Engineering Analysis of Grounding Issues
Reactor Protection/Process Control Group Replacement Project
Donald C. Cook Nuclear Plant Units 1 & 2

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I. Introduction

As a part of the Reactor Protection / Process Control Group Replacement Project, it is necessary to evaluate the various interfaces with the new equipment. One of the important interfaces to the new racks is the equipment grounding scheme, and the grounding practices to be used when maintaining this equipment.

II. Purpose

The purpose of this report is to provide an evaluation of the grounding schemes at Donald C. Cook Nuclear Plant (DCCNP) with respect to the replacement equipment. Grounding practices contained within various industry standards will be used as guides in evaluating the DCCNP grounding program.

III. Methodology

Equipment grounding accomplishes several functions in power plant applications. All of these functions should be considered during the design and installation of a grounding system.

This report will evaluate the grounding system from a design standpoint and provide recommendations for grounding practices to be used on the Foxboro and Kent-Taylor equipment to provide adequate assurance that the grounding interface for the replacement systems is acceptable. The scope of this review will include the following technical aspects of grounding systems.

A. Ground Fault Protection - Return Paths to Power Sources
B. Short Circuit Protection - Power System Faults
C. Lightning Strike Effects
D. Personnel Safety Grounds
E. Ground System Design and Life Expectancy
F. Electromagnetic Shielding for Sensitive Circuits

IV. References

IEEE 81.2; Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems.

IEEE 1050; Guide for Instrumentation and Control Equipment Grounding in Generating Stations.

IEEE 518; Guide for Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources.

IEEE 308; Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.

IEEE 384; Standard Criteria for Independence of Class 1E Equipment and Circuits.

IEEE 665; Guide for Generating Station Grounding.

Federal Information Processing Standards Publication (FIPS) 94; Guideline on Electrical Power for ADP Installations.

National Fire Protection Association "National Electric Code"; 1993 Article 250 on Grounding Systems.

Foxboro Vendor Manuals on Spec 200 and Spec 200 Micro Instrumentation.

Kent Taylor Mod 30 Vendors Manuals.

American Electric Power Co. Electrical Plant Design Section Plant Design Standards PDS-1370, PDS-1371, PDS-1373, & PDS-1383.

American Electric Power Co., Electrical Plant Designs Guidelines 70.1 through 70.4.

American Electric Power Co., Design Drawings as listed on following pages.

National Fire Protection Association (NFPA) Lightning Protection Code #78.

References cont.

Hurst Engineering Incorporated Report # 2985-HEI-06, Revision 0.

Detailed List of Foxboro Vendor Manual Information.

TI 200-260; August 1973, Spec 200, System Wiring.

TI 200-265; March 1972, Spec 200, Nest Loading.

TI 200-270; June 1972, Spec 200, Analog System Power.

TI 200-274; July 1980, Spec 200, Independently Powered Loops.

Detailed List of Kent-Taylor Vendor Manual Information.

IB-23A121 Issue 3; March 1988; Power and Signal Wiring Using 1730F Termination Board.

IB-23A118 Issue 2; June 1988; Power Wiring and Cable Connections Using 1720F, 1728F, 1733F and 6047N Termination Panels.

IM-LRS-57; 1.90; Instruction Manual for Regulated Power Supplies, LRS-57 Series.

IM-CMS-6000; Instruction Manual for Regulated Power Supplies; LMS-6000 Series.

IM-LMS-9000; Instruction Manual for Regulated Power Supplies; LMS-9000 Series.

List of AEP Drawings Reviewed

Dwg. 12-1201-16; Installation of Station Grounding Grid.

Dwg. 1-1446T-4; Plan of Elect. Equipment & Cable Troughs Aux. Bldg. Below Elevation 650'- 0".

Dwg. 1-1453A-1; Control Room Cable Vault and Grounding EL. 633'- 0" & Below.

Dwg. 2-1446-114; Plan of Elect. Equip, Conduits, & Cable Troughs Aux. Bldg. Below EL. 650'- 0".

Dwg. 2-1446B-40; Plan of Elect. Equip, Conduits, & Cable Troughs Aux. Bldg. Below EL. 650'- 0".

Dwg. 2-1452-12; Plan of Control Room Equipment-Designation and Location of Cable Plate openings EL. 633'- 0".

Dwg. 2-1453-1; Control Room Cable Vault-Trough Hanger Locations & Grounding.

Dwg. 1-1454-4; Control-Room Cable Vault BOP Cable Routing Diagram and Access Paths.

Dwg. 2-1454-1; Control Room Cable Vault BOP Cable Routing Diagram and Access Paths.

Dwg. 1-2-1202-4; Containment Building Lightning Protection.

Dwg. 2-1453A-0; Control Room Cable Vault and Grounding Elevation 633'- 0" & Below.

Dwg. 12-1453-00; Grounding Details for Control Room Cabinets.

Dwg. E-42373-1001-20; Topographical Location Plan.

V. Analysis

A ground mat provides the optimum in grounding protection for power plant equipment and systems. A grounding mat is a complex matrix of grounding conductors and bonded interconnected wire developed to provide a low resistance interface with the earth and to integrate a large plant or facility into a single ground plane. The DCCNP has designed and constructed a ground mat scheme which affords maximum flexibility and protection.

The grounding mat designed by AEP for DCCNP utilizes redundant mechanical connections between the grounding conductors and the risers that extend the ground mat upward toward the top of the facility. This redundant connection ensures that the grounding system is not broken or compromised.

The current plant configuration consists of a ground mat tied by cadwelded (bonded) connections to vertical risers which extend the ground mat to the cable vault for the main plant control complex. The existing Foxboro H-line equipment is tied to the ground mat by mechanical connection. The control panels are bolted together and bonded to the ground mat risers. This grounding configuration is depicted in Figure #1 for Unit #1 and Figure #2 for Unit #2.

As part of the RPS instrumentation replacement, the grounding configuration will be revised within the instrument racks to improve ground continuity within independent protection groups. The new configuration will consist of a solid copper bus bar traversing the rear of the rack at the base, with continuity established to the adjacent racks by a 4/O or equivalent copper ground braid. There will be two vertical ground bus bars, per rack. The ground bus bars within each rack will be mounted to the rear vertical frame channels. The equipment grounds and cable shield wires will be brought to these ground bus bars and connected in accordance with manufacturer's requirements and recommendations.

The grounding configuration is depicted on reference drawing No. 12-1453-00. Some minor improvements are also planned in the control room ground system connections as part of this replacement project, to improve overall access to the station ground.

A. Control Room Grounding Configuration:

The control room grounding configuration is defined by reference drawing No. 12-1453-00 and its associated details. The grounding system provides a redundant ground return path to the plant ground for all protection and control racks. The grounding mat scheme provided by AEP for DCCNP provides a low resistance, mechanically redundant, electrically solid system not only for protection of control room equipment and personnel but also protection of the entire plant. This scheme also provides for reduction or rejection of high frequency electrical noise signals through the use of an interconnected ground potential equalization circuit utilizing a common ground reference point. AEP Design Standards require proper termination of signal shield wires. Further, Plant Design Standards require that the grounding system be redundant and that all new electrical equipment installations have two independent paths to a secure ground bus. Electromagnetic conducted noise level data taken on equipment grounds indicated low levels compared to conducted noise tests run on power and instrument cables. This indicates both the absence of significant conducted noise entering the cabinets via this path. Further, this indicates the effectiveness of the ground paths present for higher frequencies to be dissipated in parallel with the low resistance grounding system. Based on the design standards addressed above, it is concluded that the grounding requirements for the control room are adequate.

B. Analysis of New Design Versus Vendors Requirements

Foxboro (Protection)
The Foxboro Spec 200 System to be utilized at the DCCNP has a limited set of grounding design requirements. The specifications require that all grounds, shields and signal commons shall be terminated to the bonded plant grounding mat. All cable shields should be run as directly as possible to the panel ground bus bars to reduce system impedance. The power supplies used in the Foxboro Spec 200 Instrumentation upgrade at DCCNP can be configured in either a positive (+), negative (-), or ungrounded configuration depending on the system requirements. For the DCCNP installation the power supply common will be ungrounded. The power supply ground will be taken to the bonded plant ground mat on the grounding bus bars in the racks.

Taylor (Control)

The Kent Taylor Mod 30 system requires that the primary power system ground be bonded to the plant electrical ground mat. The Mod 30 termination board is bonded to the primary power ground terminal of the AC input terminal block through a bonding jumper. The termination board is bonded to the housing after assembly of the termination to the housing.

The power supplies used for the Mod 30 instruments at AEP are Lambda series 57, 6000, & 9000, all of which can be operated with either a positive (+), negative (-), or ungrounded configuration depending upon the system requirements.

The circuit common for the Mod 30 instruments is a grounded common negative (-). The common is tied on to the Termination Board by the -24 VDC power wiring common. The system receives power and signal wiring via the instrument cable from the termination board.

The shields are to be landed on the ground bus in the control room racks wherever possible. The shields are to be terminated at one point only to eliminate potential ground loops.

Static Drain clips are to be daisy-chained through the instrument housings, and brought to ground at the nearest vertical ground bus for noise immunity.

All of the grounding/shielding requirements for the Foxboro and Kent Taylor Mod 30 instrumentation are met by the AEP/DCCNP design. The specific details for ground conductor bonding to the ground mat is provided in the attached figures of this document.

VI. Potential Sources of Ground Faults

Ground fault protection for the 26 KV system, comprised of the main generator, step-up transformers, and the associated interconnecting bus work is provided by a standard high impedance grounding system. This system of power conductors is totally enclosed in an aluminum magnetic flux shielded bus work enclosure and has its ground fault current limited to approximately 12 amperes.

The system utilizes ground fault protection relays to detect a system fault and trip the generator from service. Ground faults on this system are nearly undetectable from outside the system and are of no concern to the applications in the RPS replacement modification.

The 4160 volt system ground faults are limited to approximately 2000 amperes to avoid damage to equipment. The 2000 ampere fault load limit was chosen to correspond to the steady state current anticipated in the system for balanced three phase load operation. All the 4160 circuits are routed well away from the control room in embedded conduits or raceway and are not routed with instrument, control or low level power circuits.

The 575/600 volt system is operated ungrounded. Ground faults on this system would result in a very small capacitive current that would not be detectable by the control room instrumentation. Grounds on this system are alarmed in the control room, located and remedied promptly.

The 250 volt dc (plant battery) system is also operated ungrounded. A ground fault condition results in a displacement of the normal battery voltage distribution relative to ground and is detected by the battery ground detection system which can detect ground faults as small as 50 milliamps.

The 208 volt AC plant lighting system is grounded in many locations throughout the plant. These grounds are essential for maintenance of the ground system voltage reference and reduction of personnel hazards. The 208 volt AC lighting system is subject to varying levels of ground faults, depending upon location, and relies on the multiple ground locations, throughout the plant, for personnel protection. The lighting system fault levels are typical of low voltage distribution systems used on many other industrial applications.

The CRIDS and CCRP electrical distribution systems are primarily used to power instrumentation circuits. These systems are energized by current limited inverters and alternate regulating transformers. These systems are current limited to 120% of rated steady state operating currents and have special inrush current protection provided as described in Report # 2985-HEI-06, Rev. 0. The control room ground system is adequate to contain ground fault currents for these current limited systems.

From the above discussions, it is concluded that these potential ground faults will have no effect on the new protection and control equipment being installed in the RPS and RCS systems.

VII. Benefits of Existing Design:

The existing ground mat design used at DCCNP offers three basic benefits to the plant:

1. Minimize the potential hazards to which personnel and equipment can be exposed during normal operation and ground fault conditions.
2. Aid in isolating equipment and circuits in the event of a fault.
3. Protect equipment from the potentially destructive effects of lightning strikes.

The DCCNP ground mat design has several features. The ground mat for DCCNP is in a wet sand medium which has a relatively low resistivity. Variations in the amount of ground water distributed within the soil will influence the instantaneous soil resistance. Moisture content can cause the resistance to vary from the lowest limits to near infinity. With the sand medium being wet constantly (in excess of 4% moisture content), the ground contact hemisphere has a relatively low resistance(≈60,Kohms/cm). Soil temperature has little effect on resistivity until the temperature of the moisture reaches near the freezing point, when the resistivity of the soil increases very rapidly. Mineral content has a tremendous effect on soil resistivity. Minerals, acids, and hydroxides can improve the soils resistance.

From previous studies it appears that salts (mostly metallic salts) such as those suspended in solution in Lake Michigan will greatly lower the resistivity of the soil. The level of the lake will have no effect on the ground mat. However, with the ground water level being above the level of the ground mat installation, the soil layer will be constantly wet.

Another feature of the existing ground mat system is the fact that all of the power grounds for plant equipment and systems are connected within the confines of the grounding grid. This arrangement of structural steel and associated risers form a "box" extending upwards from the ground mat to the roof of the plant. All protection and control system components are contained within this "box" and effectively shielded from external influences and internal ground plane potential differences.

VIII. Grounding System Life:

The ground mat installed at DCCNP utilities a complex matrix of 4/O copper conductors cadwelded to the building structural steel. Because there are a multiple number of ground conductors utilized in this application, it is assumed that there is no common mode or catastrophic failure that will cause subsequent ground mat failure. Ground mat availability and location make visual inspection and testing of the mat impractical and impossible.

The corrosion effects on the ground conductors have not been quantified for this design. Industry experience is widely varied with contradictory opinions and analysis methods utilized throughout the industry.

Copper ground wire buried around Cook Nuclear Plant is not subject to corrosive attack from the ground water. From a review of the chemistry of the closest ground water wells (No.s 11 and 12) and Uhlig's Corrosion Handbook (page 67), there is no mechanism for the ground water to corrode the copper. Ground mat systems constructed of 4/O copper and cadwelded bonded connections are the most tolerant of the construction methods evaluated by AEP. It is the position of AEP that the grounding system design is adequate for the life of the facility.

IX. Lightning Strike Effects:

One basic principle for protection from lightning strikes is to provide a means by which a lightning strike can enter the earth without causing damage to structures, systems or equipment. There must be a low impedance discharge path provided to prevent the lightning strike from being dissipated by high impedance materials such as concrete, wood and other building materials. When lightning follows the high impedance paths there may be mechanical and heat forces generated that will cause damage or fire hazards. Parts of structures or facilities that are most likely to be struck by lightning are those that project above other surrounding areas, such as the top of a containment building, communication structures, and other tall structures like cooling towers and plant discharge stacks..

A sound lightning protection system is constructed of three basic elements which provide the low impedance metal path. These elements are:

1. A system of air terminals located on the high points of facility structures.
2. A system of ground terminals located within the facility (the ground mat).
3. A conductor system connecting the air terminals to the ground terminals.

When properly specified, located and installed, these components ensure that the lightning discharge will be conducted harmlessly between the air terminals and the ground terminals. The materials from which this system would be constructed should be resistant to corrosion or adequately protected against corrosion.

Air terminals should be made of solid copper unless the air terminals are to be installed on aluminum roofing, siding or other aluminum surfaces. In this case solid aluminum terminals may be used.

The purpose of a lighting protection system is to intercept, conduct and dissipate the main discharge of the lighting strike. The main discharge may also carry along with it some secondary effects unless the system is adequately bonded. There is a possibility of electrical potential differences that could cause side flashes or spark over. To ensure this bonding is achieved, the structural steel including the rebar used as reinforcement in the concrete is typically clamped, welded, bonded, or brazed to ensure continuity. Conductors should be installed to offer the least impedance from the air terminals to the earth. The most direct path to earth is best. The impedance of the conductor system is inversely proportional to the number of separated paths. Accordingly, there should be at least two (2) paths

to earth as widely separated as possible from each air terminal. The number of paths is increased and the impedance decreased by connecting the conductors to form a cage enclosing the structure.

The air terminals specified by AEP for the DCCNP are installed on the containment building only. Using the cone of protection theory provided in the National Fire Protection Association Fire Protection Code (NFPA 78), the protection area will extend approximately 90 meters in an inverted cone pattern. This cone extends in all directions and provides protection for a large portion of the site. A new series of air terminals have been specified and will be installed to provide lightning strike protection for the Diesel Generator Load Banks. This system consists of 4 air terminals elevated approximately 5 feet above the corner post of the fence that protects the load banks. This air terminal system was designed using the "rolling ball" theory and takes credit for a cone of protection provided at a 45 degree angle to the perpendicular of the air terminal. Using these theories, this system will provide total lightning strike protection for the Diesel Generator Load Banks.

The Turbine Building is a steel structure with a metal roof which will attract any lightning strike to the roof. The roof and the steel building are all bonded to the grounding mat so any lightning strike would have a low impedance path to ground.

From these discussions it can be concluded that the existing Lightning Protection System is acceptable and adequate for DCCNP.

X. Summary:

After reviewing and evaluating the requirements for the new instrumentation being installed in the RPS system at DCCNP, it is concluded that the existing grounding scheme and configuration will meet or exceed the new Foxboro and Kent Taylor equipment requirements, when the new equipment is installed in accordance with the AEP Design Standards and Design Guidelines.

XI. Conclusions:

It is concluded that the existing Design, Design Standards, Design Guidelines, and Installation Practices used by AEP for DCCNP are acceptable and conform to the intent of the industry standards.

XII Approval

Prepared by — Date 12/14/92

Reviewed by — Date 12/14/92

Approved by — Date 12/15/92

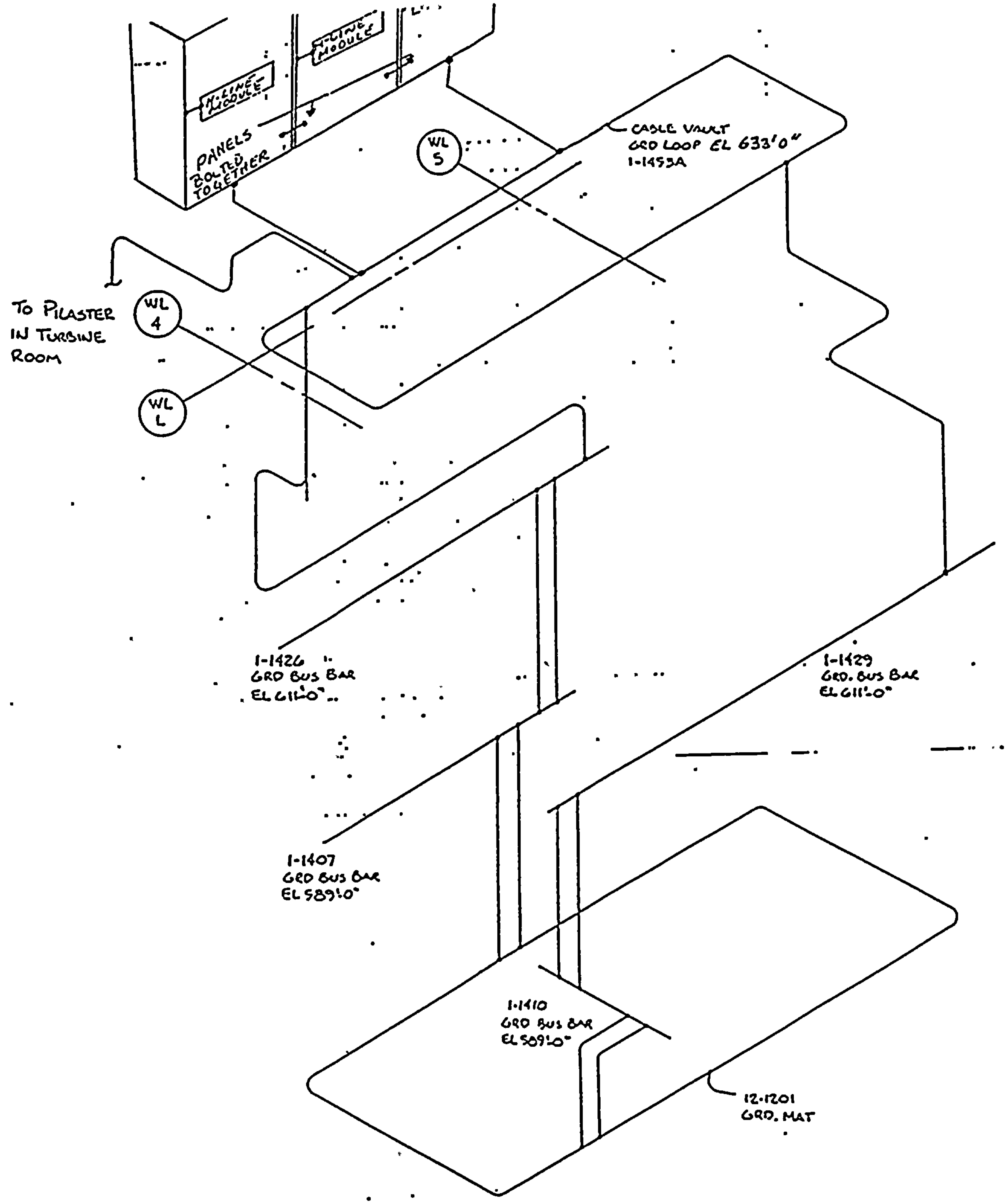

Figure 1
(TYPICAL)

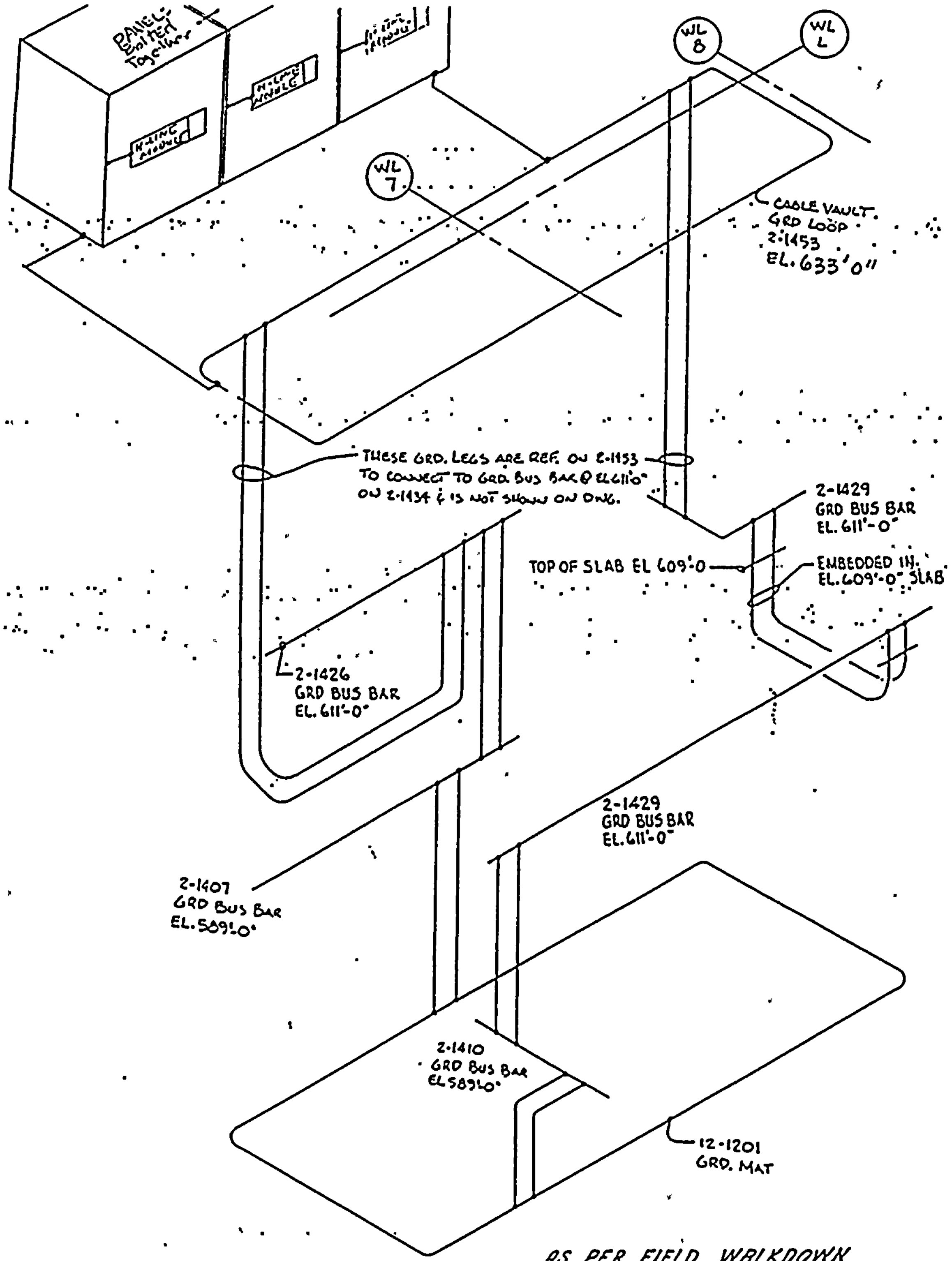

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Figure 2
(TYPICAL)