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CRITERIA FOR GROUNDING CONDUCTIVE FLOORS IN
NAVAL HOSPITALS AND ORDNANCE FACILITIES

By

James L. Brooks and Barry C. Streets

October 1976

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INTRODUCTION

At Naval ordnance facilities (where combustible materials are stored and handled) and at Naval hospitals (where flammable gases are stored and used), explosion exists as an ever-present threat. The ignition energy originating an explosion may come from many sources, all of which are well-known to personnel handling the explosive material and are carefully guarded against. The one source of ignition energy which is insidious in that it can occur without warning is the sudden discharge of accumulated static electricity. This source of ignition energy can only be eliminated by maintaining an equipotential between people, machines, and materials in those areas where the explosive materials are stored and handled. The technique presently used to establish the necessary equipotential work area is to install conductive floors in the building.

While designers at Naval ordnance facilities and hospitals recognize the need for conductive floors, they have questioned the need for grounding the conductive floors. The questions have been raised for several reasons: conflicting specifications, many new products on the market, vague or insufficient installation instructions, and outright claims by some manufacturers that grounding is not necessary. The Civil Engineering Laboratory (CEL) was tasked by the Naval Facilities Engineering Command to develop the necessary criteria for effective earth grounding of conductive floors used within Navy hospitals and ordnance facilities.

BACKGROUND

Static electricity is generated whenever two surfaces - whether liquid or solid - come into contact, no matter how gently. At the atomic level, electrons pass back and forth between the surfaces, resulting in one surface being electron rich and the other electron poor upon separation of the two surfaces. While friction or rubbing increases the charging process, mere contact and separation are enough to generate static electricity. The degree and polarity of the imparted charges depend on the relative position of the materials on the atomic scale. Static charges, being all of the same polarity on an object, repel one another and therefore accumulate on the outermost surfaces of the object. The conductivity of the surface material of the object determines how quickly the charge spreads over the surface of the material. The same time factor is involved in draining off the charge from the object. The electron-rich material is referred to as being negatively charged, while the electron-poor material is referred to as being positively charged.

It is not uncommon for very high voltages to be produced by this charge-exchanging process; however, the currents are usually low, depending upon the time factor associated with the conductivity of the charged surface.

The very high voltages generated by static electricity sometimes causes sparks when allowed to discharge suddenly. These sparks produce locally intense heat, locally intense light, small shock wave, and an electromagnetic field. These sparks have also been known to detonate electroexplosive devices or ignite flammable solvents or anesthetic mixtures. Consequently, the areas where these materials are handled and used are designated hazardous areas, and special precautions are taken to prevent buildup of static electricity. The special precautions include making all surfaces conductive and then providing a means of safely dissipating the charges to earth ground without the production of a spark.

Some examples of the practical application of these special precautions are conductive shoes worn by personnel, conductive rubber wheels on equipment carts and vehicles, and conductive floors installed in the hazardous working areas. Also, an integrated network of electrical conductors connected to earth ground is provided to safely bleed off the accumulated electrical charges.

INVESTIGATION OF CONDUCTIVE FLOOR GROUNDING

Types of Conductive Flooring

Recent studies on the subject of conductive floors have summarized the various types of conductive floors as to materials used, manufacturers, and suitability for use in hazardous areas [1,2,3]. The most recent study [3] defines each type of floor as follows:

1. Conductive Metallic Toppings. Metallic toppings for concrete are used chiefly at ordnance activities and are the most commonly used conductive floors at such activities. This topping has been designated a "metallic-type static-disseminating and spark-resistant floor finish." It is 1-inch thick and contains metallic aggregate at the upper surface. The metallic aggregate contains not only iron, which is the chief ingredient of most concrete hardeners, but also carbon black and other additives. About 1.8 lb/sq ft of this material is dusted on the surface of the freshly floated concrete and extends about 1/8 inch into the surface of the finished topping. Because the metallic concrete floors are very hard, they are well-suited for heavy traffic but are not generally used for hospital floors.

2. Conductive Organic Toppings. Conductive organic toppings are newer than the metallic toppings. They are seamless floors applied in thicknesses of about 1/4 inch (the thickness depending on the product). These floors incorporate a variety of organic binders or resins and

contain a variety of fillers, which often include cementitious materials. The organic toppings can therefore be obtained in various degrees of hardness, flexibility, and toughness. Because floors with the proper organic topping can resist heavy loads, such floors can be used in lieu of floors with metallic topping. In addition, the flexibility of the organic toppings allows their use for other purposes at ordnance activities. With few exceptions, carbon black is added to the organic toppings to provide the necessary conductivity and a black matrix results. A terrazzo surface is generally preferred for hospitals; various organic binders are used to prepare terrazzo floor toppings.

2. Conductive Floor Coatings. Besides the thicker toppings discussed above, also available are a variety of floor coatings which are generally applied in thicknesses of about 1/16 inch or less (but which may also be built up to greater thicknesses). Such coatings are used more often at ordnance activities than at hospitals, and they are generally used for converting existing floors to conductive floors, rather than in new construction.

4. Conductive Floor Coverings. Factory-prepared tiles or sheeting that are bonded to the floor constitute another category of conductive flooring. These materials may consist of ceramic tile, generally about 1 inch square; of vinyl or rubber tile, generally about 1 foot square; or of linoleum sheeting, about 6 feet wide. Electrical conductivity is maintained in the ceramic tile floors by conductive mortar, in the vinyl or rubber tile floors by copper strips or by conductive epoxy adhesive, and in the linoleum floors by electrical connectors. These coverings are sometimes used to convert existing floors to conductive floors.

5. Nonproprietary Conductive Floors. Besides the above-mentioned proprietary materials, a variety of conductive nonproprietary flooring materials are also available and may be installed according to various industrial specifications. Oxychloride concrete (often loosely called magnesite) contains magnesium oxide and magnesium chloride, is moderately conductive without additives, and can be obtained in various light colors. Oxychloride terrazzo and carbon-containing portland cement terrazzo were, until recently, the conductive floorings most widely installed in hospitals. Conductive seamless floors without terrazzo finish, using epoxy resin binders, polyester resin binders, or other organic binders, can also be installed by a variety of flooring contractors or flooring companies. Lead sheeting and aluminum sheeting are sometimes used as flooring in rooms where explosives are handled and are therefore listed with the nonproprietary flooring materials.

Existing Specifications and Codes

NAVFAC Type Specification TS-9F15a, April 1971. TS-9F15a is the most recent of many NAVFAC specifications, each of which supersedes the other. The reverse chronological order is: TS-9F15a (1971), TS-9F14 (1967), BUDOCKS Specification 48Y (1959) and BUDOCKS Typical Specification F4b

(1959). All of these specifications pertain to the conductive metallic topping or the oxychloride composition types of floors intended for use in ordnance facilities. As the specifications have changed over the years so have the grounding methods described. The most recent, TS-9F15a, allows the designer to choose between the ground rod or the ground stud methods of providing earth grounding for the conductive floor. The wording used to describe each method is extracted from TS-9F15a and presented below.

Ground Rods: At least one ground rod shall be provided for each 400 square feet of floor area. Ground rods shall be driven into the earth vertically so that the tops of the rods will be at an elevation of not less than 3/8-inch below the top surface of the finished floor level. An approximately 2-inch round or square piece of copper or brass hardware cloth (4-mesh, 0.047-inch-wire-diameter) shall be centered on and rigidly brazed to the top of the rods. A slight cup-shaped pocket or depression, about 2 inches in diameter, shall be formed in the topping finish surrounding the tops of the rods so that the conductive metallic aggregate contained in the surfacing material will flow around and be in firm and full contact with the rods and the wire discs. Each ground rod shall be connected electrically to the concrete slab reinforcement by means of brazing a copper or brass braided strip.

Grounding studs: At least one grounding stud shall be provided for each 400 square feet of floor area. Grounding studs shall be anchored in position rigidly with the tops of the studs set at an elevation of not less than 3/4 inch below the top surface of the finish floor. Care shall be exercised when placing or compacting the concrete so that studs will be disaligned. An approximately 2-inch round or square piece of copper or brass hardware cloth, 4-mesh, 0.047-inch wire diameter shall be centered on and rigidly brazed to the top of studs. A slight cup-shaped pocket or depression, about 2 inches in diameter, shall be formed in the topping finish surrounding the tops of the studs so that the conductive metallic aggregate contained in the surfacing material will flow around and be in firm and full contact with the studs and the wire discs. All of the studs shall be connected together electrically by means of a continuous no. 6 AWG copper wire brazed to each stud and to a common ground wire carried and connected electrically to a suitable and approved ground. The continuous ground wire interconnecting the studs shall be placed on and fastened to the top of the structural concrete base slab in a manner to prevent it from lifting when the topping floor finish is placed. Each grounding stud shall be connected electrically to the concrete slab reinforcement by means of brazing a copper or brass braided strap.

The designer may choose either of these two methods, and the statement is made in the specification that the type, location, and number of ground rods or grounding studs and how they are connected to the grounding system should be shown on the drawings or stipulated in the project specification.

NAVWEPS OP-5, vol 1. This document addresses the subject of conductive floors in ordnance facilities. However, it avoids stating specifically how to ground the floors. The only references to grounding occur in section 4-7.2.4: first, in paragraph (4) where it states that "the resistance of the conductive floor to ground shall be less than 1 megohm," and again in paragraph (5) that "the resistance of the floor shall be more than 5,000 ohms in areas with 110-volt service and 10,000 ohms in areas with 220-volt service, as measured between a permanent ground connection and an electrode placed at any point on the floor." The expression "ground connection" is undefined in this document.

NFPA-56A. This document published by the National Fire Prevention Association (NFPA) addresses itself to hospital construction and equipment. One reference to the grounding of conductive floors occurs in chapter 26 paragraph 2606, as follows: "the conductive floor shall be connected to the room grounding point." Then in paragraph 2608, the statement is made that, "An insulated continuous No. 10 AWG stranded copper grounding conductor shall be extended from the room grounding point to the ground bus in the electrical panel." No mention is made of a separate ground to earth or structure. Minimum resistances of the floor to ground are mentioned however: the floor must have a resistance to ground of between 25,000 ohms and 1 megohm.

It should be noted that NFPA-56A is the guideline used by industry for hospital conductive flooring installations. To receive accreditation, Naval hospitals are required to comply with the requirements of NFPA-56A.

National Electrical Code. The National Electrical Code does not address itself to ordnance facilities but does mention conductive floors in hospitals. Paragraph 517-66, entitled "Grounding," states that "In any anaesthetizing area, all metallic raceways and all noncurrent-carrying conductive portions of fixed or portable equipment including the conductive floor shall be grounded." Again, how to ground the floor or to what it should be grounded are not mentioned.

OSHA Requirements. OSHA documents do not address the subject of conductive floors; however, a section in subpart K, Grounding and Bonding, paragraph 1926.401, discusses grounding of the electrical system.

Literature Search

Of the textbook publications reviewed during the literature search, the need for dissipating static electricity in certain hazardous areas was well-documented. Many techniques for alleviating the problem were

given, including use of grounded conductive flooring. However, no specific details were given on how to ground the floors or what should be used as a "grounding point" for the floor.

The manufacturers of conductive flooring materials were contacted and asked to supply product information as well as application or technical notes relating to installation procedures and the earth grounding of their flooring. Of the 62 manufacturers contacted, 37 replied. Of these 37, 15 no longer manufacture conductive flooring. It is presumed that many of the unanswered queries also fall into this category. Thus, 22 manufacturers supplied information on conductive flooring; nine actually provided information regarding the grounding of conductive flooring. These nine companies manufacture a variety of conductive floors, and the grounding methods recommended are presented below according to the type of floor.

Conductive Metallic Topping. Two manufacturers of conductive metallic topping floors responded to the survey, referencing existing specifications for grounding the floors. One referenced BUDOCKS Specification 48Y, and the second referenced NAVFAC TS-9F14. No further description was provided.

Conductive Organic Topping. Only one manufacturer of the conductive organic topping type of floor responded to the survey and recommended that a 3 x 12-inch copper screen or plate be used to provide contact to the conductive topping. The copper screen or plate is to be attached to a no. 10 gauge, bare, copper conductor and placed in one corner of the room 3 feet from the corner sidewalls prior to applying the topping. A 25 k Ω resistor is to be inserted in series with the copper conductor, and the copper conductor is to be run to the nearest room grounding point.

Conductive Floor Coating. Two manufacturers responded to the survey with grounding instructions for the conductive coating type of floor, but each gave a different method:

1. Place a length of adhesive-backed copper tape on a primed floor and connect to a ground. Brush a layer of coating over the tape, extending over the edge by 1 or 2 inches. Two feet of tape is used for every 1,000 square feet of floor to be coated. Tape should also be used where cracking of the coating is possible.

2. Place copper strips 1 inch wide and 3 feet long on 10-foot centers over the cloth reinforcing layer of conductive flooring, the strips extending 2 feet out on the floor and 1 foot up the wall. The copper strips are clipped to a main ground previously installed. The topcoat layer is then troweled over the strips, holding them in place.

Conductive Floor Covering. Four manufacturers of conductive floor coverings responded to the survey, each company with its own method of grounding the floor:

1. Place a conductor, such as copper wire, in the conductive adhesive approximately 6 inches under the tile adjacent to a ground point, which is then connected to it.

2. Stretch a no. 20 gauge copper wire in the conductive mortar or adhesive setting bed diagonally from corner to corner, forming a cross, and connect either directly to ground or in series with a resistor to ground.

3. Place the provided copper strip directly on the conductive epoxy adhesive and extend it about 12 inches beyond the tile perimeter at a position nearest the room ground point.

4. Place a piece of copper sheet 6 x 6 inches between the floor to be installed and the subfloor at any given point, ensuring that the sheet is in direct contact with the floor to be installed. A thin copper wire is then attached between the sheet and a ground connection.

Field Survey of Selected Naval Activities

During the field survey, Naval ordnance facilities and hospitals listed in the Appendix were visited. These activities were selected as a representative sampling, based on the nature of the work performed, climate, age of the facility, expected building construction, and size. During each visit the following was accomplished:

1. Technical discussions were held with site personnel regarding the materials and techniques used at their facility to ground conductive floors.

2. Representative buildings containing conductive flooring were inspected on site and pertinent photographs obtained.

3. A search was made to locate applicable construction blueprints, project specifications, or other documents.

The following grounding techniques observed during the field survey of ordnance facilities are listed in the following sections.

Conductive Metallic Topping.

1. An excellent example of a designer's interpretation of TS-9F15a to specify grounding of a conductive metallic topping floor is shown in Figure 1. This drawing was developed in 1970 for use as a design guide at Naval Ammunition Depot (NAD) Crane, Indiana, and makes use of ground rods, ground studs, and a ground girdle. Note that the structural steel of the building is also grounded. This design is considered one of the best encountered during the field survey.

2. Figure 2 shows the grounding plan for a demilitarization facility under construction at NAD, Hawthorne, Nevada. This plan utilizes the ground rod option of NAVFAC Specification TS-9F15a. The details of the typical cell layout show how the ground bus inside the cell is connected to the grounding system; in turn, all metallic surfaces in the cell

(including the metal roof, steel beams, angles, mesh, and floor drain covers) are connected to the ground bus. This figure also provides a good description of the lightning protection system, common to most ordnance facilities.

3. In addition to the new construction described above, repairs to an existing floor had been made in 1974 at NAD, Hawthorne. The floor was a second-story floor in a gunpowder preparation facility. While drawings were not available, the work description of the grounding scheme was extracted from the project specifications as follows:

The AWG no. 6 bare copper grounding grid conductors shall be placed in the floor at an elevation slightly below the finish surface within the top 1 inch of floor material. The AWG no. 6 grid conductors are to be connected to a new AWG no. 4 bare copper grounding girdle. The wire mesh reinforcing material is also to be connected to this no. 4 wire girdle at intervals not to exceed 8 feet. The no. 4 wire girdle is to be connected to the existing columns (seven locations minimum) and door frames (four locations) with AWG no. 4 copper wire. All connections are to be secured by brazing.

The wire mesh referred to is a 20-gauge, galvanized, 2-inch hexagon steel mesh. The 2-inch-thick floor material specified was trade named "Ferro-Fax N.S.C." and was formulated to comply with NAVFAC TS-9F15.

4. An excellent example of an integrated grounding protection system is shown in Figure 3, which shows the grounding installation for a three-building propellant-mixing complex located at Naval Weapons Center (NWC), China Lake, California. The materials mixed in this facility are so hazardous that the mixing process is remotely controlled. Thus, an integrated grounding system is employed to accommodate communications, control, alarm, lightning protection, and conductive floor grounding functions. This complex was built in 1963, but the grounding scheme did not follow any of the published specifications.

5. Figure 4 shows the grounding installation used for refurbishing a large ground-floor ordnance building at Hawthorne in 1954. In this installation, extensive use is made of imbedded, parallel, no. 4 copper conductors spaced 8 feet apart and completely encircled by an internal girdle of 2/0 copper. Copper-encased 3/4-inch-diameter x 8-foot-long ground rods are spaced evenly around the girdle and are driven vertically to establish earth ground. The tops of the rods are left protruding 6 inches above the floor surface where mechanical attachment is made to the girdle, structural steel, and bus bar. Figure 5 is a photograph of one of the ground rods and girdle connections.

6. An unusual grounding method was encountered at Naval Weapons Station (NWS), Seal Beach, California, for an ASW support building constructed in 1962. One end of the single-story building required a conductive floor 23 x 65 feet. The conductive floor grounding methods are shown in Figure 6. The wording used in the installation contract specification to ground the floor is reproduced as follows:

Sparkproof flooring shall be grounded by means of 5/8 inch, 15-gauge (57.1 mils) copper ribbons laid on and pressed into the concrete slab before it sets up, and before the topping is applied. One ribbon shall run north and south along the centerline of the slab. Two ribbons shall run east and west along the centerlines of existing flush ground spools on the east wall. The intersections of the ribbon shall be sweat soldered. The eastern ends of the two transverse ribbons shall be doubled back into the slab twice to provide not less than four thicknesses for six inches in the slab and approximately three inches outside the edge of the slab. After floor is finished, the projecting quadruple thickness shall be drilled for a flat lug and connected by means of a no. 6 AWG bar copper ground bond to the existing ground spools.

One of the ground spools referred to is shown in detail in Figure 6b.

7. Another unusual conductive floor grounding scheme was encountered at the Naval Ordnance Station (NOS), Indian Head, Maryland. This technique requires that spiral windings of no. 6 AWG bare copper conductors be placed in the conductive topping of the floor. The installation details are shown in Figure 7. Several specifications are referenced on this drawing; however, they pertain to the conductive flooring material only. The grounding technique does not follow any of the standard specifications.

Conductive Organic Topping.

1. The first organic topping conductive floor encountered was at NWS, Seal Beach, California. This floor was installed in a steel frame addition to an existing building in 1968. The original building contained a metallic topping floor; however, the concrete slab floor of the addition was covered with a 3/8-inch layer of conductive latex material to meet the conductivity requirements. Figure 8 shows the grounding plan for this installation (note that there are no embedded conductors shown in the diagram). The floor was grounded by surface contact between the latex material and the structural steel and by surface contact with a small portion of the bar copper conductor "tie cable" connecting the structural steel to the external surrounding ground girdle. Detail DE4 on Figure 8 shows how the ground tie cable from the girdle is connected to the structural steel. This tie cable is imbedded in the conductive latex about 1 inch, thereby establishing the desired ground connection for the floor. Eighteen connections of this type are around the periphery of the floor.

2. The only other organic topping conductive floor encountered at an ordnance facility was at NWC, China Lake, where an old metallic topping type of floor covering had recently been removed from a small room, and a new organic topping (tradenamed "Cheminert") poured. When the old topping was removed, a no. 10 bare grounding conductor was discovered running diagonally across the floor on top of the concrete slab. This conductor was attached to the structural steel of the building

at both ends. It was left in place to establish the ground for the new organic topping. The new topping also came in contact with existing metal workbenches and fixtures inside the room; no further effort was made to ground the floor. No drawings, job specifications, or Milspec applicable to this installation were available. The new floor was tested for conductivity according to the procedure outlined in OP-5 and was found acceptable.

3. In 1972 the Naval Regional Medical Center (NRMC), Long Beach, California, renovated portions of the hospital by replacing old conductive floors with new ones. Installation drawings and specifications were available from the Public Works Officer (PWO). The new conductive floors were specified as a latex/mastic or resin-emulsion/mastic terrazzo which conforms to the requirements for Type 1 of Specification MIL-D-3134 and must contain no divider strips. Static-dissemination and spark-resistance of the terrazzo floor were to be tested after a 30-day curing time in accordance with the test method specified by NFPA-56. The subject of grounding the floor or testing for ground was not mentioned in the contract specifications. The "as-built" drawings do not show a grid or any other intentional grounding of the floor. From examining the drawings, it is apparent that the floor is indirectly grounded by making contact with the structural steel of the building: The floor contacts the steel frame doorways, metal lath in the plaster walls, water pipes, and fixed metallic equipment installed on the new floors. The original NFPA-56 did not specifically require grounding of the conductive floors, but NFPA-56A, issued in 1970, does specify that the conductive floor must be grounded.

4. NRMC, Oakland, California, was built in 1969 with organic topping conductive floors. The floors were specified as conductive latex/mastic or resin-emulsion/mastic terrazzo which must conform to the requirements of Type 1 of MIL-D-3134. In addition, the floors were required to meet the conductivity tests of NFPA-56. Divider strips of zinc alloy 1/8-inch thick were specified and were arranged to form squares 3 feet to a side throughout the field of the floor and along all edges. The divider strips are 1-1/4 inches in depth and were embedded in the concrete below the conductive floor topping, which is 3/8-inch thick.

Intentional grounding of the floor was not mentioned in the contract specification, and the electrical drawings do not show direct grounding by use of conductors. However, the floors do contact the structural steel and water pipes in many places; and, with the conductive divider strips placed throughout the field of the floors, ultimate earth grounding is assured. Since all of the conductive floors of this building are located on the fourth floor, an external ground wire of 3/4-inch stranded copper cable was run from the fourth floor to a lightning protection girdle buried in the ground similar to those used by ordnance facilities. On the fourth floor the copper conductor was electrically connected to the structural steel, the electrical service ground bus, and the water pipes. Note that this building was constructed prior to the 1970 publication of NFPA-56A which tells how the conductive floors in hospitals are to be grounded.

5. NRMCC, Camp Pendleton, California, was completed in 1974. Construction drawings and contract specifications were available. This 600-bed hospital has nine operating rooms located on the second floor. In addition to the operating rooms, two delivery rooms, a recovery room, an anesthetic equipment storage room, and interconnecting hallways required conductive floors. Almost the entire second story of the hospital is equipped with conductive floors. The construction contract specified a latex/mastic or resin-emulsion/mastic terrazzo conforming to the requirements for type 1 of specification MIL-D-3134. Plastic divider strips were specified for adjoining the conductive floor to other types of flooring. The average thickness of the floor was specified as 3/8 inch. The floor was grounded by soldering a 6 x 6-inch copper screen to the end of a no. 10 AWG bare copper conductor, imbedding the copper screen and conductor in the mastic at a point in the floor near a room grounding bus; and the copper conductor is then connected to the room grounding bus. The room grounding bus is part of the equipotential bonding which is now required in all hospital construction. Figure 9 shows a diagram for the equipotential bonding used in all the surgery and delivery rooms of the hospital. Note that an external ground loop is specified in Figure 9. This is an external ground girdle very similar to the secondary lightning protection girdles used at ordnance facilities.

Conductive Floor Coatings.

1. The first use of a conductive floor coating was observed at NAD Hawthorne. This coating had been applied to one corner of a very large building originally constructed with a conductive metallic topping type of floor. The old floor had gone out of specification in electrical resistance, and the coating was applied in an attempt to bring the resistance back to specifications. There were no drawings nor specifications for this procedure other than the manufacturer's recommended procedure of first cleaning the old floor thoroughly and then painting on the new coating. A photograph of the floor is shown in Figure 10. After application of the coating the floor was tested for electrical resistance and found to be in compliance with the requirements of OP-5. Since no new grounding measures were taken, the original grounding system of the metallic floor was apparently sufficient to provide the necessary resistance to earth ground. The original floor had been constructed in accordance with type specification F4B approximately 15 years earlier.

2. Another conductive coating type of floor was observed at NWC, China Lake. Again the coating was applied to an existing floor that no longer met the electrical resistance requirements of OP-5. There were no drawings or specification applicable to this type of floor other than the manufacturer's recommended procedure which required only that the old floor be thoroughly cleaned and dry prior to coating application. There were no instructions on how to ground the floor so the PW personnel devised their own grounding technique (see Figure 11): a 1-1/2 by 12-inch copper strap (bent into a 90-degree angle) was attached to the floor next to the wall; the coating applied over the strap as well as the floor, and the copper strap then connected to the structural steel of the building and the room ground bus by a no. 2 solid copper wire. After installation, this floor was tested for electrical resistivity and met requirements of OP-5.

3. A third conductive coating type of floor was observed at NOS, Indian Head, in a small 20 x 20-foot ordnance building. The manufacturer of this type of conductive coating did specify a grounding method (shown in Figure 12). This was an unusual floor, in that the coating became the conductive floor, rather than a coating for repair of an old conductive floor. In addition, the use of a fiberglass reinforcing layer, the rather thick (3/8-inch) layers of conductive coating, and the unusual grounding method combine to make this floor rather unique.

Conductive Floor Coverings.

The most common conductive floor coverings are vinyl tiles. The first of this type of floor covering was observed at NWS, Charleston, South Carolina, in a missile assembly and packaging building constructed in 1968. Construction drawings and contract specifications were available. The contract specification called for electrically conductive tiles (9 x 9 inches square, 3/16-inch thick) of plain backing and homogeneous material. The adhesive must be of the same material and is to be used in strict accordance with the manufacturer's recommendations. Copper foil strips, 1-inch wide and not less than 0.0025-inch thick are to be laid in the fresh adhesive, each way across the floor area at 9-inch centers, thus crossing each other at about the center of each 9 x 9-inch tile. End laps in the foil strips must be 2 inches. The vinyl tiles are then pressed into place, bonding to all floor surfaces, except that in contact with the foil strips (special precautions being taken to prevent any adhesive from spreading between the tile and the strip). The floor foil strips are connected to an internal girdle strip around the periphery of the floor; this strip is then connected to the structural steel columns by 2/0 AWG solid copper conductors as shown in Figure 13.

This building was constructed with a steel truss frame and each vertical steel beam was connected to an internal copper 1/4 x 2-inch ground bus. The ground bus was connected to the secondary external ground girdle every 20 feet around the periphery of the building. As a final precaution, all metal vents, flashing, gutters, downspouts, metal door frames, windows, ducts, pipes, reinforcing rods, machinery, and miscellaneous steel was bonded to the structural steel by a 2/0 AWG bare stranded copper conductor.

2. Another vinyl tile conductive floor was observed at NWS, Charleston, South Carolina in a small 50 x 25-foot explosive component checkout building. This building was built in 1962 and is constructed of reinforced concrete. Both drawings and contract specifications were available for this building. The applicable portions of the contract specifications are presented below.

Conductive vinyl tile shall conform to the applicable requirements of specification L-F-00450 (COM-NBC). Adhesives shall be of a type recommended by the manufacturer of the tile, and especially made for use as an adhesive bedding and fastening floor tile to concrete sub floors and base to

concrete-masonry. The area receiving conductive vinyl tile shall have conductive mastic spread uniformly over slab; copper strips (ribbon shim stock) shall be laid on mastic at centerline of each row of tile - east to west. Connect each strip at east end of building to suitable copper strap; connect two no. 6 AWG bare copper wires, one at each end of the strap, to the secondary girdle. Repeat installation at west end of building, lay conductive tile on mastic.

The drawings show the primary and secondary lightning protection system with ground connections to the structural steel and the internal ground bus bar; however, it does not show the AWG no. 6 copper conductors referred to above. Inspection of the floor revealed that the copper strip referred to above is connected to the room ground bus, thereby accomplishing the required connection to the secondary ground girdle.

3. An entirely different type of conductive floor covering was observed at NRMC San Diego, California. This hospital is a very old structure which installed the original terrazzo conductive floors in 1952. The drawings and specifications for these floors were not available. Additions to the hospital were made in 1956-57 and vinyl asbestos tiles with copper impregnation were used. These drawings and specifications also were not available. Because of the age of the conductive floors, the PWO there has recently covered some of the existing floors with a conductive sheet material called "CONDUCTIFLOR." This material consists of carbon-impregnated PVC with an adhesive on the back. The new floor meets the electrical resistance requirements of NFPA-56 when measured point to point. However, no attempt was made to ground the floor when installed; therefore, resistance measurements to ground were not made.

Nonproprietary Types of Conductive Floors. A most unusual nonproprietary type of conductive floor was observed at NAD, Crane. These floors were installed in a cluster of nine small buildings which formed a complex called the "sensitive materials" buildings. A covered walkway system interconnected the buildings as shown in Figure 14; each building contained a lead sheet floor. The floors were constructed of 1/4-inch-thick lead sheeting welded together at the seams and extended up the walls 4 inches above the floors to form a seamless pan. The primary purpose of the pan type of floor was to prevent accumulation of minute particles of the highly sensitive materials in cracks, which might occur with other types of floors. The lead floors are connected to the room ground bus and structural steel by a no. 6 AWG bare copper wire at each corner, and the ground bus is connected to the secondary girdle (Figure 14). The interconnecting, covered walkways which serve the complex are also outfitted with lead floors (Figure 15).

DISCUSSION

Existing Specifications and Codes

Only two of the existing specifications and codes are helpful to the designer of conductive-floor grounding systems. For ordnance facilities, TS-9F15a is adequate; however, it is limited to the conductive metallic topping type of floor. No other specifications exist for grounding other types of conductive floors in ordnance facilities. For hospitals, the only existing code helpful to the designer is the NFPA-56A. Even this document is lacking in that it does not tell specifically how to attach the electrical grounding conductor to the floor material. This standard does specify that the conductive floor must be attached to a no. 10 AWG copper conductor which is attached to the "room ground point." A good definition of the room ground point may be found in NFPA-76BM which originated this term and defines it explicitly.

In summarizing these two documents a difference was noted in the electrical resistance values required by TS-9F15a for ordnance facilities and NFPA-56A for hospitals. In TS-9F15a the following statement is made,

A resistance of 5,000 ohms should be specified for floor finish in a space to be provided with 110-120 volt service; 10,000 ohms should be specified when higher voltage service will be provided. The maximum electrical resistance of 250,000 ohms for ordnance is in accordance with NAVWEPS OP-5, Vol 1.

In NFPA-56A, it is stated,

The resistance of the conductive floor shall be less than 1,000,000 ohms as measured between two electrodes placed 3 feet apart at any points on the floor. The resistance of the floor shall be more than 25,000 ohms as measured between a ground connection and an electrode placed at any point on the floor, and also as measured between two electrodes placed 3 feet apart at any points on the floor.

Literature Search

As previously noted, the survey of textbooks on the subject of electrical grounding revealed scant information on how to ground a conductive floor. Specific details and design criteria were totally lacking.

The survey of manufacturers, however, was fruitful in that 9 of the 22 manufacturers replying to the survey provided suggested methods for grounding the conductive floors. The remaining 13 manufacturers never mentioned grounding of their products even though they were specifically asked for this information. The major part of the product information received was oriented toward hospitals and concerned conductive floor tiles of various types. This is one reason that grounding was not mentioned, since the older NFPA-56 did not require grounding of the

floor. Two of the conductive tile manufacturers made the flat statement, "Grounding of the floor is not required." Other manufacturers imply that the conductive floor will be sufficiently grounded by normal contact with water pipes, structural steel, and equipment normally used in the work areas for which the floor is intended. Still others imply that simply applying the conductive tile to a concrete slab in contact with the earth is sufficient grounding to dissipate accumulated static charges. All of these arguments are now invalid, not only because of the uncertainty involved but because specific guidance is now available from NFPA-56A for hospital conductive floors. Also, both TS-9F15a and OP-5 require conductive floor grounding for ordnance facilities.

Field Survey of Selected Naval Facilities

The metallic topping type of conductive floor is used primarily in ordnance facilities because of the excellent load-bearing surface obtained with this type of floor. This, plus the fact that TS-9F15a is limited to this type of floor, accounts for the preponderance of metallic-topping conductive floors in ordnance facilities. Even though TS-9F15a specifies a grounding technique, several variations of the technique were observed. One of the most common variations was to connect the floor grounding conductors directly to the secondary lightning-protection ground girdle. This is not considered detrimental since it enhances the contact to earth ground. However, deviations away from the specified ground rods or studs must be individually evaluated for compliance with the requirement for having one ground point for each 400 square feet. A careful examination of each of the metallic floor grounding systems described revealed that all met this requirement which it appears is given more importance by designers than is given to the ground rod or stud arrangement prescribed for meeting the requirement.

One problem which can occur with conductive floors poured on concrete slabs "on-grade" in high humidity or wet climates is the resistivity of the concrete. Sometimes the concrete resistivity is low enough by itself to cause a resistance-to-ground measurement of less than the required 5,000 ohms. The addition of a ground system compounds the problem by lowering the resistance further. The problem is doubly compounded if the imbedded ground rod option specified by TS-9F15a is chosen because the ground rods are inaccessible. For this reason, the ground stud option is preferred because the conductors can be disconnected from earth ground until the concrete slab cures sufficiently to exceed a measurement to ground of 5,000 ohms and then reconnected. Another reason for preferring the ground stud option is for maintenance; imbedded ground rods are inaccessible, which is not true of ground studs.

The conductive organic type of conductive floor is common to both ordnance facilities and hospitals. The application to ordnance facilities, however, is limited to light-duty areas since this type of floor does not have the heavy-load bearing capability of the metallic topping floors. Until recently, the designers of facilities requiring this type of conductive floor have been without guidance in the grounding of the floors since TS-9F15a and its predecessors did not apply to organic

topping floors and NFPA-56 did not require grounding. Guidance is now available for hospital designers from NFPA-56A, lacking only the details of how to provide an intimate contact between the no. 10 bare ground conductor and the floor material. Designers of ordnance facilities considering the use of organic toppings may also make use of the guidance provided by NFPA-56A. A good example of the practical application of the guidance provided is the description of the conductive floor grounding system for NRMCC, Camp Pendleton.

Conductive floor coatings are usually used by ordnance facilities in an attempt to repair an old floor that no longer meets the conductivity requirements of OP-5. This "paint-on" material provides a very thin (1/16 inch or less) layer of conductive surface. There are no applicable specifications or guidance other than the manufacturer's recommended procedure to help the designer. The fact that the coating layer is so thin makes it difficult to attach any kind of grounding arrangement. The two methods recommended by the manufacturers who responded to the inquiry are not considered adequate. The basic problem is the physical instability of the copper strips or tapes they recommend. The strips could easily be dislodged by heavy traffic. In addition the thin layers are subject to cracking and possibly peeling. A much better approach (shown in Figure 14) is the one used at NOS, Indian Head. In this instance a fiberglass reinforcing layer was used to obtain mechanical rigidity, and the coating was applied both above and below in very thick layers. The thick layers allow the grounding attachment to be completely immersed in the coating, thereby avoiding the problem of being easily dislodged.

Conductive floor covering is usually a vinyl tile floor intended for light load areas in ordnance facilities. The grounding methods for these floors presented by the manufacturers are regarded as inadequate. The methods of grounding observed in the facilities survey are much better since every tile is directly grounded by the crisscross copper strips. Conductive mats or sheets, however, present a different problem. The adhesive supplied with them is usually not conductive, thereby making electrical connection to the mat difficult. In order to insure a mechanical bond to a ground strap, a riveting process would have to be used, resulting in an awkward and unsightly arrangement. The conductive mats or sheets are best used as temporary conductive floors and are not regarded favorably for permanent installations.

During the survey, it was found that the personnel at the ordnance facilities were very aware of the potential hazards of static electricity and maintained their conductive floors as well as they could. However, hospital personnel were more relaxed in their attitude toward conductive floors. On 5 September 1974 the Bureau of Medicine and Surgery issued BUMEDINST 5100.52 BUMED-41-1 which clearly states that no flammable anesthetics are to be used in Navy hospitals. As a result, hospital and PWO personnel have neglected maintenance and testing of their conductive floors. The general feeling among hospital personnel is that the conductive floors are no longer required.

DESIGN AND INSTALLATION CRITERIA

Based on the results of the investigation, the grounding system for conductive floors must meet, as a minimum, the following three requirements:

1. There must be intimate contact between the conductive floor material and the ground conductors.
2. The ground conductors must be of sufficient size and number to adequately conduct the charge currents to ground.
3. There must be intimate contact between the ground conductor and earth ground.

By extracting data from the various documents reviewed and the observations made at the various Naval facilities the design criteria which will satisfy the above requirements may be derived in the following manner. From TS-9F15a, a 2-inch round or square piece of copper or brass hardware cloth (4 mesh, 0.047-inch wire diameter) is specified as providing sufficient intimate contact area between the floor material and the ground conductor. In addition, there is to be one of the intimate contacts for every 400 square feet of floor space. Further, in the ground stud method of TS-9F15a, each of these intimate contact points is to be connected to another electrically by means of a no. 6 AWG bare copper conductor by brazing at each point. It can be shown theoretically [27] that the type of ground connection used for the secondary lightning protection system provides an earth ground superior to the conventional 10-foot vertical ground rod. The ground girdle is therefore the preferred grounding method, and it is to this that the no. 6 AWG ground conductor should be attached. The exothermic type of weld is preferred for contact with buried connections. If there is no ground girdle, then the "ground rod" method described in TS-9F15a (where the ground rod for each wire mesh contacts the floor) can be used, with the ground rods located around the periphery of the building.

Thus, the design criteria for ordnance facilities are:

1. A minimum of 3 square inches of intimate contact surface area must exist for each 400 square feet of conductive floor surface area.
2. Each intimate contact area must be brazed to a no. 6 AWG solid bare copper conductor connected to a suitable and approved earth ground.
3. The suitable and approved earth ground may be either the ground girdle of the secondary lightning protection system constructed in accordance with NAVFAC DM-4, or a series of 1-inch-diameter, copper sheathed, steel ground rods 10 feet long driven vertically around the periphery of the building (one ground rod for each conductive floor contact point).
4. A minimum of 5,000 ohms must be maintained between the ground conductor and an electrode placed anywhere on the floor of the area where 110 volt AC service is used. A minimum of 10,000 ohms must be maintained between the ground conductor and an electrode placed anywhere on the floor of the area where 220 volt AC service is used.

The basic design criteria for grounding conductive floors in Naval hospitals may also be stated as follows:

1. A minimum of 3 square inches of intimate contact surface area must exist for each 400 square feet of conductive floor surface area.
2. Each intimate contact area must be brazed to a 110 volt AC, no. 6 AWG solid bare copper conductor connected to the room grounding point terminal bus.
3. The room ground point terminal bus is a wall-mounted, highly conductive, bare metal bar mounted on insulated supports and containing (a) approved terminals for grounding each electric receptacle in the room, and (b) at least three approved receptacles for grounding metal furniture in accordance with NFPA-76BM.
4. The resistance of the floor shall be more than 25,000 ohms as measured between the room ground bus and an electrode placed at any point on the floor.

CONCLUSIONS

The following conclusions were drawn in regard to Naval ordnance facilities:

1. TS-9F15a is the only existing specification that provides useful conductive floor grounding design guidance. (This specification applies to the conductive metallic topping floor but the design criteria provided can be extracted and applied to other types of conductive floors.)
2. Use of the secondary lightning protection ground girdle as the earth grounding system is very common and entirely acceptable.
3. All conductive floors in ordnance facilities must be intentionally earth grounded.

The following conclusions were drawn in regard to Naval hospitals:

1. All conductive floors must be grounded to the electrical system ground in accordance with NFPA-56A, which is the only document to provide guidance on where or how to ground the conductive floors.
2. The design criteria used in TS-9F15a to establish intimate contact between the ground conductor and the floor material can be used to supplement the guidance provided by NFPA-56A.

RECOMMENDATIONS

1. NAVFAC type specification TS-9F15a should be modified to allow grounding of conductive floors to the ground girdle of the secondary lightning protection system where convenient.

2. NAVFAC type specification TS-9F15a should be revised to include the conductive organic topping type of floor by allowing 1-inch-wide, 15-gauge-thick copper strips to be substituted for the no. 6 AWG copper conductor and by dropping the 2-inch-square mesh requirements.

3. The conductive coating type of floor should be installed in thickness not less than 1/16 inch and 1-inch-wide, 15-gauge-thick copper ribbons used to meet the grounding criteria. (This applies to new construction, converting an existing floor to a conductive floor, or repairing an existing conductive floor.)

4. The conductive tile floor coverings should be grounded by using a criss-cross pattern of 1-inch-wide, 15-gauge-thick copper ribbons laid on the mastic so that the cross of the ribbons occurs under the approximate center of the tile with no mastic between the tile and the ribbon surface.

5. Solid metal floors should be grounded by attaching no. 6 AWG or larger bare copper conductors between the floor (one for each 400 square feet) and earth ground. Note that this type of floor construction violates the minimum resistance-to-earth ground criteria, therefore the electrical hazards introduced must be handled by other means (e.g., use of double-insulated tools, isolated power, etc.).

6. Suspended conductive floors should be directly connected to earth ground rather than to the structural steel of the building.

7. The conductive floors in hospitals must comply with the requirements of NFPA-56A, using the criteria developed therein; intimate contact with the floor must be provided by the copper strip method.

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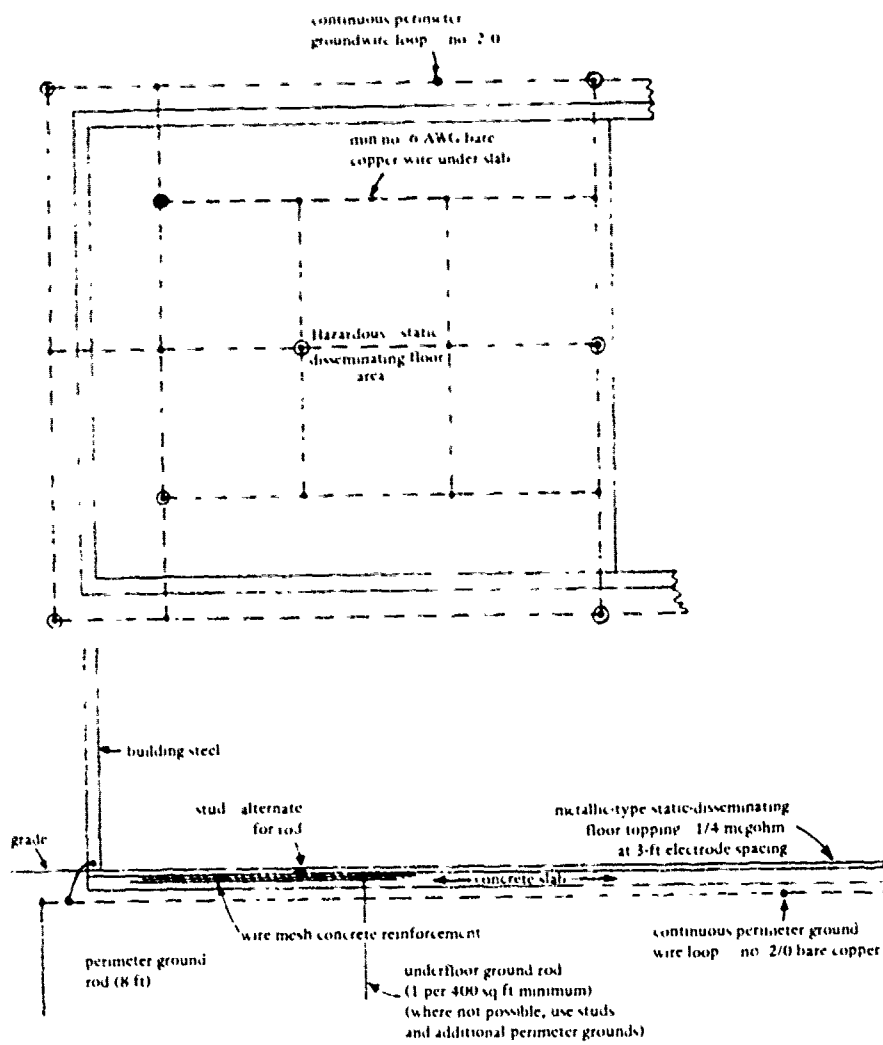


Figure 1. Conductive metallic topping floor and grounding plan at NAD, Crane, based on NAVFAC TS-9F15a.

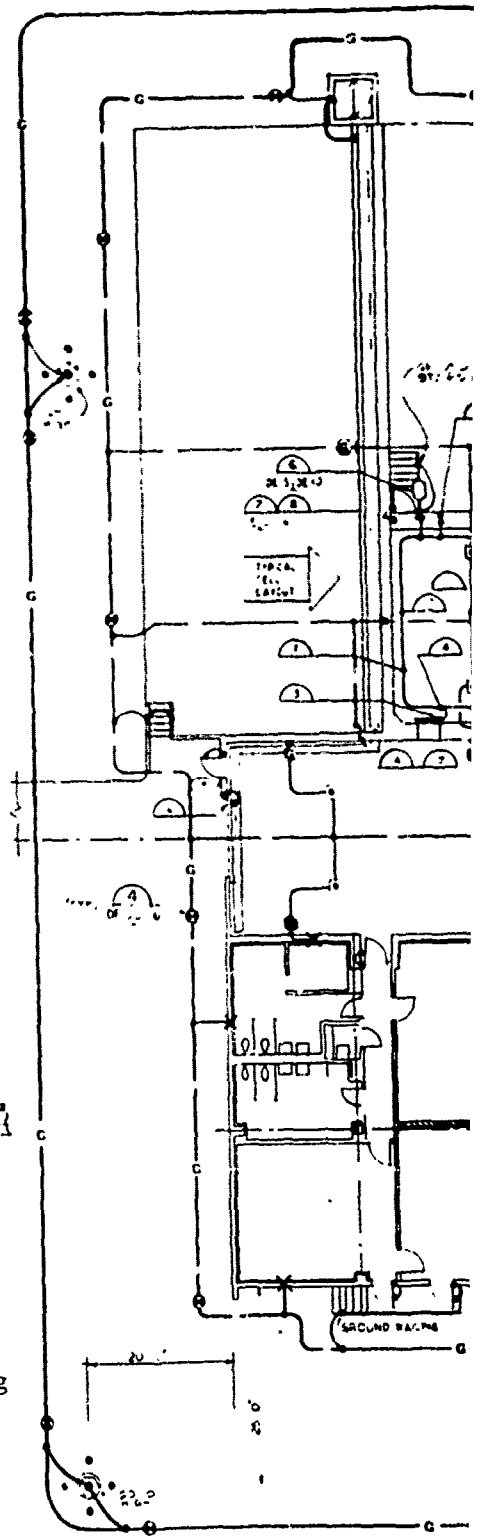


Figure 2.

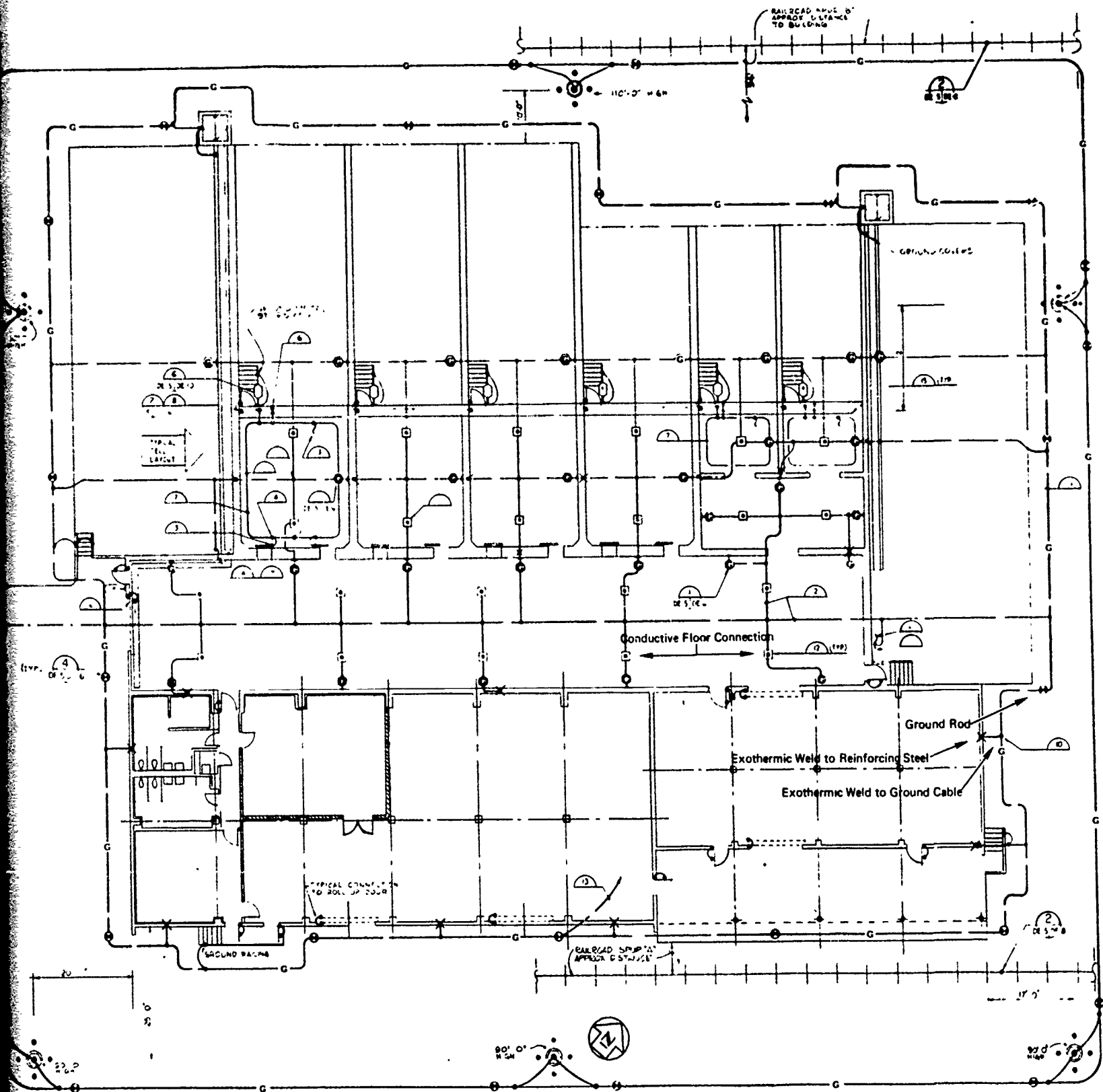


Figure 2. Reproduction of floor plan for conductive metallic topping floor and grounding installation at NAD, Hawthorne, which was based on NAVFAC TS-9F15a.

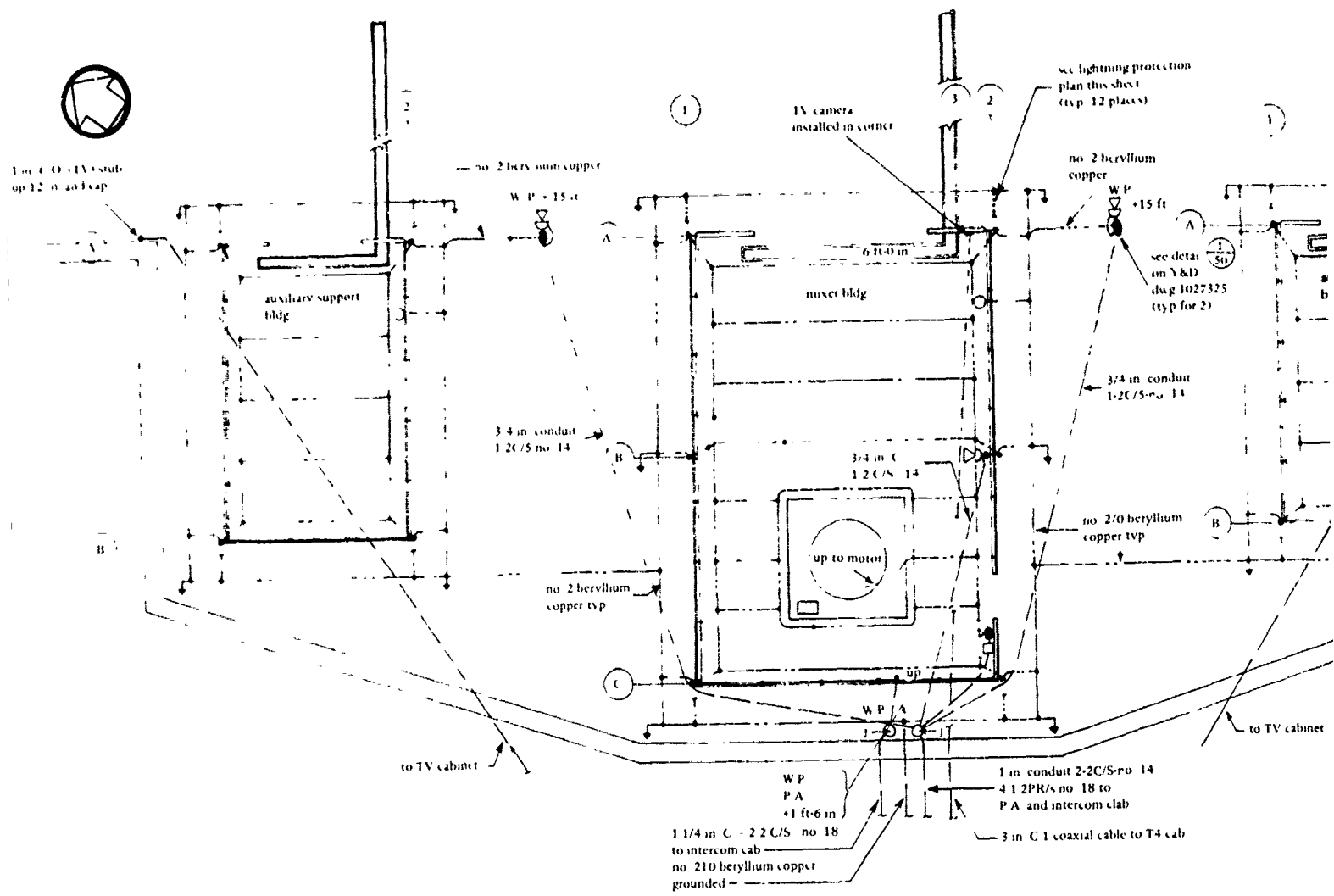
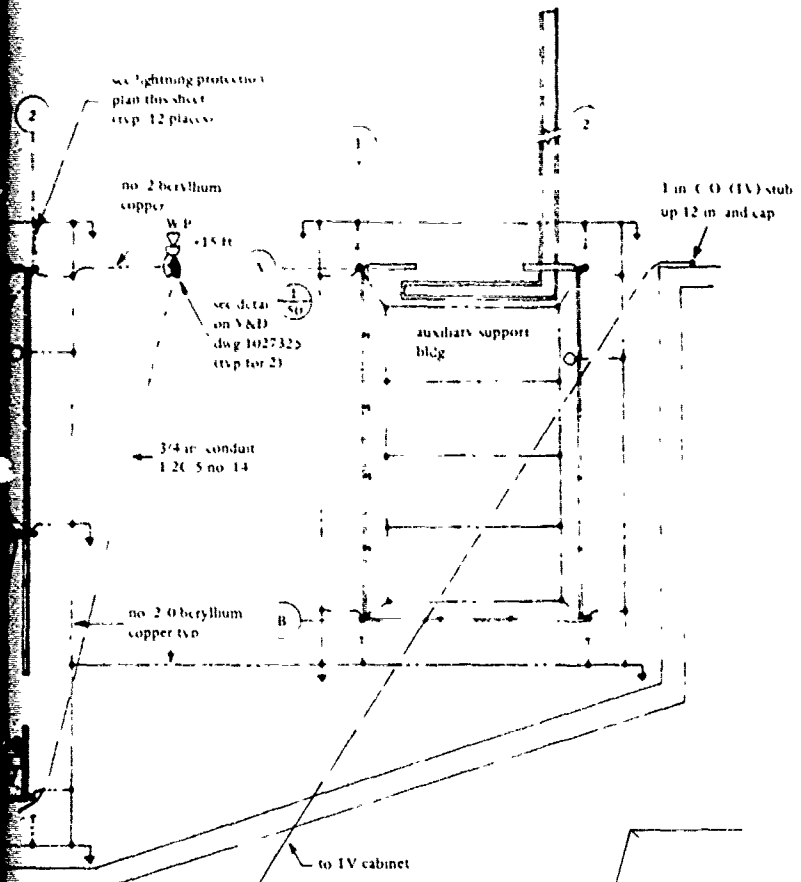
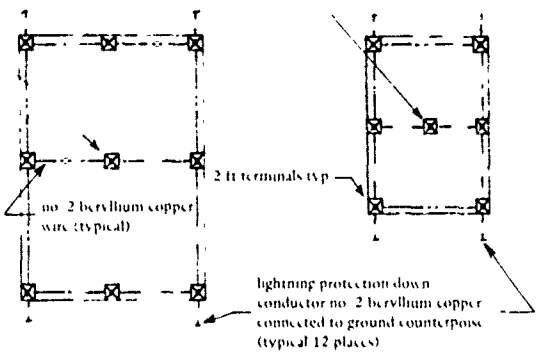
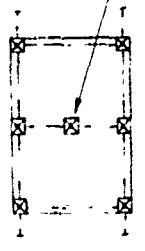


Figure 3. Conductive metallic topping floor and ground lation diagram for a remotely controlled pr facility at NWC, China Lake.

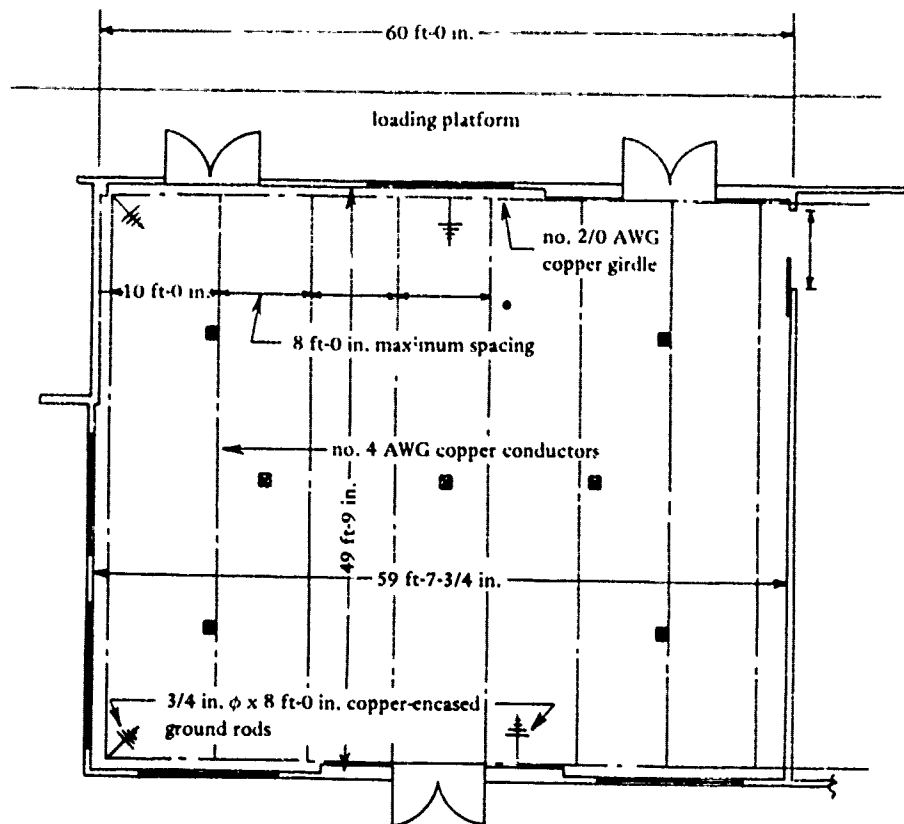


- 1 in conduit 2-2C/S-ro 14
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- 3 in C.1 coaxial cable to 14 cab



lic topping floor and grounding instal-
 for a remotely controlled propellant mixing
 China Lake.

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Symbols

- 3-1/2 in. brass cleanout plug
- 9 in. square floor drain
- 8 in. square aqua flow cap
- ⊥ 3/4 in. ϕ 8 ft-0 in. ground rod

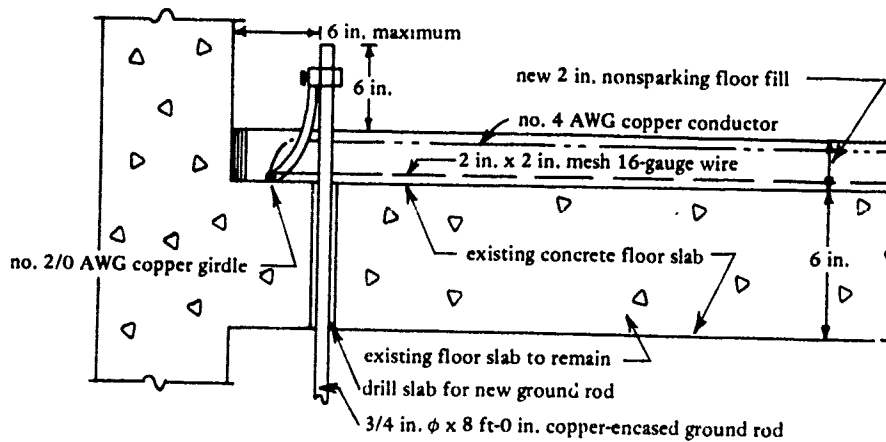


Figure 4. Conductive metallic topping floor and grounding installation diagram showing use of an internal girdle at NAD, Hawthorne.

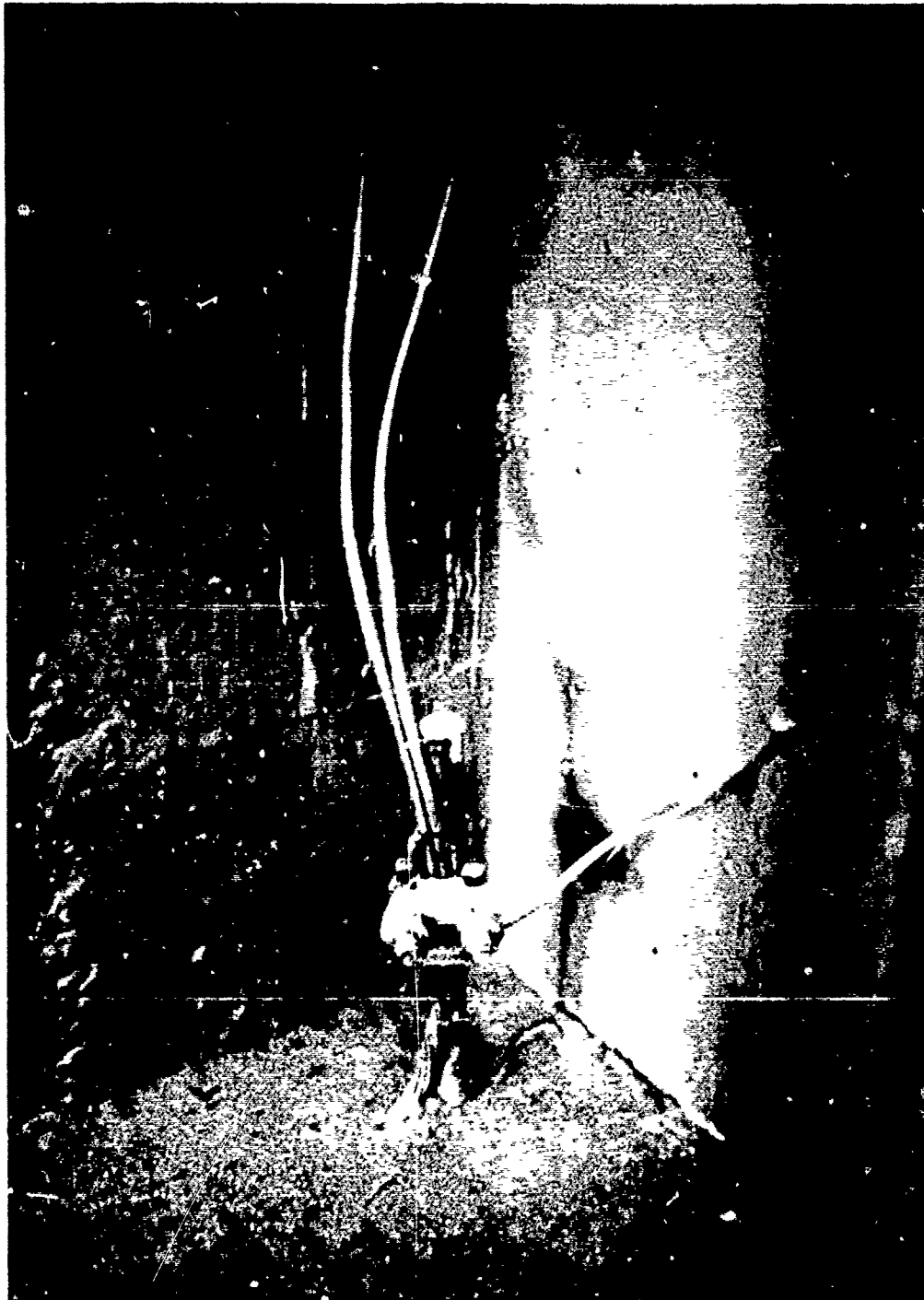
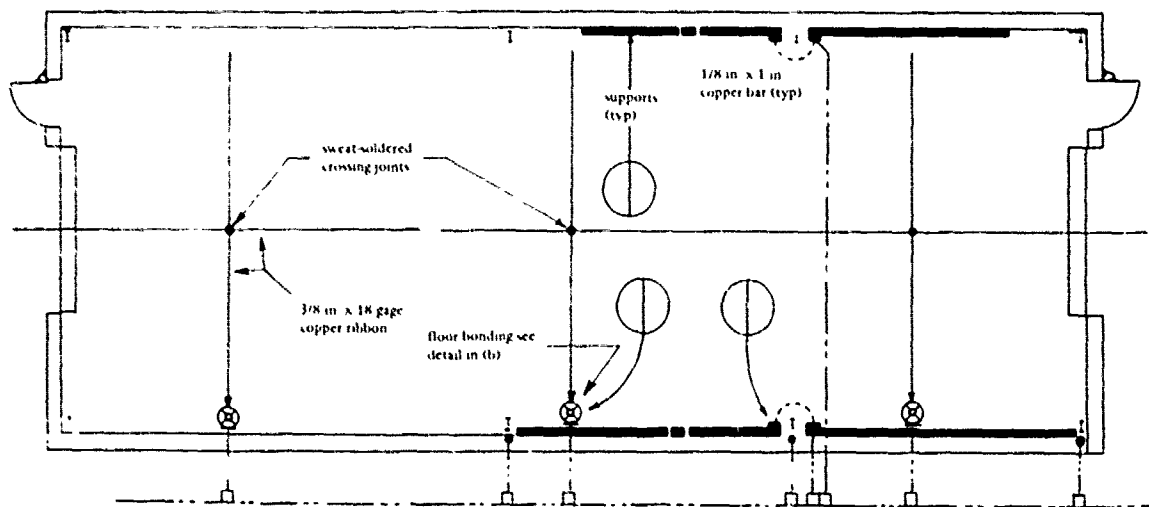
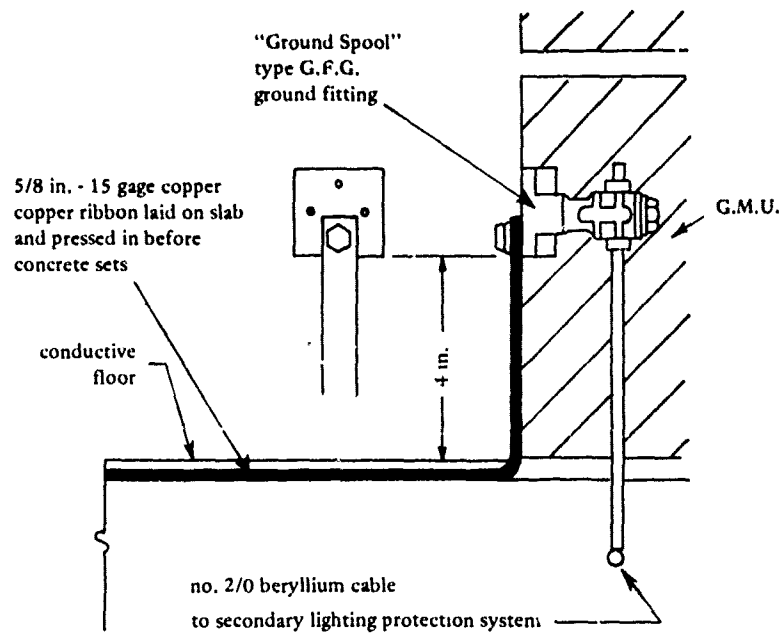


Figure 5. Internal ground rod showing mechanical connections to internal girder and ground bus.



(a) Ground strap installation diagram



(b) Conductive floor grounding detail drawing, ASW building.

Figure 6. Conductive metallic topping floor and grounding installation diagram showing use of crossed copper ribbons at NWS, Seal Beach.

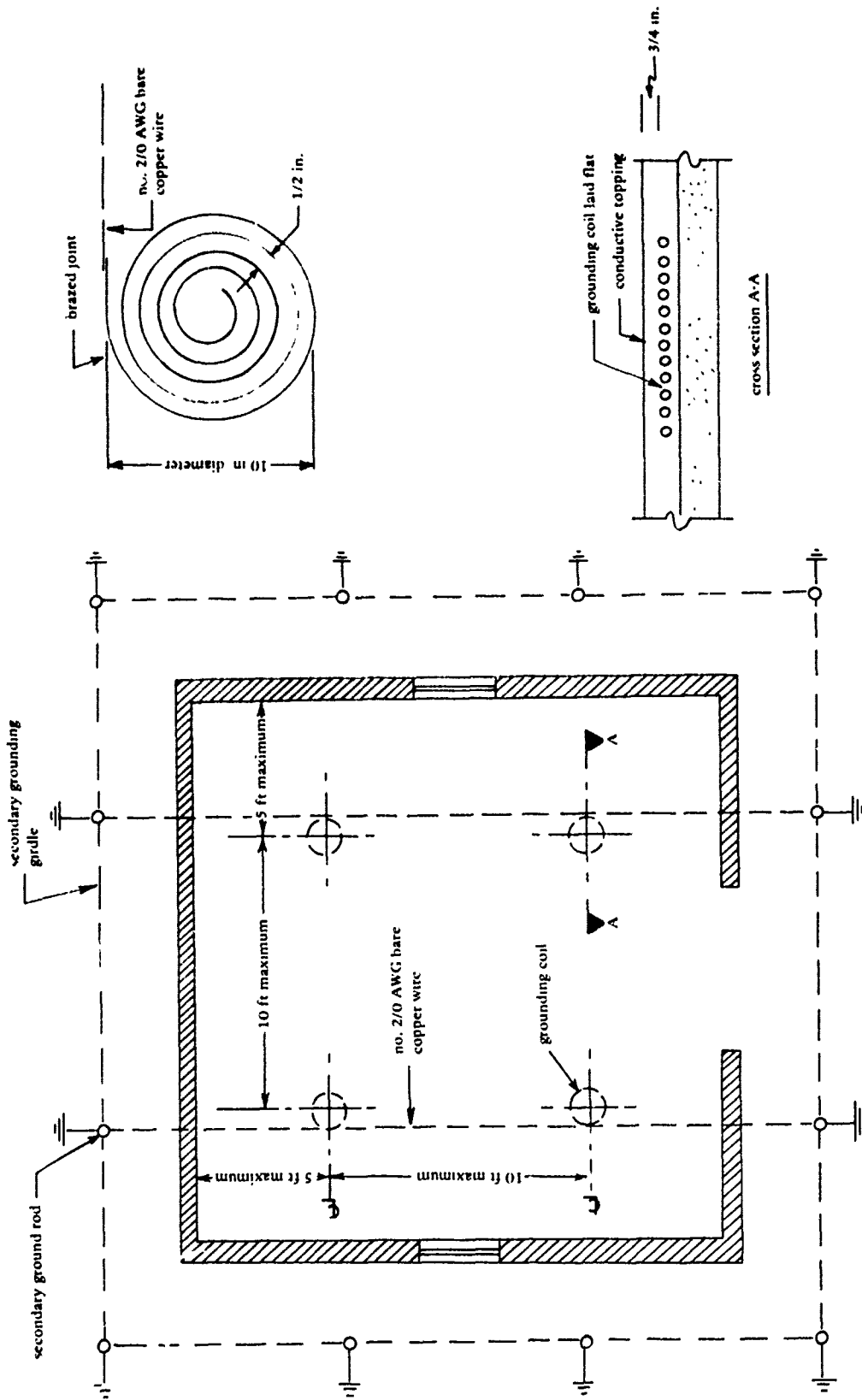


Figure 7. Conductive metallic topping floor and grounding installation diagram showing use of copper grounding coils at NOS, Indian Head.

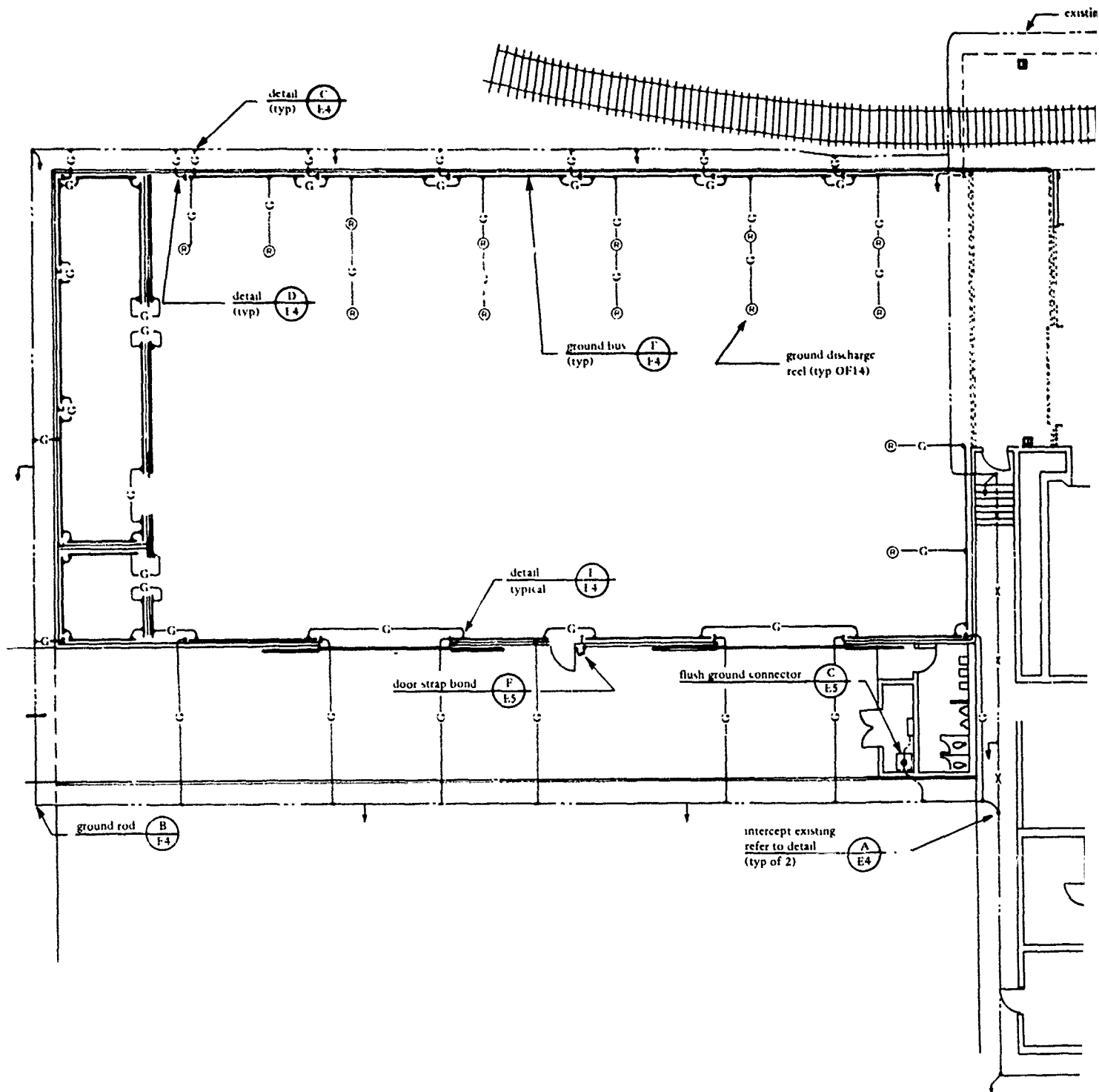
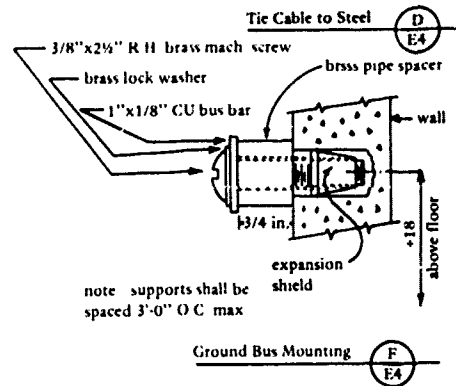
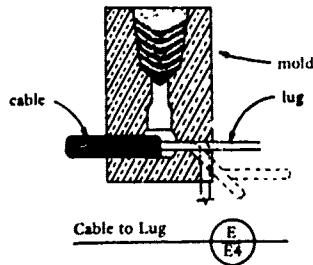
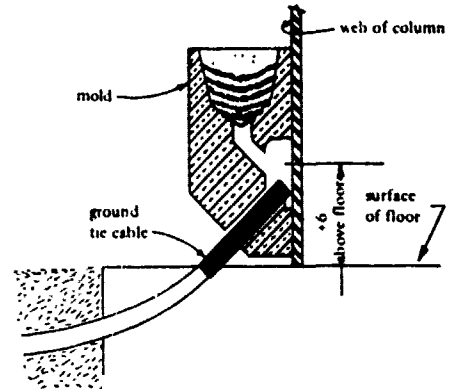
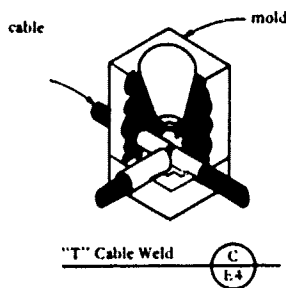
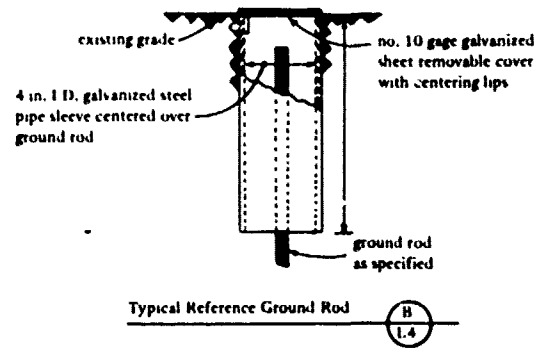
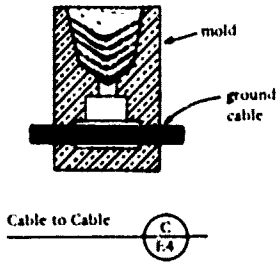
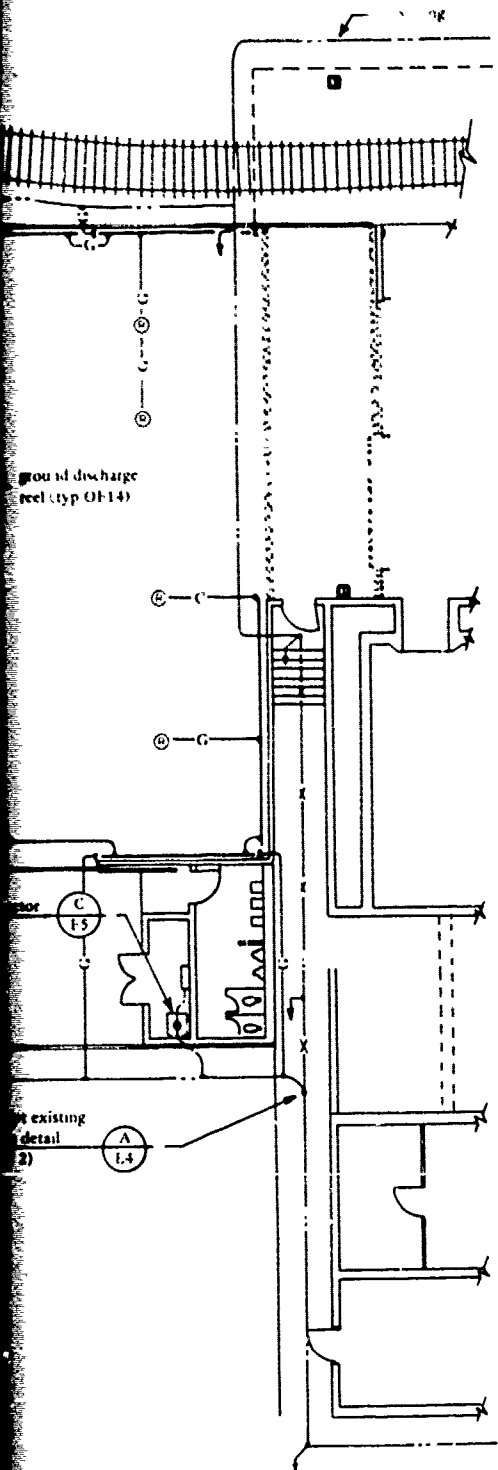


Figure 8. Conductive organic topping f
lation diagram showing periph
Seal Beach.



Conductive organic topping floor and grounding installation diagram showing peripheral grounding at NWS, Seal Beach.

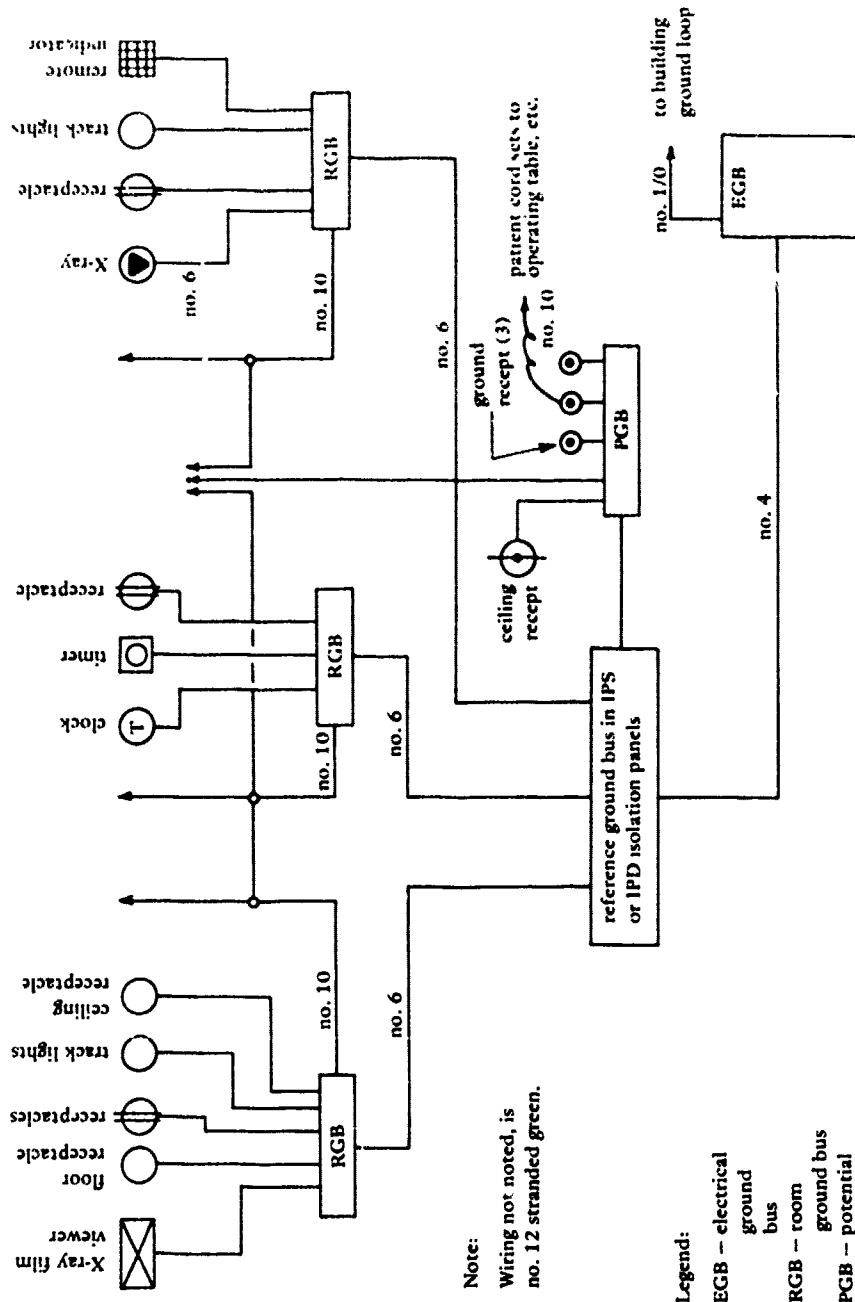


Figure 9. Typical surgery and delivery room equipotential grounding diagram for NRMC, Camp Pendleton.

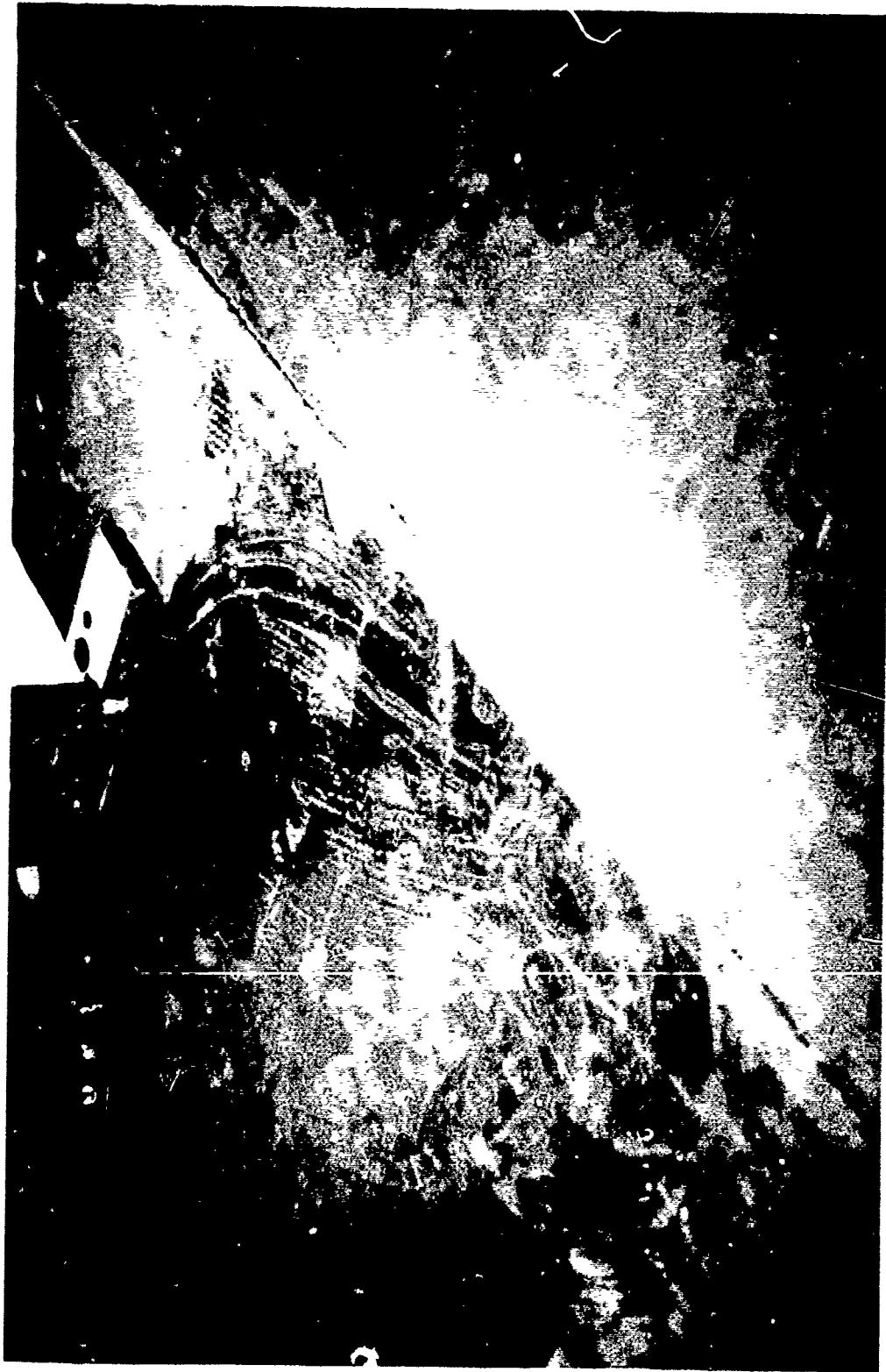


Figure 10. Conductive floor coating applied to an older conductive floor at NAD, Hawthorne, to upgrade the electrical resistivity.



Figure 11. Conductive floor coating applied to an older
conductive floor at NWC, China Lake, to upgrade
the electrical resistivity.

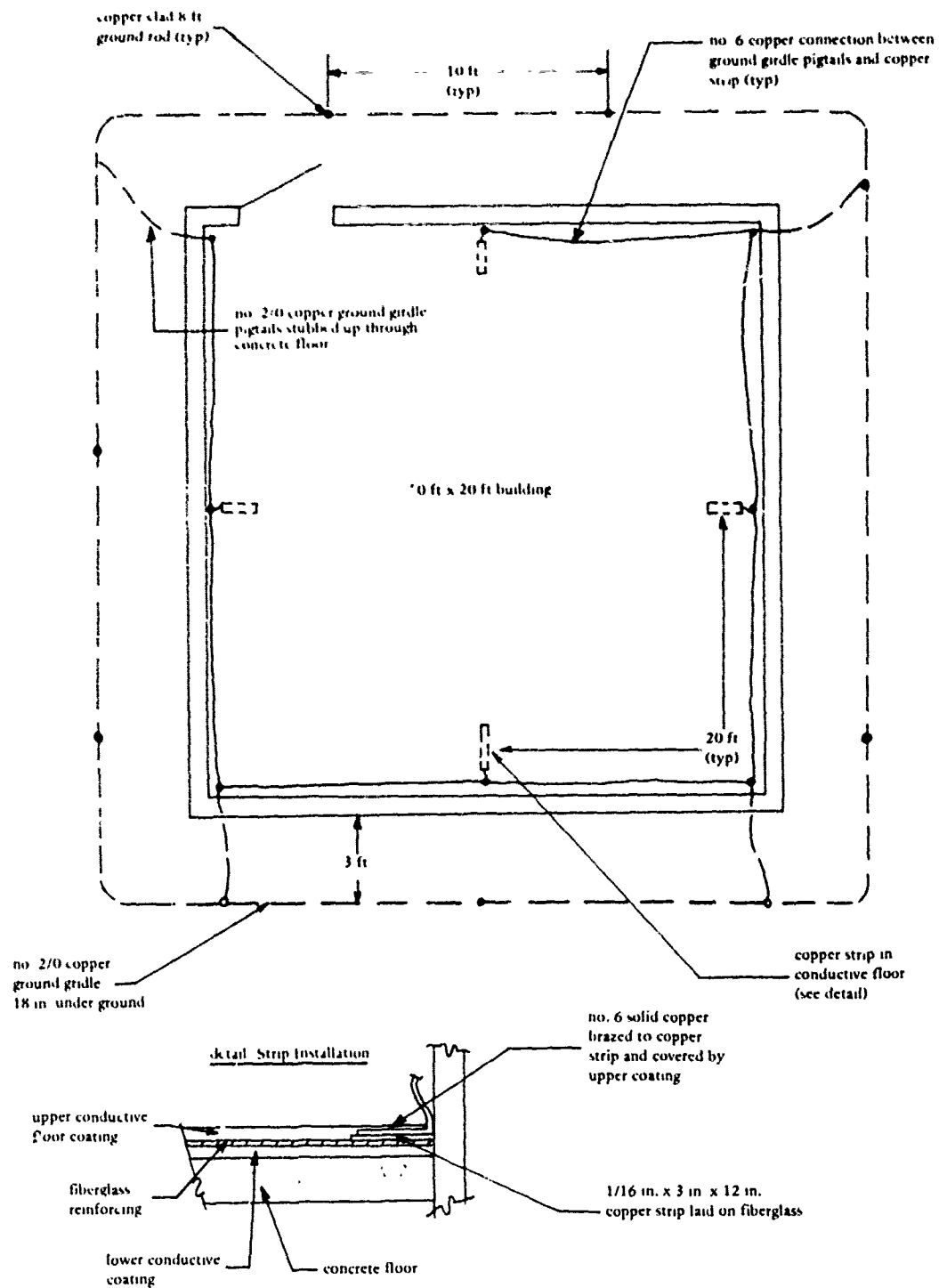


Figure 12. Conductive floor coating and grounding installation diagram used in original construction at NOS, Indian Head.

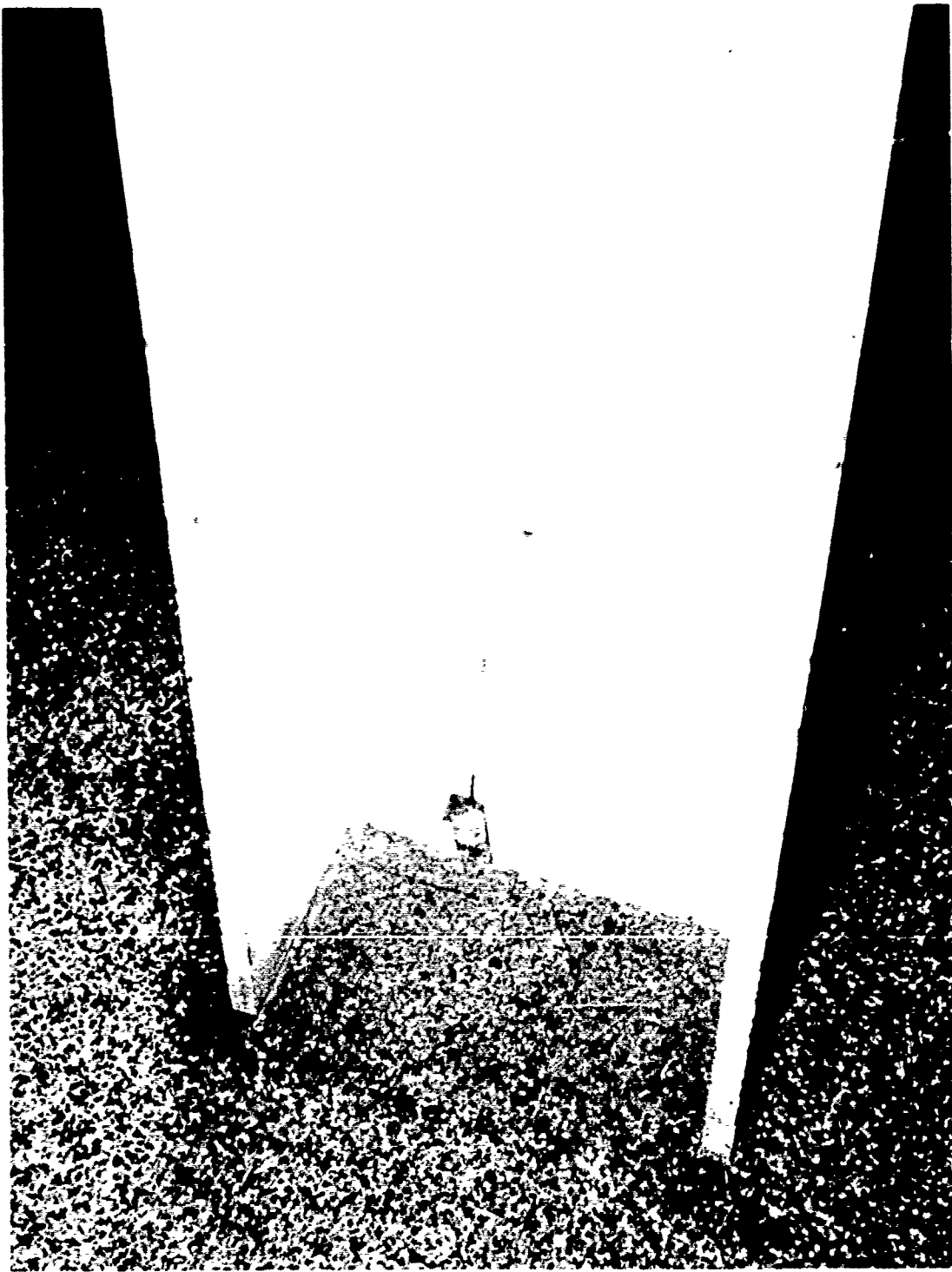


Figure 13. Conductive floor covering of 9 x 9-inch vinyl tile laid on copper strips connected to vertical structural steel for grounding at NWS, Charleston.

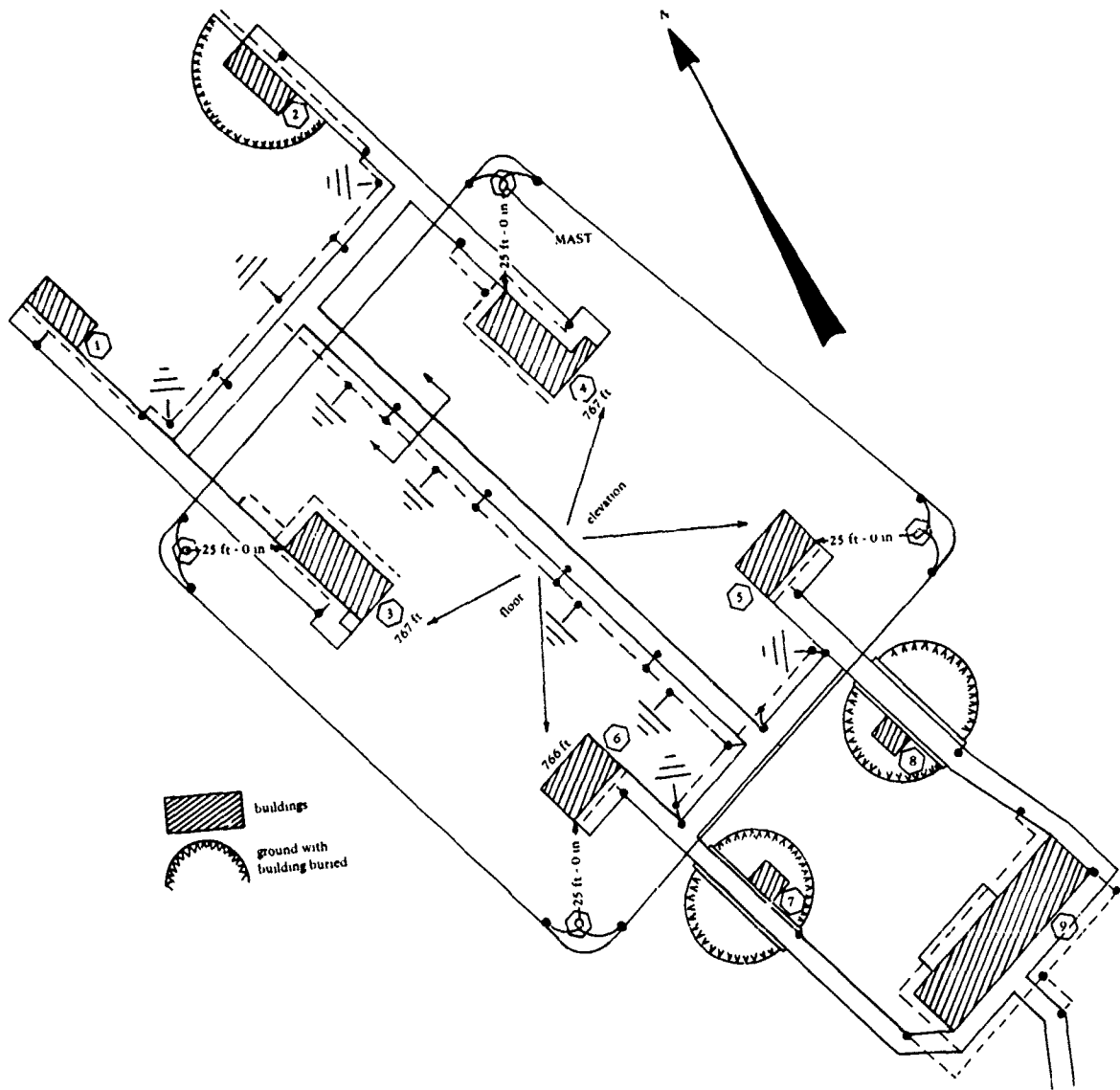


Figure 14. Building complex for handling sensitive materials designed with lead sheet floors and walkways at NAD, Crane.

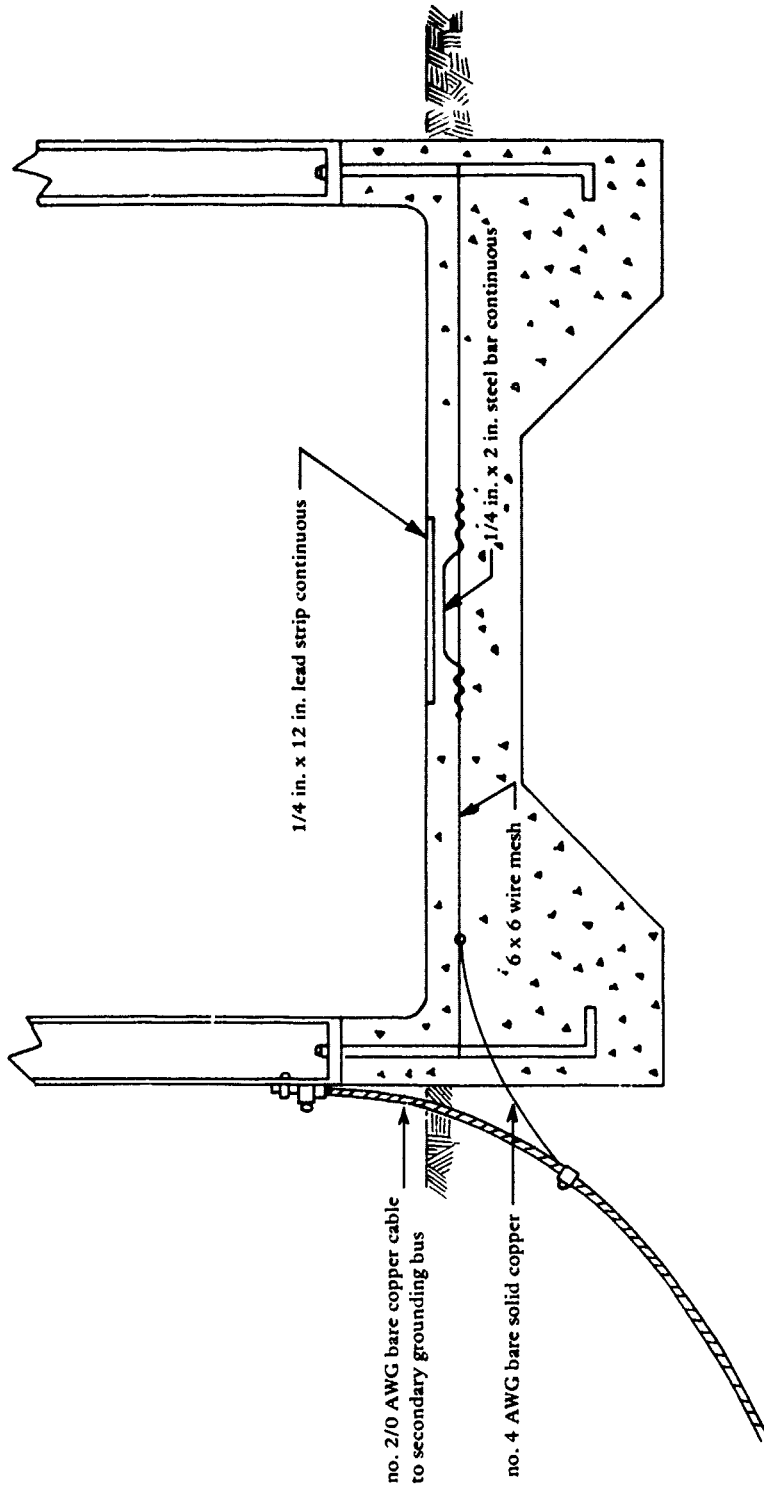


Figure 15. Cross section of grounded, lead-surfaced walkway interconnecting sensitive material buildings at NAD, Crane.

Appendix

FACILITIES VISITED DURING FIELD SURVEY

NAVAL ORDNANCE

Naval Weapons Center, China Lake, California
Naval Ammunition Depot, Hawthorne, Nevada
Naval Weapons Station, Seal Beach, California
Naval Weapons Station, Concord, California
Naval Weapons Station, Charleston, South Carolina
Naval Weapons Station, Yorktown, Virginia
Naval Ordnance Station, Indian Head, Maryland
Naval Ammunition Depot, Crane, Indiana

NAVAL MEDICAL CENTERS

Naval Regional Medical Center, Oakland, California
Naval Regional Medical Center, Long Beach, California
Naval Regional Medical Center, Camp Pendleton, California
Naval Regional Medical Center, San Diego, California

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