personnel working on rolling maintenance

ladders require a power supply for soldering irons. The busduct consists of a U-shaped steel rail enclosure mounted to superstructure with the mouth of the U facing down. Copper strap conductors are mounted in left and right sides of the U, insulated from the enclosure. Couplings and end connectors are provided to form a continuous circuit that runs the length of the equipment frame line.

4.50 A trolley type device, with contacts on either side that maintain sliding contact with the copper straps and four wheels that ride in grooves formed for the purpose in the open side of the enclosure, travels inside the duct and provides a connecting means for extending AC via a three-conductor cable to a receptacle mounted in a conduit box on the rolling ladder. AC service is thereby made available at the rolling ladder by extending an AC circuit in raceway to the trolley duct end closure, through the duct via the copper straps, and to the receptacle via the trolley and cable.

4.51 Other installations are made in equipment aisles: generally in Maintenance Test centers where rolling ladders are not used. In these applications, the cord is terminated in a parallel polarized U ground slot plug that hangs within reach above personnel. AC power available therefrom is used to power test sets and various other appliances.

4.52 Equipment grounding is provided through the AC circuit conduit metal, the duct enclosure metal, metallic parts of the trolley and the equipment ground conductor provided in the three-conductor cord. An AC EG conductor is not required in the conduit that carries branch circuit conductors from the panelboard (or other device) to the busduct end connector when it is a continuous metal raceway (4.07 Exc. 1).

4.53 Prior to the introduction of KS-20085 List 12 trolleys, equipment grounding continuity between duct enclosure and cord AC EG conductor depended on contact of duct metal with trolley wheels, which was not always dependable while the trolley was in motion. List 12 trolleys provide improved contact by means of spring type contacts. It is recommended that earlier type trolleys be replaced by the List 12 model.

5. DOCUMENTATION OF AC EQUIPMENT GROUND REQUIREMENTS

5.01 Application of AC EG conductors in the equipment grounding system, unlike the use of raceway for the same purpose, must be recorded on job record drawings so that a continuing engineering control may be maintained on the system and so that instructions for installation may be provided to the installer. Additionally, standard circuit and equipment drawings must include the requirement when AC circuits are specified thereon.

5.02 Drawings that will normally contain information pertaining to AC equipment grounding include:

- (a) Standard circuit drawings (SD-)
- (b) Manufacturing drawings: wiring diagrams and equipment assemblies
- (c) Job drawings, Architectural
- (d) Job drawings, Communication System AC distribution.

5.03 AC branch circuits fused at 20 amperes or less and branch circuits with conduit runs of less than 25 feet do not require an AC EG conductor in addition to metallic conduit, under most conditions. An AC EG conductor may be added if improvement of the grounding system is desirable. It is recommended if the length of run exceeds 250 feet in length and required if raceway is run in a corrosive atmosphere. These location oriented conditions require that a decision be made on a job basis to furnish or omit AC EG conductors in many conduit runs.

A. Standard Circuit Schematic Drawings (SD-xxxxx-)

5.04 AC branch circuits are always subject to a job decision in determining if the circuit requires an AC EG conductor. Feeder and service circuits are generally not shown on circuit schematic drawings, except for those few that cover typical or dedicated AC distribution system design. AC EG conductors shall be shown or reference shall be made to their requirement on circuit schematics as follows:

- (a) Circuit schematics containing AC circuitry shown for the purpose of indicating a requirement for an AC supply to the circuit

represented by the SD drawing shall not show an AC EG conductor in the circuit figure. A note reference shall be added at the circuit figure and a circuit note shall be added to the drawing, as follows:

Circuit Note: AC equipment ground conductor shall be provided, if required, as specified in Section 802-001-180.

(b) Circuit schematics that show AC service, feeder or other types of circuits that do not require an evaluation of job conditions to determine if an AC EG conductor may be omitted from the AC circuit shall show the AC EG conductor in the circuit figure.

5.05 Application of (a) or (b) shall be made to all new circuit schematic drawings and to existing drawings as they are reissued for other reasons.

B. Manufacturing Drawings (T-xxxxx, ED-xxxxx, J-xxxxx)

5.06 Manufacturing wiring diagram drawings shall show information pertaining to the provision of AC equipment ground conductors in the same manner as outlined above for circuit schematic drawings, except that the note in 5.04 (a) shall be an engineering note.

5.07 Standard manufacturing drawings that cover equipment assembly and connection of AC conduit or other raceway to equipment enclosures thereof shall provide instructions for the termination of AC EG conductors similar to that provided for the termination of the AC circuit conductors. These provisions will, in certain applications, require larger size conduit, or armored cable with an additional conductor. Method of terminating the AC EG conductor (ie, terminals, screws, location, etc.) should be detailed. Method of connecting the various sizes of conduit or armored cables to conform with NEC grounding requirements should also be detailed so that job records can instruct the installer on methods of installation by reference to standard information.

5.08 When the addition of an AC EG conductor requires the use of a larger conduit to maintain the fill limit to 40 percent of the conduit cross-sectional area (NEC Chapter 9, Table 1), the hole size provided for terminating the conduit in

the enclosure of many existing AC operated equipment units will be too small to accommodate the larger size conduit fitting. Manufacturing specifications need not necessarily be changed to specify a larger hole. In the majority of cases, an AC EG conductor is not required for branch circuits. Where it is, a reduction of conduit size or extension of the conduit with flexible conduit may be employed. The reduction shall not exceed 24 inches in length and a fill limit of 60 percent of the raceway cross-sectional area must be maintained. Various other methods of terminating oversized conduits, such as mounting a conduit box with a suitable sized hole over the undersized hole may also be employed. Under adverse physical conditions which preclude extensions of the AC EG conductor into the enclosure, the AC EG conductor may be terminated in a box or fitting outside the enclosure, and the raceway between the terminating point and the enclosure depended on to extend equipment ground continuity to the enclosure. A variety of conduit terminating methods are shown in Fig. 8.

5.09 The different methods of terminating raceway shown in Fig. 8 are identified alphabetically in descending order of preferability. Generally, the system that provides the least number of joints in the raceway run and provides parallel continuity of raceway and AC EG conductor to the interior of the equipment enclosure is preferable. Fittings shown in the illustration are those commonly used in Bell System installation. Other types of raceway and fittings, NEC approved for grounding purposes, are equally acceptable.

C. Job Drawings, Architectural

5.10 AC distribution system circuit requirements for specific job installations are recorded on drawings prepared by the building architect and the communication systems equipment engineer.

5.11 Architectural drawings normally include electrical plans that show the details of the service and feeder portion of the electrical system furnished by the electrical contractor. The number and size of conductors, conduits, pullboxes, etc; location thereof; and other information regarding panelboards and other electrical distribution equipment provided in the installation are shown in these plans.

5.12 An AC equipment ground system shall be provided, as specified in this section, in the portion of the AC distribution system controlled by architectural drawings. The AC EG conductors shall be shown on the plans in a similar manner to that of phase and neutral conductors. Methods of termination and other information necessary for proper installation shall be provided.

D. Job Drawings, Communication System AC Distribution

5.13 Job drawings prepared by the communication system equipment engineer are normally in the form of point to point AC distribution circuit and equipment drawings. These drawings show the extension of the AC network specified on architectural drawings to their ultimate load terminations at AC operated equipment units, frame and aisle lighting fixtures, appliance outlets and other miscellaneous units associated with the communication systems housed in the building.

5.14 An AC equipment ground system shall be provided, as specified in this section, in the portion of the AC distribution network controlled by communication system AC distribution circuit and equipment drawings. The AC EG conductors shall be shown on the drawings in a similar manner to that of phase and neutral conductors. Methods of termination and other information necessary for proper installation shall be provided.

5.15 Since the application of AC EG conductors is dependent on job parameters, the job circuit drawing shall be the engineering control

specification for the AC EG system. It shall be the responsibility of the originator of job circuit drawings to determine the requirement for AC EG conductors and to record the information on job drawings as required to provide complete installation instructions. Such instructions shall include information regarding bonding requirements to raceway at interim points in the raceway run, if required, and other detailed information as necessary to ensure the installation will conform to specifications outlined herein. Generally, circuit and equipment information contained in manufacturing drawings may be incorporated as part of the record (block schematics, equipment assembly figures) by reference thereto on the job drawing. Certain manufacturing drawings may have only note reference to a possible AC EG conductor requirement [5.04(a)] or no reference (5.05). In either case, a job decision based on physical parameters must be made for every such occurrence and recorded on the job drawing by showing or not showing an AC EG conductor associated with a circuit run. It should be understood that lack of information on standard drawings has no bearing on the job drawing originator's responsibility to determine and record AC EG conductor requirements.

E. AC EG Conductor Identification on Drawings

5.16 For the purpose of establishing a standard identification of AC EG conductors shown on circuit schematic, wiring diagram and job circuit drawing it is recommended that lead identification at points where an AC EG lead is referenced to other circuit figures or other drawings shall use letter designation as follows: AC EG.

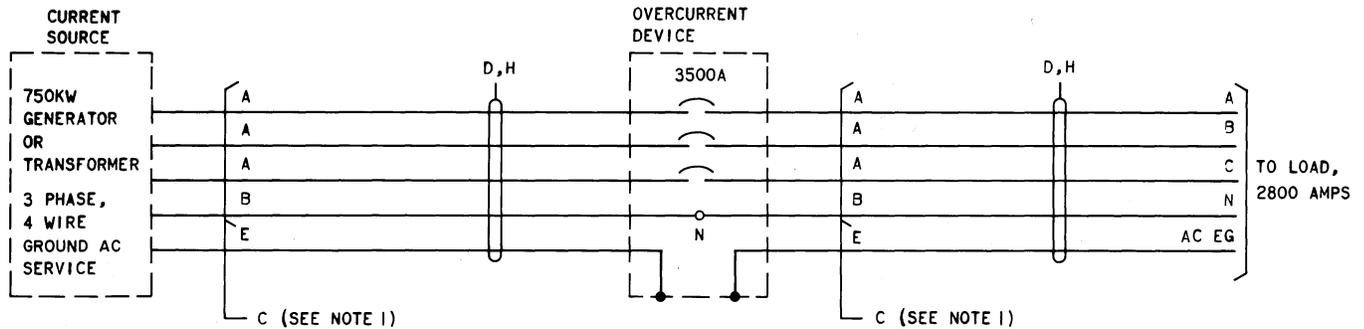
SECTION 802-001-198

TABLE I - SIZE OF AC EQUIPMENT GROUNDING CONDUCTORS FOR GROUNDING INTERIOR RACEWAYS AND EQUIPMENT

RATING OR SETTING OF OVERCURRENT DEVICE NOT EXCEEDING	NO. AND SIZE OF AC EQPT GRD CONDUCTORS REQUIRED FOR AN AC CIRCUIT UTILIZING SINGLE OR MULTIPLE PHASE CONDUCTORS RUN IN SINGLE OR MULTIPLE RACEWAYS																			
	NO. OF CONDUCTORS (COPPER WIRE)										NO. OF CONDUCTORS (ALUMINUM WIRE)									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
15 AMP	14										12									
20 AMP	12										10									
30 AMP	10										8									
40 AMP	10										8									
60 AMP	10										8									
100 AMP	8										6	8								
200 AMP	6	8	10								4	6	6							
400 AMP	2	6	6	8							0	4	4	6						
600 AMP	0	4	6	6	8	8					00	2	4	4	6	6				
800 AMP	0	2	4	6	6	6	8				0000	0	2	4	4	4	6			
1000 AMP	00	2	2	4	6	6	6	8	8		0000	0	0	2	4	4	4	6	6	
1200 AMP	0000	0	2	4	4	6	6	6	6	8	350	00	0	2	2	4	4	4	4	6
1600 AMP	0000	0	0	2	2	4	4	6	6	6	350	0000	00	0	2	2	2	4	4	4
2000 AMP	350	00	0	2	2	2	4	4	4	6	500	0000	0000	0	0	0	2	4	2	4
2500 AMP	350	0000	00	0	2	2	2	4	4	4	500	350	0000	00	0	0	0	2	2	2
3000 AMP	500	0000	00	0	0	2	2	2	2	4	750	350	0000	0000	00	0	0	0	0	2
4000 AMP	500	350	0000	00	0	0	0	2	2	2	2-500	350	0000	0000	0000	00	0	0	0	
5000 AMP	750	350	350	0000	00	00	0	0	0	2	2-500	500	350	0000	0000	0000	00	0	0	
6000 AMP	750	500	350	0000	0000	00	00	0	0	0	2-750	500	350	350	0000	0000	0000	0000	00	
NO. OF RACEWAYS	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10

- REFER TO PARA 4.09 FOR CALCULATION PROCEDURE.
- THIS TABLE SPECIFIES BELL SYSTEM STANDARD WIRE SIZES ONLY. FOR SINGLE RACEWAY APPLICATIONS, NEC TABLE 250-95 MAY BE ALTERNATIVELY USED TO DETERMINE AC EG CONDUCTOR SIZE. TABLE 250-95 IS INTENDED FOR USE IN DETERMINING AC EG CONDUCTOR SIZES FOR CIRCUITS IN OTHER THAN METALLIC RACEWAY. IT DOES NOT ALLOW A REDUCTION IN AC EG CONDUCTOR SIZE WHEN MULTIPLE AC EG CONDUCTORS ARE PARALLELED IN MULTIPLE RACEWAYS. CONDUCTIVITY OF METAL RACEWAY IS TAKEN INTO CONSIDERATION IN THE ABOVE TABLE TO ALLOW REDUCTION IN SIZE OF AC EG CONDUCTORS IN MULTIPLE RACEWAY APPLICATIONS. THEREFORE, FOR ECONOMIC REASONS, TABLE I SHALL BE USED EXCLUSIVELY TO DETERMINE AC EG CONDUCTOR SIZE IN MULTIPLE METALLIC RACEWAY APPLICATIONS.
- NUMBER AND GAUGE OF AC EG CONDUCTORS SPECIFIED IN TABLE I FOR SINGLE AND MULTIPLE RACEWAY APPLICATIONS PROVIDE CIRCULAR MILS IN EXCESS OF:
 - 131 CM PER AMPERE OF OVERCURRENT DEVICE SETTING OR RATING (COPPER)
 - 200 CM PER AMPERE OF OVERCURRENT DEVICE SETTING OR RATING (ALUM)
 SIZE OF INDIVIDUAL AC EG CONDUCTORS ARE BASED ON FORMULA:
 CM PER AMP X RATING OR SETTING + NO. OF RACEWAYS = MIN CM
 EXAMPLE: 131 X 1000 + 3 = 43,666 CM = NO. 3 (COMML) OR NO. 2 (BELL SYSTEM) AWG

Fig. 1—Table of AC Equipment Ground Conductors



FOR A GIVEN LOAD OF 2800 AMPERES WITH OVERCURRENT DEVICE SETTING OF 3500 AMPERES, TYPICAL FOR A 3 PHASE 4 WIRE GROUND AC SERVICE CIRCUIT OF 750 KW CAPACITY; NUMBER AND SIZE OF PHASE, NEUTRAL, AC EQUIPMENT GROUND CONDUCTORS AND CONDUITS MAY BE CALCULATED AS FOLLOWS:

DETERMINE:

A (NUMBER AND SIZE OF LEADS PER PHASE)

1. AMPACITY (*1) - 750MCM = 475, 500MCM = 380, 350MCM = 310
2. NUMBER - $\frac{2800}{475} < 6(750MCM)$, $\frac{2800}{380} < 8(500MCM)$, $\frac{2800}{310} < 10(350MCM)$
3. A = 6 - 750MCM OR 8 - 500MCM OR 10 - 350MCM

B (NUMBER AND SIZE OF NEUTRAL LEADS) = A (NOTE 1)

C (TOTAL PHASE AND NEUTRAL LEADS) = 3A + B (NOTE 1)

$$C = 3 \times 6 + 6 = 24 - 750MCM \text{ OR } 3 \times 8 + 8 = 32 - 500MCM \text{ OR } 3 \times 10 + 10 = 40 - 350MCM$$

D (NUMBER OF CONDUITS)(*2) = $\frac{C}{\text{NO. OF PHASE LEGS} + \text{NEUTRAL}}$

$$D = \frac{24(750MCM)}{3 + 1} = 6 \text{ CONDUITS OR } \frac{32(500MCM)}{3 + 1} = 8 \text{ CONDUITS OR } \frac{40(350MCM)}{3 + 1} = 10 \text{ CONDUITS}$$

E (NUMBER AND SIZE OF AC EQUIPMENT GROUND CONDUCTORS) (*3)

1. 3500A OVERCURRENT DEVICE SETTING, 6 CONDUITS, E = 6 - #0 AWG
2. 3500A OVERCURRENT DEVICE SETTING, 8 CONDUITS, E = 8 - #2 AWG
3. 3500A OVERCURRENT DEVICE SETTING, 10 CONDUITS E = 10 - #2 AWG

F (AREA IN CONDUIT OCCUPIED BY LEADS) (*4) = AREA (SQ IN.) OF $\frac{C}{D} + \frac{E}{D}$

$$750MCM = 1.4082, 500MCM = .9834, 350MCM = .7620, \#0 = .3107, \#2 = .2067$$

$$F = 1.4082 \times 4 + .3107 = 5.94, .9834 \times 4 + .2067 = 4.14, .7620 \times 4 + .2067 = 3.25$$

G (ALLOWABLE CONDUIT FILL) (*5) = 40% FOR 3 OR MORE CONDUCTORS

H (CONDUIT SIZE REQUIRED FOR F) (*6) = 4-1/2 FOR 5.94, 4 FOR 4.14, 3-1/2 FOR 3.25

NOTES:

1. FOR 1PH 2W GRD'D SYSTEM C = A + B; FOR 1PH 3W GRD'D SYSTEM C = 2A + B; FOR 3PH 3W UNGRD'D SYSTEM C = 3A, B = 0; FOR 3PH 4W GRD'D SYSTEM C = 3A + B.

2. REFERENCE TABLES-

TABLE	PUBLICATION	DESCRIPTION
*1 310-12 TO 15	NEC	CONDUCTOR AMPACITY
*2 3, CHAPTER 9	NEC	NO. CONDUCTORS IN CONDUIT
*3 1	802-001-198	AC EG CONDUCTORS
*4 5, CHAPTER 9	NEC	DIMENSIONS OF CONDUCTORS
*5 1, CHAPTER 9	NEC	PERCENT OF CONDUIT FILL
*6 4, CHAPTER 9	NEC	DIMENSIONS OF CONDUIT

Fig. 2—Typical Calculation of Phase, Neutral, AC Equipment Ground Conductors, and Conduit

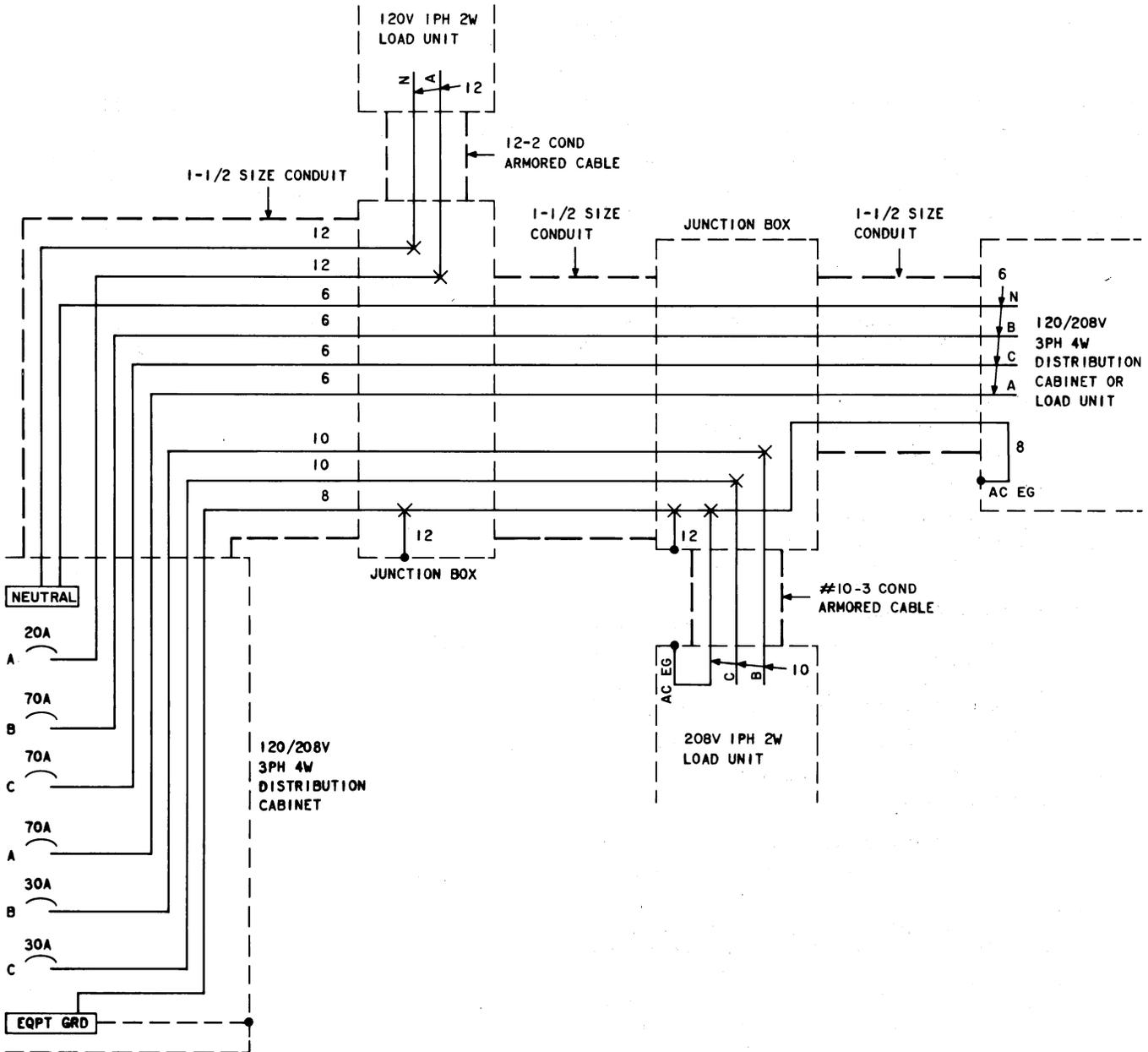


Fig. 3—Single AC EG Conductor Serving Multiple AC Circuits in a Common Conduit Run

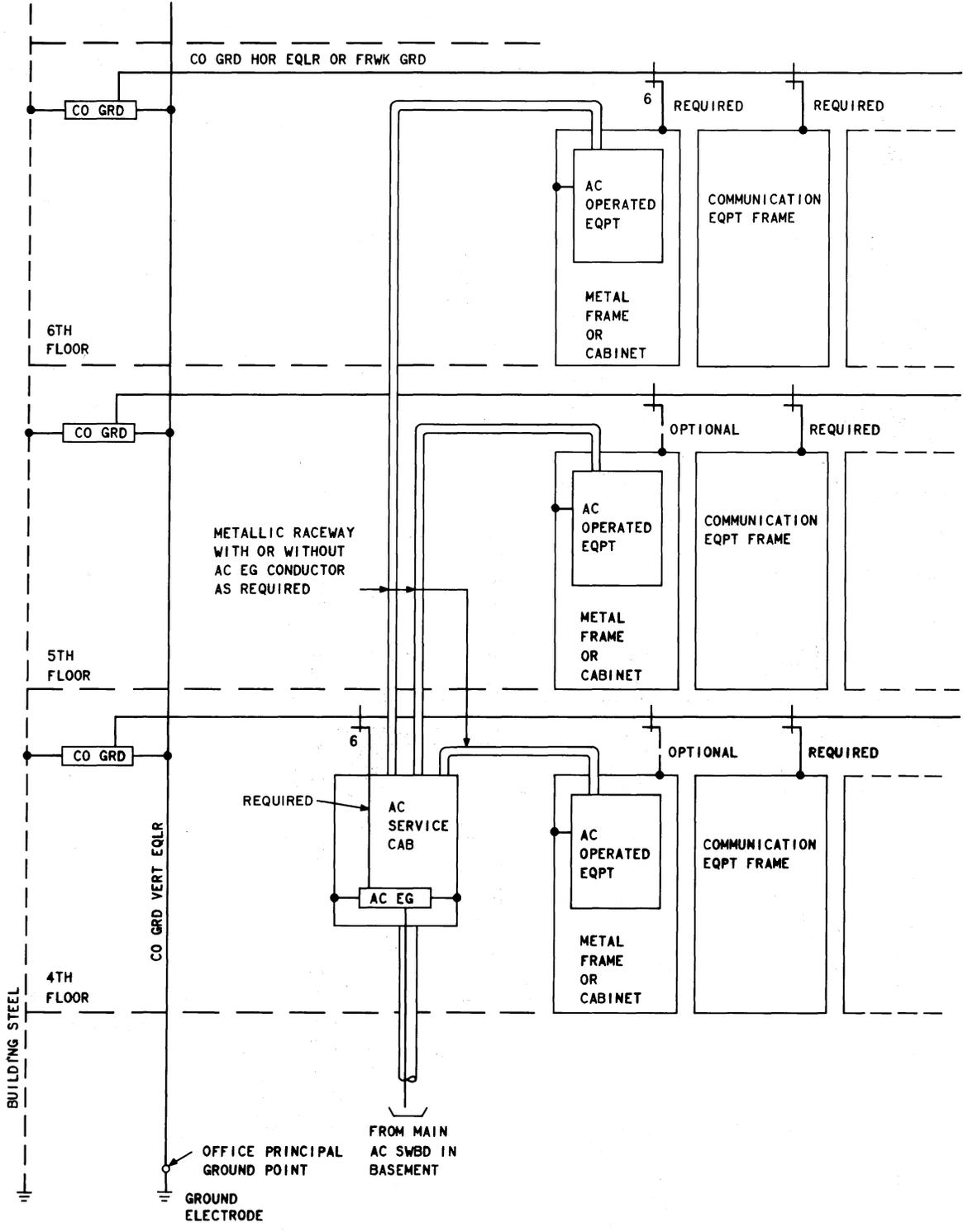
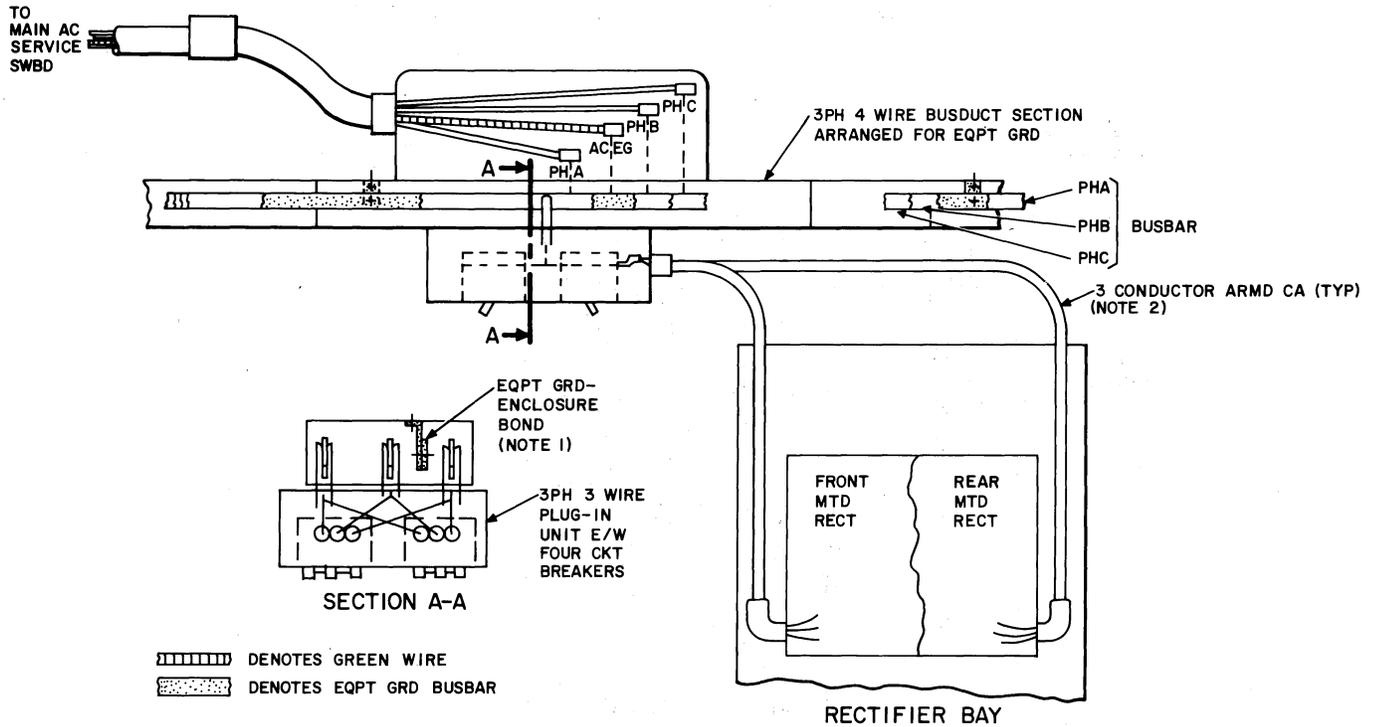


Fig. 4—Requirements for Grounding Frames Mounting AC Operated Equipment Units (Par. 4.16)



NOTES:

1. EQUIPMENT GROUND BAR-ENCLOSURE BOND (BUS OR CABLE) IS REQUIRED IN EACH BUSDUCT SECTION.
2. EXTENSION OF EQUIPMENT GROUND BEYOND THE SECTION ENCLOSURE BOND IS NOT REQUIRED WHEN LENGTH OF CONDUIT OR ARMORED CABLE FROM OVERCURRENT DEVICE TO LOAD UNIT ENCLOSURE IS ELECTRICALLY CONTINUOUS AND NOT MORE THAN 25 FEET IN LENGTH. WHEN OVERCURRENT DEVICE RATING IS 20 AMPS OR LESS LENGTH RESTRICTION DOES NOT APPLY.

Fig. 6—Typical Busduct System Equipment Grounding Arrangement for 3-Phase, 3-Wire System When Load Unit is 25 or Less Feet From Busduct or When Overcurrent Device Rating is 20 Amp or Less

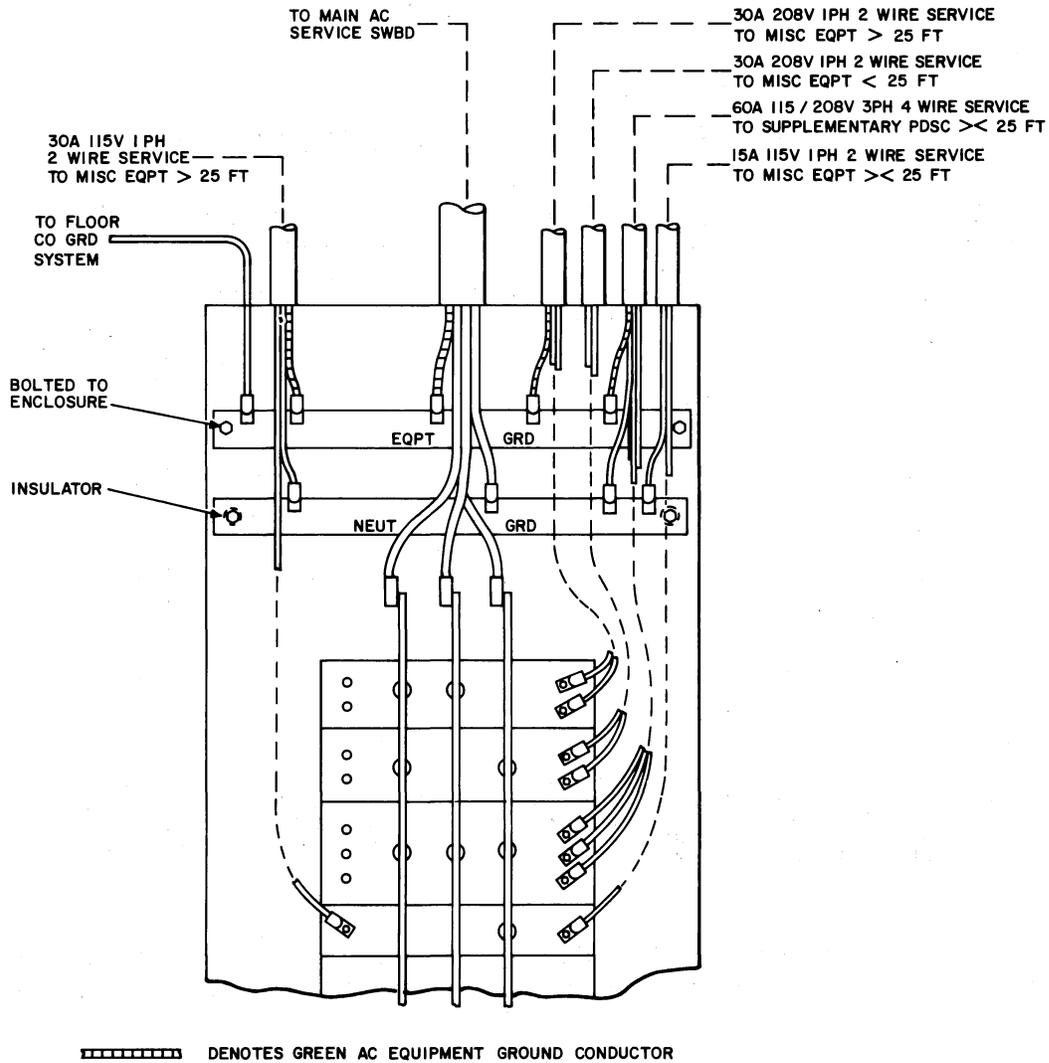
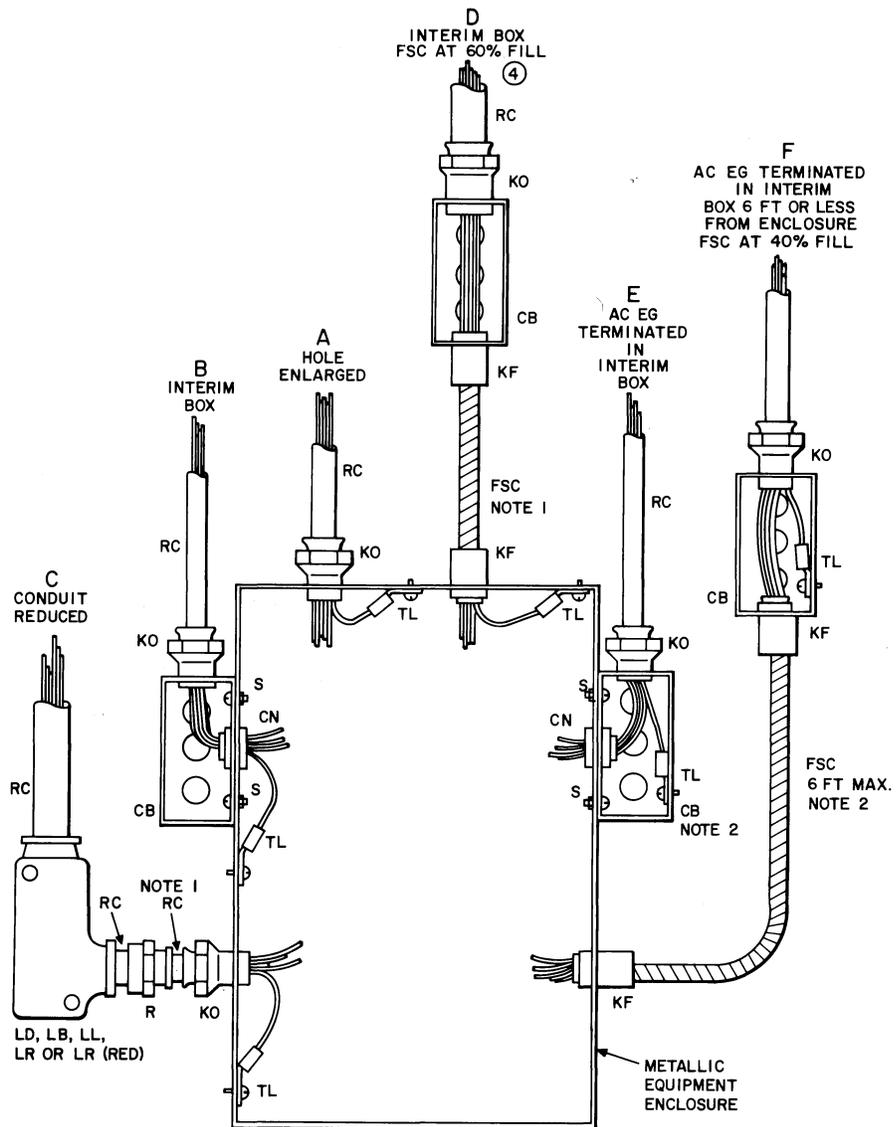


Fig. 7—Typical Power Distribution Cabinet Equipment Grounding Arrangement



LEGEND
 RC - RIGID CONDUIT
 FSC - FLEX STEEL CONDUIT
 KO - KONDU KNOCK-OUT FITTING
 LD, LB, LL, LR, LR (RED) - KONDU CONDUIT FITTINGS
 R - KONDU REDUCER FITTING
 CB - CONDUIT BOX
 TL - TERMINAL LUG, AC EG LEAD
 CN - INSULATED CHASE NIPPLE, LOCKNUT
 S - SCREW, NUT, WASHER
 KF - KS-5497-01 KNOCK-OUT FITTING

NOTES:
 1. MAXIMUM CONDUIT FILL SHALL BE 40 PERCENT, EXCEPT THAT EXTENSIONS OF LESS THAN 24 INCHES FROM AN INTERIM BOX OR FITTING TO AN EQUIPMENT ENCLOSURE MAY BE FILLED TO 60 PERCENT.
 2. TERMINATION OF AC EG LEAD IN AN INTERIM BOX OR FITTING SHALL BE WITHIN 6 FEET OF THE ENCLOSURE. SUCH TERMINATION SHOULD BE MADE ONLY WHERE RUNNING OF AC EG LEAD TO ENCLOSURE IS UNUSUALLY DIFFICULT OR COSTLY.

Fig. 8—Typical Conduit and AC EG Conductor Terminating at Equipment Enclosures When Enclosure Conduit Holes are Too Small To Terminate Rigid Conduit Fittings