PROTECTIVE GROUNDING SYSTEMS
GENERAL EQUIPMENT GROUND REQUIREMENTS
FOR MICROWAVE RADIO MAIN AND AUXILIARY STATIONS

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1. SCOPE

1.01 This section provides equipment requirements and engineering information pertaining to the design of a Ring Ground System for Microwave Radio installations.

1.02 This section is supplementary to Section 802-001-180, General Grounding Requirements for Communication Systems in Central Offices, Radio Stations and other Structures.

1.03 Other Protective Grounding System sections applicable to the design of a Ring Ground system are:

802-001-190—Ground System Material
802-001-191—Office Ground Electrodes
802-001-192—Equipment Ground System, Central Offices — General Equipment Requirements and Engineering Information

1.04 Equipment Ground Requirements for AC Service Distribution systems installed in Radio Stations are covered in Section 802-001-198.

1.05 Refer to Section 802-001-180, Bibliography, for a listing of publications pertaining to equipment grounding requirements.

2. GENERAL

2.01 Electrical protection requirements for radio stations are covered in Section 876-210-100. Recommendations contained hereunder are intended to establish standard design parameters for a ring ground system conforming to mechanical and electrical requirements expressed therein.

2.02 Protection measures for co-axial dipole antennae are covered in Section 876-210-100. Information on bonding and grounding of guyed and self-supporting towers is contained in the Section AG 25 series. Information on tower lightning rod application is contained in the Section AG 17 series. Descriptions of pole and tower structures are contained in the Section 261 series. In relation to such structures, this section is confined solely to methods of bonding such structures to earth. In the descriptions hereunder, the word "tower" shall be construed to define either a self-supporting steel tower or a pole supported with guy wire, and reference to grounding of tower legs shall be construed as grounding of a metal pole and supporting guys when a pole and guy structure is involved.

2.03 The ring ground system is designed to provide low impedance bonding between neighboring metallic objects and to establish low impedance paths to earth. The primary purpose is to reduce the level of voltage differential between objects during lighting discharges. The system also provides ground reference for normal operation of communication circuitry, equivalent to the function of the CO ground system described in Section 802-001-192.

2.04 A complete ring ground system is composed of:

(a) a buried exterior ring ground system

(b) an interior ring ground system consisting of:

(1) a peripheral bus

(2) supplementary buses

(3) interior-exterior ring bus bonds

(c) inter-object (unit) bonds.

LIGHTNING CURRENT

2.05 Any conductive member represents an impedance to the flow of lightning current seeking a path to ground. The impedance is a combination of resistive and inductive properties of the member. Any conductive member is self-inductive. In the presence of rapidly surging current pulses characteristic of lightning discharges, the resistance of a conductor does not change significantly. The inductive reactance does however increase in relation to the rate of current increase. The effective impedance of a conductor is therefore variable, primarily due to inductance, and the magnitude depends on the rate of current change. Extreme voltage differential between different points on a conductor may develop during a lightning stroke. Since inductive reactance is the major voltage producing factor, voltage differential between different points of a path for lightning current cannot be eliminated or significantly minimized by reduction of resistance (increasing wire size). The differential can be minimized, however, by ensuring that the path is of lowest practical inductive and resistive impedance and/or providing parallel paths of minimum impedance. In providing such low impedance paths a straight wire of shortest possible length is recognized as the optimum path of lowest impedance. Reduction of resistance by provision of wire sizes larger than No. 2 AWG provides little practical reduction of impedance. A No. 2 wire is of adequate capacity to carry total current of heavy discharges without thermal damage and is physically resistant to accidental mechanical damage, therefore No. 2 wire is recommended for external ring buses, internal-external ring bus bonding, external unit bonds to objects, and internal peripheral and supplementary buses. Internal unit bonds from peripheral and supplementary buses to objects shall be made with No. 6 AWG wire, primarily because that size provides adequate strength to resist inadvertent damage.

2.06 A brief, simplified description of the probable paths of current during a discharge is included here to establish factors for recommendations covered hereunder. Figure 1 illustrates the description. Letter references hereunder, (A), (B), etc., apply to that figure.

2.07 Dipole antennae and supportive structures such as metallic poles and guy wires, and self-supporting towers of the type used to mount microwave radio antenna horns are highly susceptible to lightning stroke. Conversely, buildings and other structures in the vicinity of these structures are not, since the structure tends to shield lower objects from hits (cone of protection). The probable current path, therefore, of a lightning stroke in the vicinity of a radio station is from the cloud (A) to top of the antenna structure (C) to earth (E). When discharge occurs, a surge of electrons build up rapidly in the discharge path and immediately decays to a relatively nominal flow. Often, recurrent surges occur. Electron flow in such a discharge may reach a peak of 10,000 to 100,000 amperes or more in 3 microseconds or less, decay to half of the peak flow in perhaps 25 to 50 microseconds, and "tail off" to a relatively nominal flow in the order of hundreds of amperes for several milliseconds. Recurrent surges may occur at perhaps 40 millisecond intervals for as many as 10 or more recurrences. Total time involved in the discharge sometimes exceeds 1/4 second.

2.08 The metallic components of a tower afford low, but not insignificant, impedance to the flow of discharge current. Waveguides and/or antenna cables, tower lighting conduits and metallic supportive structures are extended to a building from some height on the tower above earth. During discharge a voltage V(L) is impressed on the waveguides, etc., that is a product of current flow through the impedance between earth (E) and the lowest point of ground bond of waveguides, etc., and tower (L). This impedance would consist solely of tower leg impedance if the tower was earth supported and no other ground path existed between waveguides, etc., and earth. In fact, however, ground paths of such nature occur spontaneously through direct (F), resistive (G) inductive or capacitive coupling (H) of waveguides, etc. to metallic members that are part of or housed in buildings. These members, some of which are incidentally connected or close coupled to members connected to earth, constitute current paths in parallel with tower legs and contribute to some degree in reducing the inductive reactance between the tower-waveguide bond and earth, thereby reducing the peak voltage differential impressed on waveguides, etc. and members that are connected thereto. Since wire is self-inductive, a simple straight wire bond of waveguides, etc., to earth at the point of entry into the building (D - F to E), which is most effective in supplementing the tower leg current path, is not totally effective in reducing voltage impressed on waveguides, etc. Supplementary measures, therefore, must be taken within the building to ensure that a multiplicity of low impedance paths for flow of current between waveguides and earth exist so that potential difference between earth and waveguides, etc., and between neighboring objects, is kept to a minimum. The primary purpose of the ring ground system is to accomplish that objective. As shown in Fig. 1, the ring ground system (K) short circuits points of indeterminate impedance (G) and points of isolation (H) between components (J) of the station.

3. THE EXTERIOR RING BUS SYSTEM

3.01 The exterior ring bus system establishes a station ground electrode that tends to equalize potential in earth surrounding the building and tower, regardless of earth resistivity, by ensuring that a low resistivity current path exists throughout the area. The system is comprised of exterior ring buses encircling the building and the tower. The bus is composed of a No. 2 AWG solid tinned copper wire buried at least 18 inches below grade and spaced 2 feet minimum from building foundation and tower footings. The ends of the wire are joined together to form a ring. Driven ground rods are connected to the bus at 10 to 15 foot intervals to ensure contact with permanent earth moisture. Under adverse soil resistivity conditions or when bedrock prohibits driving of rods, horizontal counterpoise wires are employed to improve equalization of the system. Design requirements are identical to that of the driven ground electrode system described in Section 802-001-191 and illustrated in Figure 3 therein. Wire, ground rod and connector specifications are covered in Section 802-001-190.

3.02 Figure 2 illustrates a typical exterior-interior ring bus system and relationship between various components of the ring ground system. As shown therein the exterior bus is bonded to tower legs, exterior buried and above surface objects, other electrodes; and to the interior ring bus and waveguide hatch plate. The tower ring portion is bonded with two wires to the building ring. Bonding wire shall be the same as used for the exterior ring bus.

3.03 A buried exterior ring bus around the building is not required when the building is a central office, wherein the radio equipment area comprises a relatively minor part of the communication equipment area, and the building is adequately grounded by means of water pipe or other acceptable ground electrode.

3.04 A roof mounted ring bus system is required when a tower is roof mounted on a relay station or cental office building. A ring shall be formed around tower legs similar to a buried tower ring and bonds extended to tower legs and other metallic objects on the roof to ensure equalization. On a steel frame building the ring shall be bonded with at least two bonds at opposing points on the ring to building steel. On a reinforced concrete building or other type of construction where continuity to earth through building steel is not assured, at least two No. 2 bonds shall be extended from the ring to the building exterior ring bus (if provided) or the water pipe. Connection may be made to water pipe on the exterior of the building or at the street side of the water meter within the building. Roof mounted tower rings shall also be bonded to waveguide hatchplates. Where practical and reasonably economical, four bonds, one from each corner of the roof ring to building steel or ground electrode is preferable to the minimum two bonds described above. A typical roof ring ground system is shown on SD-81805-01.

3.05 When the radio equipment is mounted on a floor directly below the roof mounted tower, the path to earth afforded for the interior ring ground system may be utilized for the tower ring by connecting tower ring bonds to the interior ring bus rather than running them directly to the ground electrode.

4. THE INTERIOR RING BUS SYSTEM

4.01 The interior ring bus system consists of 1) a No. 2 AWG wire extended around the periphery of the Radio equipment area (peripheral bus), 2) a number of No. 2 AWG bonds between the peripheral bus and the exterior buried ring bus 3) supplementary buses and 4) unit bonds. The system is illustrated in Fig. 2 and 3. It provides a means of establishing low impedance between neighboring metallic objects within the communication building, and also, low impedance paths between that bonding network and earth. Any metallic object within or part of the building may function as a current path during discharge, dependent on it's relationship in terms of coupling to the focal point of current flow between the tower and the building interior, and to earth. The probable focal point is assumed to be the waveguide hatchplate (or hatchplates) or coaxial cable outer sheath. Coupling of objects to hatchplates may be 1) direct (by direct metal contact with waveguides), 2) through indeterminate impedance paths (objects in mechanical contact with direct coupled objects), or 3) through air gaps or other forms of insulation when proximity is such that a high voltage differential will allow a spark-over between the isolated objects. A flow of current to earth may occur through direct or indirect paths, or insulating separations. Current flow through indeterminate impedance or through insulation (arcing) can produce excessive heat resulting in damage to equipment. Current arcing is a danger to personnel, who may, if interposed between two objects of high potential difference (eg. one coupled to waveguide, other coupled to ground, isolated from each other), act as a conductor for discharge current. Indeterminate impedances can be neutralized by formation of a parallel conductive path with a conductor of known low impedance. Points of isolation, except for electrical circuitry requiring isolation from ground for proper operation, can be neutralized by the same method. The interior ring ground system is designed to provide bonding of this nature in a practical and reasonably economical manner.

4.02 Certain objects within or part of the building are spontaneously grounded through incidental ground paths during installation. Other objects are not. A spontaneously grounded object, when bonded to the interior ring bus system constitutes a direct path for discharge of lightning current and acts to reduce the impedance between the focal point and earth represented by all of the parallel paths of this type. The voltage differential between the focal point and earth is thereby less than it would be if the spontaneous grounds did not occur. Regardless of their number, parallel ground paths cannot eliminate the voltage differential. Practical minimization of voltage differential is achieved when these spontaneous paths are supplemented with additional current paths of lowest practical impedance between the focal point and earth. The interior ring ground system is bonded to earth with such low impedance paths by means of interior-exterior ring bus bonds. They provide short straight runs from focal points (eg. waveguide hatchplate) and various points on the interior peripheral bus to the exterior ring bus.

A. Peripheral Bus

4.03 A peripheral bus is provided to act, in series with the interior-exterior or CO GRD bonds, as the primary low impedance path for current between the current focal point(s) and earth. The bus shall be constructed of No. 2 AWG copper wire supported from walls, cable rack stringers or framing channels at a convenient height from the floor for bonding supplementary buses thereto. In an installation with 9-0 high frames the recommended height is 9-8.

4.04 In a building, or floor thereof, used primarily for housing of radio and associated power equipment, the perimeter bus is routed on outer walls around the entire building or floor and the two ends are joined to form a ring. When a radio area is part of a floor area (eg. less than half) in a cental office building, the ring shall surround the radio area, only. Power equipment associated with the radio system, if separated from the radio area, need not be equipped with a ring ground system in central office installations, but should be grounded per equipment ground requirements described in Section 802-001-193.

4.05 The No. 2 AWG wire may be bare solid, bare stranded or insulated stranded wire, as described in Section 802-001-190, Interior Ring Ground Wire. Generally, stranded insulated wire will provide an installation of least expense and greatest reliability. In the following descriptions, use of green insulated wire is assumed. With the exception of supportive strap sizes, method of construction using bare stranded wire is virtually identical. Method of construction using solid wire is covered on ED-82138-31.

Forming and Support of Peripheral Bus

4.06 Crimp type parallel connectors or cadwelds are recommended for bonds to the peripheral bus (Section 802-001-190). Such connections need not be insulated. Space for tools between the supporting surfaces and wire is necessary to make such bonds. A standoff support assembly, as shown in Figure 4, is recommended for support of wire on walls. A nylon expansion anchor, as illustrated, shall always be used to fasten the support to dry-wall, concrete, brick or other types of walls. When used in dry-wall a wood sleeper, as illustrated in Figure 4, is not mandatory. It is, however, recommended at the height that buses are intended to be supported from walls. Supports shall be provided at approximately 2 foot intervals. Additional supports at points that tend to distort the peripheral bus, such as at bonding points, may be provided on basis of need. Peripheral bus wire not run on walls are generally supported from cable racks or framing channels. See "Supplementary Buses" for methods of support.

4.07 For the purpose of minimizing impedance and incident of arcing, the peripheral bus shall be installed with a minimum number of bends, and such bends as are required shall be made with the greatest practical radius. In general, the nominal bend radius shall not be less than 1 foot. When that radius is not practical, the minimum radius shall not be less then 6 inches. Use of 90° bends to route around obstructions shall be avoided when lesser bends (eg. 45°) can be adequately supported. The probability of arcing may be significantly increased by unnecessary bends. Unnecessarily small radius and severe bends may concentrate stress, producing ionization and spark-over. Since voltage differential occurring between members within the building is a product of the impedance to flow of current, installation of the peripheral bus so as to minimize unnecessary impedance is of prime importance.

4.08 Any closed ring of metal around a ground bus acts as an inductive impedance to the flow of other than steady state discharge current. For this reason, routing of ground buses through metallic objects that form a ring around the bus, such as metallic conduits or sleeves through walls or floors is not recommended. Use of non-metallic material such as PVC plastic conduit is recommended. Where use of metal conduit is unavoidable (eg. non-metallic conduit prohibited by local code) the ground bus shall be bonded to each end of the metal conduit 1) to avoid increasing inductive impedance, and 2) to reduce voltage drop by paralleling the metal conduit conductance with that of the ground bus.

4.09 The peripheral bus shall be run exposed so that visual inspection of the system may be made, and any point is available for bonding. Routing of a bus through PVC conduit for purpose of support should be avoided for these reasons.

4.10 When stranded wire and cadwelds or crimp type parallel connectors are employed, the peripheral bus need not be installed as a single continuous run of wire. Unnecessary splices should be avoided, but where installation is greatly simplified by installing the peripheral bus in several segments, with the segments joined by a cadweld (preferred) or crimp type parallel connector, such segmentation is permissable. Solid wire peripheral bus may be segmented only if segments are joined with cadwelds.

B. The Interior-Exterior Bus Bonds

4.11 When a buried exterior ring ground system is used as a station ground electrode, multiple bonds are required between that system and the interior ring system peripheral bus. These bonds complete the low impedance current path between waveguide hatchplates and earth afforded by the peripheral bus.

4.12 Such bonds shall be of the same wire as the buried exterior ring bus to which they connect. One bond wire shall be run directly from the exterior ring bus to each waveguide hatchplate. These bonds are referred to herein as primary bonds. Figure 8 depicts a typical installation of a primary bond. As shown therein, the primary bond wire is No. 2 AWG bare tinned solid copper wire extended from a cadweld connection at the exterior ring bus through PVC conduit to the interior wall below the hatchplate. The wire is shown connected to a green insulated No. 2 AWG stranded copper wire (of the type used for the peripheral bus) with two crimp type parallel connectors similar to that depicted in Figure 5. Crimp connectors shall not be used with solid copper wire, other than to join the solid wire to stranded wire, in which case two connectors must be employed. Termination of stranded wire on the hatchplate may be made with a two-hole bolted tongue crimp connector. The solid wire may alternatively be joined to the stranded wire with a cadweld connection, if expedient, or extended to the hatchplate. A pressure or cadweld type two-hole bolted tongue connector must be used to terminate solid wire to the hatchplate. The primary bond wire shall be supported on the interior wall with supports as shown in Figure 4. Unnecessary bends shall be avoided. Necessary bends shall be of greatest practical radius.

4.13 Secondary interior-exterior bus bonds are required to bond the peripheral bus to the exterior bus as a means of assuring equalization of voltage throughout the interior ring ground system, and to provide additional low impedance current paths in parallel to tower legs and primary bonds. No. 2 solid wire secondary bonds shall be provided at least at four points on the peripheral bus, located at corners of the building. Connection of the solid wire to the stranded peripheral bus wire shall be made with parallel cadweld (preferred) or two parallel crimp connectors. The solid wire shall turn in the direction of the hatchplate. When the length of peripheral bus between corner bonds or between a corner and primary bond exceed 50 feet (nominal) to 80 feet (maximum) an additional secondary bond shall be provided at an approximate midpoint of the run. Method of installation of secondary bonds shall be similar to that of primary bonds, as described in 4.12. Alternatively, instead of extending the solid wire to the peripheral bus, a bond connection to a No. 2 AWG green insulated stranded copper wire may be interposed, if expedient. The joint between the solid and stranded wires shall use two crimp connectors or a cadweld connection as described above (see Fig. 8). The connection between the vertical stranded wire and the peripheral bus shall be made with a crimp connector (see Fig. 5).

C. Supplementary Buses

4.14 Metallic objects in the radio area must be bonded to the ring bus system. Additionally, objects within 6 foot mutual proximity must be bonded together. This is normally accomplished via paths established by unit bonds connected to the ring bus system. Impedance of such inter-connective paths is dependent on the length of the path, therefore a practical limitation of path length is necessary to ensure effective equalization. For this purpose the following general guidelines are presented as a guide in determining acceptable path lengths:

(a) For objects located within one foot of each other the bond path length shall not exceed 15 feet.

(b) For objects located from one to six feet of each other the bond path length shall not exceed 30 feet.

(c) When (a) or (b) cannot be met, a supplementary bus shall be provided, or direct bonds between objects shall be provided in addition to bonds to the bus, to meet requirements of (a) or (b).

Note 1: Bond path length shall be calculated as the shortest path between points of closest proximity of the two objects via object metal and interconnective bond paths.

Note 2: Mechanical connections between objects (eg. inter-frame bolting) shall not be considered as a bond path except where the interconnective device is a junctioned ground bus, (eg, relay rack ground), continuous pipe used as a frame ground (eg. unequal flange duct bays) or an equivalent device intended for frame line grounding purposes.

4.15 It is recognized that the preceding rules are not always applicable to every occurrence of object proximity. They express limits considered desirable to ensure equalization of potential. In certain cases it will be expeditious to exceed the length limits for physical or economic reasons. It is recommended, where limits are exceeded via the path through unit bonds and ring bus and addition of a direct bond between objects or ring buses are not practical, that under no circumstance shall the lengths be more than double lengths expressed in the guidelines.

4.16 The inter-object bond path shall be kept as short as possible. In order to facilitate this objective, supplementary buses shall be provided over frame lines within the area bounded by the peripheral bus.

4.17 Supplementary bus arrangements are shown in Figure 3. Supplementary buses shall be provided as required to satisfy the inter-object bonding requirements. These buses also function to provide minimal length low impedance paths between the current focal point (hatchplates) and earth, in parallel with peripheral buses. To provide a parallel path the supplementary buses must be connected at both ends to the peripheral bus. The bus wire shall be the same as that of the peripheral bus.

Forming and Support of Supplementary Buses

4.18 Parallel crimp connectors (Fig. 5) are used for connection of supplementary buses to the peripheral bus. Special attention must be paid to the direction of turn at the joint, so that the joint will not create an impedance to current flow. Principal current flow during a discharge will be between the focal point (hatchplates) and earth over paths of lowest impedance. A reverse bend, which would require an abrupt change in direction of current, could seriously reduce the effectiveness of a supplementary bus. For this reason, the end of a supplementary bus connected to a point on the peripheral bus nearest a waveguide hatchplate shall turn in the direction of the hatchplate. The other end shall turn in the opposite direction, toward an interior-exterior bond connection on the peripheral bus more remote from the hatchplate than the supplementary bus connection (see Figure 3) or, when an external ring ground system is not employed (Central Office installation), in the direction of the CO GRD bond connection point to the peripheral bus. When there is no significant difference in the length of the bond paths to a hatchplate from either extremity of a supplementary bus, both ends shall turn in the direction of the hatchplate. When the building is equipped with more than one hatchplate equipped with waveguides, the nearest hatchplate shall be considered as the primary focal point and a supplementary bus wire end nearest the primary focal point shall turn in that direction. If one or more of several hatchplates are not initially equipped with waveguides, supplementary bus turns shall be made in the direction of the nearest equipped hatchplate. Bus turns so located that the unequipped hatchplate will become the primary focal point when equipped with waveguides (eg. on peripheral bus between hatchplates, etc.) shall be made non-directional by adding a short bond, at the turn, in the opposite direction as illustrated in Figure 3. Where doubt exists as to the optimum direction of turn, other bonding points may be made non-directional, as well. For reason of economy, universal application of non-directional bonds is not recommended.

4.19 Supplementary buses are normally supported from cable rack stringers (see Figure 6) or framing channels furnished for support of cable racks, conduits and similar structures. When so routed, the bus shall be bonded to the supportive unit at not more than 15 foot intervals. In order to avoid drilling of cable rack, it is recommended that supports of the type shown in Figure 6A be used at 2 foot intervals. The spring type universal clamp, when mounted on a cable rack stringer, ensures a maintenance free bond to the cable rack. The assembly supports the wire away from the rack to avoid interference from rack supporting hardware. At points of rack junction or other points of interference with the bus run, a job fashioned detail equivalent to the 840254080 zinc plated steel bracket may be used to route the wire around obstructions. Removal of paint from the stringer is not required when the clamp is installed. Scratches in the finish shall not be painted, and the clamp, which is black, shall not be painted.

4.20 Where cable racks are not available for support of supplementary bus wire, framing channel superstructure may be utilized (see Figure 9). Such channels shall be bonded to the wire at both ends of a bus run portion supported in this manner and at 15 foot or lesser interim intervals when the run portion exceeds 20 feet. The bond shall be made by drilling the channel and mounting a ground clamp (Dossert GF13 or equivalent, see Section 802-001-190 figure 3) thereon, so that the lower edge of the wire insulation is close to the bottom edge of the channel. Supplementary supports for the wire, consisting of 840255434 clips, shall be provided at 2 foot intervals along the channel.

Waveguide Hatchplate Bonds

4.21 Waveguides, metallic supportive framework and tower lighting system conduits extend the current path from the tower to the building. The waveguides are bonded to the hatchplate by the mounting flanges furnished with the pressure window section that passes through the hatchplate. Metallic supportive framework, if not mechanically connected to establish continuity, shall be bonded with a No. 2 AWG bond to the hatchplate exterior surface. Conduit entering the building, when in proximity to the hatchplate, shall be bonded to the hatchplate exterior and, if run on the building exterior before entering the building, shall be bonded to the exterior ring bus, if furnished, or roof ground ring or other equivalent low impedance path to earth immediately prior to entry through the building wall or roof. The conduit shall also be bonded to the interior ring bus system immediately on entry into the area served by the ring bus.

4.22 The hatchplate shall be directly bonded to earth with a primary bond, as described under "The Interior-Exterior Bus Bonds" when a buried exterior ring ground system exists. When hatchplates are located in the roof, the primary bond shall be bonded to the exterior ring bus. The primary bond shall be connected to the hatchplate on the interior side, routed in proximity to and connected to the interior peripheral bus and extended to the exterior ring bus in PVC conduit, similar to the arrangement shown in Figure 8, connected to the peripheral bus. When wall mounted, the hatchplate shall be bonded twice to the peripheral bus, as shown in Figure 8.

4.23 Where a CO GRD system is used for a current path between the peripheral bus and earth, a primary bond to earth is not required. Roof mounted hatchplates shall be bonded to peripheral or supplementary buses near the hatchplates. Wall mounted hatchplates shall be bonded to the peripheral bus as shown in Figure 8. It should be noted that the direction of turn of these bonds, and location of connectors at the hatchplates should be applied as shown in Figure 8 and described in 4.18.

4.24 Waveguides require no interbonding or wire bonds to the interior bus system when the hatchplate is located within 25 feet of the interior ring ground system. When the hatchplate is located further away, as when antennas are roof mounted and radio equipment is on a lower floor of a multifloor central office building, waveguides shall be bonded to the interior bus system. Waveguides within 6 feet of each other shall be bonded together, by means of metal wire clamps fastened under waveguide flange bolts and No. 6 wire, similar to the multiple conduit bonding arrangement in Figure 7. The bond shall be extended to a peripheral or supplementary bus. The point of bonding shall be at the entry point of waveguides into the area protected by the interior ring bus system. In such an arrangement the waveguides act as discharge current paths between hatchplate and interior ring ground system, therefore, primary bonds between such remotely located hatchplates and interior buses may be omitted when waveguides are so bonded.

Office Ground Bus - TD, TH Microwave Systems

4.25 Modern microwave radio systems (TD-3, TH-3) are energized by single voltage (24V) multi-load power supplies provided by dedicated power plants or from a central office plant. Distribution to individual units is accomplished through a battery distribution circuit breaker board or circuit breakers mounted on the power plant battery control board. Distribution circuit conductors are paired: An equal ampacity discharge ground conductor is provided with every battery discharge conductor serving load units. Pairing ensures adequate paths for return of current to the battery and tends to reduce voltage transients in the power distribution system which may introduce noise into communication circuits. An inter-junctioned frame line ground bus system is not employed. Relatively little discharge ground current is interchanged through the ring ground system. An office ground bus and associated bonding conductors, as employed in earlier systems, is not employed in modern systems. Communication system equipment requiring earth potential reference, such as dedicated power plants located within the protected area, may obtain such reference from any point on the interior ring ground system peripheral or supplementary buses.

4.26 Early types of microwave radio systems require several power plants (J86425 series plants typical) that provide a multiplicity of voltages (12V, 24V, 130V, 250V, etc.) to operate the radio system equipment. An office ground bus located in the radio area is employed as a common ground point for the station. In the earliest installations, an interior ring system was not employed for lightning protection. Interior-exterior bonds were run directly from two opposing points on the exterior ring bus to the office ground bus and bonds were provided from the bus to inter-junctioned ground buses on radio frame lines, power plant BCB ground buses, waveguide hatchplates, building steel and other units within the building. Inter-bonding of the various radio frame lines via the office ground bus provided a discharge ground path for circuits grounded to frame ground buses. The bonds provided from the office ground bus supplied earth potential reference to the power plants and communication equipment, and served as a ground current path to batteries in parallel with the ground conductors of the battery discharge system. The effect of this bonding system was to equalize ground voltage throughout the installation.

4.27 The office ground bonding system was later supplemented by an interior ring ground system, to improve lightning protection. In such stations that are not equipped with an interior ring ground system (SD-81094-01 typical) it is recommended that consideration be made to adding it. When modern microwave radio systems are added in an existing station, it is imperative that an interior ring ground system be added, and it is recommended that such an addition shall include the entire station installation. Bonding of modern system frame lines to an existing office ground bus is not required.

4.28 The early microwave stations generally employed frames equipped with frame line inter-junctioning ground bars, to which circuit grounds and the frame line-office ground bus bonds were terminated. When new frame lines are added to installations of such early systems, frame line ground bus runs shall be bonded to the office ground bus (SD-81094-02 Figure 8 typical) to ensure that continuity exists between frame line ground buses that is not solely dependent on paths through the ring buses.

4.29 When an interior ring bus system is not provided the office ground bus is joined directly to the exterior ring bus. When an interior ring bus system exists the office ground bus is connected at both ends to a peripheral or supplementary bus. On occasions where the original office ground bus is fully equipped with terminals an additional bus may be provided. This bus shall be located in the vicinity of the original bus and bonded thereto with a 750,000CM conductor. Both ends of the bus shall be bonded to peripheral or supplementary buses to form the equivalent of a supplementary bus.

4.30 In some installations that use J86425 or similar power plants, generally main stations in central office building, the power plants are located on other floors or at some appreciable distance outside the radio area and the location of the office ground bus. When so located the normal requirement to provide individual grounds bonds between the office ground bus and the various power plants may be ignored. Instead, a single office ground bus-power bond shall be run to the BCB ground bus of the predominant plant (largest ampere capacity, such as 12V plant). The wire size shall be of the size normally specified to be run to the predominent plant, (eg, 750,000CM). Individual bonds of the size specified to be run from the office ground bus to other plants shall be furnished from the ground bus of the predominant plant, or from an interim tap on the office ground bus-power bond, if expedient. The vertical equalizer of a CO GRD system, if available, shall not be used in lieu of a direct bond between the office ground bus and the predominant power plant. As an alternative to bonding directly to the ground bus of the predominant plant, the bond extended from the radio area office ground bus may be terminated at an office ground bus located in the power area and individual bonds furnished therefrom to the power plants. This bus shall be bonded to a floor CO GRD bus, if extant; otherwise to building steel in a steel frame building, if extant; or to a cold water pipe having continuity to earth. The bond shall be No. 2 AWG KS-5482-01 or equivalent.

D. Unit Bonds

4.31 Every metallic object buried or above ground on the building exterior, part of the building structure, or installed within the building may constitute a path for discharge current, dependent on its coupling to earth. The impedance of such spontaneously occurring paths is virtually impossible to determine, except when the object is known to be assembled and joined in a manner that ensures low impedance electrical continuity between its various components. Such assembled objects include equipment units mounted on a common metal frame or cabinet, electrical conduit runs, water pipes, steel frames of buildings, air ducts (when joined to constitute a reliable electrical juncture) and other assemblies of like structure. Generally, objects assembled to produce low impedance continuity throughout the assembly do not require additional inter-component bonding.

4.32 When such assembled units (eg. equipment bay, cabinet, etc.) are installed in or on the exterior of a building, buried, or mounted on earth surface, continuity to earth and/or continuity between units may be established through metallic supportive hardware, building metal, earth, or by other inter-connective paths. Conversely, a unit may be isolated by air gap or other forms of insulation. One common form of insulation that allows close coupling of units while isolating them is paint. Occurrence of isolation and of indeterminate impedance in spontaneously occurring inter-unit or unit-earth conductive paths can produce high voltage differential between units. To ensure minimal voltage differential between units, or unit and earth, it is necessary to provide low impedance paths that effectively short-circuit impedance and insulation.

4.33 The peripheral and supplementary buses, in series with bonds to the earth electrode affords a low impedance path in close proximity to units installed in a building. The exterior buried ring bus ensures that a rise of potential in the earth due to a discharge of lightning current will be equalized throughout the building site. Roof mounted tower rings in series with building steel and bonds to the interior ring ground system ensure low impedance paths to earth. The bonds that extend from individual objects to these buses complete a ground system that ties metallic objects tegether and to earth with reliable low impedance continuity. Such bond wires are referred to herein as ***unit bonds.***

Exterior Unit Bonds

4.34 Figures 2 and 3 illustrate some of the exterior unit bonds required in a typical installation. Also depicted are some of the other various components of the ring ground system. As shown therein the exterior bus is bonded to tower legs, exterior buried and above surface objects, other electrodes and to the interior ring bus and waveguide hatchplate. The tower ring portion is bonded with two wires to the building ring.

4.35 A large variety of metallic objects external to or mounted on the building must be bonded to the exterior ring bus to ensure equalization of potential. They include:

(a) Buried metallic objects:

(1) lightning rods

(2) Power Co. or other driven electrodes

(3) fuel tanks unless protected with cathodic system utilizing sacrificial anode rods.

(4) conduits, pipes

(5) other objects with metallic connection to the building (potential earth electrodes).

(b) Earth supported metallic objects located within, or less than 6 feet beyond, perimeter of ring:

(1) tower legs

(2) air conditioning condenser units

(3) metal fences (including bond across gate openings, multiple bonds at 25 foot intervals if run continuously within 6 feet of ring).

(4) other metallic objects of significant size.

(c) Metallic objects mounted on building:

(1) cable entrances

(2) down spouts

(3) aluminum (or similar) exterior wall siding

(4) conduits, pipes (multiple grounds required every 25 (nominal) to 50 (maximum) feet when run parallel to earth on exterior walls.

(5) air exhaust hoods

(6) parapets (at each corner of building when parapets are electrically continuous, otherwise at least one bond to each discontinuity in addition to corners)

(7) metallic structures supported on roof

(8) lightning protectors (arresters) associated with AC service.

(9) outer sheath of co-axial antenna cables

(10) other metal of similar nature

(d) Metallic components of building structure.

(1) Steel members in foundation wall (eg. bond each building perimeter column).

(2) Outer layer of reinforcing bars in exterior walls of reinforced concrete building (eg. one bond per area between adjacent columns or 25 foot intervals maximum)

(3) reinforcing bars of concrete knockout panels (rebars not in contact with building structure rebars)

(4) other building structure metal exposed on outer surface of building.

4.36 Unit bonds connected to the exterior ring buses shall be No. 2 AWG bare solid copper wire. Connections to ring buses shall be cadweld, when buried. Connections to above ground units shall be made with cadweld, where practical, or with pressure type connectors. Crimp type connectors are not recommended for use with solid wire. Connectors other than cadweld shall be located so as to facilitate periodic inspection and maintenance.

4.37 Generally, a "tree" grounding system provides the most efficient and economical method for grounding groups of objects located in the same general direction from the grounding point. Units buried in earth, mounted above ground away from the building, mounted on the building exterior or within the building all require bonds to the ground electrode. Individual bond wires run to each unit is not only unnecessary but it can be potentially hazardous when units so bonded are located close together. If, during a discharge, one bond wire is conducting lightning current and another used to ground a neighboring unit is not, voltage drop across the conducting wire can cause an extreme difference of potential to occur between the two units. This build-up of potential can cause spark-over of current and is hazardous to personnel interposed between such objects.

4.38 A "tree" is generally applicable to grounding on the building exterior. A "tree" system consists of a single conductor run from a ground point in a generally direct route toward a group of units requiring grounding. Branch conductors are extended to individual units from points on the main or "trunk" conductor. Sub-branches may also be extended from branch conductors. The trunk conductor is extended to the furthest unit from the ground point. This method provides minimal impedance bonding between units via the branch conductors thereby reducing the probability of high potential difference caused by individual ground paths. It is recommended that branch conductors be generally, limited to about 15 feet so that the inter-unit bond length does not become excessively long. Where units bonded to different trunk conductors are located within six feet of each other branch conductors of the two trunk systems should be bonded together so that a direct bond not greater than 30 feet in length exists between the units. In the builing interior, the peripheral and supplementary buses form a network for inter-bonding of units, as described under "Supplementary Buses".

Interior Unit Bonds

4.39 In the following discussion of interior unit bonds reference to lengths of bonds in terms of feet are provided to establish working objectives. They are not absolute values and may be exceeded where conditions warrant. General limitations are expressed in 4.14 and 4.15. Figure 3 illustrates some of the interior unit bonds required to ensure equalization of potential between neighboring units and to establish low impedance paths between units, earth and the current focal point (hatchplate). Communication equipment, building heating, air conditioning and similar facility units, steel roof girders and numerous other metallic units, members and objects require bonding. Certain of these objects, such as an equipment bay secured to the floor with expansion anchors inadvertently in contact with metallic reinforcing mesh in the floor, may constitute a low impedance current path between the unit bond point and earth. An adjacent bay or other object may be low impedance coupled to the current focal point, but not to earth. Bonding of each object to peripheral or supplementary buses, thereby creating a bond between objects, ensures that the voltage generated by current flow through the impedance of the grounded object is also impressed on the neighboring ungrounded object. This voltage equalization reduces the possibility of sparkover of current from one object to the other.

4.40 As outlined under "Supplementary Buses" the self-impedance characteristics of wire reduces the ability of a bond to equalize voltage as the length of the bond increases. Assemblies of known low impedance (eg. conduits, frameworks, etc.) may be considered as extensions of unit bonding wires to the point of closest proximity of the two objects bonded together. However, the run length shall be calculated to include that additional length of conductivity from the bond points to the proximity points. By way of example, two adjacent bays (1 inch separation) with 3 feet between unit bond points, unit bonds 4 feet long, separately connected 3 feet apart to a supplementary bus results in a total bond between the points of proximity (at top of frame assumed) of 2 feet 11 inches (frame) + 4 feet (unit bond 1) + 3 feet (supplementary bus) + 4 feet (unit bond 2) = 13 feet 11 inches, an acceptable bond (less than 15 feet) under the guidelines outlined under "Supplementary Buses" (4.14a). Under a similar dimensional condition except that a more distant location of the supplementary bus results in unit bonds of 4 1/2 feet or greater, an additional supplementary bus closer to the unit bond points, or direct bonds between unit bond points or some point on unit bonds near bond points should be provided to satisfy the requirements for an acceptable bond.

4.41 Unit bond wire shall be identical to interior ring bus wire except for the wire gauge, which shall be No. 6 AWG. Unit bond wire connections to stranded copper wire buses shall be made with parallel crimp connectors. Direction of turn at the connection shall be in the direction of hatchplates, except that a single bond wire, connected to the bus as approximate midpoint and used to bond two units, as illustrated in Figure 6, may be used without regard to direction of turn. The reverse turn portion of the unit bond wire shall not exceed 6 feet in length.

4.42 Sharp bends in unit bond wires should be avoided. Generally, bends of less than 6 inch radius (nominal) or 3 inch radius (minimum) should be avoided. Right angle bends should be avoided when lesser bends can be employed. When unavoidable, bends to 2 inch radius may be employed.

4.43 Generally, individual No. 6 AWG wires between units and buses are preferred. When the conductive path length through two unit bonds and the intervening bus exceeds the acceptable length limits specified under "Supplementary Buses", and addition of a supplementary bus to satisfy the requirement is undesirable, a direct bond between two units within 6 feet of each other is required. When only two such units require inter-bonding, and the units are within 1 foot of each other, one of the two unit bonds may be omitted if the inter-bonding conductor is less than five feet long. The inter-unit branch bond may connect to the unit bonding point of the unit equipped with the unit bond, or it may be connected at a point along the unit bond with a crimp connector, whichever provides the shortest path to the ring bus. The total conductive length of the bond wires from the point of connection at the further unit to the ring bus shall not exceed 30 feet.

4.44 Ring buses run on interior wall partitions and units located next to such partitions may be in proximity with other buses or units mounted on the other side of the partition that normally, under rules expressed herein, would require extensive inter-bonding through the partition to satisfy the restrictions on the length of the inter-bonding path between units. When the ring buses that run on either side of a wall partition are bonded together at both ends, as shown in Figure 3, intermediate through-partition bonds may be omitted, except where units such as conduit or pipe, penetrate the intervening partition. Such units shall be bonded to both ring buses so as to form a bond via the unit metal between buses. This exception to the requirement for interbonding when proximity is less than 6 feet is predicated on the probability that two buses of approximately equal length and joined together at extremities will tend to produce approximately equi-potential voltages on bonded units connected equi-distant from extremities of the individual buses. Probability of spark-over through the partition is considered to be remote.

Frame Bonding Requirements

4.45 Every metal frame, cabinet, battery stand and individual electrical unit (such as engine alternator sets) located within the area bounded by the peripheral ring bus requires unit bonding.

4.46 Bay frame lines may not be equipped with inter-bay ground junction facilities, or they may be equipped with inter-bay junctioned copper ground busbars (eg, relay rack ground busbars) or with an inter-junctioning pipe utilized for frame grounding (eg, duct type frame-work). Bays not equipped with inter-junctioning ground devices must be individually unit bonded to supplementary or peripheral buses. Bays inter-junctioned by means of copper ground bars require connection to a ring bus at each end of the continuous ground bus run, to form the equivalent of a supplementary bus in which the RR GRD bus serves as part of the supplementary bus. Duct bays supported by a common pipe are considered adequately unit grounded when ground bonds between pipe and individual frames per ED-3C014-51 or equivalent exist and the ends of the pipe are connected to form the equivalent of a supplementary bus.

4.47 The unit bonding points of frames requiring individual bonds are variable in accordance with the facilities provided with the frame. Certain frames may be equipped with ground buses located near the top of the frame but not afforded with facility for interbay junctioning. The optimum unit bond point for such frames is the ground bus, when the bus is not isolated from framework metal. The optimum unit bond point for frames not equipped with ground buses is the frame metal at the top of the frames. Such frames may be shop equipped with ground lugs, or holes for mounting job furnished lugs or may have no provision for mounting ground lugs. Two hole bolted tongue crimp connectors are preferred for unit bond connections. It is recommended that other type lugs be discarded, if furnished, and replaced with crimp connectors where practical. Where ground lug holes are not provided and a 1/4 inch thick top or upright angle is part of the framework, a universal clamp (Cat. No. M-2-4-5, Erico Prod. Co.) may be mounted on the 1/4 inch thick angle leg to avoid effort of drilling (see Figure 6). A two hole (3/4 in. centers) bolted tongue crimp connector (KS-15977L-302 typical) shall be mounted thereon with a 1/4-20 hex nut and lock washer on the clamp stud and a 1/4-20 X .250 RHM SCR and lockwasher in the tapped hole of the clamp. When the frame construction is such that a clamp cannot be mounted, the frame shall be drilled to mount a two hole crimp connector (preferred). A one hole crimp connector may be mounted in the top tapped hole provided in the frame for mounting of panels or on other points on the frame when use of a two-hole connector is not practical (alternate).

4.48 Relay rack type frameworks equipped with ground bars and inter-bar junction plates are grounded through mechanical connection of bars to frame, and inter-bonding between frames is accomplished by use of junction plates. The ground bars are considered equivalent to supplementary buses, therefore frames of this type, used primarily in TD-2 microwave stations, are considered adequately grounded for lightning protection and equipment grounding purpose when No. 2 supplementary bus wires are extended from crimp connectors mounted on each end of the continuous ground bus and run to peripheral or other supplementary buses (see Figure 3, RR FRWK).

4.49 The common pipe support for a line of duct type bays, when equipped with individual frame ground bonds per ED-3C014-51 or equivalent, and extended with No. 2 supplementary bus wire from 2 hole crimp lugs (KS-15977L-304 typical) connected at each end of the pipe to peripheral or other supplementary buses is considered adequate for lightning protection and equipment grounding of a line of duct bays (see Figure 3).

4.50 Electrical apparatus cabinets, such as AC service distribution, control, lighting, and similar metallic cabinets, shall be unit bonded to nearby ring buses. Termination of the unit bond shall be made with 2 hole crimp lugs (preferred) or alternative connectors (Section 802-001-190, Connectors) on the exterior surface of the cabinet. Non-electrical metal cabinets such as tool cabinets mounted within 6 feet of units requiring unit bonding, shall be bonded to the ring bus system.

4.51 Metal battery stands and similarly constructed metallic units shall be bonded to the ring bus system. Connection, utilizing 2 hole crimp lugs, shall be made to the stand body or upright that affords shortest inter-unit bonding path to neighboring structures. Some of these units are long enough that additional unit bonds may be required to maintain low impedance paths, between points of proximity of the stand to other units, within the limits outlined in guidelines under "Supplementary Buses".

Miscellaneous Unit Bonding

4.52 Electrical and mechanical units, not classifiable as bays, cabinets or stands, such as engine-alternator sets, fuel tanks, motor driven fans and similar units require unit bonding. Connection of the unit bond shall be made with 2 hole crimp connectors (preferred) or by other reliable means dependent on the facility provided for grounding purpose.

4.53 Units of similar nature to the above, that are associated with heating, air conditioning, personnel facilities (such as electrical toilets, including metallic partitions) protective grill-works and other metallic items furnished as part of building facilities, except such items as electric clocks or other units of relatively insignificant bulk that are located at least 1 foot from unit bonded items) shall be unit bonded.

4.54 Portable items of metallic composition, such as ladders, wheel mounted test cabinets and equipment of similar nature are commonly used in microwave stations. If interposed between metal units that are susceptible to lightning induced charges, even though isolated from direct contact with earth or focal point bonded units, such items can act as a conductor of current if voltage differential between the interposed units reaches a level that causes dielectric break-down of the reduced separation resulting from interposition of the portable item between such units. Generally, portable items have an assigned storage space in the station. When the item, placed in its storage space, reduces the air space separating objects subject to charge to less than 6 feet but not less than 1 foot and the interposing item is entirely isolated from incidental contact with metalwork, the item may be considered adequately protected when a bond of less than 15 feet exists between the interposed objects. When a lesser air space results from interposing of an item between objects, it is recommended that a direct inter-unit bond of shortest practical length be provided between the interposed objects, at or near the point of nearest proximity formed by the interpositioning of the unit, so as to ensure that a bond of lowest possible impedance exists in parallel with the current path formed between objects by the unit. The portable unit need not be bonded when surrounding objects are bonded as described above.

Conduit, Pipe and Duct Bonding

4.55 Conduits, pipes and ducts invariably are routed throughout the area bounded by the peripheral bus, and in central office installations they usually extend beyond that area into areas of a floor occupied by other types of communication equipment or building facilities. Pipes and conduits, raceways and air ducts, when joints are permanently joined by conventional means (without slip joints), are excellent electrical conductors. When these objects terminate in bonded units (eg, cabinets, etc.) within the peripheral bus area, they may be considered to be adequately bonded by that unit bond for a distance of:

(a) 15 feet if electrically insulated from supportive steel hardware

(b) 30 feet if metallically fastened to supportive steel hardware (eg., high level superstructure) at intervals of less than 15 feet.

Note: Recognition that continuity to earth exists through incidental paths, generally otherwise not recognized is allowed when conduits, pipes, and ducts are fastened to a superstructure grid adjoined through metal to cable racks that are bonded to supplementary buses. In this respect, a conduit run between two unit bonded wall mounted cabinets, where a path of continuity from ring bus to ring bus through unit bonds, cabinet metal and conduit of less than 60 feet exists; and conduit is supported from superstructure with U bolts; would require no direct conduit-bus unit bonds. A similar run, except ceiling or wall supported, would require a conduit-bus unit bond when the continuity path exceed 30 feet.

4.56 It is recommended that conduit and pipe unit bond connections be made using spring type conduit clips, rather than strap type clamps illustrated in Section 802-001-190 Figure 2 (SK.A). These clamps are spring loaded, and periodic maintenance to ensure a tight connection is not required. The clips, and recommended methods of terminating unit bonds thereon are shown in Figure 7. They may be used on conduits and pipes from 1/2 size to 2 size.

4.57 Points of discontinuity in conduit, raceway, pipe and duct runs may be made electrically continuous by bonding across points of discontinuity with No. 6 wire terminated in crimp lugs on the outside surface of the unit being bonded, utilizing spring type conduit clips, self tapping screws, nuts and bolts or equivalent methods of obtaining reliable continuity between the unit and connectors.

4.58 Fluorescent lighting system fixtures and interconnecting conduit installed in frame lines within the ring ground system area shall be considered as conduit runs. Unit bonds therefrom shall be provided in accordance with requirements outlined above for conduits. Additionally, an AC equipment ground conductor shall be furnished in conduit runs per instructions in Section 802-001-198.

4.59 When a ring ground system serves radio equipment in a portion of a floor and conduits, pipes, ducts, or similar units supported above the radio bays are run continuously from the radio area into other areas of the floor, each such unit shall be bonded to the peripheral bus at the exit point from the ring ground system area. A single bond "tree" (4.37) connected to closely spaced units, a supplementary bus equivalent or individual unit bonds may be employed.

Bonding of Units Outside the Ring Ground Periphery

4.60 Electrical units of communication systems other than the radio system that may be installed on the same floor are considered to be adequately protected from lightning damage by the CO GRD and framework bonding arrangements provided for such systems in accordance with requirements covered in Section 802-001-192, Equipment Grounding System. Such electrical units that are located outside the area but within 6 feet of ring buses, or of units located in the area, shall be unit bonded to the peripheral bus so that ground system continuity exists between the CO GRD and ring ground systems components. Such bonds may be direct unit bonds; or where a number of unit bonds are required, such as when a number of frame lines terminate within bonding range of radio frame lines, a supplementary bus may be employed with individual unit bonds extended to the points of closest proximity to radio area equipment. Unit bonds shall be terminated at the point on the unit that serves as the framework ground point for the CO GRD system (eg. 1 inch pipe of duct bay line) so as to ensure optimum continuity between the radio ring ground and framework ground systems. A frame line that runs parallel to the perimeter of a ring ground system and within 6 feet of components or units bonded to the ring ground system shall be bonded at both ends of the line. If the bond path via the frame line ground continuity device between points of unit bond connections at the peripheral bus exceeds approximately 60 feet, it is recommended that an additional bond at approximate midpoint of the frame line be provided.

Building Structural Member Bonding Requirements

4.61 The large variety of building construction methods used requires that individual studies be made to determine bonding requirements for each structure. General requirements for bonding of structural members to exterior ring buses are covered under "Exterior Unit Bonds". Recommendations for bonding for structural members to interior ring buses are outlined hereunder.

4.62 It is recognized that the descriptions included hereunder do not cover all of the unique conditions of metallic structure inter-relationships to be found in a building. The intent is to provide general bonding recommendations that will aid in recognizing conditions that require deliberate bonds to ensure continuity throughout the structural metal, so that points of high impedance in the path of discharge current are minimized. Spark-over between points of discontinuity or between structural metal and units installed in the building can cause structural damage or hazard to personnel. As an example, close proximity of concrete encased structural metal to a wall mounted unit may cause an explosion of the intervening concrete if potential difference becomes great enough to overcome the insulating properties of the concrete, permitting an arc to develop.

4.63 A central office building of steel frame or reinforced concrete construction is considered to be inherently self-protective and adequate equalization of potential between structural members and the ring ground system is assumed when the ring ground system is bonded to the building CO GRD system for continuity to earth. Small buildings, such as auxiliary microwave repeater stations afford a higher concentration of current through fewer paths and, dependent on construction features, deliberate bonding to ensure voltage equalizing is recommended.

4.64 General construcion features normally encountered are listed below:

(a) Walls:

(1) Concrete block

(2) Brick veneer, concrete block

(3) Reinforced concrete

(4) Precast reinforced concrete panels

(b) Columns:

(1) Concrete block

(2) Reinforced concrete

(3) Steel section in concrete

(4) Steel section or pipe, exposed

(c) Roof beams:

(1) Steel beams or fabricated metal

(2) Pre-stressed reinforced concrete

(3) Reinforced concrete

(d) Metal framed openings in walls and roofs.

4.65 Concrete block and similar forms of masonry walls provide no continuity to earth. Steel mesh is often used between courses to strengthen the wall. Each course integrated mesh, if employed, shall be provided with a bond wire that protrudes from the wall. The mesh bonds shall be interbonded and extended with a unit bond to the peripheral bus, or to an interior-exterior bond wire when mesh bonds are located in close proximity thereto.

4.66 Rebars (reinforcing bars or welded steel mesh) in poured concrete walls are usually inter-connected, and connected to rebars or structural steel in columns, by welding or wire-wrap to form a suitable path throughout the structure for lightning current. Rebars are connected at the bottom of the wall, at intervals, to the exterior ring ground. They shall also be connected at intervals (eg, at or between columns), near the top of the wall, to the interior peripheral bus. Rebars known to be not inter-connected shall not be bonded to exterior or interior ring buses, so that inherent impedance of such series discontinuities is not reduced.

4.67 Precast concrete panels are usually reinforced with steel bars or mesh. The reinforcement steel in each panel is bonded on the building exterior to the exterior ring ground. Connection to the internal ring system is not required.

4.68 Small buildings may utilize concrete block columns in outer walls. Such columns are non-conductive and ground bonds are not required except for steel mesh used as reinforcement between courses, which shall be bonded same as mesh in masonry walls.

4.69 Steel reinforced poured concrete columns, when rebars therein are deliberately joined to wall rebars, are mutually grounded with wall rebars by unit bonds provided at intervals between wall or column rebars and interior and exterior ring buses, as described above. When column rebars are not in electrical contact with wall rebars (eg. knock-out wall panels) the column rebars shall be unit bonded near the top to the peripheral or supplementary buses. When rebars are not made electrically continuous throughout the column they shall not be bonded to the exterior or interior buses.

4.70 Structural steel columns (eg. steel H sections or pipe, encased in concrete or masonry or bare), when not part of a steel frame construction that affords continuity between tops of columns, shall be unit bonded to the interior ring buses. When horizontal steel beams or trusses provide continuity, bonds shall be provided to corner columns; and when distance between corner columns exceed 50 feet, at interim exterior wall columns at approximate equi-distant points of 60 feet or less. The peripheral columns shall be bonded at bottom to the exterior ring bus, as shown in Figure 3.

4.71 Steel structural beams and fabricated trusses supporting the roof of a building are generally sufficiently bonded to earth through numerous hanger rods and other hardware that support superstructure, conduits, pipes, ducts and other metallic units above the radio equipment area to preclude any additional bonding. Individual beams not obviously grounded in this manner or by contact with grounded steel frame or columns of the building shall be unit bonded to the peripheral bus at both ends.

4.72 Pre-stressed concrete beams are reinforced with rebars that normally make no contact with grounded structural members. Rebars of such beams shall be unit bonded to peripheral buses at both ends of the beam. Ordinarily, a No. 6 AWG pigtail wire should be provided at each end of the beam to facilitate the connection.

4.73 Rebars of poured concrete roof beams are normally integrated with column rebars so that continuity exists throughout the structure. When such continuity exists, unit bonds to such beams are not required. Otherwise, the rebars shall be bonded at both ends of the beam to the peripheral bus.

4.74 Metal framed openings in walls, such as door frames (bucks), air intake and exhaust openings, etc., may or may not be grounded through continuity extended by rebars, hoods or other metallic objects from bonds connected to the exterior ring bus. Such frames shall be bonded to the peripheral ring bus, regardless of other paths of continuity to earth, except where metallic units coupled directly thereto by a reliable metallic connection, such as bolting, are bonded to the peripheral bus. In this respect, frames of waveguide openings, where peripheral bus is bonded to the hatchplate, need not be bonded.

4.75 Metal frames in the roof, other than those bonded through contact with unit bonded metal objects (eg. hatchplates), shall be unit bonded to peripheral or supplementary buses.

4.76 Small prefabricated buildings or huts of metallic frame and exterior surface construction, mounted on a concrete pad, are often used to house radio equipment. They are usually equipped with an interior peripheral ring bus (J rail) and all unit bonds terminate thereon. The metallic structure requires no bonding other than that afforded by the bonds furnished for connection of the structure to the buried exterior ring system.

E. Protection of Station Facilities From Lightning Discharge Over Communication Wire and AC Service Distribution Conductors

4.77 The application of protectors and other devices for protection from lightning or other occurrences of high voltage on conductors leading into the building is outside the scope of this and other sections comprising the Protective Grounding Systems Practices in the 802-001-series. The following comments are included to point out that the measures outlined in this section are only part of the total consideration that must be given to the subject of protection from potential surges.

4.78 When a station is grounded for protection of equipment from strokes on the tower as described in the preceding portions of this section, the most common cause of damage of electrical equipment by lightning discharge is that introduced into the station by hits on communication cables or electrical conductors that enter into the building. Such conductors are frequently energized at some point away from the station.

4.79 Communication wires may consist of open wire or cable run on telephone poles, or buried cable. Usually, cable is sheathed with a metallic covering which serves to protect the conductors from environmental conditions and electrical disturbances. Lightning hits on the sheath of cable can cause a high voltage to develop along the sheath. The sheath is grounded at intervals, and at its termination in the station. If the grounding conductor is of sufficiently low impedance, the voltage is attenuated as lightning current is shunted to ground and the probability of damage to equipment or communication wire insulation by spark-over is minimized.

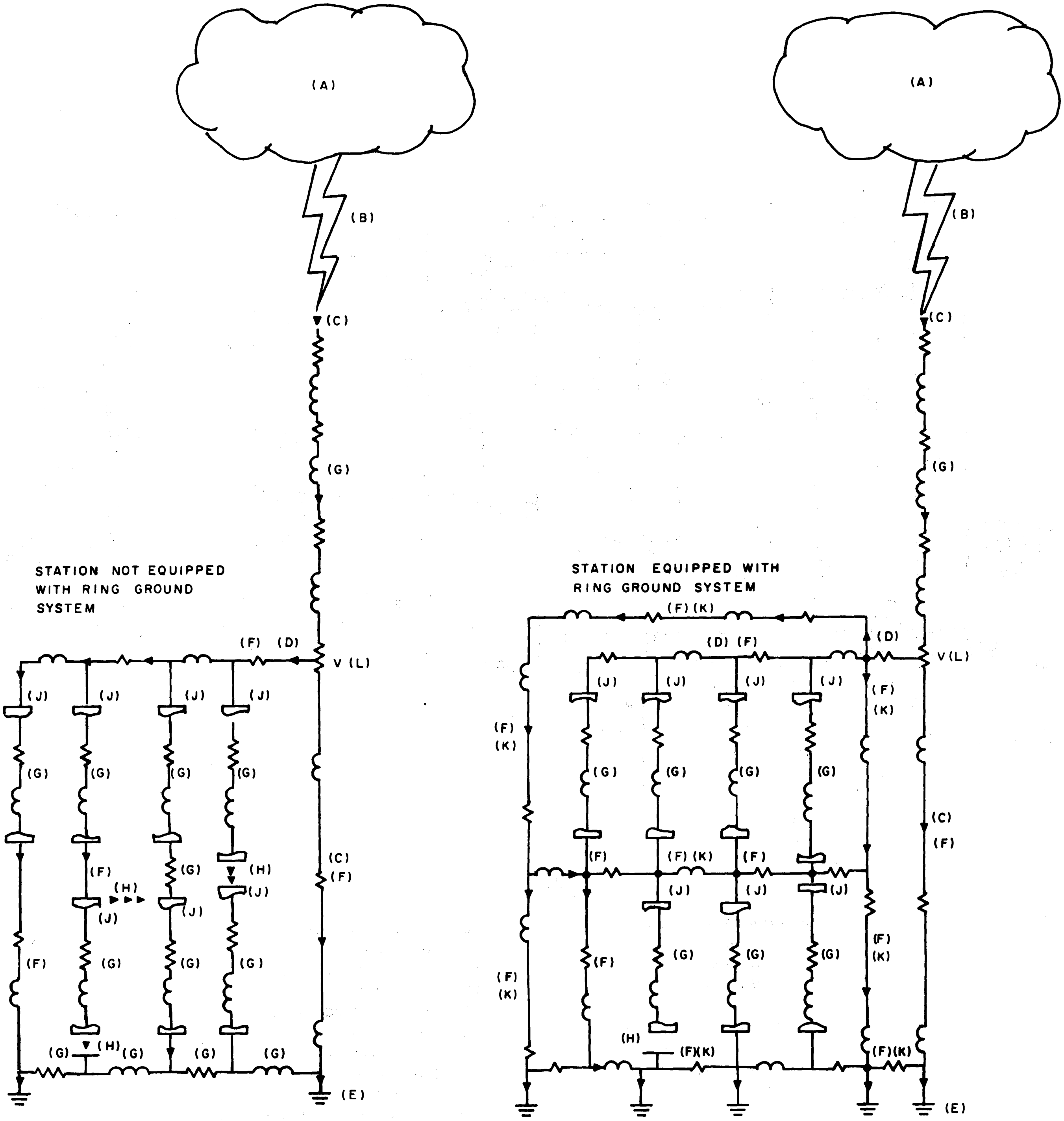
4.80 Communication wire may also be excited to a high voltage by lightning hits. Since these are insulated conductors that ordinarily have no direct connection to ground, damage to wire or component insulation results from arcing to grounded objects if the potential exceeds the withstanding ability of the insulation. Methods of limiting the potential include the use of protectors.

4.81 Protectors located near the building cable entry are installed between each communication conductor and a ground point that has low impedance access to earth. A controlled isolating gap (eg, 3 mil gap between carbon blocks) or other forms of isolation having known spark-over rating shunts lightning (or other high voltage electrical energy) current to ground when the rating is exceeded. Voltage impressed on components of the communication "system" is thereby limited to that of the spark-over rating plus that of the voltage drop generated by the current flow over the grounding conductor. It is important, therefore, that the grounding conductor be of as low impedance as practicable if optimum protection is to be realized (see Section 802-001-193, 5A)

4.82 The AC transmission network that supplies AC service to the building is particularly susceptible to lightning hits. It is reasonable to expect that voltage spikes generated by hits will be impressed on AC operated equipment in the building at least several times a year. In lightning prone areas many hits of varying magnitude can be expected. Lightning arresters (a form of protector) are usually provided at the service entrance, and occasionally on branch circuits within the building. The usual arrangement is to connect the arresters between phase and neutral conductors. This usually results in a path of lowest practical impedance between the arresters and earth for most efficient discharge of lightning current: via, the grounding electrode conductor (see Section 876-210-100 for application information).

4.83 Protectors of the types described above are capable of providing only a moderate level of protection to electrical components. It is of utmost importance that designers of electrical equipment be fully aware of the limitations of such protection devices. Often, the level of protection necessary depends on the designers choice of circuit components; the dielectric strength of component insulation; spacing between conductors on printed wiring boards and the type of substrate; the shape of points of close proximity (pointed, curved, flat, etc.) and many other parameters. It is the designers responsibility to consider the protection requirements and to incorporate protective elements into the circuit design if protectors appear to be inadequate. Some of the devices used to achieve lower level protection include neutralizing transformers, filters, capacitors, thyrectors, metal oxide varistors, zener diodes, resistors, fuses and others. They are used singly or in a variety of combinations to afford paths to ground for lightning current with dielectric breakdown less than that of other circuit components. They may be used to suppress voltage spikes that could destroy solid-state devices. They may be capable of withstanding repeated discharges or may be one-shot protection, requiring replacement. New devices, new combinations of application arrangements, new requirements for protection are being and will continue to be introduced as miniturized circuitry and solid-state components are applied in communication systems.

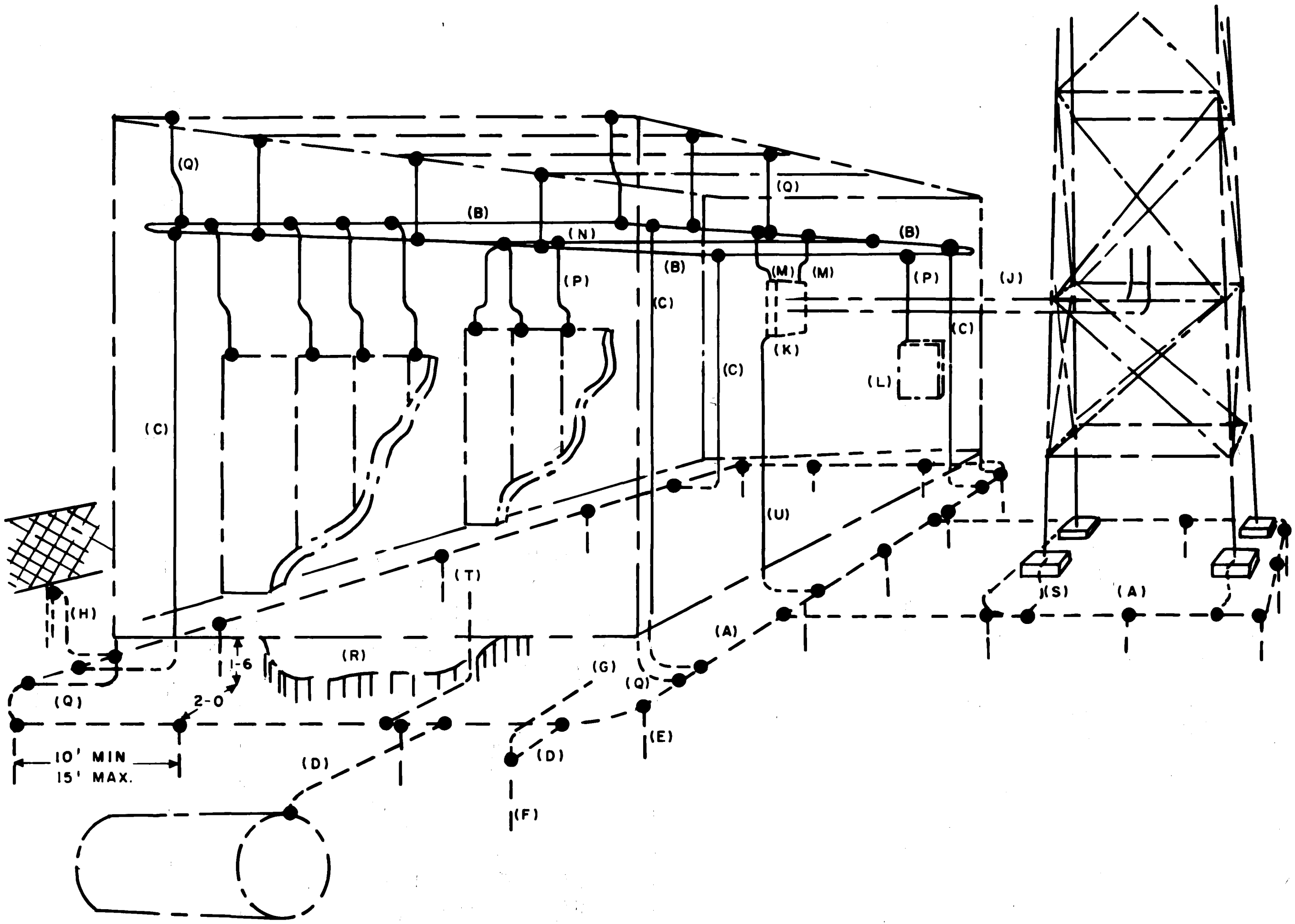
4.84 These remarks are intended solely to point out that a grounding system supplements and enhances protection from voltage transients by internal or external protective components in a communication system but it is not a substitute for such devices. The grounding system described herein is intended to provide the lowest practical impedance between the devices used to intercept the lightning energy and earth. Further protection depends on the designers evaluation of the need for protection and provision of circuitry to meet those needs. This section does not cover any technical aspects pertaining to provision of such circuitry.



LEGEND

(A) CHARGED CLOUD
(B) LIGHTNING STROKE
(C) TOWER
(D) WAVEGUIDE
(E) EARTH
(F) LOW IMPEDANCE PATH
(G) INDETERMINANT IMPEDANCE PATH
(H) CLOSE COUPLED ISOLATION
(J) METALLIC OBJECT (FRAME, ETC)
(K) RING GROUND
(L) VOLTAGE IS PRODUCT OF IMPEDANCE TO EARTH
► PRINCIPAL CURRENT PATH

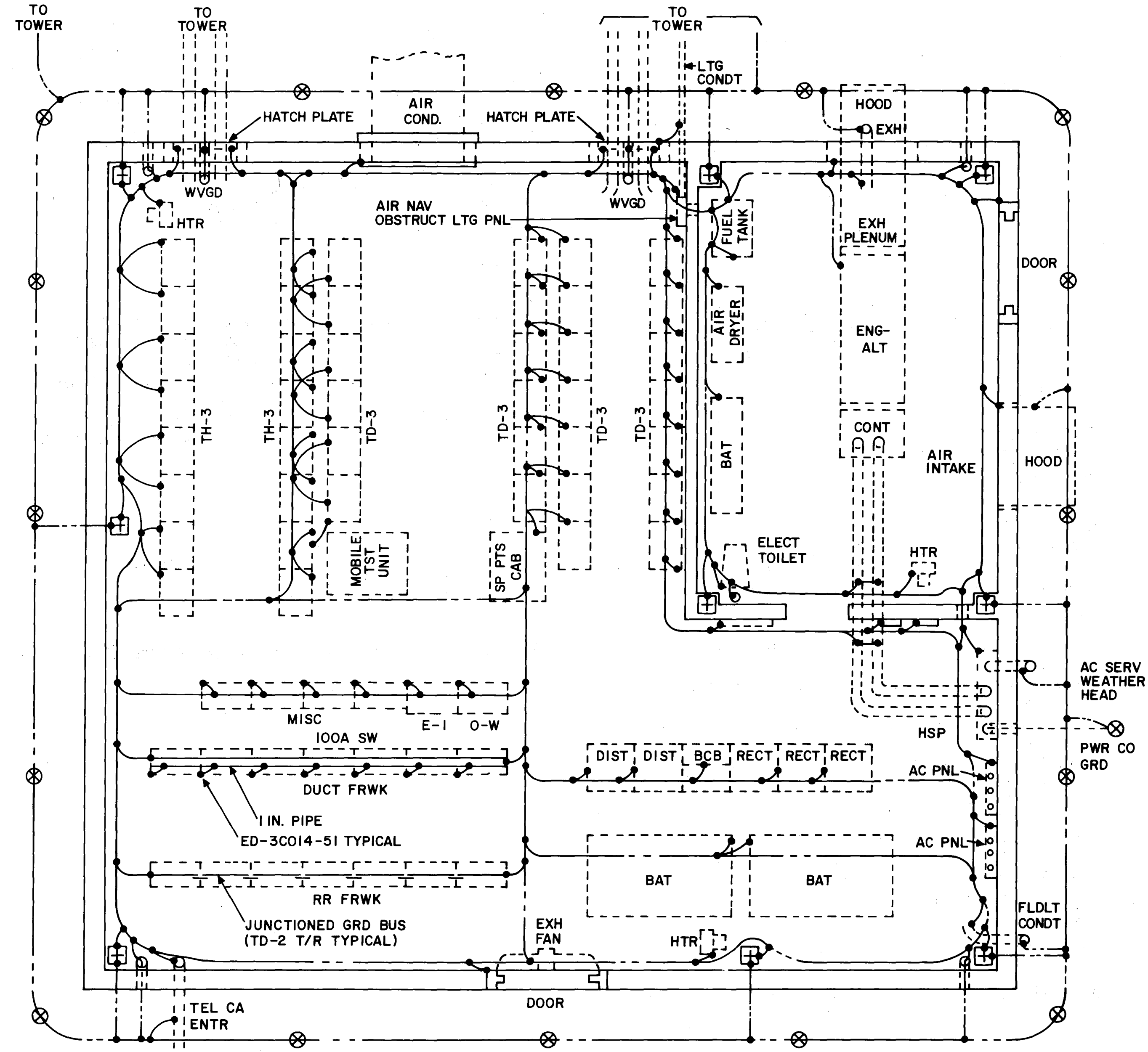
Fig. 1—Effect of Ring Ground System on Current Flow During Lightning Discharge



LEGEND

(A) BURIED EXTERIOR RING BUS
(B) PERIPHERAL BUS
(C) INTER-BUS BONDS
(D) BOND TO BURIED OBJECTS
(E) GROUND ROD
(F) POWER CO GROUND ELECTRODE
(G) POWER CO NEUTRAL BOND
(H) BOND TO FENCE WITHIN 6 FT
(J) WAVEGUIDE
(K) WAVEGUIDE HATCH
(L) WALL MOUNTED CABINET
(M) HATCH BOND
(N) SUPPLEMENTARY BUS
(P) EQPT BOND
(Q) BUILDING STEEL BOND
(R) GRADE LEVEL
(S) TOWER BASE SHOE BOND
(T) BOND TO METALLIC OBJECT ON BUILDING EXTERIOR
(U) WAVEGUIDE HATCH PRIMARY BOND

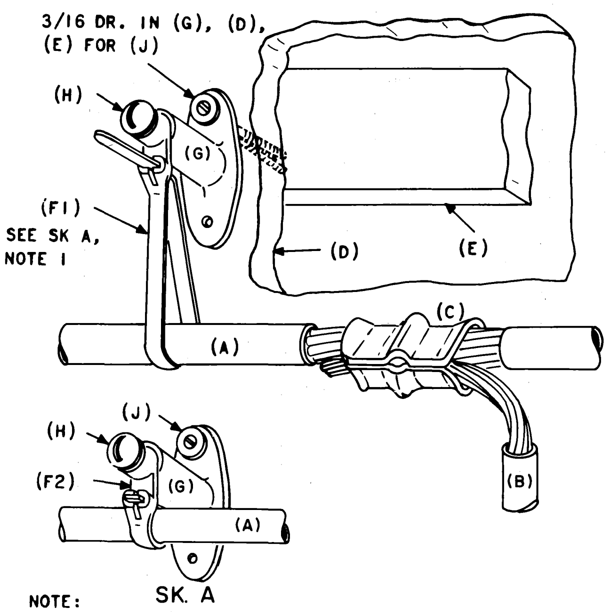
Fig. 2—Illustration of Microwave Ring Ground System and Principal Ground Bonds



NOTES:

1. ⊗ DRIVEN ROD
2. ———— NO. 2 SOL OR STR WIRE
3. ———— CADWELD OR CRIMP
4. ———— NO. 6 GRD CONNECTION
5. ———— 12 IN. NOM, 6 IN. MIN RADIUS BEND IN NO. 2 WIRE
6. WALL SUPPORTS-SEE FIG. 4
   CRIMP CONNECTION-SEE FIG. 5
   CABLE RACK SUPPORT-SEE FIG. 6
   UNIT BOND-SEE FIG. 6
   CONDUIT BOND-SEE FIG. 7
   HATCH PLATE BONDS-SEE FIG. 8
   FRAMING CHANNEL SUPPORT-SEE FIG. 9

Fig. 3—Typical Ring Ground Installation in Microwave Station. Exterior Ring System and Every Ground Bond Represents a Potential Path to Ground. Waveguides Represent Optimum Current Path to Point of Lightning Strike. Interior Ring Bus Shall be Routed to Provide Minimum Impedance Between Potential Ground Points and Waveguide Hatches

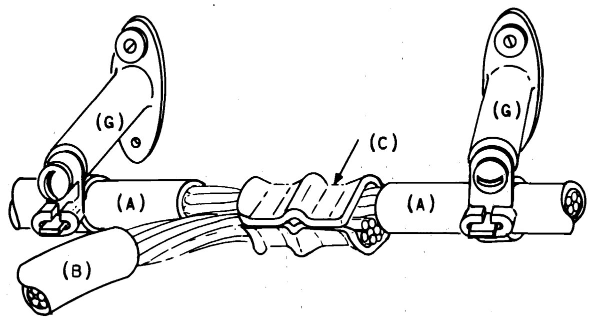


NOTE:
TO FACILITIATE CRIMPING OF WIRES TO (A), STRAP (F) SHALL BE INSTALLED IN POSITION (F1) UNTIL ALL CRIMPS ARE MADE, THEN ADJUSTED TO POSITION (F2).

LEGEND

(A) NO.2 AWG GREEN INSULATED STRANDED COPPER WIRE (PERIPHERAL BUS)
(B) NO.6 AWG GREEN INSULATED STRANDED COPPER WIRE (UNIT BOND)
(C) CRIMP TYPE PARALLEL TAP (T&B CO "C TAP" CAT 54730 TYPICAL
(D) DRYWALL (ILLUSTRATED), CONCRETE, BRICK OR OTHER WALL MATERIAL
(E) 1 X 2 WOOD SLEEPER 9' 8" FROM FLOOR (TYPICAL FOR DRYWALL)
(F) T&B CO "TY-RAP" CAT TC-15 CABLE TIE OR EQUIVALENT (1) IN INSTALLING POSITION (2) IN FINAL POSITION
(G) T&B CO "TY-RAP" CAT SO-405A STANDOFF OR EQUIVALENT
(H) P.168625 RHM SCREW
(J) U.S. EXPANSION BOLT CO "TAP-IT" CAT. NO 463250 NYLON FASTENER OR EQUIVALENT

Fig. 4—Wall Support Assembly for Peripheral Bus

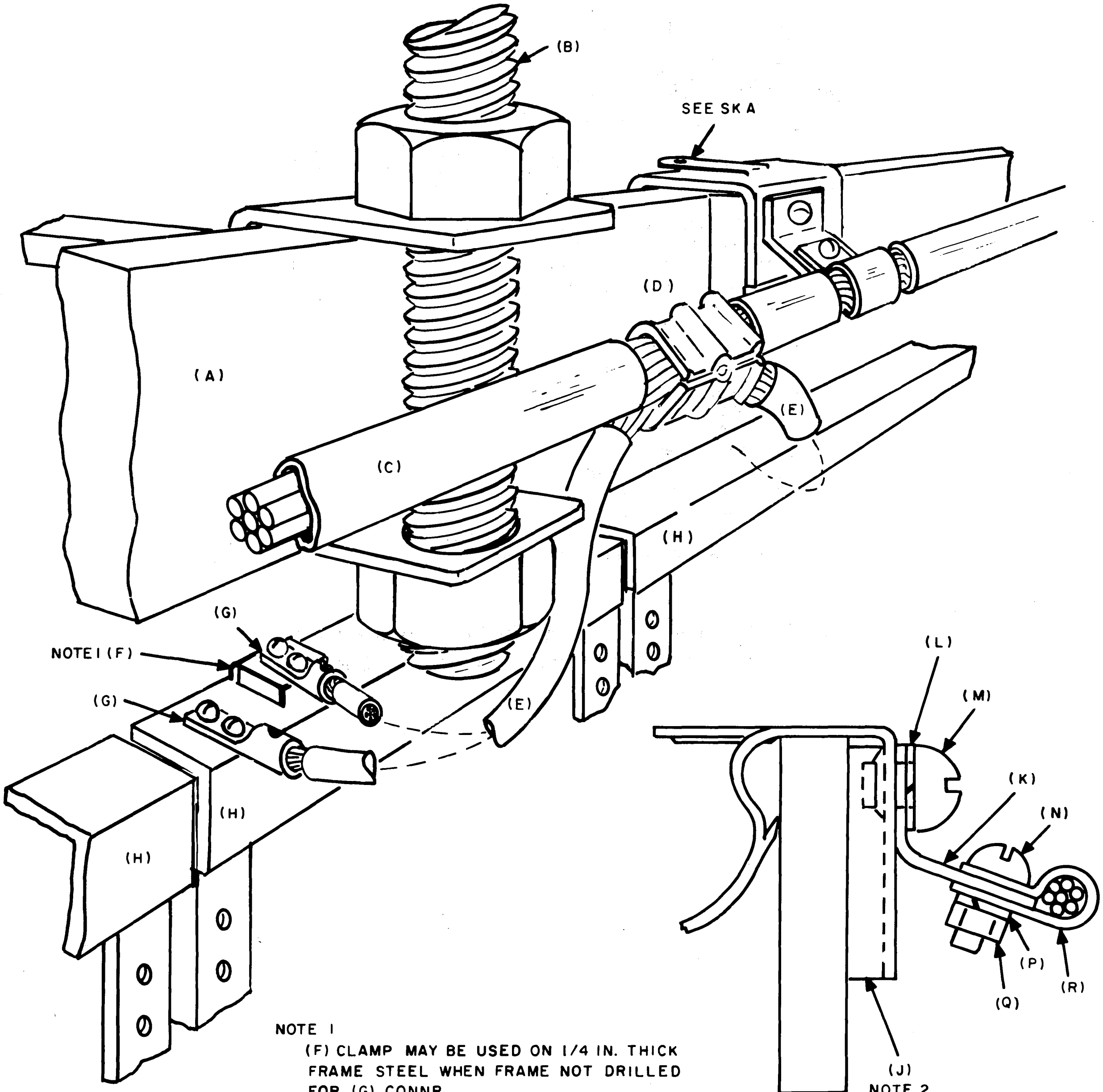


NOTE:
SUPPLEMENTARY BUS (B) MUST HAVE CONTINUITY TO PERIPHERAL BUS (A) AT BOTH ENDS. THE END CONNECTED TO (A) THAT IS NEAREST THE WAVEGUIDE HATCHPLATE SHALL TURN IN THE DIRECTION OF THE HATCHPLATE. THE OTHER END SHALL TURN IN THE OPPOSITE DIRECTION. WHEN CONTINUITY TO THE HATCHPLATE IS VIRTUALLY EQUAL FROM BOTH ENDS OF (B) BOTH TURNS SHALL BE IN DIRECTION OF THE HATCHPLATE.

LEGEND

(A) PERIPHERAL BUS
(B) SUPPLEMENTARY BUS
(C) CRIMP TYPE PARALLEL TAP (T&B CO "C TAP" CAT 54740 TYPICAL)
(G) STANDOFF ASSEMBLY (SEE FIG. 4)

Fig. 5—Typical Supplementary Bus Crimp Connection



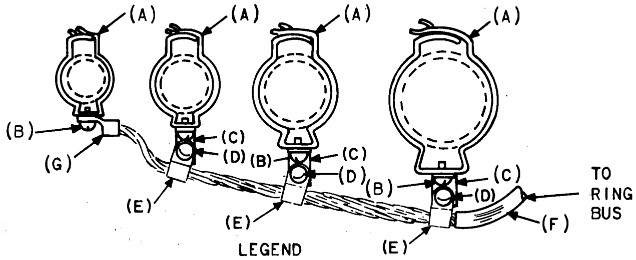
NOTE 1
(F) CLAMP MAY BE USED ON 1/4 IN. THICK FRAME STEEL WHEN FRAME NOT DRILLED FOR (G) CONNR

NOTE 2
(J) CLAMP MAY BE MOUNTED ON TOP OR BOTTOM OF STRINGER

LEGEND:

(A) 3/8 IN. THICK CABLE RACK STRINGER
(B) CABLE RACK SUPPORT HARDWARE (TYPICAL)
(C) NO. 2 AWG GREEN INS TYPE THW SUPPLEMENTARY BUS WIRE
(D) PARALLEL CRIMP CONNR (CAT. 54730 T&B CO TYPICAL)
(E) NO. 6 AWG GREEN INS TYPE THW UNIT BOND WIRE
(F) CADDY UNIV CLAMP, CAT. M-2-4-S (ERICO PROD. CO)
(G) TWO HOLE BOLTED TONGUE CRIMP CONNR OR EQUIV
(H) UNITS REQUIRING GROUND BONDS
(J) CADDY UNIV CLAMP, CAT. M-5-8 (ERICO PROD. CO)
(K) 840254080 BRACKET
(L) P-382825 LOCKWASHER
(M) P-210426 RHM SCR
(N) P-143985 RHM SCR
(P) P-421681 LOCKWASHER
(Q) P-81293 HEX NUT
(R) CLAMP, STEEL, CAT. MP-4 (HOLUB INDUSTRIES, INC)

Fig. 6—Method of Supporting Ring Bus Wire on Cable Rack and Connection of Bond Wire



LEGEND

(A) CADDY CONDUIT CLIP (ERICO PROD. CO.)
CAT 8-M-41 FOR 1/2 CONDT
CAT 12-M-41 FOR 3/4 CONDT
CAT 16-M-41 FOR 1 CONDT
CAT 20-M-41 FOR 1-1/4, 1-1/2 CONDT
CAT 32-M-41 FOR 2 CONDT
(B) P-210426 RHM SCR
P-382825 LOCKWASHER
(C) 840254080 BRACKET
(D) P-143985 RHM SCR
P-429681 LOCKWASHER
P-81293 HEX NUT
(E) CLAMP, STEEL (HOLUB IND. INC.)
CAT MP-2 FOR 6 AWG WIRE
CAT MP-4 FOR 2 AWG WIRE
(F) NO. 6 OR 2 AWG GREEN INS TYPE THW STR COPPER WIRE
(G) 1 HOLE BOLTED TONGUE CRIMP CONNR

Fig. 7—Method of Bonding Single or Multiple Runs of 1/2 to 2 Size Conduit or Pipe to Ring Bus

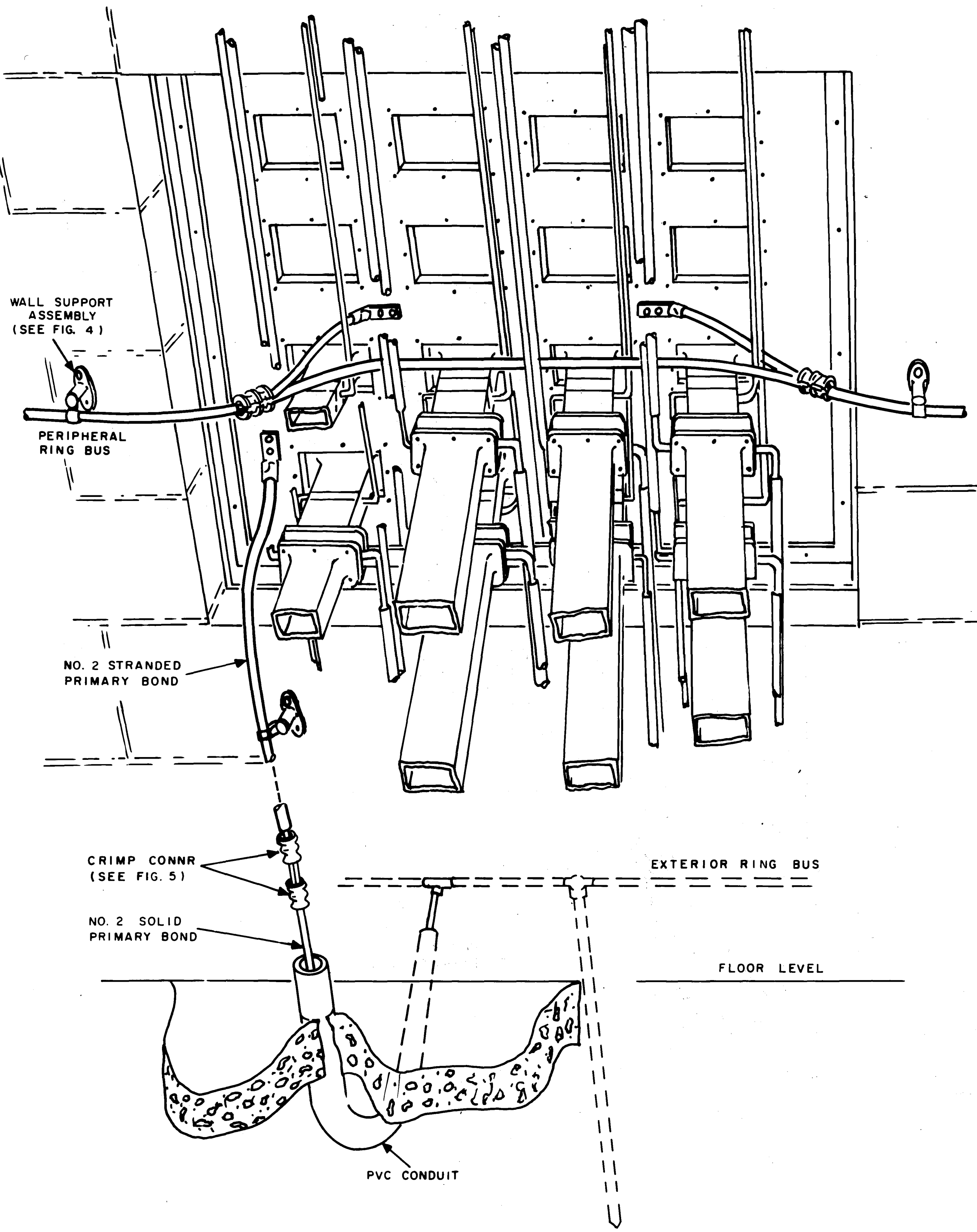


Fig. 8—Typical Arrangement of Peripheral and Exterior Ring Bus Bonds at Waveguide Hatchplate

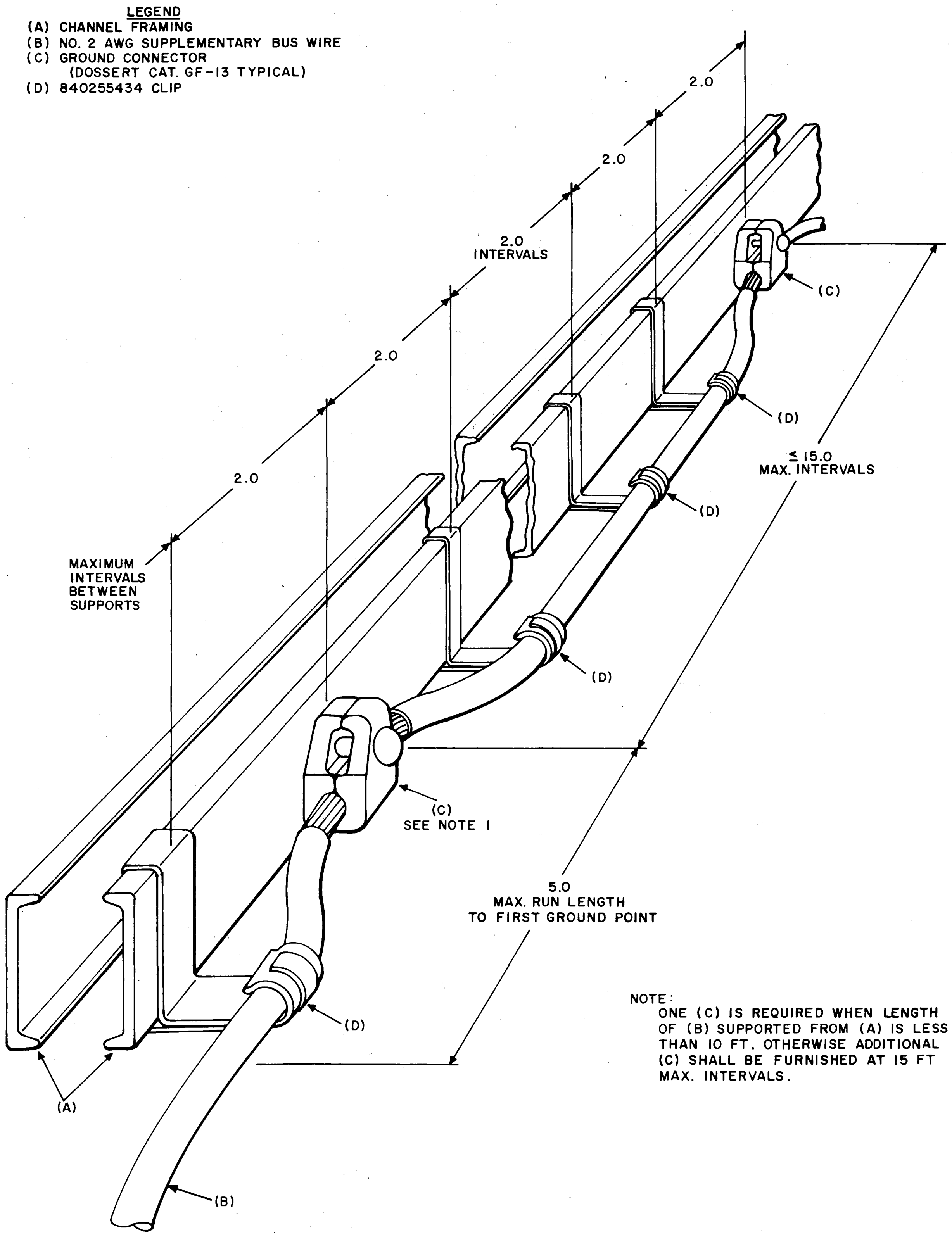


Fig. 9—Method of Supporting Supplementary or Peripheral Bus Runs From Channel Framing