Engineering Analysis of Airfield Lighting System Lightning Protection

University of Florida

PI: Dr. Vladimir A. Rakov, Co-PI: Dr. Martin A. Uman

50% Submittal Report (July 1, 2005)

Following is a my interpretation of the report.

Different Methods of Lightning Protection & Safety Grounding

- No consensus on proper method
- Should the counterpoise be bonded to light fixtures?
- Should circuits have an insulated safety ground?
- Should the counterpoise and safety ground be bonded to each other?

- Provide engineering analysis, modeling, simulation, and other analyses as required…

- Scenarios to be studied:
  - A: Separate Grounding Conductor
  - B: Interconnected Counterpoise and Separate Grounding Conductor
  - C: Interconnected Counterpoise without Separate Grounding Conductor
  - D: Individual Ground Rods without Separate Grounding Conductor

Various Grounding Requirements.

FAA AC No.: 150/5340-30, dated 4/30/04

12.6 SAFETY (EQUIPMENT) GROUND.

A safety ground must be installed at each light fixture. The purpose of the safety ground is to protect personnel from possible contact with an energized light base or mounting stake as the result of a shorted cable or isolation transformer. The safety ground may be a #6 AWG bare jumper connected to the ground lug at the fixture base or stake to a 5/8" by 8 foot minimum ground rod installed beside the fixture. A safety ground circuit may also be installed and connected to the ground bus at the airfield lighting vault. The safety ground circuit may be a #6 AWG insulated wire for 600 volts (XHHW). Insulation should be colored green. Attach the safety ground circuit to the ground lug at each light base or mounting stake, and secure the entire lighting circuit to the ground bus at the vault. The safety ground circuit must be installed in the same duct or conduit as the lighting power conductors.

Later in appendix 5, it states bare wire in all conduits.

Various Counterpoise Requirements.

UFC 3-535-01

12.1.5. EQUIPMENT GROUNDING SYSTEM.

Install #6 copper AWG green-jacketed wires identified as an equipment ground, in ducts with primary circuit and connect all light bases. Note, if used for approach lights without a light base, connect ground to each light fixture and to the vault lighting system.

12.1.5.1. GROUND CRITERIA.

The ground wire serves as a safety ground, protecting against high voltages that could be brought to the light base. As an alternative, each aviation light base will be grounded with a ground rod. System safety ground wires are to be bonded only at the vault, manholes and handholes, light bases and cans. See the following paragraphs for providing a counterpoise system for lightning protection.

NAVAIR 51-50AAA-2

15. GROUNDING.

Each light fixture and metal case or frame of equipment shall be grounded. Grounding is primarily for safety in case of cable faults. The grounding may be provided by driven ground rods or connection to a grounding cable. Preferably the equipment grounds should not be connected to the counterpoise to avoid equipment damage from lightning strikes being conducted by the counterpoise through the equipment.

Various Counterpoise Requirements.

FAA AC No.: 150/5340-30, dated 4/30/04

12.5 COUNTERPOISE (LIGHTNING PROTECTION). The counterpoise system is installed on airfields to provide some degree of protection from lightning strikes to underground power and control cables. The counterpoise conductor is a bare solid copper wire, #6 AWG. The conductor is connected to ground rods spaced a maximum of 500 feet apart. Connection to the ground rod is made using exothermic welds. Where cable and/or conduit runs are adjacent to pavement, such as along runway or taxiway edges, the counterpoise is installed 8" below grade, located half the distance from edge of pavement to the cable and/or conduit runs. The counterpoise is not connected to the light fixture base can or mounting stake. Where cable and/or conduit runs are not adjacent to pavements, the counterpoise is installed 4" minimum above the cable and/or conduit. The height above the cable and/or conduit is calculated to ensure the cables and/or conduits to be protected are within a 45° zone of protection below the counterpoise. The counterpoise will be terminated at ground rods located on each side of a duct crossing. Where conduit or duct runs continue beneath pavement (i.e., apron areas, etc.), install the counterpoise a minimum of 4 inches above conduits or ducts along the entire run. Counterpoise connections are made to the exterior ground lug on fixture bases of runway touchdown zone lights, runway centerline lights, and taxiway centerline lights installed in rigid pavement. The counterpoise is bonded to the rebar cage around the fixture base. Where installed in materials that accelerate the corrosion of the proper conductor, the counterpoise must be type TW insulated. Coat any exposed copper/brass at connections to the base can with a 6 mil layer of 3M ScotchKote electrical coating or approved equivalent. Ensure all counterpoise connections are UL listed for direct earth burial and/or installation in concrete as applicable. Refer to Figure 108 for counterpoise installation details.

Various Counterpoise Requirements.

UFC 3-535-01

12.1.6. COUNTERPOISE LIGHTNING PROTECTION SYSTEM.

Provide a continuous counterpoise of number 4 (minimum) AWG bare, stranded copper wire over the entire length of all primary circuits supplying airfield lighting: outside pavements, with a minimum 2.4 meter (8 foot) ground rod installed at least every 300 meters (1,000 feet). Do not connect counterpoise system to the light bases.

12.1.6.1. COUNTERPOISE CRITERIA.

Along runway/taxiway or apron shoulders, install the counterpoise halfway between the pavement and at approximately half the depth of the duct (or cable, if direct buried) if at all possible. If this is not practical, install counterpoise 10-15 centimeters (4-6 inches) above the duct or direct buried cable. Route the counterpoise around each light base or unit, at a distance of about 0.6 meters (2 feet) from the unit; do not connect to the unit. For duct not along a shoulder or for duct bank, lay the counterpoise 10-15 centimeters (4-6 inches) above the uppermost layer of direct buried ducts, or on the top of the concrete envelope of an encased duct bank. Provide only one counterpoise wire for cables for the same duct bank. Connect all counterpoise wires leading to a duct bank to the single counterpoise wire for the duct bank. Lay the counterpoise at least 0.3 meters (12 inches) from any light cans or in routing counterpoise around manholes or handholes. Do not connect the counterpoise to the lighting vault power grounding system. Use brazing or thermoweld for all connections. The counterpoise resistance to ground must not exceed 25 ohms at any point using the drop of potential method.

Various Counterpoise Requirements.

NAVAIR 51-50AAA-2

12. CABLES.

d. Counterpoise. The wire for the counterpoise shall be a single, bare, copper, No. 4 AWG, stranded conductor. The connections shall be exothermic welds or brazed.

16. COUNTERPOISES.

Counterpoises are installed to protect the circuits and equipment from lightning damage. Counterpoises should have a separate grounding system and should not be connected to fixtures or equipment because this may channel the voltage and current from the lightning into the circuit. Counterpoises shall be installed for new circuit installations at Naval Air Station or equivalent airfields and may be installed at auxiliary fields in areas of frequent thunderstorms. The counterpoise shall be bare, stranded, copper wire size No. 4 AWG. This wire shall be installed not less than 4 inches and preferably 6 inches above the circuit which it protects. Except under paved areas the counterpoise should be direct burial and preferably not in direct contact with the duct bank. Not less than 6 inches clearance should be provided between the counterpoise and metal parts of the fixtures and equipment grounds. The counterpoise shall be continuous along the circuit. The counterpoise shall be connected to driven ground rods at the lighting vault, where the feeders connect to the lighting circuit, and at intervals not more than 2000 feet apart along the circuit. The ground rod resistance shall be less than 25 ohms. The ground rods shall be not less than 3 feet and preferably 10 from any equipment grounds. Counterpoises for other circuits shall be connected together where this is practical. The connections of the counterpoise to ground rods shall be exothermic welds or brazed.

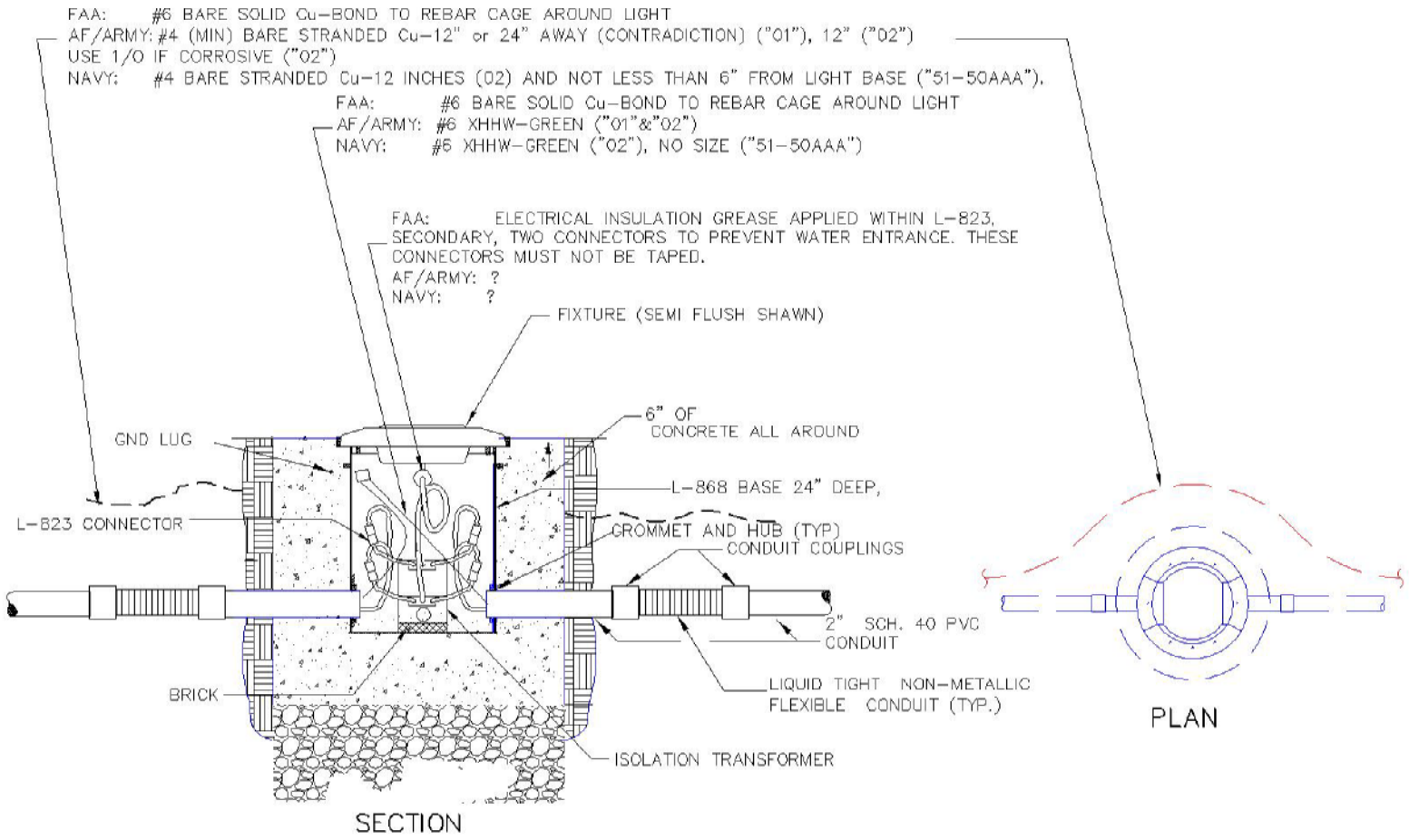
Scenario A: Separate Grounding Conductor

- **Equipment Grounding System Assumptions:**
  - #6 Cu insulated (equipment ground), in ducts with primary voltage series circuit.
  - #6 connected to all steel light bases.
  - Ground wires bonded only at the vault, manholes/hand holes, light bases.

- **Counterpoise Lightning Protection System Assumptions:**
  - Continuous counterpoise of #4 bare, stranded Cu wire over the entire length of all primary circuits supplying airfield lighting: outside pavements, with a minimum 2.4 m (8 ft) ground rod installed every 300 m (1,000 ft).
  - Counterpoise system is not connected to the light bases or to the lighting vault power grounding system
  - Series cable is non-shielded in conduit (Schedule 40 PVC).
  - Counterpoise around each light base/unit a distance of 0.6 m (2 ft) from the unit.
  - For duct not along a shoulder or for duct bank, counterpoise to be 10-15 centimeters (4-6 in) above the uppermost layer of direct buried ducts. One counterpoise wire for cables for the same duct bank.
  - Along runway/taxiway or apron shoulders, counterpoise is halfway between the pavement and at approximately half the depth of the duct. Assume light fixture is 1.2 m (4 ft) from the paving.

Different Methods of Lightning Protection & Safety Grounding

Scenario A: Separate Grounding Conductor



L-868 BASE DEEP CAN METHOD (GREEN GROUNDING CONDUCTOR-SEPARATE COUNTERPOISE)

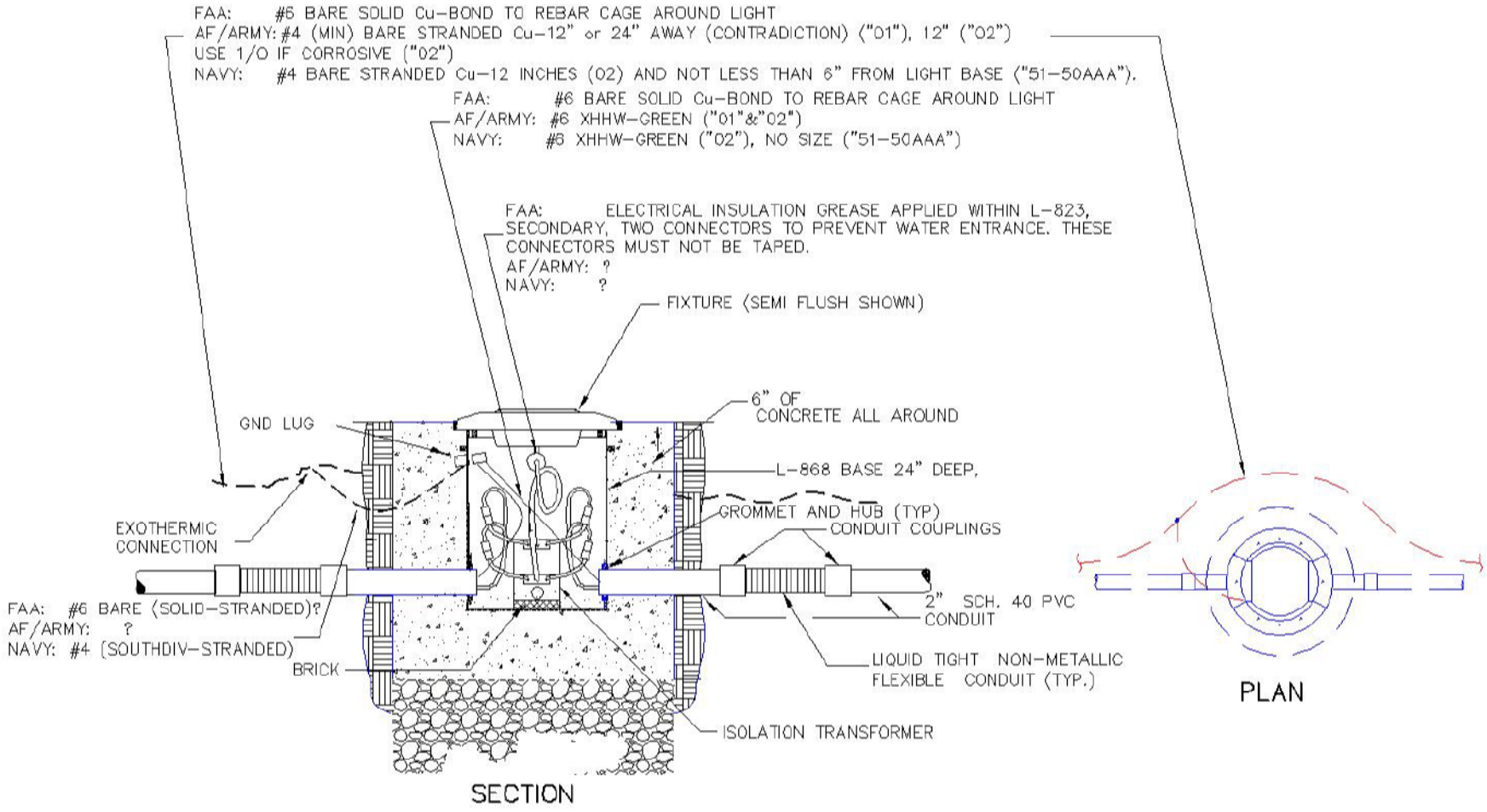
Scenario B: Interconnected Counterpoise and Separate Grounding Conductor

- **Equipment Grounding System Assumptions:**
  - Same as Scenario A, consisting of insulated grounding conductor connecting metallic fixtures to equipment light bases, except adding light bases interconnected to the counterpoise.

- **Counterpoise Lightning Protection System Assumptions:**
  - Same as Scenario A, except that counterpoise system is connected to the light bases and is connected to the lighting vault power grounding system.

Different Methods of Lightning Protection & Safety Grounding

Scenario B: Interconnected Counterpoise & Separate Grounding Conductor



L-868 BASE DEEP CAN METHOD (GREEN GROUNDING CONDUCTOR CONNECTED TO COUNTERPOISE)

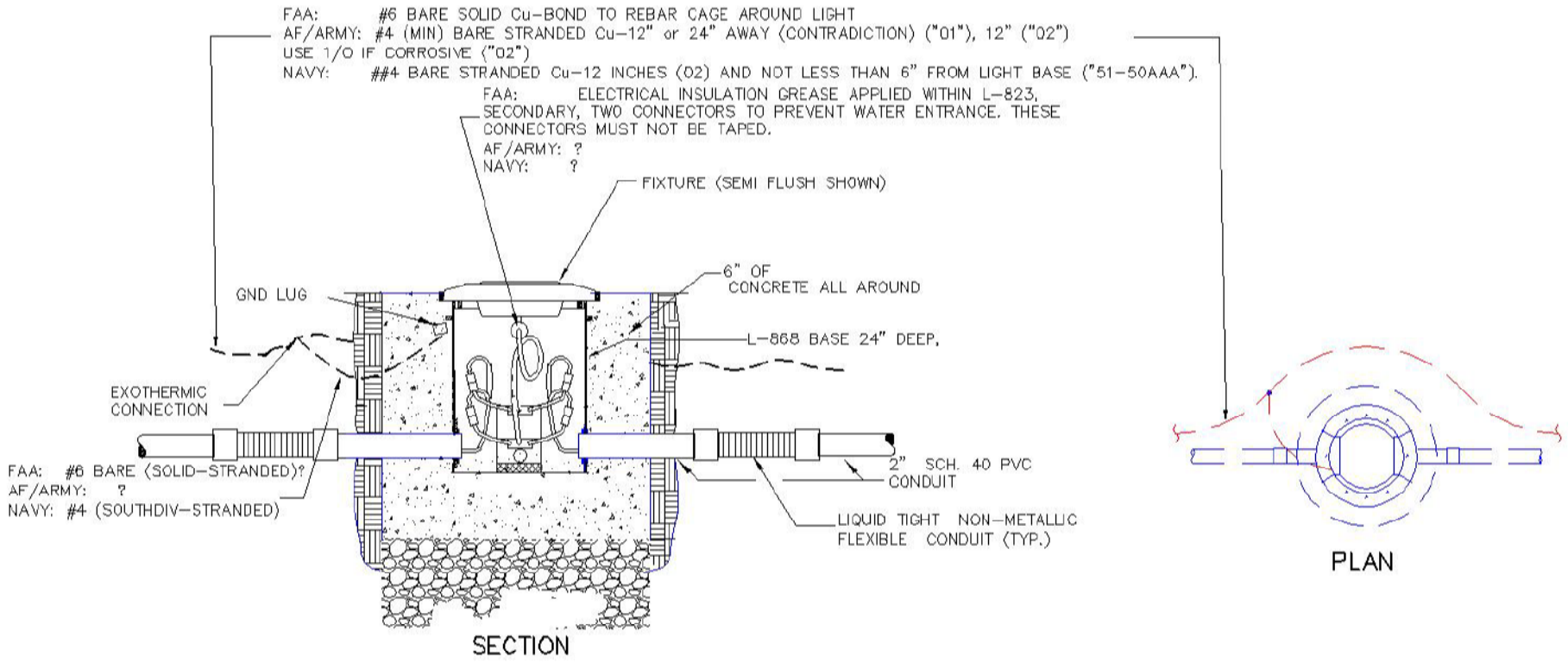
Scenario C: Interconnected Counterpoise without Separate Grounding Conductor

- **Equipment Grounding System Assumptions:**
  - **No insulated conductor included in ductbank system.**

- **Counterpoise Lightning Protection System Assumptions:**
  - **Same as Scenario A, except that counterpoise system is connected to the light bases and is connected to the lighting vault power grounding system.**

Different Methods of Lightning Protection & Safety Grounding

Scenario C: Interconnected Counterpoise w/o Separate Grounding Conductor



L-868 BASE DEEP CAN METHOD (BASE CONNECTED TO COUNTERPOISE)

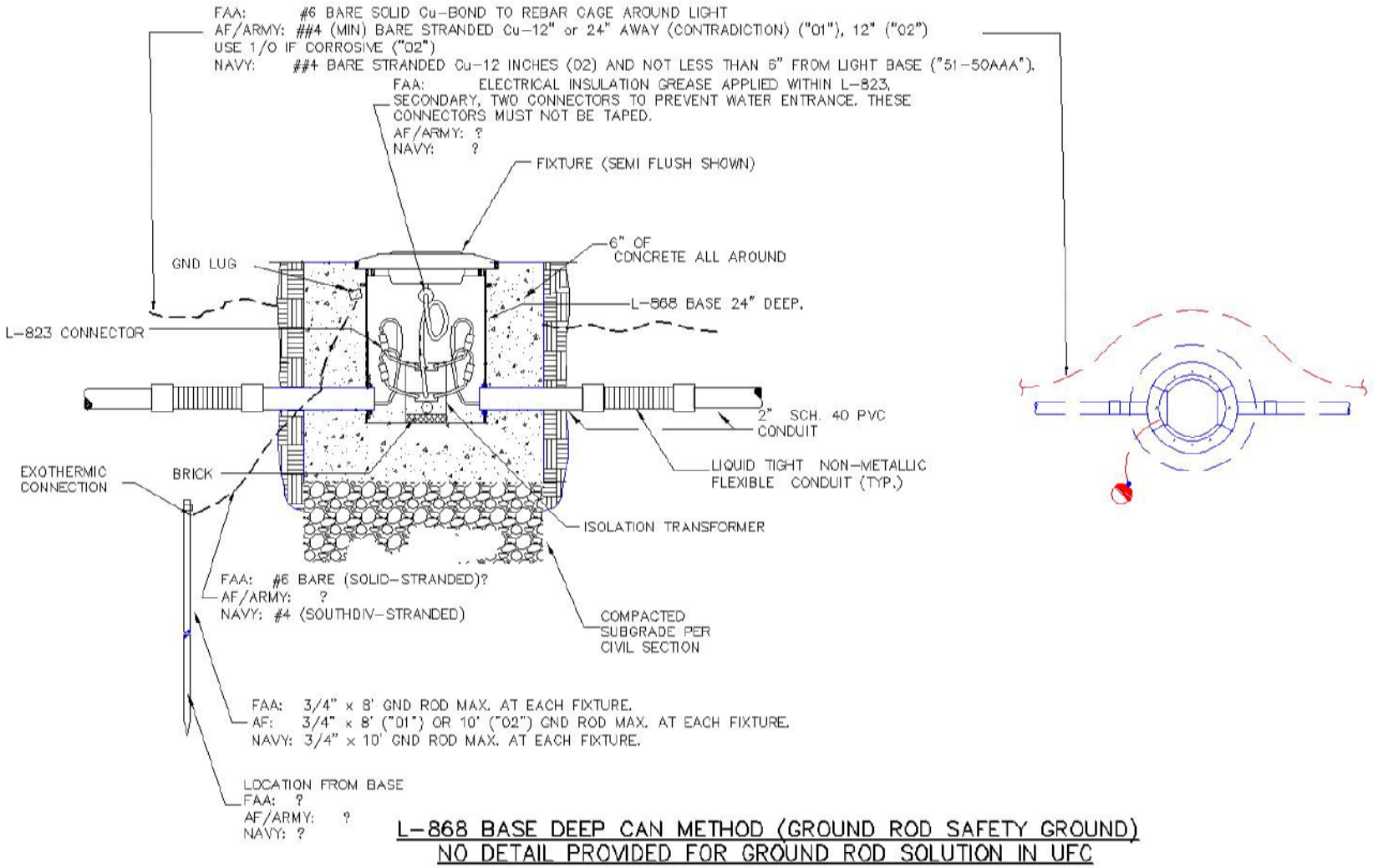
Scenario D: Individual Ground Rods without Separate Grounding Conductor

- **Equipment Grounding System Assumptions:**
  - **No insulated conductor included in ductbank system.**

- **Counterpoise Lightning Protection System Assumptions:**
  - **Same as Scenario A, except that ground rod is installed at each light fixture or group of light fixtures.**

Different Methods of Lightning Protection & Safety Grounding

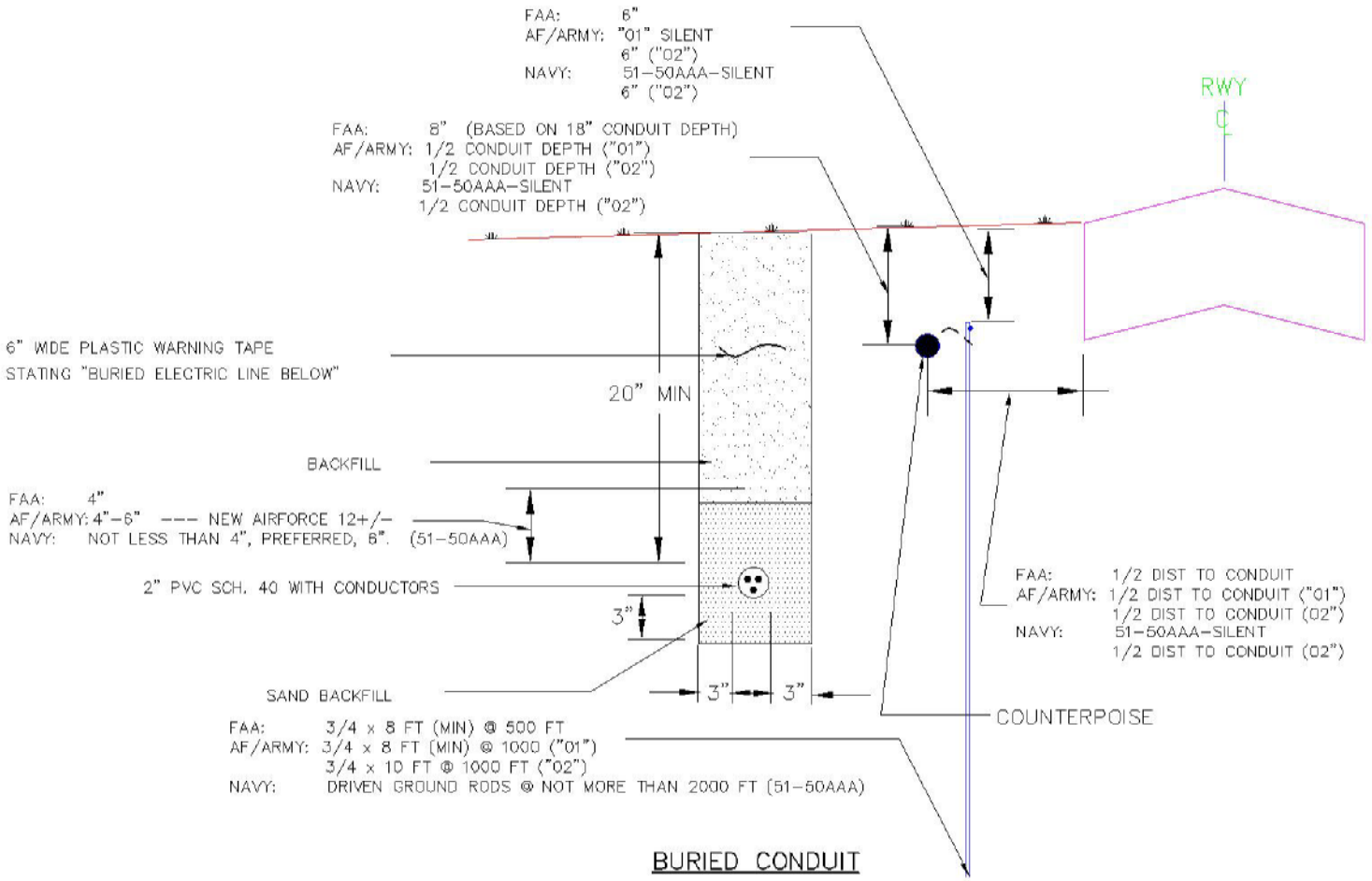
Scenario D: Individual Ground Rods w/o Separate Grounding Conductor



L-868 BASE DEEP CAN METHOD (GROUND ROD SAFETY GROUND)
NO DETAIL PROVIDED FOR GROUND ROD SOLUTION IN UFC

Different Methods of Lightning Protection & Safety Grounding

More Details



The twofold objective of lightning protection is

- To force the current flow where one wants it to go and
- Not to allow the development of hazardous potential differences

Prevent Dangerous Arcing

Equipotential bonding. Ideally, when lightning current causes a properly protected system's potential to rise momentarily to as much as some megavolts, all points of bonded conductors "rise" together

or

Adequate electrical insulation or isolation. Isolating approaches usually depend on whether it is possible or not to separate LPS conductors and other conductors of the system by distances that are larger than the so-called safety distance.

Safety Distance

Adequate isolation distances are required to prevent damaging arcs. These distances are:

$$D_{air} = 3 \text{ m}$$

$$D_{soil} = 5 \text{ m (assumes 60 kA peak current)}$$

Preliminary comments on Scenarios A, B, C, and D

- Scenarios A and D. LPS and safety grounds are separated. These separations are considerably smaller than the safety distances in the soil, which, as estimated above, are of the order of meters. Thus, uncontrolled and potentially hazardous arcing from the counterpoise to a light fixture or to the series cable is likely.

- Scenarios B and C. In Scenario B, LPS and safety grounds are bonded, and in Scenario C the LPS ground is also the safety ground. Arcing between the counterpoise and light fixtures is eliminated and the overall grounding impedance is reduced, since the bonded light fixtures help in dissipating lightning current. However, arcing to the series cable is still possible.

- Additional analysis of scenarios B and C is needed.

Goals

- What is the best solution?
  - Separate Safety and Counterpoise Systems
  - Combined Safety and Counterpoise Systems
  - That is, what is the best topology
- What are the definitive conclusions?
  - Size counterpoise
  - Location of counterpoise
  - Stranded or solid counterpoise
  - Use of ground rods
- What is the best design solution?