

**PROTECTIVE GROUNDING SYSTEMS**  
**EQUIPMENT GROUND SYSTEMS MATERIAL**  
**GENERAL EQUIPMENT REQUIREMENTS**  
**POWER SYSTEMS**

	PAGE		PAGE
1. SCOPE . . . . .	2	B. Equipment Frame Ground . . . . .	8
2. GENERAL . . . . .	2	Combination Discharge Framework Ground . . . . .	9
3. GROUND RODS . . . . .	2	Relay Rack Ground . . . . .	9
4. WIRE . . . . .	3	C. Distributing and Protector Frame Ground . . . . .	10
A. Exterior Buried . . . . .	3	D. AC Equipment Ground . . . . .	10
B. Interior Ring Ground . . . . .	4	7. RACEWAYS . . . . .	10
C. Equipment Ground . . . . .	4	CO Ground System Raceway Applications . . . . .	10
D. AC Equipment Ground . . . . .	5	AC Equipment Ground System Applications . . . . .	11
E. Restrictions on Use of Armored Cable . . . . .	5	8. INSTALLATION REQUIREMENTS . . . . .	11
5. CONNECTORS . . . . .	5		
A. Thermal Welding . . . . .	5	<b>Figures</b>	
B. Clamp Type Pipe . . . . .	6	1. Thermal Welded Connections For Driven Ground System . . . . .	12
C. Crimp Type, Bolted Tongue . . . . .	6	2. Pipe and Conduit Ground Clamps . . . . .	13
D. Pressure Type, Bolted Tongue . . . . .	6	3. Crimp and Pressure Type Connectors . . . . .	15
E. Cable, Parallel . . . . .	6	4. Typical Commercial Connectors . . . . .	16
F. Cable, Cross Tap . . . . .	7	5. Typical Combined Bond and Support of Co GRD Bus From Steel Column . . . . .	17
G. Miscellaneous Commercial . . . . .	7	6. Typical Design of CO GRD Bus . . . . .	18
H. Solder Type . . . . .	7	7. Typical Mounting of CO GRD Bus on Reinforced Concrete Wall or Column . . . . .	19
6. BUS BARS . . . . .	7		
A. CO Ground . . . . .	7		

## SECTION 802-001-190

### 1. SCOPE

**1.01** This section provides requirements and application information pertaining to material to be used in the assembly of protective grounding systems in Central Offices, Radio Stations and other structures housing Bell System communication equipment.

**1.02** Design information for the various protective grounding systems is contained in the following sections:

802-001-180—General Equipment Grounding Requirements for Communication Systems in Central Offices, Radio Stations and Other Structures

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** Material used principally for a specific grounding system is referenced herein to the section that provides design information for that system (eg., Section 802-001-191). Material not so referenced is generally applicable in various systems.

### 2. GENERAL

**2.01** The information contained in this section is intended to aid the application engineer in

selecting reliable components for ground systems application. It is recognized that all components listed are not always readily available. For normal application, commercial products designed specifically for ground system application, with physical characteristics equivalent to those specified herein, will be an acceptable substitute. The application engineer shall assume responsibility for quality of such substitutions.

**2.02** A listing of Bell System publications relating to requirements for protective grounding is contained in Section 802-001-180, Bibliography.

### 3. GROUND RODS (802-001-191, 802-001-197)

**3.01 Size:** The minimum size of ground rods recommended for use in driven ground, ring ground, and supplementary ground systems is 5/8 inch diameter, 8 feet long. This size is chosen to provide adequate surface contact with earth and penetration to permanently moist earth under generally encountered earth conditions. These dimensions equal or exceed National Electrical Code (NEC) article 250-83 requirements.

**3.02 Type:** Solid stainless steel or copper clad steel rods may be used. Copper exposed to earth moisture in the vicinity of buried metal objects such as water pipes, fuel tanks, etc., can cause accelerated corrosion of iron or steel through electrolytic action. Copper is significantly more electropositive (cathodic) than iron or steel. Stainless steel is not significantly electropositive to iron or steel; therefore, it does not create the corrosive effect of copper. The choice of whether to use stainless steel or copper clad rods is dependent on the presence of buried steel objects, desirability of protecting such objects and relative cost of the two types of rods. These factors must be determined on an individual job basis. Generally, where buried steel objects are located around a building requiring a driven ground electrode system, the use of stainless steel rods is recommended. The stainless steel rods shall be of A.I.S.I grade 302 or 304 alloy, which are resistant to corrosion. Copper clad rods, or stainless steel rods may be used indiscriminately where corrosion of buried objects is not a significant factor. Copper clad rods shall be of a manufacture similar to the "Copperweld" process, where molten copper is applied to a steel core. Steel rods, bare or galvanized, or covered with copper tubing or stainless steel tubing, or hollow core pipes of any type shall not be used as driven ground rods.

**3.03 Sources of Supply:** Copper clad rods are available from numerous electrical supply distributors. Stainless steel rods are not generally available. They may be fabricated from grade 302 or 304 rod stock, generally available from steel distributors, by cutting a drive point on one end, or they may be obtained from the following manufacturers:

MEFCO TELEDYNE CO,  
1937 Sterling Ave,  
Elkhart, Indiana 46514.

THOMPSON LIGHTNING PROTECTION,  
INC.,  
903 Sibley Hwy.,  
St. Paul, Minnesota 55118.

#### 4. WIRE

##### A. Exterior Buried Wire

**4.01** Ground electrode systems employing driven rods or wire counterpoise are constructed by use of copper wire buried in the earth. The wire is subject to corrosion. Copper wire is used exclusively because it corrodes at a slower rate than any other economically acceptable metal. It does, however, affect the corrosion rate of dissimilar metal, such as iron and steel buried in the vicinity of the wire, through galvanic action: electrolytic cell effect of current flow between dissimilar metals immersed in a conductive medium (earth moisture). Tinned copper wire is significantly less corrosive than untinned wire.

**4.02** The recommendation of wire sizes and types listed hereunder are based on the relative significance of a number of factors: adequate conductivity, maximum longevity of the ground system, minimum galvanic effect on other buried objects, and physical resistance to damage. Recommended types of wire for buried applications are:

- (a) **Preferred:** No. 2 AWG bare solid tinned copper. For general applications this wire provides adequate conductivity, maximum longevity, minimum galvanic effect, adequate strength.
- (b) **Alternate:** No. 2 AWG bare solid untinned copper. Lack of tinning may slightly reduce life, will increase galvanic effect on buried steel or iron objects.

(c) **Prohibited:** Insulated conductors for general bonding of driven ground systems. Insulated conductors may be used only for connection of cathodic protection systems utilizing sacrificial anode rods and a DC current supply to render buried objects cathodic. Use of insulated conductors reduces efficiency of a driven ground system without equivalent benefit.

(d) **Prohibited:** Stranded copper wire, tinned or untinned. This wire, generally acceptable for industrial systems ground electrodes, is prohibited because of reduced life expectancy and increased galvanic effect. The life probability of the individual small diameter strands simultaneously exposed to corrosive conditions is significantly less than that of a single solid large diameter wire, and galvanic effect on buried steel or iron is greater.

(e) **Prohibited:** Aluminum wire, all types. Aluminum grounding wires shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions [REF: NEC Code 250-92 (a)].

(f) **Wire Grade:** Wire shall be soft (annealed) or semi-hard drawn commercial grade.

**4.03** Solid copper wire, tinned and untinned, is generally not stocked commercially and often cannot be purchased from commercial sources in specific quantity suitable for individual installations. It may be purchased through Western Electric Service Centers by Bell System customers, who may in turn make it available to contractors. Solid tinned bare soft (annealed) wire may be ordered as follows:

\_\_\_\_Ft RM 535026 No. 2 AWG bare solid tinned copper wire.

\_\_\_\_Ft RM 535020 No. 6 AWG bare solid tinned copper wire.

**4.04** Pigtail leads, when employed to connect individual rods to No. 2 wire, shall be No. 10 (minimum) to No. 2 (preferred) tinned solid copper. The use of pigtail leads is minimized when cadwelding or equivalent thermal welding is employed, since the primary ground conductor can be connected directly to the top of the ground rod.

## SECTION 802-001-190

### B. Interior Ring Ground Wire (802-001-197)

**4.05** Microwave radio installations employ an interior ring ground system as a means of protection to personnel and equipment from the effects of lightning stroke on the highly susceptible antenna tower. The basic ring consists of a conductor surrounding the equipment area, multiply connected to the buried exterior ring ground system so as to ensure low impedance current paths between earth and the building interior. Supplementary conductor runs are extended from the internal peripheral ring to frame lines and other equipment. Station equipment is bonded to the peripheral or supplementary runs (buses) to afford a low impedance bond between closely located units and between the units and earth.

**4.06** It is recommended that the peripheral and supplementary buses be No. 2 AWG copper wire, and that equipment bonds therefrom be No. 6 AWG copper wire. From a protection standpoint, such conductors provide adequate conductivity to assure reasonable voltage equalization. Recommended types of wire are as follows:

(a) **Preferred:** Stranded type THW green insulated copper wire. This wire can be connected with crimp connectors, is easy to install and is commercially available. The insulation affords protection of the wire from painting and corrosion. It ensures a bare bright surface for bond connections, eliminates strand separation at bends and incidental contacts of indeterminate impedance with metallic structures. It requires more frequent support than solid wire and requires stripping of insulation at bond points. The green color affords visual identification of components of the ring ground system. Green insulated copper wire of other than type THW may be substituted if that type is not readily available. Other colors of insulation shall not be used.

(b) **Alternate:** Stranded bare copper wire. This wire can be connected with crimp connectors, is easy to install and is commercially available. Special care must be employed to avoid separation of strands at bends. Separation does not reduce protective property but is often objectionable in appearance. Stranded wire requires more frequent support than solid wire. Bare stranded wire supported from walls shall not be painted when walls are painted.

(c) **Alternate:** Solid tinned or untinned bare copper wire. This wire cannot be connected with crimp connectors, therefore cadwelds or pressure type connectors are required for bonds. Pressure type connectors are less reliable. The wire is somewhat more self-supporting than stranded wire, but difficult to install and straighten. It is not always available from commercial sources (See 4.03).

(d) **Prohibited:** Peripheral ground rings composed of lengths of rigid conductive material such as UNISTRUT channels, bonded with straps or other conductive material around corners or other points of channel discontinuity. Experience with this form of peripheral ring indicates that it is less reliable than a wire system. Dependence on continuity through numerous bolted joints increases probability of high impedance in, or discontinuity of, the ring. Visual verification of ground continuity is often impossible. The cost is greater than that of a ring system using stranded wire and crimp connectors. It is not recommended that existing systems of this type be replaced.

(e) **Prohibited:** Aluminum wire, all types.

### C. Equipment Ground Wire (802-001-192, 802-001-193, 802-001-194, 802-001-195)

**4.07** Wire employed in the equipment grounding system, which comprises the CO GRD system and extensions therefrom to frameworks, cabinets and other units requiring equipment grounding, shall be KS-5482-01 or commercial grade type RHW copper wire. Aluminum conductors shall not be used in the equipment grounding system.

**4.08** The vertical riser conductor of the CO GRD system may be furnished by an electrical contractor or Western Electric, at the option of the Telephone Company. When provided by an electrical contractor, commercial grade type RHW copper wire may be used. Connectors other than those recommended herein under "connectors" shall not be used for connections of the vertical riser.

**4.09** Wire employed for interframe bonding in Electronic type communication installations (No. 1 ESS is typical) shall be in accordance with system specifications. Generally, the wire is No. 6 AWG bare stranded copper wire. The 750,000 CM wire used for interground bus bonding between

PD frames therein is normally KS-5482-01 type RHW.

#### D. AC Equipment Ground Wire (802-001-198)

**4.10** Wire run in AC service raceways for the purpose of providing an AC equipment ground (AC EG) system shall be copper, except that when phase leads are aluminum, the AC EG leads may also be aluminum. The wire may be bare or insulated. Insulation may be the same as furnished with phase leads or may be any other commonly available commercial grade of plastic or rubber insulation such as types T, TW, THW, RH, RHW, provided that the insulation temperature rating is at least equal to that of phase conductor insulation. When armored cable is used the AC EG conductor shall be one of the conductors provided therein.

**4.11** The AC EG conductor shall have green colored insulation or shall be uninsulated (bare) at all exposed points of possible connection, for purpose of identification. Insulation of other color shall be painted or otherwise colored green, or shall be removed, from point of egress from raceway to point of connection.

**4.12** Commercial connectors furnished as part of electrical equipments, for the purpose of connecting the AC EG conductors, may be utilized. Otherwise, connectors recommended herein under "connectors" shall be used.

#### E. Restrictions on Use of Armored Cable (802-001-198)

**4.13** Refer to KS-20785 (Power Data Section 16.22) for conductor sizes, quantity, and color normally available. Armored cable containing No. 14 to 1 AWG wire contains a bare bonding strip to decrease sheath resistance. This strip shall be cut at the ends of the sheath. It shall never be used as an AC equipment ground conductor. If an AC equipment ground conductor is required in an armored cable used for AC distribution, one additional insulated or bare conductor must be provided. Insulation must be stripped from point of egress from armor or insulation must be colored green for identification. The maximum number of conductors available in an armored cable is limited to three in certain sizes and not more than four. Commercial types of armored cable cannot be used for 3-phase, 4-wire AC circuits requiring an AC equipment ground conductor, or certain single phase 3-wire circuits requiring sizes of conductor and an

AC equipment ground conductor. KS-20785 cable may be obtained with an AC EG conductor.

### 5. CONNECTORS

#### A. Thermal Welding

**5.01** Thermal welded connections are recommended for all connections buried in earth: Between copper conductors or for termination of copper conductors to steel or iron objects. Such connections are superior to other methods. No significant impedance is introduced in the conductive path. Maintenance problems are eliminated. The connections do not require encapsulation for protection from corrosion. Their use is also recommended for above ground terminations on the exterior of the building, and within the building, where practical. Two basic methods of thermal welding are described hereunder, cadwelding and brazing. Equivalent methods of molecular welding similarly utilizing brass or copper to form the bond may also be employed.

**5.02 Cadwelding:** "Cadweld" is a trade name for a process of forming welded joints developed by Erico Products, Inc., Cleveland, Ohio. An equivalent process marketed by Burndy Corporation, Norwalk, Connecticut, is covered under the trade name, "Thermoweld". The term, cadweld, will be used exclusively herein to identify "Cadweld" or equivalent processes.

**5.03** The cadweld process is an exothermic type welding process utilizing graphite molds to form welds (See Fig. 1). A crucible in the top of the mold holds a metallic powder which, when ignited, produces molten copper that flows by gravity into the form surrounding the joining point. The hot copper melts the material of the items being welded, forming a molecular bond. Each configuration of weld requires a unique graphite mold, and because of limitations imposed by the gravitational flow requirement and heat generated by the process there is some restriction of application.

**5.04** The superior electrical properties, plus elimination of need for maintenance, of cadwelded joints tend to make their use in grounding systems both technically and economically attractive, not only for buried connections but for connection in the interior of the communication structure: For bonding at water pipes, connection of the CO GRD riser at floor CO GRD busbars and bonding

## SECTION 802-001-190

to building column steel. Other applications within buildings may also be practical, such as connection to the peripheral ground ring in microwave stations and elsewhere, if space limitations and heat are not a limiting factor. Cadwelding is not recommended for connections to thin wall pipe or tubing (.035 inch wall typical).

**5.05** Cadwelding and brazing are not performed by Western Electric installation personnel. Contractors that perform cadwelding and brazing are located in most areas of the country. The Telephone Company may directly contract for their services or may request installation personnel to arrange for their services.

**5.06 *Brazing:*** Brazing may be used in place of cadwelding, where expedient. Brazing provides the same benefits derived from cadwelding. It requires the use of an external heat source (brazing torch) and brazing rod to provide the material for the molecular weld between parts to be joined. Cadwelding is superior in some respects. Cadwelding creates a uniform weld shape, and it produces heat so quickly that the weld is completed before dissipation of heat affects conductor insulation. It can also be used in areas where brazing might be prohibited because of nearby combustible material.

### **B. Clamp Type Pipe Connectors**

**5.07** Ground clamps may be utilized for termination of ground conductors at water pipes and conduits. Such clamps require periodic maintenance to ensure that a low impedance connection exists. For this reason, principally, they are deemed inferior to cadweld connections. There are a variety of designs available from prominent electrical connector manufacturers which are adequate for such connections. The clamps illustrated in Fig. 2 are recommended for applications where pipe clamps are required.

Reference: NEC Article 250-116.

### **C. Crimp (Compression) Type Bolted Tongue Connectors (Fig. 3A)**

**5.08** Crimp type connectors are always preferable to types that depend on pressure exerted by a threaded device to maintain low resistance conductivity between wire and connectors, for the reason that they do not require periodic maintenance.

**5.09** KS-15977 crimp type bolted tongue connectors shall preferably be used for terminating stranded wire ground conductors to frames, cabinets and other units requiring a bolted ground connection. These connectors are available only in a limited variety of sizes and only for connections to be made by the Western Electric Company. When wire sizes for which no KS-15977 connector is available, commercial crimp lugs may be used (T & B Co. "Color-keyed" connectors are typical). Crimp lugs shall not be used for solid copper wire larger than No. 10 AWG. For use of KS-5517 or equivalent pressure connectors, see 5.12.

**5.10** KS-15977 and KS-5517 lugs are not available to electrical contractors who may be employed by the Telephone Company to install portions of the grounding system. When cadweld connections are not employed, commercial crimp connectors or pressure type lugs, in lieu of KS types, may be employed, in accordance with restrictions outlined in the preceding paragraph.

**5.11** Wherever practicable, two hole bolted tongue connectors are preferred over one hole connectors. Contact area of metal to which the connectors are bolted shall be prepared to a bare bright finish and coated with an anti-oxidant compound before joining.

### **D. Pressure Type Bolted Tongue Connectors (Fig. 3B)**

**5.12** Wherever cadweld or crimp type connectors are impractical to employ, KS-5517 or commercial equivalent (T & B Co "Locktite" is typical) pressure type lugs may be used for terminating copper ground conductors. Use of such lugs with aluminum conductors is prohibited. Joining practices are identical to that outlined for crimp connectors in the preceding paragraph.

### **E. Parallel Cable Connectors (Fig. 3C, 3D)**

**5.13** Until such time that KS coded crimp type parallel cable connectors are made available, KS-5537 pressure type connectors or equivalent commercial connectors are recommended for parallel connection of stranded copper wire and No. 14 to 10 AWG solid copper wire. Use of KS-5537 connectors for aluminum wire is prohibited.

**5.14** As an alternative, in the interim until KS coded connectors are introduced, commercial crimp type parallel connectors may be utilized for

No. 2 AWG and smaller gauges of stranded copper wire in grounding systems. A special installing tool is required for these connectors. For reason of standardization of the tool, use of Thomas and Betts compression "C Tap" connectors and TBM5 installing tool are recommended.

#### F. Cross Tap Cable Connectors (Fig. 3E)

**5.15** Pressure type cross tap connectors are useful for joining large copper conductors that run perpendicularly and do not terminate at the point of connection. In the CO GRD system, they are particularly useful at points where the 750,000 CM horizontal ground equalizer conductors are bonded to 750,000 CM main aisle ground equalizer conductors associated with Crossbar and Manual Toll discharge ground systems and it is not desirable to bend one of the cables to make the use of a parallel cable connector practical. Because of the high cost of such connectors they are not recommended for use where a parallel connector is practical.

**5.16** Use of Frankel catalog No. 2632 750MCM-750MCM cross tap connectors is recommended for such connections. Cross tap covers are not required.

#### G. Miscellaneous Commercial Type Ground Connectors (Fig. 4)

**5.17** A variety of commercial pressure type cable connectors designed to serve as AC service tap or ground connectors are available from manufacturers of electrical connectors, such as Burndy, Frankel, Dossert, O.Z. and others. Where use of cadweld, crimp or recommended pressure connectors is unsuitable because of space or other limitations and the physical design of the commercial connectors make them desirable for a specific application, they may be used for ground connections. One such application might be connection of the AC EG (green wire) conductor to interior of pullboxes in conduit runs. Other manufacturers products of equivalent quality may also be applied to ground systems.

#### H. Solder Type Connectors

In conformance with NEC Article 250-113, connections which depend on solder shall not be used for ground connections.

## 6. BUS BARS

**6.01** Bus bars are employed throughout the ground systems as a means of facilitating branch distribution of ground conductors. Bus bars shall be copper, except that ground bars furnished as part of a standard assembly may be employed without regard to material. Bus bars used in the CO GRD system are normally job designed to fit the requirement of the application.

### A. CO GRD Bus Bars

**6.02** CO GRD bus bars are used to facilitate distribution of horizontal ground conductors on various floors of a central office building. The bars are normally mounted on a column of the building. Ground continuity is usually established by bonding the bus bars to a large (ie, 750,000 CM copper) conductor connected at the office principal ground point (ie, water pipe) and run vertically in proximity to the column. When the column is constructed of H sections or similar substantial structural steel shapes and is permanently made electrically continuous by welding a bond across butt joints, the column steel may be utilized as the vertical conductor and the 750,000 CM Vertical Conductor run may be omitted. A 750,000 CM conductor is required from the column to the water pipe.

**6.03** Methods of bonding the CO GRD bus bars to the vertical 750,000 CM conductor and/or the column steel are covered in Section 802-001-192, under "Design Parameters of Vertical Equalizer System".

**6.04** GO GRD bus bars are normally designed on a job basis to fit the requirement of the application. A typical design is depicted in Fig. 6. Fig. 5 illustrates a method of supporting a CO GRD bus bar from from a column with welded studs that also forms a suitable CO GRD bond between bar and column steel. A welded plate that assures low impedance continuity across column butt joints is also depicted. When all butt joints in a column are bonded in this manner or bonded by a cadwelded or brazed 750,000 CM copper conductor, a column may be used as the vertical equalizer of a CO GRD system. Other methods of bonding that provide equivalent conductance may be employed to suit construction requirements, if expedient.

## SECTION 802-001-190

**6.05** When structural steel column section butt joints are not bonded, or when columns are reinforced concrete and reinforcing bars are welded or wire wrapped continuity suitable for discharge of lightning current (but not CO GRD current) through the column steel is assumed. A bond between one such column and each CO GRD bus bar, similar to Fig. 5 or by means of a 750,000 CM conductor or equivalent, shall be provided when such continuity exists. Refer to Section 802-001-180, "Incidental Ground".

**6.06** When CO GRD bus bars are mounted on columns or walls of reinforced concrete construction and reinforcing bars are not welded or wire wrapped so to ensure continuity to ground for lightning currents, a method of mounting bus bars similar to that depicted in Fig. 7 is recommended. This method ensures that the bolts that penetrate the concrete and may be close to or touching reinforcing bars will be separated from components of the CO GRD bus assembly by at least 2 inches. The separation reduces the possibility that lightning current will spark over from mounting bolts to the bus bar in seeking a path to ground.

### B. Equipment Frame Ground Bus Bars

**6.07** Switch frames, fuse bays, relay racks, battery distributing fuse boards, and other equipment frames of certain electromechanical switching systems; toll, carrier and manual relay racks; distributing frames; power plant distribution bays and various other miscellaneous equipment frames are equipped with frame ground bus bars. The ground bars, with the exception of discharge ground bus bars of power plants serving Electronic systems such as No. 1 ESS (isolated ground plane), are mounted in electrical contact with the frame metal. The ground bars thereby form a part of an integrated ground plane in common with frame metal and any other metallic components that are electrically adjoined thereto. In an electromechanical switching system or other installation, excluding electronic systems, no effort is made to isolate a system ground plane from incidental contacts with building steel, either directly or through cable racks, superstructure or other paths. The integrated ground plane therefore is a single plane extending throughout the building with multiple points of interface between building and discharge ground system through the equipment frame ground bars.

**6.08** In an electronic system, the integrated plane is comprised of deliberately interbonded frames (without frame ground bars) bonded to Power Distribution (PD) ground buses. It also includes the system cable racks, discharge ground conductors from PD frames to DC plants and the plant discharge bus bar, which is isolated from the plant frame. This plane is isolated from the ground plane of the building except for a single point connection that references the isolated ground plane voltage to that of the building plane. The single point connection assures that ground currents originated outside the isolated plane cannot flow through any member thereof.

**6.09** Frame ground bars, when provided, normally function as a common ground point for circuit ground conductors from equipment units mounted on the frame. The ground current must return to the DC plant batteries. A current return path, dependent on the ground system design of individual communication systems, may be afforded; (1) by discharge ground conductors run from individual frames or; (2) by interjunctioning ground bars in a frame line into a common conductor, and extending the run with wire to discharge ground paths that ultimately terminate at the ground terminal of the battery or; (3) by various combinations of methods 1 and 2, above.

**6.10** When method 2, above, is applied it is possible that the cumulative current imposed on the junctioned bus run can cause a voltage drop in excess of that allowed for that portion of the DC discharge circuit loop. Ground bus bars provided on most of the communication frames are small: 1 inch wide, 1/8 inch thick copper bars with resistivity slightly less than that of No. 00 AWG copper wire. The maximum voltage drop normally allotted to the ground bus is 1/8 volt, less the drop encountered in the bond wire that connects the bus run to a Main Aisle Ground Equalizer (802-001-193, 802-001-194). In a typical frame line with interjunctioned bus bars and an end connected No. 00 bond totaling 50 feet in length, and with circuit ground current evenly accumulated throughout the bus run length, the maximum ground current imposed on the bus run cannot exceed 70 amperes without exceeding the allowable voltage drop. Allowable amperes for 1/8 volt drop may be calculated as follows:

$$I_{PK} = \frac{2420}{1.61 L_C + .665 L_B} \leq 175$$

Where:  $I_{PK}$  = Allowable Amperes for 1/8V drop  
 $L_B$  = Length of 1/8 X 1 inch bus run  
(feet)  
 $L_C$  = Length of No. 00 AWG bond (feet)  
175 = Maximum capacity of No. 00 AWG  
bond (ampere)

**6.11** When ground current accumulated on a frame line ground bus bar run would cause a voltage drop in excess of that allowed by the system design, additional No. 00 or larger size bond conductors must be provided. Power Distribution Systems schematic drawings that cover the design of Equalizing Center type DC distribution circuits contain instructions for the application of ground bonds for this purpose.

**6.12** Communication systems employing a battery distribution system that distributes power through fuse bays and returns ground current to battery by means of a Main Aisle Ground Equalizer commonly bonded to frame line ground bus bar runs generally require modification of ground bus bars. The Manual Toll Switching system (Battery Distribution Circuit SD-81142-01), comprised of a manual switchboard (3C and 5 types) and lines of RR type equipment bays, testboard, etc., is the only system of this type that is still being installed as a new installation. The RR ground bus bars provided with the equipment bays may be 1 x 1/8 or 1 x 1/4 copper or of other metal. Since about 1962, the ground system has been job modified to replace other than 1 x 1/4 copper bars with such bars, and to use 350,000 CM bonds to Main Aisle Ground Equalizer conductors and other measures to increase the conductivity of the ground system. Methods of applying these modifications were covered in various memoranda. They are now covered in Section 802-001-194.

#### **Equipment Frame Bus Bar Function As Combination Discharge—Framework Ground Bus Bar**

**6.13** Ground bus bars that mount directly on framework may function as combination paths for current return to battery and for framework grounding. Switching systems that utilize such combination ground paths in frame lines include Crossbar No. 1, Crossbar Tandem, Crossbar No.

4A Toll and Manual Toll Systems. Equipment units mounted on frames are circuit grounded at frame ground bus bars in electrical contact with frame metal. Bus bars mounted in a frame line are junctioned to form a continuous conductive path. The continuous run is connected at the head of the frame line to a main aisle ground equalizer conductor which extends along the main aisle to allow connection thereto from each frame line comprising the system. This equalizer is in turn connected to the discharge ground conductor of the battery discharge circuit feeding the system to provide a current return path, and to the floor CO GRD system to equipment ground the frames. This arrangement is referred to as a Combination Discharge—Framework Ground System, and the frame bus bars, which may otherwise be variously referred to as Equipment Frame or Relay Rack Ground bus, bars, may also be referred to as Combination Discharge—Framework bus bars, in deference to their function in this configuration.

#### **Relay Rack Ground Bus Bars**

**6.14** This term originally denoted frame ground bus bars provided on equipment frames that mounted units of equipment located remotely from manual switchboards. These units employed magnetic relays extensively. The frames were referred to as Relay Racks. Subsequently, frame assemblies equipped with dedicated equipment having a single function were introduced. These frame assemblies were given names indicative of their functions and were no longer referred to as relay racks. Generally, the dedicated frames retained a ground bus bar which continued to be known as a Relay Rack Ground bus bar. The term, "RR GRD", is used extensively on communication systems circuit schematic drawings to denote that equipment units mounted on an equipment frame should be circuit grounded to the frame ground bus bar. Reference to a Relay Rack Ground bus bar may be construed to mean an Equipment Frame Ground bus bar. The description provided under "Equipment Frame Ground Bus Bars", preceding, also describes the function of Relay Rack Ground bus bars. In modern communication systems, "Relay Rack" is no longer used as a generic term to denote frames. Lines of frames are referred to as "Equipment Frame" lines. Certain frames utilize the term "Relay Rack" in the name: such as "Miscellaneous Relay Racks", "Trunk Relay Racks", and "Toll Relay Racks". Generally, these equipment frames are no longer equipped with frame ground bus

## SECTION 802-001-190

bars and units mounted thereon receive power by means of paired battery and ground conductors.

### C. Distributing And Protector Frame Bus Bars

**6.15** Protector frames are equipped with ground bars furnished for the primary purpose of providing a direct path to ground for high potential energy intercepted from cables entering the office through the cable vault. Protectors may be mounted on an individual framework in proximity to a distributing frame or may be mounted on a distributing frame, as practiced in No. 5 Crossbar systems, where protectors are mounted on the vertical side and terminal strips are mounted on the horizontal side of the MDF. A protector ground bar is normally mounted along the top of the frame, fastened to each protector mounting support. A frame ground bar is furnished near the bottom of protector frames or distributing frames mounting protectors. A cable bond ties the upper and lower bars. The lower bar functions as a FRWK GRD, a grounding point for cable sheaths and for miscellaneous ground connections. When a distributing frame is not equipped with protectors, ground bars are not normally provided.

### D. AC Equipment Ground Bus Bars

**6.16** Certain equipment bays and cabinets provided for distribution of AC service are equipped with equipment ground bus bars by the manufacturer, for the purpose of providing a convenient terminating point for AC equipment ground (green wire) conductors. Other AC service equipment units may not have such facility furnished. Units in which such terminating facilities may be found include house service boards, power service cabinets, lighting distribution cabinets and other units that may be employed as a distribution point for AC service circuits. When an equipment ground bus is provided it is mounted within the equipment enclosure so that it is electrically bonded to the enclosure, and all AC equipment ground conductors shall be terminated thereon. When no bus is furnished by the manufacturer, a bus may be provided if it deemed economical and convenient; otherwise it is acceptable to terminate AC equipment ground conductors to the interior of the enclosure as close as practicable to the entry point, using suitable terminals bolted to the enclosure panels or framework. Continuity between conductors so terminated is provided through the enclosure metal.

## 7. RACEWAYS

**7.01** Raceways are defined as any enclosing channel for holding wires, cables or bus bars which is designed expressly for, and used solely for, this purpose. Raceways shall be of metal or insulating material and the term includes rigid metal conduit, rigid nonmetallic conduit, flexible metal conduit, armored cable, surface raceways, wireways and busways.

### CO GRD System Raceway Application

**7.02** The use of raceways for support of equipment grounding conductors other than those associated with the AC equipment ground system is generally prohibited except for sleeves through floors and walls, and for short pieces used as guards against damage, or where no other form of support is practical. When raceways are so employed they shall be of insulating material, such as PVC plastic conduit or fibre pipe (NEC Article 347). The equipment grounding conductors should always be run and supported so that as much of the runs as practicable may be visually inspected.

**7.03** The only exception to the use of nonmetallic raceways shall be for installations where local electrical codes prohibit the use of raceways of insulating material, in which case, short runs of metallic raceway, principally, rigid conduit, may be used. These sleeves, guards, or short supporting runs must be short-circuited at each end by means of a No. 6 AWG cable bond between each end of the sleeve and the ground conductor (or conductors) run therein. Connectors at conduit ends shall be clamp type pipe connectors and at the conductor shall be parallel cable connectors.

**7.04** The bonding of metallic raceway to the enclosed ground conductor is important. A ring of magnetic material around a ground conductor creates an inductive impedance in the ground conductor during periods of fluctuating current flow. In addition to raceway, any magnetic material that forms a complete ring, such as U bolt supports, should be avoided. Bonding of such rings to the ground conductor therein effectively short-circuits the turn to eliminate the inductive impedance and in addition provides equipment grounding for the metal enclosure. In the past, many such installations were inadvertently left unbonded. Therefore, use of plastic or other nonmetallic sleeves is recommended to ensure a reliable equipment grounding system.

**AC Equipment Ground System Applications**

**7.05** AC conductors in communication buildings should always be run in grounded metallic raceways. AC equipment ground conductors shall be run within the raceway that contains associated phase conductors and shall be electrically continuous between enclosures of equipment units (refer to Section 802-001-198). Raceway continuity shall be maintained by means of conduit fittings or other raceway components designed specifically to provide such continuity. Metallic raceway may, for purpose of isolation from vibration or for other reason, be ended without connection to the metallic enclosure of a unit in which the phase conductors terminate. Electrical continuity between the raceway and enclosure must be provided by means of a suitable bond wire. An AC equipment ground conductor, if furnished in the raceway, shall provide the continuity. The conductor shall be bonded to the raceway at point of egress. A separate bond wire is required when the raceway does not contain an AC equipment ground conductor. The raceway shall be bonded to the enclosure wherein the phase conductors are terminated. The size of the bond wire shall be in accordance with NEC Article 250-95.

**8. INSTALLATION REQUIREMENTS**

**8.01** The reliability of a grounding system is as much dependent on careful and proper installation as it is on the proper choice of materials. Improper preparation of surfaces to be joined to make an electrical path, loose joints and corrosion can introduce impedances that will seriously impair the ability of the ground path to protect personnel and equipment and to absorb transients that can cause noise in communication circuits.

**8.02** The following functions are particularly important to ensure a reliable ground system.

(a) Metallic surfaces to be joined shall be prepared to a bare, bright finish.

Reference: NEC Article 250-118.

(b) Aluminum wire shall be coated with NO-OX-ID "A" or equivalent corrosion preventive compound, then scraped to remove oxide coating immediately before joining to terminals.

(c) Metallic surfaces shall be coated with corrosion preventive compound before joining.

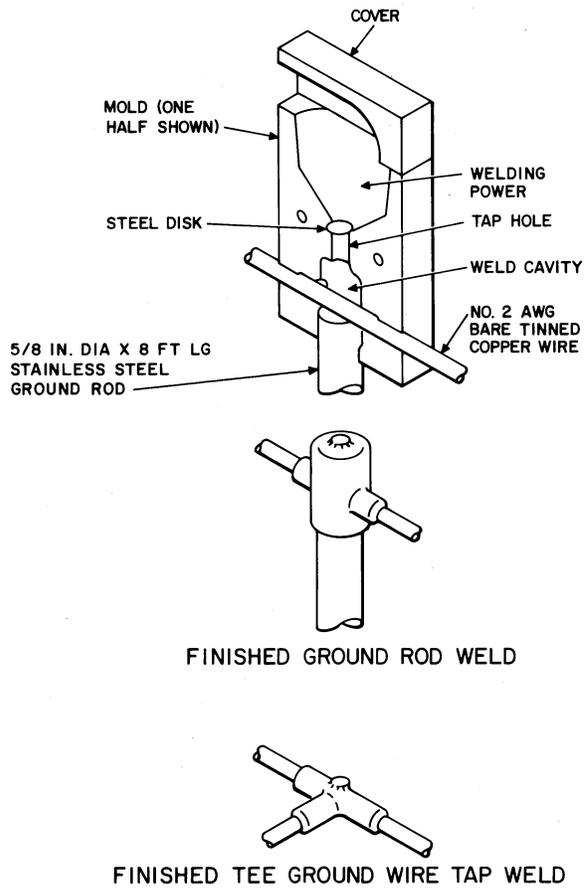
(d) Bolts, threaded pressure devices, and similar connecting devices shall be adequately tightened to ensure a good connection and shall be accessible for periodic inspection and maintenance.

(e) Raceway fittings shall be made up tight to provide a permanent low impedance path for fault currents.

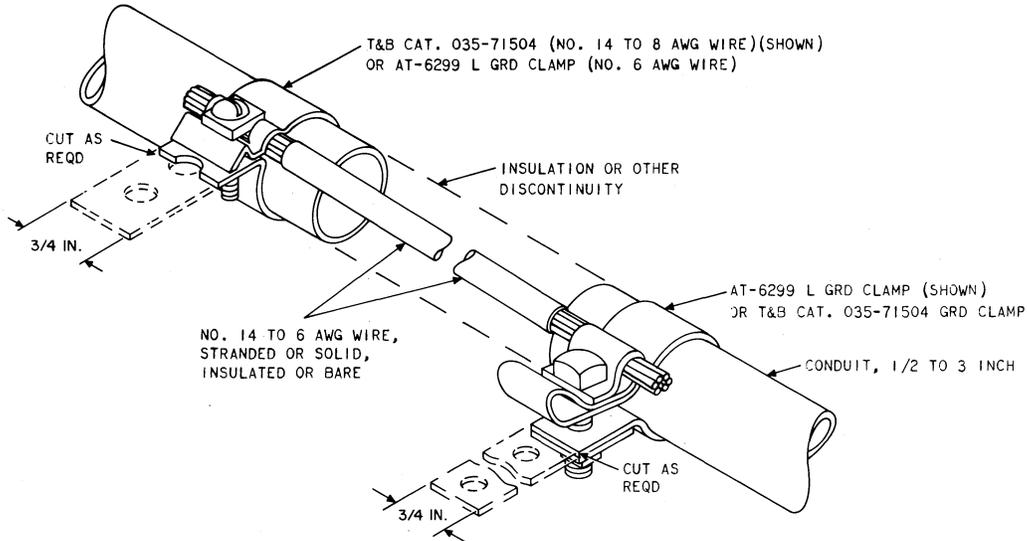
**8.03** Corrosion preventive compound shall be applied wherever the possibility of corrosion formation in ground conductor joints exists. The use of NO-OX-ID "A" compound (Dearborn Chemical Co.) is recommended.

**8.04** Every ground conductor terminated at a water pipe or bus bar serving as the building principal ground point and at CO GRD bus bars of the CO GRD system, when terminated with a bolted tongue connector or other device that could be inadvertently disconnected (other than cadwelded or brazed), shall be equipped with a P-411719 "DO NOT DISCONNECT" tag.

**8.05** Every grounding conductor extended to equipment from a floor CO GRD bus shall be equipped with a 145C number plate stamped to designate area or equipment grounded by the conductor.



**Fig. 1—Thermal-Welded Connections for Driven Ground System (Cadweld or Thermoweld Processes Typical)**



SK A  
CONDUIT BONDING CLAMPS (SEE TABLE 2A)

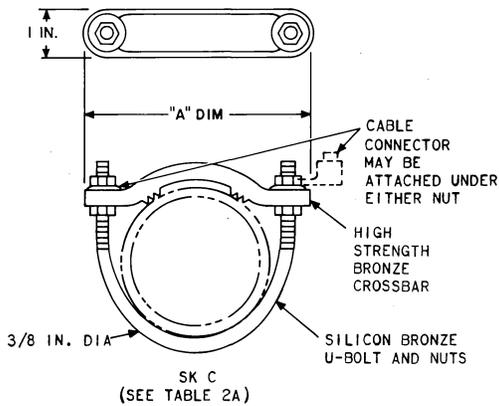
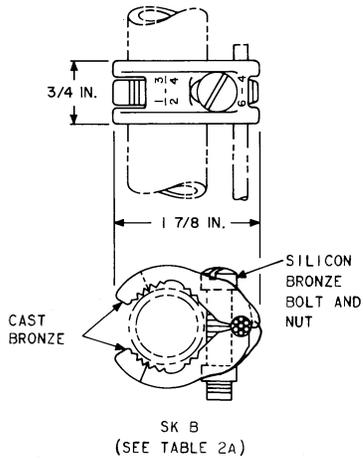
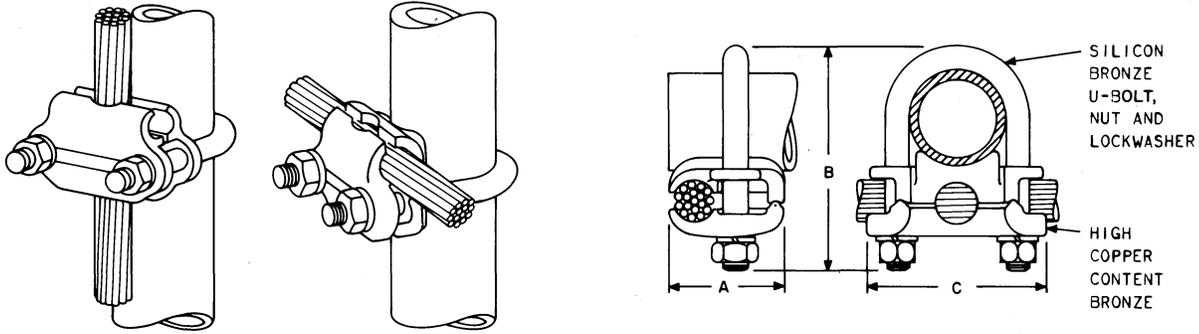


TABLE 2A - PIPE AND CONDUIT GROUND CLAMPS						
SEE SK	THOMAS AND BETTS CO. CATALOG NO.	PIPE OR CONDUIT SIZE	LEAD SIZE	TERM REQD	"A" DIM	NOTE
A	035-71504	3/8 TO 1	14 TO 8	NONE		2.3
	(NOTE 4)	1/2 TO 3	6	NONE		3
B	035-71459	1/2, 3/4	8, 6, 4	NONE		2
C	035-71153-4	5	14 TO 750,000 CM	SEE NOTE 1	7	2
	035-71153-5	6			8-1/16	
	035-71153-6	8			9-1/16	
	035-71153-7	10			11-3/16	
	035-71153-8	12			12-3/16	
	035-71153-9	14			16-1/4	

1. FOR ALUMINUM WIRE USE COMPRESSION CONNECTOR KS-15977 OR COMMERCIAL EQUIVALENT EXCLUSIVELY. FOR COPPER WIRE USE COMPRESSION CONNECTOR (PREFERRED) OR PRESSURE CONNECTOR KS-5517 OR COMMERCIAL EQUIVALENT (ALTERNATE) FOR WIRE SIZES 8 AWG TO 750,000 CM. FOR COPPER WIRE 14 TO 10 AWG, USE T AND B CONNECTORS - CAT. NO. 81003 - REL WITH TONGUE DRILLED WITH 13/32 INCH HOLE.
2. SPECIAL CLAMPS FOR BELL SYSTEM USE, NOT LISTED IN T AND B GENERAL CATALOG.
3. FOR CONDUIT AND CABLE SHEATH GROUND BONDING. NOT SUITABLE FOR WATER PIPE GROUND POINTS.
4. (BELL SYSTEM SPEC) AT-6299 L GROUND CLAMP.

Fig. 2—Pipe and Conduit Ground Clamps (Sheet 1 of 2)

SECTION 802-001-190

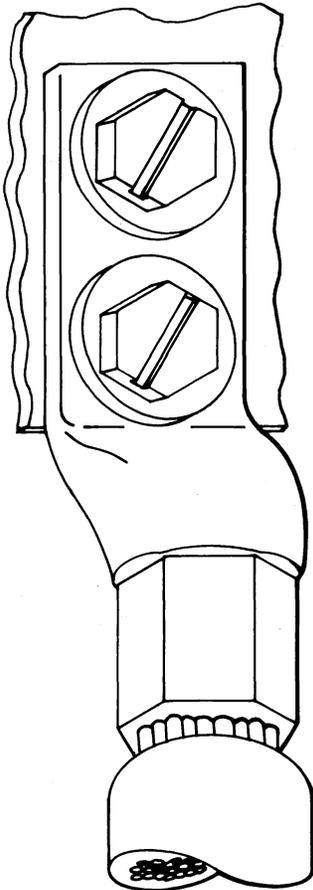


SK D  
(SEE TABLE 2B)

TABLE 2B-PENN-UNION GROUND CLAMP CONNECTOR CATALOG NUMBERS AND DIMENSIONAL DATA						
SEE SK	WIRE PIPE	8 SOL-4 STR	4 SOL-00 STR	00 STR-250 MCM	300 MCM-500 MCM	750 MCM
D	1/2 IN., 3/4 IN.	GPL-8 11-21-19 *	GPL-9 13-21-19	GPL-10 15-24-19	GPL-11 19-30-22	GPL-12 ** 21-30-22
	1 IN.	GPL-14 11-22-21	GPL-15 13-22-21	GPL-16 15-26-21	GPL-17 19-36-24	GPL-18 ** 21-36-24
	1-1/4 IN.	GPL-20 11-28-24	GPL-21 13-28-24	GPL-22 15-28-24	GPL-23 19-34-27	GPL-24 22-40-30
	1-1/2 IN.	GPL-26 11-32-26	GPL-27 13-32-26	GPL-28 15-32-26	GPL-29 19-37-29	GPL-30 22-42-32
	2 IN.	GPL-32 11-34-30	GPL-33 13-34-30	GPL-34 15-34-30	GPL-35 19-42-32	GPL-36 22-44-36
	2-1/2 IN.	GPL-38 11-40-34	GPL-39 13-40-34	GPL-40 15-40-34	GPL-41 19-45-36	GPL-42 22-48-40
	3 IN.	GPL-44 11-44-38	GPL-45 13-44-38	GPL-46 15-44-38	GPL-47 19-50-42	GPL-48 22-54-44
	3-1/2 IN.	GPL-50 11-50-42	GPL-51 13-50-42	GPL-52 15-50-42	GPL-53 19-54-46	GPL-54 22-60-48
	4 IN.	GPL-56 11-51-46	GPL-57 13-51-46	GPL-58 15-51-46	GPL-59 19-54-50	GPL-60 22-64-52
DIM *	A-B-C	A-B-C	A-B-C	A-B-C	A-B-C	
U-BOLT DIA	3/8 IN.	3/8 IN.	3/8 IN.	1/2 IN.	5/8 IN. (** 1/2 IN.)	

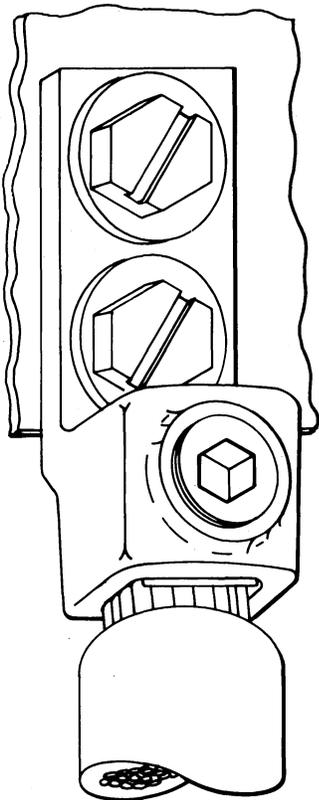
\* CLAMP DIMENSIONS EXPRESSED IN 1/8 INCH INCREMENTS:  
(1E, 11-21-19 = 1-3/8(A), 2-5/8(B), 2-3/8(C))

Fig. 2—Pipe and Conduit Ground Clamps (Sheet 2 of 2)



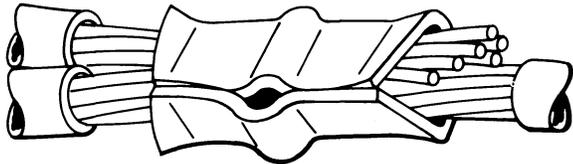
TWO HOLE BOLTED TONGUE  
CRIMP (COMPRESSION) TYPE  
CONNECTOR (KS 15977 OR  
T AND B "COLOR-KEYED", TYPICAL)

SK. A



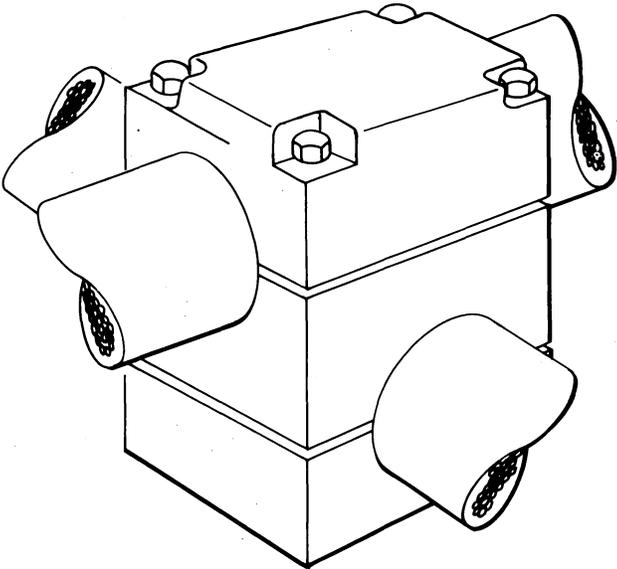
TWO HOLE BOLTED TONGUE  
PRESSURE TYPE CONNECTOR  
(KS 5517 TYPICAL)

SK. B



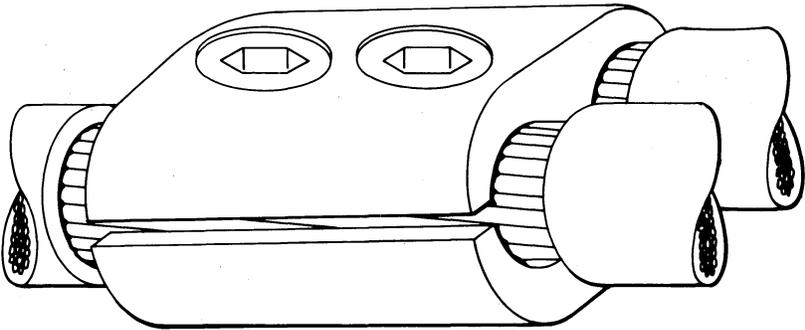
CRIMP TYPE PARALLEL CONNECTOR  
(T AND B "C" TAP, TYPICAL)  
FOR USE WITH NO. 2 AWG AND SMALLER  
STRANDED COPPER WIRE

SK. D



750 MCM-750 MCM CROSS TAP  
CONNECTOR, FRANKEL  
CAT NO. 2632

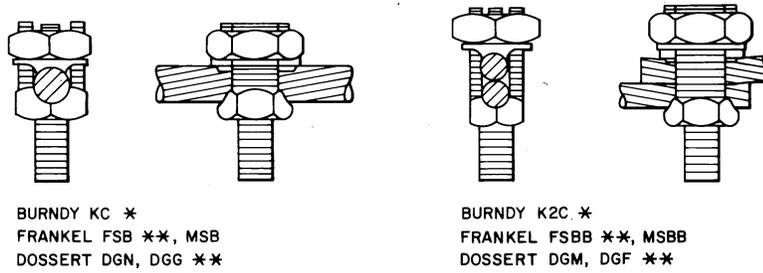
SK. E



PRESSURE TYPE PARALLEL CABLE CONNECTOR  
(KS 5537 TYPICAL)

SK. C

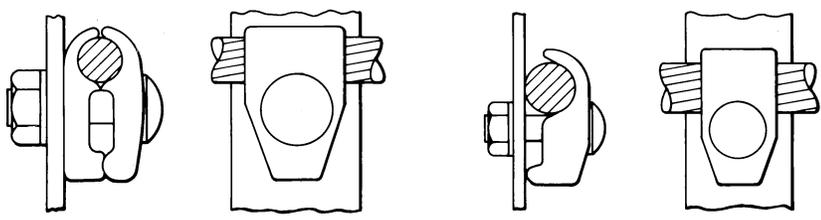
Fig. 3—Crimp (Compression) and Pressure-Type Connectors



BURNDY KC \*  
FRANKEL FSB \*\*, MSB  
DOSSERT DGN, DGG \*\*

BURNDY K2C \*  
FRANKEL FSBB \*\*, MSBB  
DOSSERT DGM, DGF \*\*

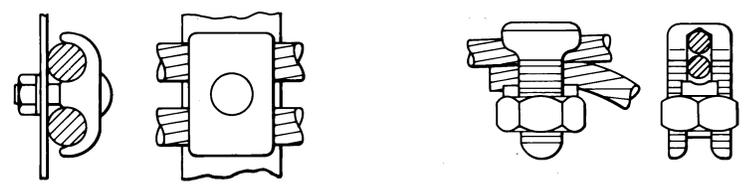
SK. A - GROUND STUD CONNECTORS



BURNDY GB \*  
DOSSERT GR  
O.Z. KG

BURNDY GBM \*  
DOSSERT GFM

SK. B - GROUND CONNECTORS

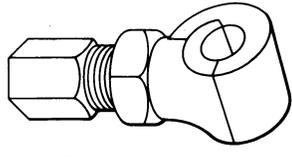
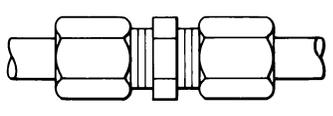


BURNDY GCM \*  
DOSSERT GAM

BURNDY KS \*  
FRANKEL B, DB  
DOSSERT DS  
O.Z. ST

SK. C - TWO WIRE  
GROUND CONNECTOR

SK. D - SERVICE  
TAP CONNECTOR



DOSSERT TW \*\*\*

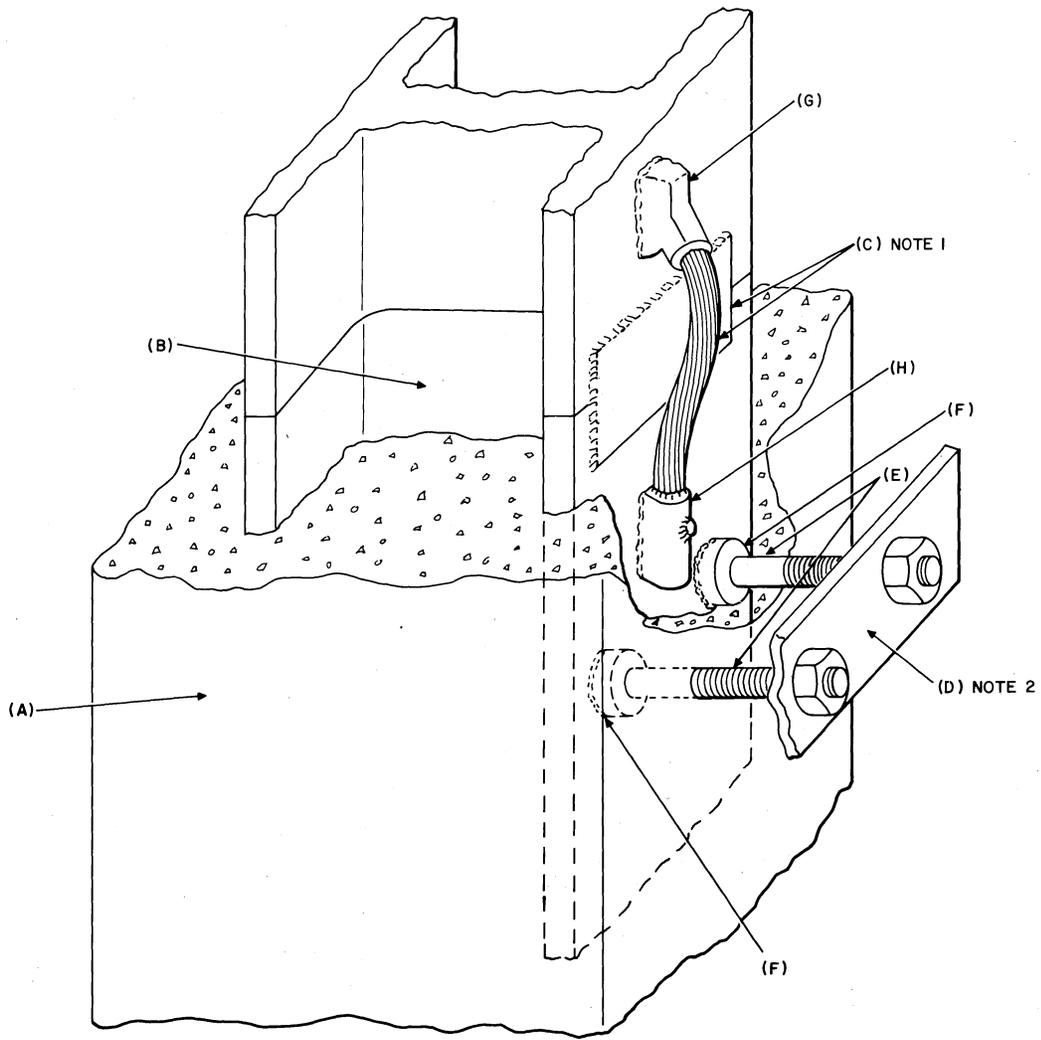
DOSSERT DHT \*\*\*

SK. E - TWO WAY  
CONNECTOR

SK. F - HOOK TYPE  
TEE CONNECTORS

\* DEPICTED, OTHER MANUFACTURERS PRODUCTS ARE SIMILAR  
\*\* DENOTES STUD OMITTED, FEMALE THREAD FURNISHED  
\*\*\* FOR USE IN INTERNAL RING OF GROUND SYSTEM, NO. 2 AND 6  
AWG SOLID COPPER WIRE

Fig. 4—Typical Commercial Type Connectors Suitable for Ground System Connections When Cadwelds, Crimp, or Pressure-Type Bolted Tongue Connectors Cannot Be Used



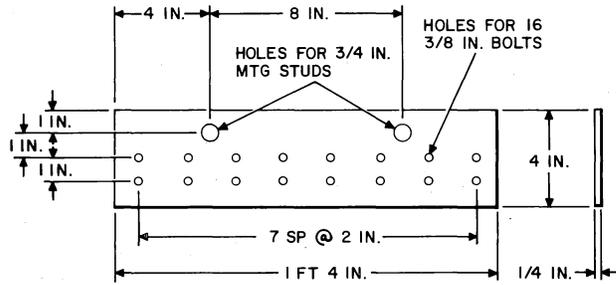
LEGEND

- (A) BUILDING COLUMN
- (B) STEEL SECTION
- (C) WELDED BOND BETWEEN SECTION JOINTS
- (D) FLOOR CO GRD BUS (SEE FIG. 6)
- (E) 3/4 IN. OR 1 IN. STEEL THREADED ROD OR STUD
- (F) CADWELD CO. TYPE HV WELD OR BRAZE
- (G) CADWELD CO. TYPE VS WELD OR BRAZE
- (H) CADWELD CO. TYPE VF WELD OR BRAZE

NOTES:

1. BOND MAY BE WELDED STEEL PLATE OR 750,000 CM COPPER WIRE CADWELDED ACROSS JOINT.
2. 1/4 X 4 MINIMUM BUS RECOMMENDED. MAY BE MOUNTED VERTICALLY.

**Fig. 5—Typical Combined Bond and Support of Floor CO GRD Bus From Steel Column**



**Fig. 6—Typical Design of CO GRD Bus for Mounting in Horizontal Position on 1-4 Wide Column With Studs Welded to Column Steel**

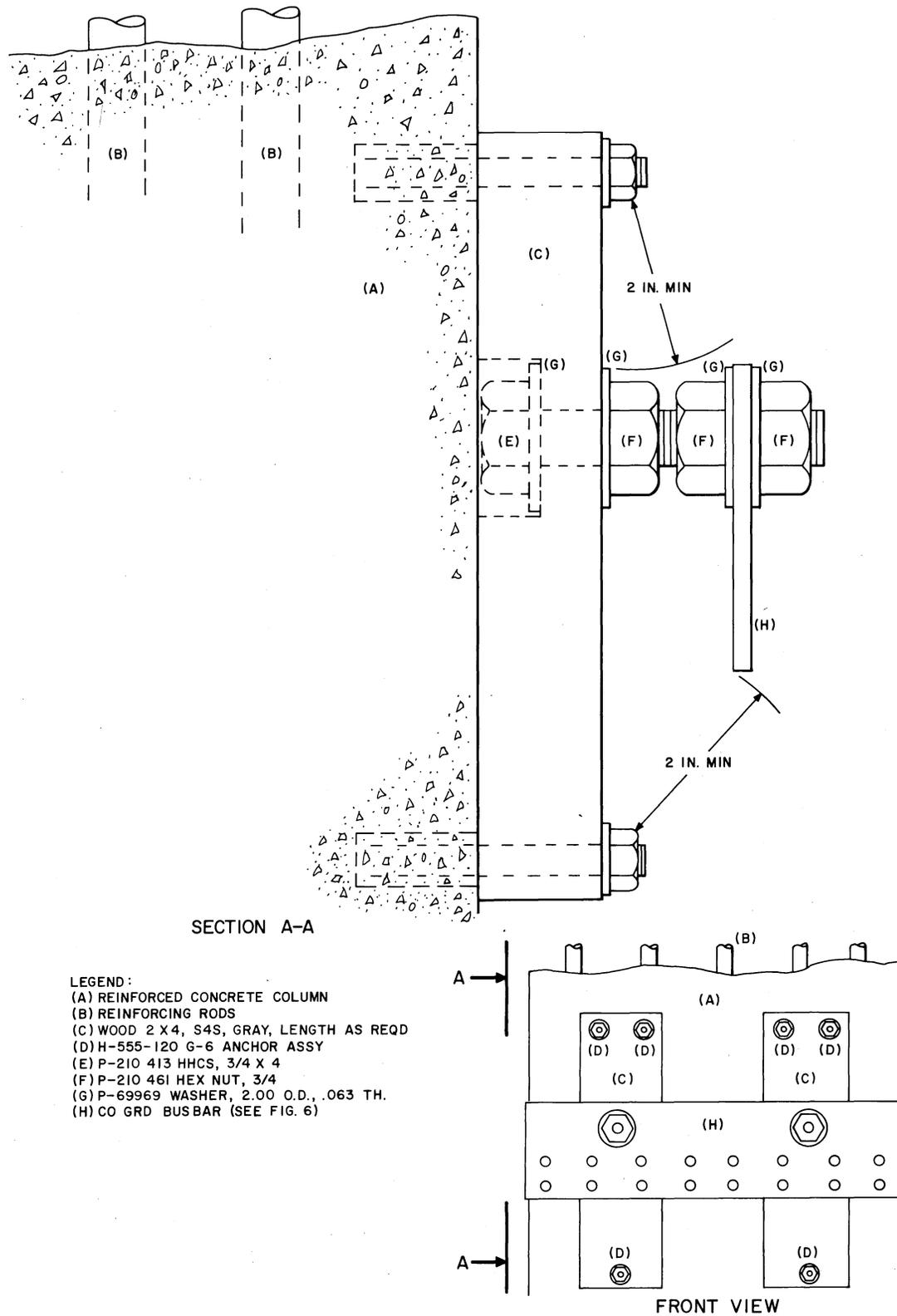


Fig. 7—Typical Mounting of CO GRD Bus Bar on Reinforced Concrete Column or Wall To Avoid Lightning Current Sparkover