PROTECTIVE GROUNDING SYSTEMS
GENERAL GROUNDING REQUIREMENTS FOR COMMUNICATION SYSTEMS IN CENTRAL OFFICES, RADIO STATIONS AND OTHER STRUCTURES
POWER SYSTEMS

CONTENTS PAGE

REASONS FOR REISSUE

This section is being reissued to expand information covering equipment requirements and engineering information pertaining to the design of protective grounding systems. Information previously covered in Section 802-001-180 and SD-81899-01 is expanded and covered in Section 802-001-180 (which has been retitled and covers general requirements) and a new series of supplementary sections, numbered 802-001-190 through 802-001-198. The text has been completely rewritten and reillustrated. Generally, the intent and purpose of the grounding systems described in the previous issue of Section 802-001-180 is unchanged: Certain intrasystem application restrictions have been modified. More definitive information and instructions have been added. Theoretical information has been included in instructions covering physical configurations to facilitate the design of an effective grounding arrangement for equipments not covered in detail in these sections. Since this reissue is a general revision, arrows ordinarily used to indicate changes have been omitted.

1. SCOPE

1.01 This section consists of general information pertaining to the requirement for effective protective grounding systems in structures having Bell System communication systems equipment. A general description of the grounding systems utilized to maintain equalization of potential on ground planes, to minimize impedance produced noise and to provide personnel and equipment protection is included. Principal characteristics of the various grounding systems and parts thereof are defined herein.

1.02 Specific equipment requirements and design information for the various grounding systems are covered in the following supplementary sections:

SECTION	TITLE
802-001-190	Equipment Ground Systems Material—General Equipment Requirements
802-001-191	Office Ground Electrodes—General Equipment Requirements and Engineering Information
802-001-192	Equipment Ground System, Central Offices—General Equipment Requirements and Engineering Information
802-001-193	Equipment Ground System, Central Offices—General Interface Requirements for DC Power Plants and Communication Systems
802-001-194	Equipment Ground System, Central Offices—General Interface Requirements, Manual Toll Relay Rack Ground System
802-001-195	Equipment Ground System, Central Offices—General Interface Requirements for Electronic Switching Systems
802-001-196	General Equipment Ground Requirements for Private Branch Exchanges on Customers Premises
802-001-197	General Equipment Ground Requirements for Microwave Radio Main and Auxiliary Stations
802-001-198	General Equipment Ground Requirements for AC Service Distribution Systems in Communication System Buildings

1.03 Communication system specifications generally do not provide detailed information on the method of providing ground reference to the system. Ordinarily, an engineering note stating that grounding shall be provided in accordance with Section 802-001-180 is included in the specification. Where such reference is encountered, it shall be assumed that it also includes reference to appropriate supplementary Protective Grounding Systems sections listed in 1.02.

1.04 Grounding practice recommendations contained in the Protective Grounding Systems sections conform with or exceed requirements defined in the National Electrical Code (NEC). References to the Code in these sections are based on the 1971 edition. The provisions defined in these sections do not cover every unique grounding application to be encountered in a communication systems complex. Grounding arrangements may be devised for unique applications, based on design criteria outlined herein. They must conform to NEC and local code requirements. Where additional Bell System restrictions are expressed in these sections for comparable applications, those requirements shall be incorporated.

1.05 The bibliography of Bell System publications contained herein is intended as a complete reference for the series of Protective Grounding Systems sections and is not reiterated in the supplementary sections.

2. INTRODUCTION

2.01 The primary purposes of a dependable low impedance grounding system in offices and stations containing communication transmission facilities are:

(a) ***Personnel Safety:*** To maintain low potential between frames, cabinets, ironwork and other conductive components so as to minimize possibility of electrical shock hazard.

(b) ***Equipment Protection:*** To provide adequate fault current paths so that overcurrent devices may function efficiently and to avoid fire hazard through elimination of high impedance points.

(c) ***Equipment Operation:*** To provide an equalized ground reference throughout the ground plane to communication circuits connected thereto.

(d) ***Noise Reduction:*** To assist in the reduction of noise in communication circuits by ensuring that impedance is minimal between ground points throughout the communication system area.

(e) ***Reliability:*** To provide a ground network that resists deterioration or inadvertent disconnection and requires minimal maintenance to retain optimal effectiveness for the life of the installation.

2.02 The protection of personnel from AC service and lightning stroke shock hazard, and equipment from fire or other damage resulting from electrical faults or lightning energy, is of prime importance. From a standpoint of service quality, reduction of noise in communication circuits caused by current flow through impedance in ground planes is equally important. The simple grounding practices expressed in this section prior to Issue 9 consisted primarily of providing an earth potential reference to Power systems, provision of ground paths for discharge of lightning energy from protectors connected to communication systems entrance cables, and rudimentary bonding of conduits. These measures were, and are presently, adequate to meet minimal NEC protection requirements. Issue 9 of this section, in 1967, introduced improved grounding requirements. Primarily they consisted of ground networks, 1) imposed on DC battery ground current paths and 2) added in AC service raceways. Evaluations of earlier grounding practices had indicated that they were only marginally adequate. The improvements reduce the incident of high impedance in ground paths that create potentially hazardous conditions and cause noise on communication circuits.

2.03 In communication circuits, disturbances that impair transmission by obscuring the signal are called noise: a broad term that includes hum, crosstalk and spurious signals. One of the important methods of reducing noise is to intercept the interference energy and dissipate it in a low impedance ground system.

2.04 Prior to the introduction of the improved grounding practices in 1967, central office communication circuits depended mainly on ground paths through the discharge ground conductors of the power distribution systems and incidental paths through frameworks, conduits, cable racks and building steel to provide a ground plane throughout the building. These paths did not always provide the conductivity necessary to keep noise levels low enough to ensure the provision of noise-free service. The introduction of high-speed data transmission and solid-state devices operating on extremely low voltage potentials makes it increasingly important that an equipotential ground plane be available throughout the communication network. To ensure that such as ground plane exists it has become necessary to supplement the existing ground paths with an engineered ground system.

2.05 The improved equipment ground system for communication equipment in central offices provides an engineered ground conductor path of known low impedance between frames, cabinets and other units on each floor to form horizontal ground planes. A vertical conductor, connected to the office ground electrode and bonded to the horizontal ground plane conductors integrates the various horizontal planes into a single low impedance ground plane referenced to earth. The system is identified as the CO (central office) Ground system. Because of its vertical "trunk" and its method of horizontal branching, it is also commonly referred to as the "Tree" ground system.

2.06 Issue 9 of this section introduced the use of an equipment ground conductor in raceways containing AC service conductors. Previously, in accordance with National Electrical Code requirements, equipment grounding of the AC system depended on continuity through the metallic raceway, exclusively. A low impedance path between a point of fault and the source of energy in an AC system (eg, transformer secondary) is necessary to ensure that the circuit overcurrent protection device will operate quickly. A high impedance could result in insufficient current to the overcurrent device, which would prevent it from interrupting the circuit before the fault current has time to cause heating which may result in a fire. A disconnection may cause a high potential to appear on an enclosure, presenting shock hazard to personnel. Additionally, any significant impedance may allow AC hum to be impressed on communication circuits.

2.07 Ground paths that depend on the integrity of a series of raceway joints have been proven to be unreliable. They have not always provided the protection to personnel and equipment that is considered essential in Bell System structures and have been a source of undesirable noise. A supplementary equipment ground system, consisting of a grounding conductor run in raceway with the circuit conductors, is used to increase the AC system equipment ground reliability. The design parameters are based on requirements for grounding conductors specified in the National Electrical Code Article 250. It should be noted that the Code does not require that a grounding conductor be provided when raceways and fittings are approved for grounding. For Bell System applications covered in this and supplementary Protective Ground Systems specifications, the use of both an approved raceway and a grounding conductor is mandatory. The grounding conductor application is identified herein as the AC Equipment Ground system. It has often been referred to as the "Green Wire" system. The wire may be uninsulated or insulated. If insulated, a green colored covering is required as a means of identification.

2.08 Generally, the CO GRD system, the AC Equipment Ground system and incidental ground paths form an integrated ground plane. The various ground conductors terminate on frames, unit enclosures and other metallic objects and continuity exists between such terminations through frame metal and other incidental conductive paths. Certain types of communication systems require an isolated ground plane. These systems utilize solid-state devices that may be damaged by transient current surges. The isolated ground plane insulates the system from any contact with the integrated ground plane except for a single point on the CO GRD system that provides earth reference to the isolated plane. The isolated ground plane is presently used with the family of communication systems referred to as Electronic systems. It is expected that new communication systems will generally specify the use of an isolated ground system in the future.

2.09 Radio systems require special protection from lightning strokes. They employ a Ring Ground system designed specifically to create minimum impedance to the flow of lightning induced current and a method of bonding between metallic components of the station that suppresses arcing. The Ring Ground system provides an equipment grounding function in Radio stations similar to that of the CO GRD system in Central Offices.

2.10 Communication systems installed on customers premises are equipped with a simple ground system that provides, within the limits of practicability, an equipment grounding arrangement similar to that of the CO GRD system. For maximum protection of solid-state components, electronic type systems employ a form of isolated ground plane with a single point bond to a ground point that functions as a "ground window".

2.11 This section and the supplementary sections listed under Part 1, Scope, provide equipment requirements and engineering information pertaining to the design of equipment grounding systems to be installed in Central Offices, Radio Stations and other structures housing communication systems. Methods of connecting the equipment ground systems to building steel and for provision of grounding conductors for discharge of protectors are included. These instructions do not constitute a complete summary of measures required to protect an installation from lightning stroke damage. A list of Bell System practices covering lightning protection measures and general protection and bonding requirements is included under "Bibliography", herein.

Earth vs Ground

2.12 As described hereunder, ground potential is not necessarily the same in all parts of a grounding system; or of the same potential as the earth in the vicinity of, or remote from, the installation. In this, and associated Sections, the term "ground" defines some point on a system of conductors provided to afford a low impedance path to earth, or on conductive material provided for other purpose that co-incidentally provides such a path. The term "earth" refers to that part of the current discharge path through soil beyond the grounding electrode.

3. GENERAL

3.01 In a working Central Office, a difference of potential between different points on the ground plane is unavoidable. DC power plants supply current to communication equipment throughout the installation. Current constantly flows back to the batteries or rectifiers over discharge ground conductors furnished for this purpose. Therefore a difference of potential, dependent on the impedance of the current return path and the magnitude of current flow, always exists between the originating and terminal points of the ground path.

3.02 Two systems of grounding are employed in Central Offices: Integrated grounding and Isolated grounding. In the integrated system, the discharge ground conductors are not isolated from contact with metallic members that may provide ground paths in parallel with discharge ground conductors. These paths, which consist of incidental continuity through framework, cable racks, superstructure, piping, ductwork, steel members of the building, etc.; and of deliberate equipment grounding systems such as AC service conduit and the Central Office Ground (CO GRD) system; will be in contact with the discharge ground conductors at various points between the battery and load units. When the various ground paths are integrated in this manner, battery return current will flow in all of them. An isolated grounding system is deliberately designed to insulate the discharge ground system from incidental ground paths and employs only a single point connection to the CO GRD system for ground reference.

3.03 The isolated ground system is used with installations of Electronic Switching systems and similar types of equipment requiring special protection of solid-state components and circuit packs from damage or malfunction due to transient surges of current. The integrated system is employed with electromechanical systems and others that are not as susceptible to surges.

3.04 Installations of both types of grounding systems are usually found in the same building. Both require ground reference. The CO GRD system, which connects to the terminus of the office ground electrode within the building (principal ground point), is extended throughout the building to connect to various points on the discharge ground conductors between power and load units of communication systems that utilize an integrated ground system. Other equipments requiring equipment grounding are bonded to the CO GRD system. Isolated ground systems are single point bonded to the CO GRD system, also. The CO GRD system thereby forms a direct path of known low impedance between earth and the various power, communication and other equipments that effectively extends an approximation of ground reference throughout the building.

3.05 Since the CO GRD system provides a path in parallel with discharge ground conductors for return of current to batteries, it carries a portion of that current. A voltage drop is developed by the flow of current, equal to the voltage drop developed in the discharge ground conductors. This voltage drop will never exceed the allowable voltage drop allotted to discharge ground conductors by power plant design requirements during normal operation (other than fault conditions or lightning strokes). Generally, the voltage differential between extremities of the CO GRD system will fluctuate in relation to the office DC power load, to a maximum of less than 2% of the principal office power plant battery voltage. In an office with a 48-volt plant supplying the bulk of DC power, the differential will be less than 1 volt between the ground electrode and any point on the integrated ground plane, or on an isolated ground plane receiving ground reference from the CO GRD system, under normal operating conditions.

3.06 Ground reference obtained from an equipment grounding system integrated with DC power distribution systems is never true (zero) ground potential. It is not essential that every portion of a ground plane be at precisely the same potential. It is essential however that every portion be at a potential near enough to ground potential that for practical purpose of protection or operation it is, in effect, at zero potential. Communication systems equipments are effectively circuit grounded when the voltage differential at different points on the ground plane cannot exceed a value that will interfere with proper operation of electrical circuits. Personnel and equipment protection is afforded when, during an occurrence of an electrical fault, the ground system provides a path for sufficient current to operate overcurrent devices quickly; or during a lightning stroke provides a low impedance path for current to earth.

3.07 The CO GRD system is designed specifically to equalize potential on the office ground plane, to afford a direct low impedance path to earth, and to supplement fault current paths provided by discharge ground conductors to overcurrent devices. Fig. 1 illustrates the battery return current paths available in a typical installation using an integrated ground plane.

3.08 A variety of grounding arrangements are required, in addition to or as an alternative to the CO GRD system, to ensure protection of personnel and equipment. The arrangements are dependent on the physical and electrical properties of the communication systems, facilities and structural properties of buildings, and other factors. The presence of ground paths through Power and Communication system installations and through building metallic structures can have a significant effect on the function of the various ground systems. For the purpose of defining the parameters of the various ground systems and subsystems thereof, and of ground paths that integrate with these systems to form a ground plane, identifying nomenclature is established in Part 4 of this section.

3.09 Methods of connecting various Power and Communication systems, equipment frames, cabinets and other components to the equipment ground systems are described in the supplementary Equipment Ground System sections listed in Part 1, Scope. These instructions define the points to which the equipment ground must be extended to provide continuity between earth and frames, between neighboring frames, cabinets and other metal work, and between load ends of DC power systems discharge ground conductors. In some communication system design configurations, the discharge ground conductors have electrical continuity to frame metal. The equipment ground conductor is terminated at a point where discharge ground conductors from a Power Plant are branched to serve individual frames and the branch ground conductors serve as both a return path for battery current and to provide equipment grounding. Where continuity to frame metal does not exist via the discharge ground paths, the equipment ground system must be extended to the frames. Other methods of providing equipment grounding that takes advantage of the physical design to eliminate the necessity of providing an equipment ground conductor to every frame in a system complex, are described in these sections, as well.

3.10 The descriptions of methods of interfacing system complexes with the equipment grounding systems refer to specific communication systems. They describe the available ground paths that may be used to equipment ground these systems. A number of communication systems that may be encountered in Central Offices, Radio Stations and on Customers Premises are not described herein. It is recognized as well that certain unique grounding applications not covered herein will be encountered. It is not intended that every unique grounding arrangement be covered. Systems and conditions not described in detail will generally be comparable to one of the arrangements described. An analysis of the available ground paths will reveal similarities. Generally, an equipment grounding arrangement can be devised on a job basis by applying the principles of the compatible system and general principles of equipment grounding covered in the Protective Ground Systems sections. Unusual conditions that cannot be identified as compatible should be submitted to the controlling organization of the Protective Ground Systems practices for job analysis.

3.11 Metal sheathed structures are used to house various types of communication facilities. The sheathing may be used as part of the ground plane which, in buildings of conventional construction, would be provided by ground conductors. Information pertaining to equipment grounding in metal sheathed structures is contained in Section 802-001-192.

4. GROUND SYSTEM NOMENCLATURE

4.01 Nomenclature used in the Protective Grounding Systems sections listed in Part 1, Scope to describe the various equipment grounding systems, subsystems and other ground paths that form the ground planes is defined hereunder. The terms are based on names commonly used in the electrical industry and/or the Bell System to identify grounding arrangements. The terms defined herein, listed categorically, are:

(A) Office Ground Electrodes:

- (1) Water Pipe Ground
- (2) Driven Ground
  - (a) Supplementary Ground Field
  - (b) Ring Ground.

(B) Equipment Ground System:

- (1) Central Office Ground (CO GRD)
  - (a) Relay Rack Ground (RR GRD)
  - (b) Framework Ground (FRWK GRD)
  - (c) Shielded Wire and Cable Ground
  - (d) Electronic Office Ground
  - (e) Unit Ground.

(C) AC Equipment Ground System (AC EG).

4.02 Nomenclature, purpose and effect of ground systems formed as part of systems other than Equipment Ground systems are defined in:

- (a) AC Service Ground, Part 5.
- (b) Incidental Ground, Part 6.
- (c) Discharge Ground, Part 7.

4.03 References (802-001-191), etc, identify Protective Grounding Systems Sections that provide detailed information on systems defined below.

A. Office Ground Electrodes (802-001-191)

4.04 The term "Office Ground Electrode" refers to the ground electrode whose extension into the building is used as the principal ground point for connection to equipment grounding systems serving communication installations.

4.05 Ground (Zero) potential is established by means of an electrode buried in the earth surrounding the installation. The electrode may be a metallic water pipe, when suitable; or a system of buried driven rods interconnected with bare wire; or a ground plane of horizontal buried wires; or a combination of these systems dependent on physical and electrical properties of the water system, building design, soil and bedrock.

4.06 ***Water Pipe Ground.*** A metallic underground water piping system, when available, shall always be used as the office ground electrode. The water pipe shall be an electrically continuous underground public system or a private system of buried metallic pipe or well casing. The water piping system must be checked for continuity or verified as such with the water company.

4.07 Water companies have been increasingly employing nonmetallic pipe and insulating couplings to eliminate corrosion problems. Use of nonmetallic gaskets may also render the water pipe system useless as a ground electrode. The possibility that the water company may create one of these conditions at a future time should also be considered.

4.08 It is ***NOT*** a requirement to provide a supplementary ground field where the water system is determined to be adequate. It is recommended, however, that a field be considered for installation during initial construction when it appears that installation at a later date, required by loss of ground reference on the water system, will be excessively expensive.

4.09 Where water pipe is of nonmetallic material or is not electrically continuous (ie., equipped with insulating couplings at the water meter) or where assurance cannot be obtained that the water system will remain as an effective ground electrode, a supplementary ground field must be provided.

4.10 A private water system may be used as the office ground electrode. Minimum requirements, which normally will be exceeded in a practical system, are as follows: The buried portion of the pipe (including well casings bonded to the piping system) shall exceed 10 feet. The use of a drilled well for the ground electrode will normally result in substantially lower resistivity than that obtained by means of a driven ground.

4.11 ***Driven Ground:*** A driven ground (made electrode) system shall be utilized as the office ground electrode for structures housing communication systems whenever the water pipe ground electrode is not available. This system consists basically of a set of ground rods driven into earth around the perimeter of the structure, interconnected with buried wire with multiple (at least two) bonds extending the reference potential to the ground system in the building.

4.12 ***Supplementary Ground Field:*** Where a water system pipe cannot be relied on for continued use as the principal electrode, a supplementary ground field is required. A field may consist of a driven ground system installed under the building or around the building foundation terminated at the point of entry of the water pipe into the building.

4.13 ***Ring Ground:*** This equipment grounding system employs a driven ground system as the station ground electrode for buildings housing Microwave Radio equipment. The conductor that interconnects the driven rods forms a ring around the building. The exterior ring is used in conjunction with an inner ring ground system, surrounding communication equipment in the building interior. Multiple bonds between exterior and interior rings, plus connections to antenna towers and to individual metallic objects in the building form an equipotential plane, primarily for protection of personnel and equipment from lightning damage. It also serves as ground potential reference for proper operation of electrical circuits. It is used principally in microwave relay stations, in rural areas, equipped with antenna towers susceptible to frequent lightning strokes.

B. Equipment Ground Systems

4.14 ***Equipment Ground:*** Equipment grounding ensures that personnel and equipment are protected from shock hazard or damage resulting from faults that may develop in the electrical system. Deliberately engineered ground conductors are provided throughout the AC distribution and communication systems to afford electrical paths of sufficient capacity to permit protective devices (fuses, circuit breakers) to operate efficiently and to equalize potential difference between equipments of the installation. Two systems of equipment grounding are employed. One system, applied to the AC service system, will hereafter be referred to as the "AC Equipment Ground". This system has been commonly referred to as the "green lead ground". The conductor may be insulated or bare. When covered, it employs a green colored insulation on the conductors for identification purpose. The other system will be identified as "Equipment Ground", with further identification of portions of the system as "CO ground", "Relay Rack Ground" and "Framework Ground". This system provides for equalization of potential between equipments other than those connected to AC service. The Ring Ground system provides a function, equivalent to the equipment ground system, in radio and microwave stations, as previously described under "Ring Ground".

4.15 ***CO (Central Office) Ground*** (802-001-192): The Central Office Ground (CO GRD) system consists of a 750,000 CM equipment ground conductor that effectively extends earth potential from its appearance point within the building (principal ground point) to convenient bus bar connection points on various floors that contain central office equipment requiring earth potential reference. This conductor is referred to as the vertical equalizer.

4.16 The CO GRD system also includes 750,000 CM horizontal equalizer branch conductors that extend from the CO GRD bus bars on each floor to power plant, battery distributing fuse board, power distribution equalizing center, main distribution frame and other discharge ground bus bars or main ground conductors to create equalizer networks between them. The purpose of the networks is to allow an interchange of ground currents so as to effectively maintain equal potential at these critical points in the communication circuit.

4.17 The CO GRD system, dependent on the size and number of floors in the building, may range from a complex branching system utilizing one or more vertical equalizers emanating from the water pipe ground point and connected to numerous CO GRD bus bars on various floors for multifloor buildings, to a single CO GRD bus bar located near the principal ground point in single floor buildings. The CO GRD system is often referred to as "tree" ground since, in multifloor applications the large capacity vertical conductors resemble a trunk and the numerous horizontal conductors, many of which are tapped as they extend through the individual floors, resemble branches emanating from the trunk.

4.18 ***RR (Relay Rack) Ground (802-001-194):*** Prior to the recognition of the advantage of using paired battery and ground discharge conductors between DC power supply and load units as a measure in suppressing noise, communication systems utilized a common discharge path to return current to batteries. In these systems, of which the Manual Toll system is one of those still in common use, miscellaneous electrical equipments are mounted on relay rack type frames arranged in one or more frame lines. Circuit grounds terminate on ground bars mounted on the frames. The bars are formed into a continuous conductor by means of junction plates. These frame line ground bus runs are bonded to a Main Aisle equalizer which also is bonded to fuse bay, battery distributing fuse board and/or power plant ground buses so as to form a common path for circuit ground current to the battery. When a CO GRD system exists, a CO GRD horizontal equalizer extended to the Main Aisle ground equalizer provides earth potential reference to the RR GRD system. It also provides framework grounding to frames equipped with ground buses via the ground current paths, since the buses are in electrical contact with frame metal.

4.19 ***FRWK (Framework) Ground*** (802-001-193): FRWK GRD refers to that portion of the equipment ground system that is furnished solely to provide ground continuity to frames, cabinets and other metallic objects in the communication system installation area that do not receive ground reference from other ground systems such as the RR GRD or AC Equipment Ground and is primarily provided for protection purposes. It also functions to reduce noise in communication circuits. Prior to the inception of the "tree" grounding concept, these units depended on incidental ground paths for ground potential reference.

4.20 ***Shielded Wire or Cable Ground*** (802-001-193): Metallic shielding is specified for communication systems conductors that carry signals which may induce noise in other cable or equipment, or to block noise emanating from other sources that may interfere with the function of a system. The purpose of the shielding is to reduce inductive energy. Such shielding is effective only when it is electrically continuous between grounding points. The shield at each end of the wire or cable run shall be connected to the CO GRD (or equivalent equipment ground) system unless otherwise specified in the system specifications.

4.21 Metallic conduits and armored cable carrying other than AC power conductors shall be connected at each end to the CO GRD system. A connection by means of conduit fittings to a metal cabinet or similar enclosure in contact with a frame or similar mounting unit connected to CO GRD is an adequate connection. Otherwise, a bond must be provided from conduit end to a grounded frame or other point in the CO GRD System. The bonding strip furnished in armored cable need not be connected.

4.22 ***Electronic Office (Single Point) Ground*** (802-001-195): Electronic type switching systems (No. 1 ESS is typical) cannot tolerate transient voltages and noise that are tolerable in electromechanical switching systems. The ESS-type equipment is isolated from all ground paths except one to eliminate the possibility of the ESS equipment being used as a conductive path for transient ground currents generated in other than ESS equipment. The single point of interface between ESS ground and CO Grd is known as the ground window.

4.23 ***Unit Ground:*** Units of electrical equipment, consisting of components assembled on a metallic chassis whether mounted on frames or cabinets or separately mounted on insulating surfaces, must be equipment grounded when the chassis is not designed for specific isolation from ground. All units of electrical equipment mounted on a frame or cabinet with mounting screws, or in a similar manner that establishes a ground path between the frame and the unit enclosure, are considered to be grounded to CO GRD via the ground bond serving the frame. In certain applications, covered in Section 802-001-198, "AC Equipment Ground", all units mounted in a frame or cabinet are equipment grounded through the AC equipment ground conductor serving one or more units mounted thereon. Other units, not so mounted, such as those mounted on a wall or an insulated surface require a deliberate bond to some point in the CO GRD System. Metallic mounting structures that support electrical equipment but are electrically isolated from the equipment, such as battery stands, require a bond to a point in the CO GRD System or equivalent equipment ground system.

4.24 Continuity through chassis or frame steel or through ground bonds furnished for equipment bonding purpose shall not be utilized for return of DC ground current to batteries. Conversely, discharge ground conductors furnished for current return are utilized for equipment grounding of chassis and frames in numerous communication systems (See RR Ground).

C. AC Equipment Ground System (802-001-198)

4.25 Two separate requirements for ground are required in the AC service distribution system used in buildings housing communication installations. One is used to supply ground reference to the AC system, and is referred to as the ***SERVICE GROUND*** (see Part 5). The second is an ***EQUIPMENT*** grounding system. The latter, referred to herein as the ***AC EQUIPMENT GROUND*** system, is provided to ensure that a ground path of dependable low impedance exists throughout the ground network formed by raceways and enclosures of AC operated equipment.

4.26 The AC Equipment Ground system is composed of two components, 1) raceways and 2) a network of conductors, either bare or green insulated. The conductors are extended through the raceways that carry AC phase conductors and connected to noncurrent carrying chassis of the apparatus associated with the AC system. The purpose is, 1) to provide a low impedance path for fault current from a point of fault to overcurrent protective devices to ensure fast operation, 2) to bond across inadvertent discontinuities in raceway conductance so that difference of potential across such points is nullified, 3) to short out noise producing high impedance joints in raceways.

4.27 The equipment grounding facility afforded by metallic raceway installed in accordance with NEC requirements satisfies Code equipment grounding requirements. The addition of equipment grounding conductors in the raceways is a Bell System requirement.

4.28 Requirements for installation of raceway to form effective equipment grounding networks are not covered herein. NEC requirements are considered to be common knowledge. The equipment ground conductor installation requirements are similar, but not identical, to NEC requirements for grounding of equipment when AC circuit conductors are not run in metallic raceway. The conductor system requirements are covered in Section 801-001-198, and the term "AC Equipment Ground System" refers principally to that system. It is assumed that a metallic raceway system conforming to NEC requirements always exists with the conductor system.

5. AC SERVICE GROUND

5.01 AC service distribution systems in buildings housing communication systems are almost without exception solid grounded systems. The basic characteristic of a solid grounded system is that the AC secondary network is equipped with a grounding conductor that provides a low impedance bond from one of the AC service conductors directly to a ground electrode. The most common AC system encountered employs a service transformer with a wye-wound secondary and provides three phase grounded AC service. In small installations the secondary system may be a single phase grounded system.

5.02 The conductor provided for the purpose of grounding the AC service system is defined in NEC Article 100 as follows: ***"Grounding Electrode Conductor:*** The conductor used to connect the grounding electrode to the equipment ground conductor and/or to the grounded conductor of the circuit at the service". It has also variously been referred to as the "AC Service Grounding conductor", the "AC System Grounding conductor", the Main Grounding conductor" and the "Common Main Grounding conductor" in the National Electrical Code prior to the 1971 edition.

5.03 The current carrying conductor of an AC circuit that is connected to ground by use of a ***grounding*** conductor per 5.02 above is referred to as the ***grounded*** conductor. It is also known as the ***grounded neutral*** or ***neutral*** conductor.

5.04 In this discussion, which covers grounded AC distribution systems, the grounding conductor is referred to as the AC Service Grounding Electrode conductor, or ***Grounding Electrode conductor.*** The grounded circuit conductor is referred to herein as the ***neutral conductor.*** The Equipment Ground conductor referred to herein is the AC Equipment Ground System defined in Part 4.C.

A. Three Phase Grounded AC Systems

5.05 A three phase grounded system employs four wires: one each connected to the three phase windings and one connected commonly to the opposite end of each phase winding of the Wye secondary. The common conductor is termed the ***neutral.*** It is bonded to earth with an AC service grounding electrode conductor, from some point between the transformer and the secondary service main disconnect means, to serve as a point of ground reference for AC voltages. The neutral carries current when a load unbalance exists between phases. It functions as a path for fault currents between the ground point and the transformer when phase to ground faults occur. Any connection of the neutral to a grounded object between its ground point and load units is prohibited, since this would create a permanent path in parallel to the neutral through the multiple ground connections.

B. Single Phase Grounded AC Systems

5.06 Single phase grounded systems employ a service transformer with a single secondary winding. Three conductors are extended from the center and the two ends of the secondary winding. The centertap wire serves as the neutral. It is bonded to earth and serves the same function as the three phase grounded system neutral.

C. Neutral Conductor

5.07 Grounded AC systems provide two utilization voltages. In a typical three phase, four wire grounded system connected to a 120/208 Volt Wye wound transformer secondary winding, 208 volts is obtained by connecting loads across phase legs (line to line), 120 volts is obtained by connecting loads between one phase leg and the neutral conductor (line to neutral). Both voltages are used in Central Offices. The higher voltage is used in both single and three phase configurations to power DC rectifiers, large motors and other AC operated major equipments. The lower voltage is generally used to serve lighting fixtures, appliance receptacles, and various units requiring relatively small amounts of power. A neutral conductor is extended with only those feeder or branch circuits that in part or whole serve equipment designed to operate on the lower utilization voltage. A neutral conductor is also extended to alternators of emergency engine sets in the office, when grounded service is supplied therefrom.

5.08 It is of utmost importance that it be understood that a ***neutral is not a common grounding conductor.*** It is a single point grounded current carrying circuit conductor. It is imperative that the single point concept be kept inviolate so that AC current is confined solely to the neutral conductor. In order to maintain the single point concept, neutral bus bars installed in AC distribution facilities must be insulated from mounting framework. Special care must be exercised during installation to ensure that an inadvertent connection between the neutral and grounded metal does not occur at any point on the load side of the service disconnect equipment. The neutral shall never be used as source of ground for the purpose of providing equipment grounding for any equipment, except as specified by National Electrical Code Article 250-61.

D. AC Service Grounding Electrode Conductor

5.09 The AC service grounding electrode conductor connects the neutral of the secondary distribution system directly to the office principal ground point, or to a ground electrode provided for service grounding. When the service ground electrode is other than that used for equipment grounding of communication equipment, the electrodes must be bonded together to form a single electrode system.

5.10 The grounding electrode conductor shall be copper or other corrosion resistant wire, solid or stranded, bare or insulated. Wire size shall be in accordance with NEC Article 250-94. It should be run as direct as practical with minimum bends and no sharp bends. Preferably, it shall be surface supported and visible for inspection. Where run through walls, partitions, etc., the wire should be routed through nonmetallic sleeves. It should not be routed through metal that forms a ring, or in metallic conduit, where avoidable. If so routed, the conductor must be bonded to any enclosing ring, and at each end of metallic conduit.

5.11 The grounding electrode conductor, at the point of connection to the neutral, must also be bonded to the frame of the enclosure in which the service bond is made. In a typical installation, the neutral connection is made at a neutral bus in a cabinet that mounts the service disconnecting switches or breakers (ie, House Service Board). This cabinet may also be equipped with an Equipment Ground bus mounted in electrical contact with the enclosure metal. When provided, the Equipment Ground bus is used to terminate AC Equipment Ground conductors run in distribution circuit raceways. Otherwise, such conductors terminate on the metallic enclosure, as do the raceways.

5.12 In the event of line-to-line or line-to-neutral fault in a secondary service network, a low impedance circuit exists through shorted AC service conductors that allows a heavy current surge through protective devices, ensuring quick clearing of the circuit. A line to ground fault dumps current into the AC equipment ground system. Without a direct bond between equipment ground conductors and the neutral, only a circuitous route is available for current. It must flow via equipment ground paths to the electrode end of the grounding electrode conductor, through that conductor to the neutral, then via transformer windings and phase leg conductors to the protective device. In practice, the impedance in the loop through the grounding electrode conductor is avoided by use of a bond from the neutral bus within the main disconnect switch enclosure to the Equipment Ground bus or to the enclosure metal. This bond forms a low impedance path from raceways and AC equipment ground conductors that carries fault current directly to the neutral, and therefrom via transformer windings and phase leg conductors to protective devices. The bond size required is the same as the service ground conductor size specified in NEC Article 250-94. Typical bonding arrangements at service disconnect points are illustrated in Section 802-001-191, Fig. 4.

E. Step-Down Transformers

5.13 Transformers are interposed in distribution circuits when a voltage other than the two utilization voltages supplied by the service transformer is required to power loads. Typical loads of this type are those requiring 120 volts in buildings served with a 480/277 volt AC System. Generally, the distribution circuit powered by the transformer secondary winding must have a grounded (neutral) conductor as specified in NEC Article 200-2. Certain exceptions are listed under Exception 1, therein.

5.14 A grounding electrode conductor shall be provided from a suitable ground source to the neutral at a point between the transformer and downstream disconnect means. At that point, a bond shall be provided between the neutral and raceway or transformer case or other metal that is part of the AC equipment grounding system, so as to complete a circuit for fault current to the transformer winding from the AC equipment grounding system.

5.15 Service transformers must be grounded directly to the building service electrode. Step-down transformers, which may be located at any point in the building, do not necessarily need to be bonded directly to the service electrode. The grounding electrode conductor may alternatively be terminated at a floor CO GRD bus on the floor containing the transformer. When a CO GRD system or an equivalent equipment ground system is not available, it is customary to terminate the grounding conductor on a cold water pipe or building steel having permanent continuity to earth. The grounding conductor shall never be connected to a neutral of the distribution system providing power to the primary winding of the transformer. The size of grounding conductors shall be as specified in NEC Article 250-94(a).

F. AC Generating Devices

5.16 Separately derived AC systems requiring ground reference shall be connected to ground similarly to secondary systems when the circuit is completely independant of any other ground reference. Engine alternator and inverter derived AC supplies provided for emergency service in case of commercial AC failure are controlled through automatic or manual switching means so that the emergency supply is never connected to the commercial supply. The neutral conductor of the emergency supply, when required, is permanently connected to the neutral of the commercial supply and the ground connection to the commercial supply suffices as the single point ground reference for both systems. One exception is when an engine alternator set is located in a separate building with its own ground electrode, where the alternator neutral may also be connected to that ground electrode.

G. Interbonding of Separate Ground Electrodes

5.17 The grounding electrode conductor is normally installed by the electrical contractor during installation of the secondary system switch gear. It is normally terminated at a power service driven ground or at the water pipe ground point. Section 802-001-191 contains information pertaining to methods of interbonding AC service grounding electrodes to electrodes used for other equipment ground systems.

H. Conductor Identification

5.18 Neutral conductors are always identified as such by a white or neutral gray colored covering (NEC 200-6). White or gray conductors shall not be used as other than a neutral except as outlined in NEC 200-7.

5.16 Color identification of a grounding electrode conductor is not required. The conductor may be solid or stranded, bare or insulated copper or other corrosive-resistant wire of a size specified in NEC 250-94(a).

I. Code Requirements

5.19 The preceding information summarizes basic National Electrical Code requirements pertaining to grounding of neutral conductors for service of 600 volts or less. Individual installations must conform with all of the requirements expressed in the Code for the service furnished. Refer to Article 200 for requirements for grounded (neutral) conductors and Article 250 for requirements for service grounding. Where local Codes differ from the NE Code, installations shall conform to the local code requirements.

6. INCIDENTAL GROUND

6.01 In offices and stations where no effort is made to isolate communication equipment from building steel, conduits, piping, ducts and other conductive objects inherent therein, numerous ground paths through such objects usually exist. Bolting of adjacent frames, frames to superstructure, superstructure to ceiling inserts in contact with building steel and other metallic facilities create many channels for the interchange of current within the communication facilities. Discharge ground bus bars are normally bolted directly to, or intentionally bonded to framework.

6.02 Incidental ground connections between various metallic objects occur spontaneously: without conscious design effort to construct an electrical path on the part of building designers, communication application engineers, or craftsmen. They occur with such frequency and in such complexity through building steelwork, piping, conduit, air ducts, superstructure framing, equipment framework and other conductive structural material that for many years the incidental paths were considered adequate to act as a ground equalizer in communication installations.

6.03 Extensive investigation of noise problems by operating companies has revealed that some of the noise problems are caused by inadequate ground paths, and that noise could be reduced by improving the grounding network. Their studies indicated that dependence on incidental grounds was not reliable at every point throughout the office. Painted surfaces, loose connections, discontinuity of building metal and many other conditions contribute to the isolation of individual equipments from the low impedance path generally afforded through incidental grounds.

6.04 As a result of the noise studies, a program was initiated to design a grounding system that did not depend on incidental ground paths. The CO GRD system is a result of that design effort.

6.05 Incidental ground paths should never be considered as a contributing factor in the design of a ground system, but neither can they be ignored. Where they exist between two objects they will act as a current conductor whenever the interconnected points are forced to different potential levels, as indicated in the discussion of the discharge ground system in Part 7. Since the impedances of such paths are never known, their effect on the discharge ground and CO ground systems cannot be precisely calculated. In general, incidental ground paths in parallel with these other systems will contribute to the equalization of potential. There is also a possibility that an incidental ground path, through proximity with an inductive energy source or by other means, may introduce noise into a communication system. These occurrences are not predictable, and can only be eliminated after they occur.

Incidental Ground Paths Through Building Steel

6.06 Building steel often affords an excellent path for the discharge of lightning current to earth. Steel sections of structural steel building columns and reinforcing bars in concrete columns, when welded or wire wrapped, are generally assumed to be effective lightning current conductors. When such paths exist, they can be utilized to enhance the equalization of potential afforded by the CO GRD system.

6.07 Where it is ascertained that the columns have continuity to earth, a bond shall be provided between one such column of the building and each floor CO GRD bus bar as described in Section 802-001-190, "CO GRD BUS BARS". This bond integrates the ground network of the CO GRD system with the ground network formed by building steel. It ensures that minimal difference of potential will occur between members of the two networks. This is of particular importance during lightning discharges.

6.08 During a lightning discharge through a building column or columns, an extremely high voltage will momentarily exist on the column steel. In a multifloor building, a voltage differential will build up between different points on the vertical column as the current pulse travels through it. The bond ensures that the potential at each floor level is extended to equipment served by the CO GRD system on that level, thereby reducing the possibility of damage or injury from current arcs between building and equipment metal.

6.09 The bond between column metal and the CO GRD system shall be omitted when it cannot be ascertained that a lightning discharge path through column steel exists. In certain reinforced concrete construction, reinforcing bars are not deliberately connected by welding or wire wrapping. This generally results in a series of discontinuities. In this type of structure, the engineered path formed by the vertical equalizer of the CO GRD system is solely depended upon to conduct lightning current imposed on the communication system ground plane to earth.

7. DISCHARGE GROUND

A. Primary Function of Discharge Ground Conductors

7.01 DC power plants are used to convert commercial AC power into direct current supplies suitable for operation of relays and other forms of electrical control apparatus, to provide talking current for telephone circuits, to furnish plate and filament supplies to radio circuits, and to enable other electrical apparatus in a central office or radio station to function. These plants employ rectifiers or charging machines to convert the energy, and utilize storage batteries as an energy store to enable continued operation in case of commercial power failure. A variety of plants, each producing a unique range of necessary voltage within the voltage limits set by the design of the load equipment served, are often installed in a single communication facility. Power is delivered from the rectifiers or battery to load equipment through battery control boards (BCB) integral to each power plant. The BCB functions as a main distributing point to battery distribution fuse boards (BDFB) or equalizing centers (EQL CTR) located on various floors near associated load equipment. They in turn distribute DC power to fuse boards (F BD) or to fuse panels on equipment frames where the power is distributed to load units.

7.02 The voltage range within which a particular power plant must operate is governed by a number of factors:

(a) Load operating voltage range

(b) Voltage control facilities of the power plant during emergency operation

(c) Minimum discharge voltage of battery cells

(d) Allowable voltage drop in conductors between battery and load units.

7.03 The allowable voltage drop in conductors between Battery Control boards and BDFB or Equalizing Centers is generally restricted to about 2 percent of the battery voltage. Generally, discharge conductors in this portion of the discharge circuit are very large. Often they consist of multiple 750,000 CM conductors serving each of the numerous BDFB or Equalizing Centers located throughout a multifloor Central Office building. Discharge conductors are defined as Battery Discharge (BD) and Discharge Ground (DG). The BD conductor carries current to the BDFB or Equalizing Center. The DG conductor provides the path for current return to the battery. The voltage drop allotment is divided evenly between the BD and DG conductors.

7.04 If no load is impressed on a discharge circuit, there is no differential in voltage at either end of a DG conductor. At a full load for which the DG conductor has been calculated, a voltage differential of about 1 percent of the battery voltage will be impressed on the DG connector. Generally the load on a particular distribution center (BDFB, EQL CTR, etc) varies constantly in accordance with momentary changes in load requirements, therefore the voltage differential between ends of a DG conductor constantly changes. This can result in a differential of ground voltage between two distribution centers of as much as 1 percent of the battery voltage if one is momentarily at no load while the other is at full load. If a ground path exists between these two distribution centers through frame steel and other incidental paths, current will flow through the incidental path. The amount of current will be governed only by the amount of voltage differential between the two points, and the impedance in the incidental path.

7.05 The primary function of discharge ground conductors, therefore, is to provide a current return path to battery of sufficient low impedance that voltage at load equipment will remain within operating range. A residual effect of the impedance in these conductors is to force a flow of current through incidental ground paths. This residual effect is recognized as a prime cause of noise in communication circuits.

B. Effect of Discharge Ground Conductors on Equipment Grounding

7.06 The flow of DC ground current through paths not specifically designed as electrical conductors is undesirable. It is impossible to determine or to control the impedance in such paths. The paths are not dependable. Corrosion or loose joints can allow the impedance to change. Vibration and arcing can cause rapid fluctuation in the impedance of a current path, resulting in noise.

7.07 There are two methods of minimizing current flow through such incidental paths: isolation and integration.

7.08 In order to eliminate current flow by isolation, the entire battery discharge circuit, from the battery to each termination in every load unit, must be divorced from contact with any grounded object, except for a single point ground bond that provides earth potential reference for the ground plane of the discharge system. This arrangement is identical to the neutral system employed in AC distribution systems. It is normally not applied in telephone systems grounding arrangements. A variation of the system, which excludes the single point ground connection, is used with small PBX systems that receive DC power from the Central Office over cable pairs. Contact with ground is avoided to ensure that battery current return will be made via cable conductors rather than through earth. Repeaters located outside the Central Office that receive power from Central Office battery also use this system.

7.09 Electromechanical Switching and Toll systems utilize a fully integrated ground plane. No effort is made to isolate the discharge ground system from framework or any other grounded objects in the building, and ground current is free to flow through any available ground path. Electronic Switching Systems employ an integrated-isolated method. The discharge ground conductors are integrated with the system framework but isolated from power plant framework. The entire discharge-framework ground plane is isolated from contact with any foreign ground with the exception of a single point contact with the CO GRD system through a ground window. The discharge ground terminations at Power Distributing (PD) frames within the Electronic System ground plane are bonded together with 750,000 CM conductors to ensure a low impedance bond for free interchange of current. The individual frames are bonded together and to the ground buses of PD frames to ensure interframe bonding that is not dependent on incidental connections. The single point connection to the CO GRD system ensures that current generated outside the isolated ground plane cannot flow through any part of the isolated plane.

7.10 Prior to the introduction of the CO GRD system, there was no effective method of minimizing the effect of DC current flow through incidental ground paths in integrated ground planes. The CO GRD system provides a facility similar to the bonding between discharge ground conductors at PD frames employed in Electronic Systems ground planes. Horizontal equalizers are extended into each quadrant of a building floor from a floor CO GRD bus. The horizontal equalizer, a 750,000-CM conductor, is connected to BDFB ground buses, Equalizing Center ground equalizers, and other terminating points of principal discharge ground conductors to form paths of known low impedance between such terminal points. These paths in effect short-circuit any impedance that may exist in parallel incidental paths, minimizing their ability to produce undesirable disturbances in the integrated ground plane. The CO GRD system also provides a method of interfloor equalization of ground through its vertical equalizer, improved equipment grounding and reduction of hazard from lightning discharges. Fig.1 illustrates the short circuiting function of the CO GRD system on an integrated ground plane.

7.11 Offices equipped with multiple DC plants of same potential require special consideration to determine if conditions exist where a significant amount of current from one DC plant is transmitted via communication system intercabling to a discharge ground system of another DC plant. Such current, in seeking a path back to the originating battery through incidental ground paths and through CO GRD conductors, may cause a serious voltage differential to occur between the ground systems. In certain cases, discharge ground conductors must be added between the ground discharge point of such communication circuits and the originating battery. Refer to Section 802-001-192 "Design Parameters of Vertical Equalizer System", and Section 802-001-193 "Signaling Systems Ground Requirements", for a description of the effect of multiplant battery return current paths on the CO GRD system and recommendations for relief thereof.

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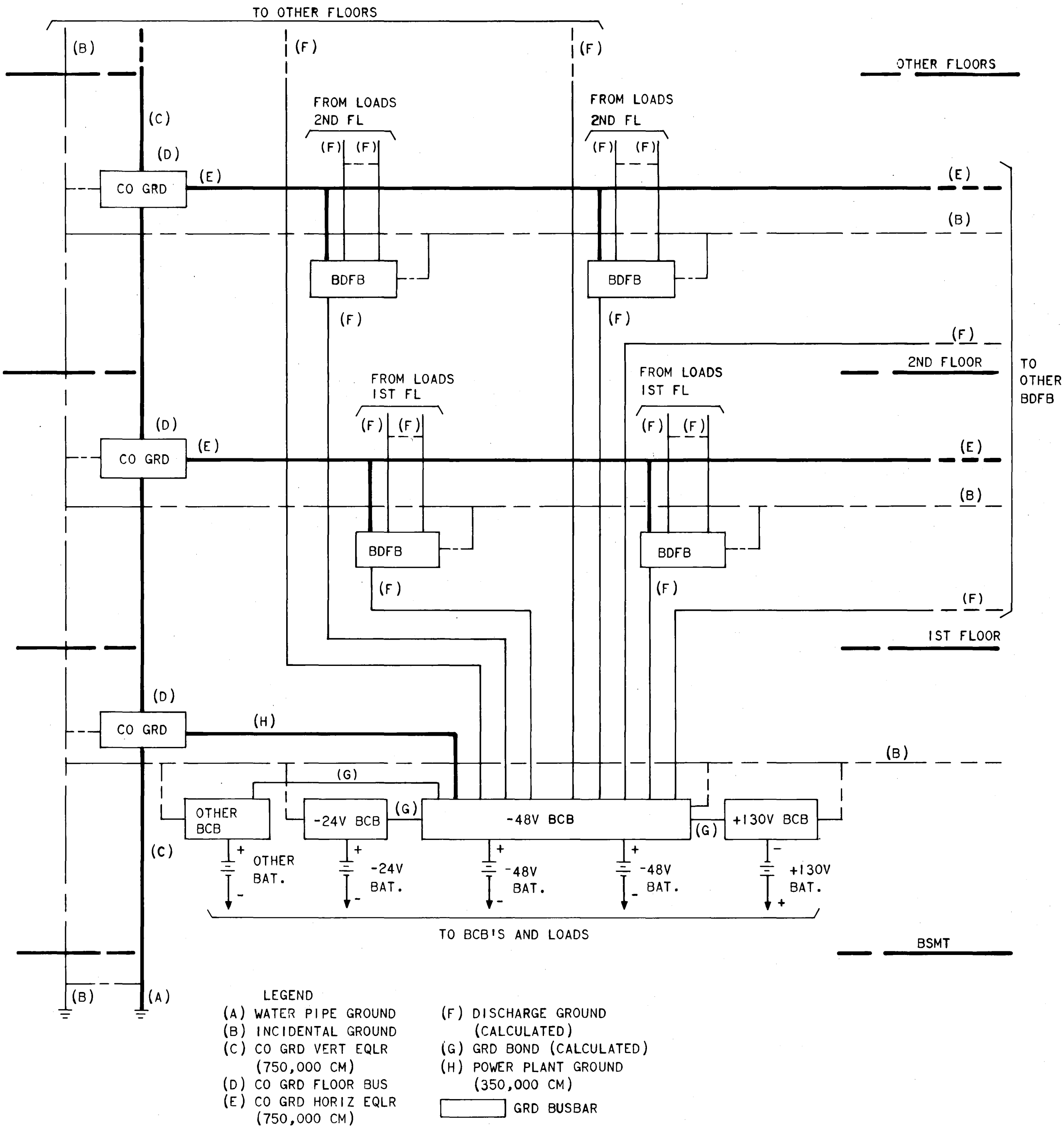

Fig. 1—CO GRD System Imposed on an Electro-mechanical Switching System Integrated Ground Plane, Showing Method of Short-Circuiting Impedances in the Incidental Ground Paths