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Site Considerations for Equipment Installation, Grounding, and Wiring

FB1100/1200 Flow Computer

FB2100/2200 Flow Computer

ControlWave Family of Flow Computers and RTUs

Remote Automation Solutions

EMERSON

Device Safety Considerations

- **Reading these Instructions**
  Before operating the device, read these instructions carefully and understand their safety implications. In some situations, improperly using this device may result in damage or injury. Keep this manual in a convenient location for future reference. Note that these instructions may not cover all details or variations in equipment or cover every possible situation regarding installation, operation, or maintenance. Should problems arise that are not covered sufficiently in the text, immediately contact Customer Support for further information.

- **Protecting Operating Processes**
  A failure of this device – for whatever reason -- may leave an operating process without appropriate protection and could result in possible damage to property or injury to persons. To protect against this, you should review the need for additional backup equipment or provide alternate means of protection (such as alarm devices, output limiting, fail-safe valves, relief valves, emergency shutoffs, emergency switches, etc.). Contact Remote Automation Solutions for additional information.

- **Returning Equipment**
  If you need to return any equipment to Remote Automation Solutions, it is your responsibility to ensure that the equipment has been cleaned to safe levels, as defined and/or determined by applicable federal, state and/or local law regulations or codes. You also agree to indemnify Remote Automation Solutions and hold Remote Automation Solutions harmless from any liability or damage which Remote Automation Solutions may incur or suffer due to your failure to ensure device cleanliness.

- **Grounding Equipment**
  Ground metal enclosures and exposed metal parts of electrical instruments in accordance with OSHA rules and regulations as specified in *Design Safety Standards for Electrical Systems*, 29 CFR, Part 1910, Subpart S, dated: April 16, 1981 (OSHA rulings are in agreement with the National Electrical Code). You must also ground mechanical or pneumatic instruments that include electrically operated devices such as lights, switches, relays, alarms, or chart drives.

- **Protecting from Electrostatic Discharge (ESD)**
  This device contains sensitive electronic components which be damaged by exposure to an ESD voltage. Depending on the magnitude and duration of the ESD, it can result in erratic operation or complete failure of the equipment. Ensure that you correctly care for and handle ESD-sensitive components.

Contents

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Chapter 1 – Overview

1.1 Introduction

This document provides information pertaining to the installation of RTUs, controllers, and flow computers from Emerson Remote Automation Solutions including the ControlWave family of flow computers and RTUs and the FB1100, FB1200, FB2100, and FB2200 flow computers. More specifically, this document provides information covering reasons, theory and techniques for protecting your personnel and equipment from electrical damage. Your instrumentation system affects the quality of service provided by your company and many aspects of its operational safety. Loss of instruments means lost production and profits as well as increased expenses.

Note: Information contained in this document is for educational purposes. Emerson Remote Automation Solutions offers no warranties or guarantees on the effectiveness of the safety of techniques described herein. Where the safety of installations and personnel is concerned, refer to the National Electrical Code Rules and rules of local regulatory agencies.

1.2 Major Topics

Topics are covered in seven sections designed to pinpoint major areas of concern for the protection of site equipment and personnel. The following provides an overview of each of the major chapters.

- **Chapter 2 - Protection**

  This section provides the reasons for protecting instrumentation systems. An overview of the definition of quality and what we are trying to accomplish in the protection of site installations and how to satisfy the defined requirements is presented. Additionally, this section provides considerations for the protection of personnel and equipment.
- **Chapter 3 - Grounding & Isolation**

  This section provides information pertaining to what constitutes a good earth ground, how to test and establish such grounds, as well as when and how to connect equipment to earth grounds.
- **Chapter 4 - Lightning Arresters & Surge Protectors**

  This section presents some interesting information dealing with lightning strikes and strokes in technical and statistical form along with a discussion of how to determine the likelihood of a lightning strike. Protecting equipment and personnel during the installation of radios and antenna is discussed in a review of the dangers to equipment and personnel when working with antennas. Reasons for the use of lightning arresters and surge protectors are presented along with overviews of how each device protects site equipment.

- **Chapter 5 - Wiring Techniques**

  This section discusses installation of power and “measurement & control” wiring. Information on obscure problems, circulating ground and power loops, bad relays, etc. is presented. Good wire preparation and connection techniques along with problems to avoid are discussed. This sections list the ten rules of instrument wiring.

Chapter 2 – Protection

In This Chapter

2.1 Protecting Instrumentation Systems

Electrical instrumentation is susceptible to damage from a variety of natural and man-made phenomena. In addition to wind, rain and fire, the most common types of system and equipment damaging phenomena are lightning, power faults, communication surges, noise and other electrical interference caused by devices such as radios, welders, switching gear, automobiles, etc. Additionally there are problems induced by geophysical electrical potential and noise plus things that are often beyond our wildest imagination.

2.1.1 Quality is Conformance to Requirements

A quality instrumentation system is one that works reliably, safely and as purported by the equipment manufacturer (and in some cases by the system integrator) as a result of good equipment design and well defined and followed installation practices. If we accept the general definition of quality to be, "conformance to requirements," we must also accept the premise that a condition of "quality" can't exist where requirements for such an end have not been evolved. In other words, you can't have quality unless you have requirements that have been followed. By understanding the requirements for a safe, sound and reliable instrumentation system, and by following good installation practices (as associated with the personnel and equipment in question), you enhance the operational integrity of the equipment and system.

Understanding what is required to properly install equipment in various environments, safely, and in accordance with good grounding, isolating and equipment protection practices goes a long way toward maintaining a system which is healthy for the owner and customer alike.

Properly installed equipment is easier to maintain and operate, and is more efficient and as such more profitable to our customers. Following good installation practices minimizes injury, equipment failure and customer frustration that accompanies failing and poorly operating equipment (of even the finest design).

Additionally, personnel involved in the installation of a piece of equipment add to or subtract from the reliability of a system by a degree which is commensurate with their technical prowess, i.e., their understanding of the equipment, site conditions and the requirements for a quality installation.

2.2 Protecting Equipment and Personnel

Installations must be performed in accordance with National Electrical Code Rules, electrical rules set by local regulatory agencies, and depending on the customer environment (gas, water, etc), other national, state and local agencies. Additionally, installation at various customer sites may be performed in conjunction with a "safety manager" or utility personnel with HAZMAT (hazardous material) training on materials present (or potentially present) as required by OSHA, the customer, etc.

2.2.1 Considerations for the Protection of Personnel

Always evaluate the site environment as if your life depends on it. Make sure that you understand the physical nature of the location where you will be working. Table 2-1 provides a general guideline for evaluating an installation site.

Table 2-1. Consideration for the Protection of Personnel

#	Guide
1	Indoor or outdoor – Dress Appropriately
2	If outdoor, what kind of environment, terrain, etc. Watch out for local varmints (bees, spiders, snakes, etc.)
3	If indoor or outdoor – determine if there are any pieces of dangerous equipment or any processes which might be a risk to your safety
4	If in a tunnel, bunker, etc. watch out for a build up of toxic or flammable gases. Make sure the air is good. Watch out for local varmints (bees, spiders, snakes, etc.)
5	Hazardous or Non-Hazardous Environment – Wear appropriate safety equipment and perform all necessary safety measures.
6	Before installing any equipment or power or ground wiring, make sure that there are no lethal (life threatening) voltages between the site where the instrument will be installed and other equipment, pipes, cabinets, etc. or to earth itself.
7	Never assume that adjacent or peripheral equipment has been properly installed and grounded. Determine if this equipment and the RTU or flow computer can be touched simultaneously without hazard to personnel and/or equipment?
8	Before embarking to remote locations where there are few or no human inhabitants ask a few simple questions like, should I bring water, food, hygienic materials, first aid kit, etc? Be Prepared!
9	Observe the work habits of those around you – for your own safety!

Some of the items that a service person should consider before ever going onsite can be ascertained by simply asking questions of the appropriate individual. Obviously other safety considerations can only be established at the installation site.

2.2.2 Considerations for the Protection of Equipment

You must evaluate the site installation/service environment and equipment. Understand the various physical interfaces you will be dealing with such as equipment mounting and supporting, RTU/flow computer analog and digital circuits, power circuits, communication circuits and various electrical grounds. Table 2-2 provides a general guideline for evaluating the equipment protection requirements of an installation site.

Table 2-2. Consideration for the Protection of Equipment

#	Guide	Reference Section
1	Environment - Class I, Division 2 – Nonincendive Environment - Class I, Division 1 - Intrinsically Safe Other - Safe or unrated area	See appendices in hardware instruction manual.
2	Earth Ground - Established by mechanical/electrical or (both) or not at all.	See Chapter 3
3	Is the area prone to lightning strikes?	See Chapter 4
4	Are there surge suppressors installed or to be installed?	See Chapter 4
5	Are there overhead or underground power or communication cables in the immediate area?	See section 2.3
6	Is there an antenna in the immediate area?	See section 4.1.2
7	How close is other equipment? Can someone safely touch this equipment and the RTU/flow computer simultaneously?	See section 2.3
8	Determine equipment ground requirements. How will the RTU/flow computer and its related wiring be grounded? Consider Earth Ground, Circuit Ground, Conduit Ground, Site Grounds!	See Chapter 3
9	Are there any obviously faulty or questionable power or ground circuits?	See section 2.3

2.3 Other Site Safety Considerations

You must identify overhead or underground power or communication cables prior to installing a new unit. Accidentally cutting, shorting or simply just contacting power, ground, communication or process control I/O wiring can have potentially devastating effects on site equipment, the process system and or personnel.

Don’t assume that it is safe to touch adjacent equipment, machinery, pipes, cabinets or even the earth itself. Adjacent equipment may not have been properly wired or grounded, may be defective or may have one or more loose system grounds. Measure between the case of a questionable piece of equipment and its earth ground for voltage. If a voltage is present, something is wrong.

AC powered equipment with a conductive case should have the case grounded. If you don’t see a chassis ground wire, don’t assume that it is safe to touch this equipment. If you notice that equipment has been grounded to pipes, conduit, structural steel, etc., you should be leery.

Note: AWWA’s policy on grounding of electric circuits on water pipes states, “The American Water Works Association (AWWA) opposes the grounding of electrical systems to pipe systems conveying water to the customer’s premises….”

Be sure that the voltage between any two points in the instrumentation system is less than the stand-off voltage. Exceeding the stand-off voltage will cause damage to the instrument and will cause the instrument to fail.

Chapter 3 – Grounding and Isolation

In This Chapter

3.1 Power and Ground Systems

Controllers and flow computers from Emerson Remote Automation Solutions support DC power systems. AC power supplies are not provided. Our devices typically include a ground lug that accommodates up to a #4 AWG size stranded copper wire for establishing a connection to Earth ground.

3.2 Importance of Good Grounds

Controllers and flow computers are utilized in instrument and control systems that must operate continually and within their stated accuracy over long periods of time with minimum attention. Failures resulting from an improperly grounded system can become costly in terms of lost time and disrupted processes. A properly grounded system helps prevent electrical shock hazards resulting from contact with live metal surfaces, provides additional protection of equipment from lightning strikes and power surges, minimizes the effects of electrical noise and power transients, and reduces signal errors caused by ground wiring loops. Conversely, an improperly grounded system may exhibit a host of problems that appear to have no relation-ship to grounding. It is essential that the reader (service technician) have a good under-standing of this subject to prevent needless troubleshooting procedures.

⚠ **Warning** **This device must be installed in accordance with the National Electrical Code (NEC) ANSI/NEPA-70. Installation in hazardous locations must also comply with Article 500 of the code. For information on the usage of this device in a hazardous location, see appendices in the applicable hardware instruction manual. For information on the usage of ControlWave units in Class I, Division 1, Groups C & D hazardous locations, see appendix B of the applicable hardware instruction manual.**

3.3 Earth Ground Connections

To properly ground the device, the unit's chassis ground must ultimately be connected to a known good earth ground. Refer to *Establishing a Good Earth Ground* and *Ground Wire Considerations* (located in this chapter).

3.3.1 Establishing a Good Earth Ground

A common misconception of a ground is that it consists of nothing more than a metal pipe driven into the soil. While such a ground may function for some applications, it will often not be suitable for a complex system of sophisticated electronic equipment. Conditions such as soil type, composition and moisture will all have a bearing on ground reliability.

A basic ground consists of a 3/4-inch diameter rod with a minimum 8-foot length driven into conductive earth to a depth of about 7-feet as shown in Figure 3-1. Number 3 or 4 AWG braided copper wire should be used for the ground wire. The end of the wire should be clean, free of any coating and fastened to the rod with a clamp. This ground connection should be covered or coated to protect it from the weather and the environment.

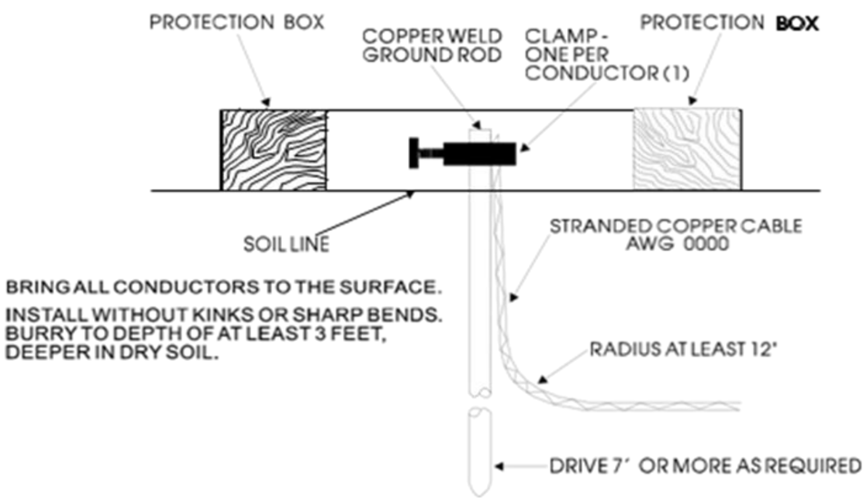

Figure 3-1. Basic Ground Rod Installation

3.3.1.1 Soil Conditions

Before installing a ground rod, the soil type and moisture content should be analyzed. Ideally, the soil should be moist and moderately packed throughout to the depth of the ground rod. However, some soils will exhibit less than ideal conditions and will require extra attention.

Soil types can be placed into two general categories with respect to establishing and maintaining a good earth ground, i.e., “good soil” and “poor soil”.

To be a good conductor, soil must contain some moisture and free ions (from salts in the soil). In rainy areas, the salts may be washed out of the soil. In sandy or arid area the soil may be to dry and/or salt free to a good conductor. If salt is lacking add rock salt (NaCl); if the soil is dry add calcium chloride (CaCl2).

3.3.1.2 Soil Types

Good	**Poor**
Damp Loam	Back Fill
Salty Soil or Sand	Dry Soil
Farm Land	Sand Washed by a Lot of Rain Dry Sand (Desert) Rocky Soil

Ground beds must always be tested for conductivity prior to being placed into service. A brief description of ground bed testing in “good soil” and “poor soil” is provided herein. Details on this test are described in the *National Electrical Code Handbook*. Once a reliable ground has been established, it should be tested on a regular basis to preserve system integrity.

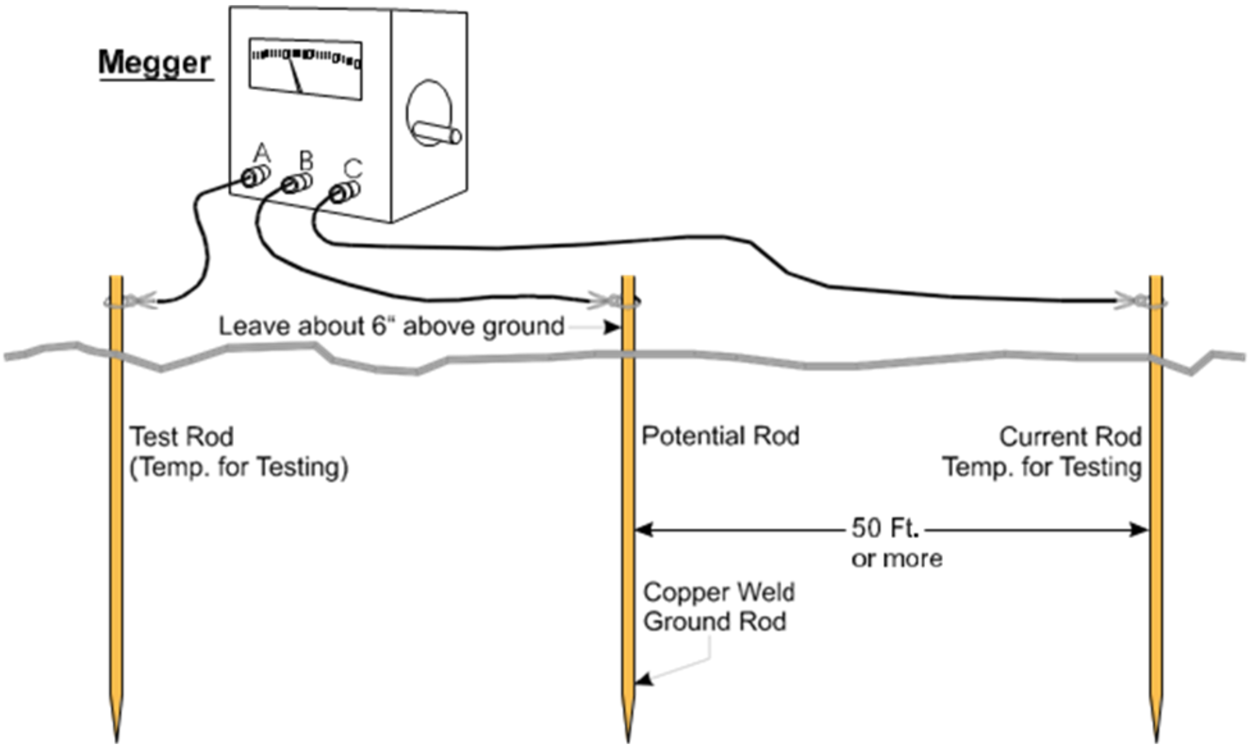

Figure 3-2. Basic Ground Bed Soil Test Setup

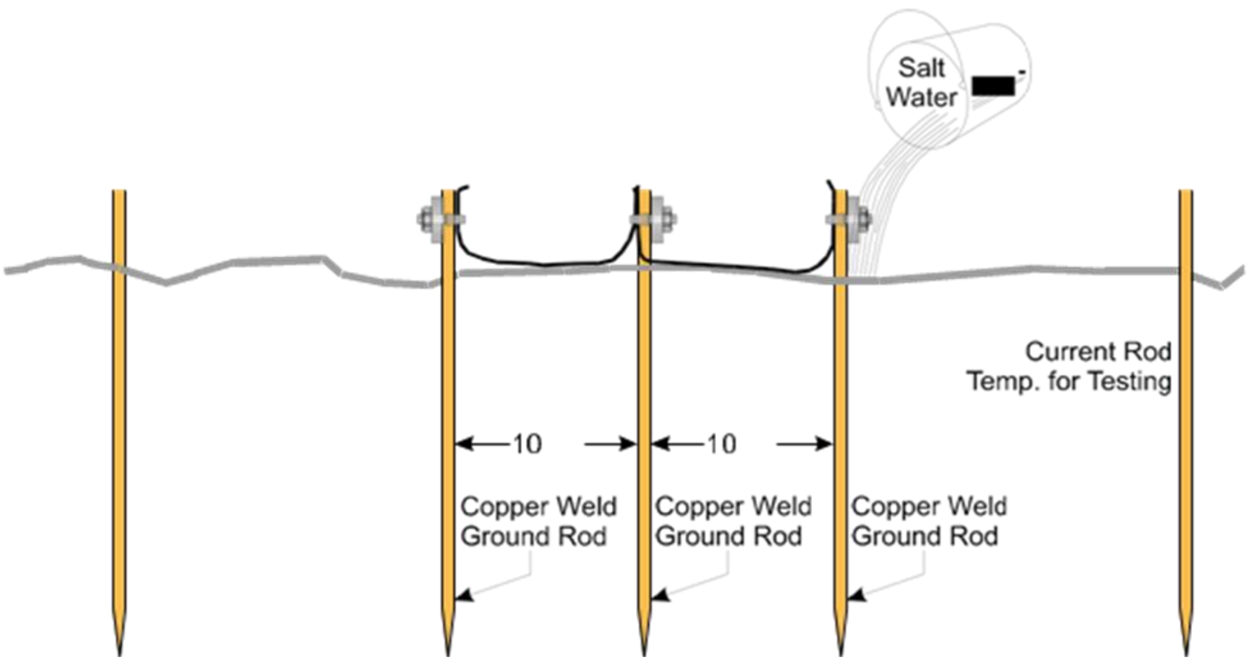

Figure 3-3. Basic Ground Bed Soil Test Setup with Additional Ground Rods

Figure 3-2 shows the test setup for "good soil" conditions. If the Megger* reads less than 5 ohms, the ground is good. The lower the resistance, the better the earth ground. If the Megger reads more than 10 ohms, the ground is considered "poor". If a poor ground is indicated, one or more additional ground rods connected 10 feet from the main ground rod should be driven into the soil and interconnected via bare AWG 0000 copper wire and 1” x ¼-20 cable clamps as illustrated in Figure 3-3). *

Note: Megger is a Trademark of the Biddle Instrument Co. (now owned by AVO International). Other devices that may be used to test ground resistance are “Viboground”; Associated Research, Inc., “Groundmeter”; Industrial Instruments, Inc., and “Ground-ohmer”; Herman H. Sticht Co., Inc.

If the Megger still reads more than 10 ohms, mix a generous amount of cooking salt, ice cream salt or rock salt with water and then pour about 2.5 to 5 gallons of this solution around each rod (including the test rods). Wait 15 minutes and re-test the soil. If the test fails, the soil is poor and a ‘Poor Soil Ground Bed’ will have to be constructed.

Figure 3-4 shows a typical poor soil ground bed electrode. A poor soil ground bed will typically consists of four or more 10-foot long electrodes stacked vertically and separated by earth. Figure 3-5 shows the construction of a poor soil ground bed. For some poor soil sites, the ground bed will be constructed of many layers of “capacitive couplings” as illustrated. In extremely “poor soil” sites one or more 3’ by 3’ copper plates (12 gauge or 1/16” thick) will have to be buried in place of the electrodes.

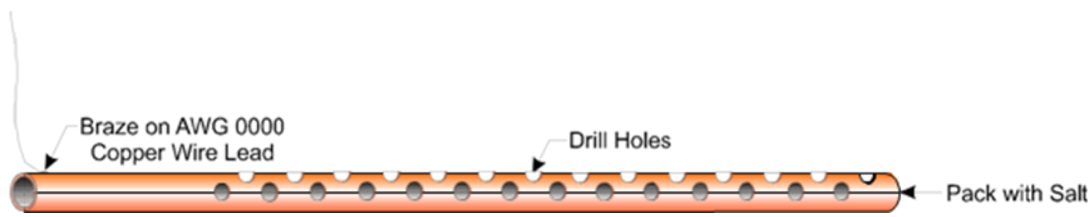

Figure 3-4. Ground Electrode Construction for poor soil conditions

3.3.1.3 Dry, Sandy or Rocky Soil

A very dry soil will not provide enough free ions for good conductance and a single ground rod will not be effective. A buried counterpoise or copper screen is recommended for these situations. It will be necessary to keep the soil moist through regular applications of water.

Sandy soil, either wet or dry, may have had its soluble salts leached out by rain water, thereby reducing conductivity of the ground. High currents from lightning strikes could also melt sand and cause glass to form around the ground rod, rendering it ineffective. A buried counterpoise or copper screen is preferred for these installations along with regular applications of salt water.

Rocky soil can pose many grounding problems. A counterpoise or copper plate will probably be required. Constructing a trench at the grounding site and mixing the fill with a hygroscopic salt such as calcium chloride may help for a time. Soaking the trench with water on a regular basis will maintain conductivity.

Units with phone modems require the use of a lightning arrester. The lightning arrester must be situated at the point where the communication line enters the building.

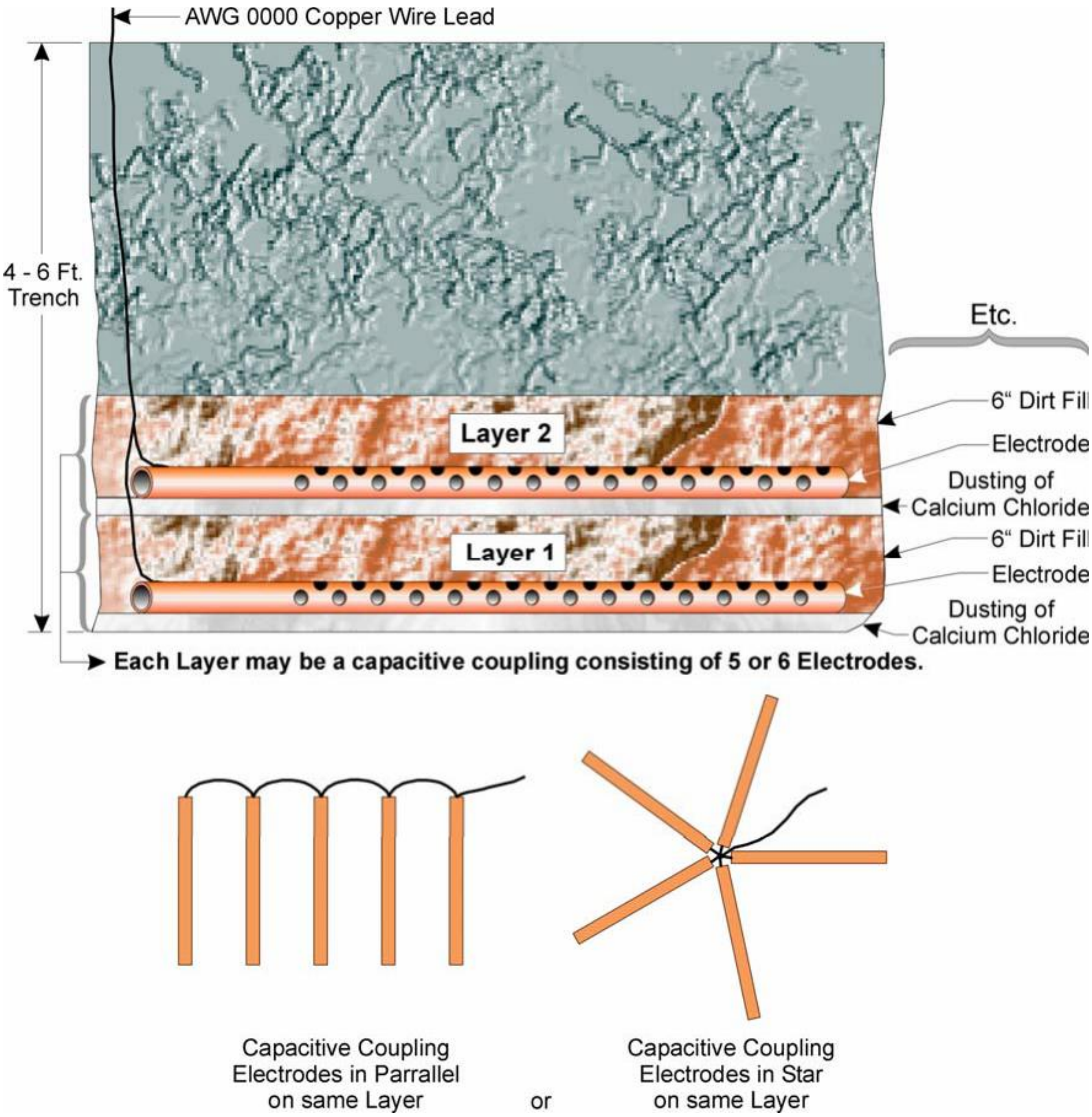

Figure 3-5. Poor Soil Ground Bed Construction Diagram

3.3.2 Ground Wire Considerations

Controllers and flow computers are provided with a ground lug that accommodates up to a #4 AWG wire size. A ground wire must be run between the chassis ground lug and a known good earth ground. The cases of the various modules are automatically connected to the chassis ground when they have been installed and secured in the chassis.

For ControlWave Devices Only:
A #14 AWG wire be run from PSSM (Chassis Ground) (PSSM Connector TB1-3 for ControlWave Micro unit) (SCM Connector TB1-3 for ControlWave EFM) to the same known good earth ground.

General Considerations

The following considerations are provided for the installation of controller/flow computer system grounds:

- Size of ground wire (running to earth ground should be #4 AWG. It is recommended that stranded copper wire is used for this application and that the length should be as short as possible.
- This ground wire should be clamped or brazed to the ground bed conductor (that is typically a stranded copper AWG 0000 cable installed vertically or horizontally).
- The wire ends should be tinned with solder prior to installation.
- The ground wire should be run such that any routing bend in the cable has a minimum radius of 12-inches below ground and 8-inches above ground.

The unit earth ground cable should be clamped to an exposed ground rod or to an AWG 0000 stranded copper ground cable that in turn should be connected to either an earth ground rod or earth ground bed. Both ends of the unit earth ground cable must be free of any coating such as paint or insulated covering as well as any oxidation. The connecting point of the ground rod or AWG 0000 ground cable must also be free of any coating and free of oxidation. Once the ground connection has been established (at either the ground rod or ground cable) it should be covered or coated to protect it from the environment.

3.3.3 Other Grounding Considerations

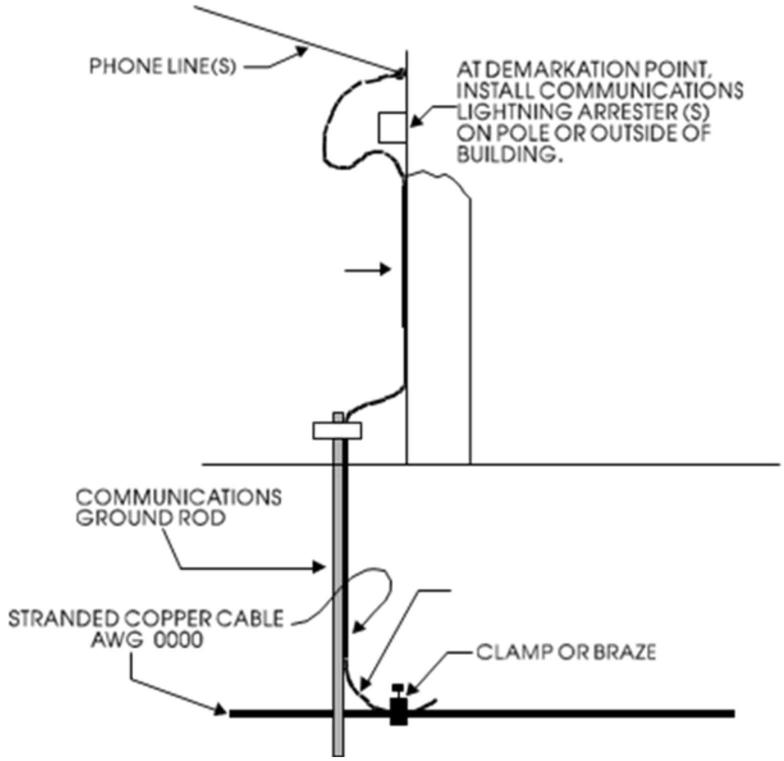

Figure 3-6. Grounding of Phone Line

For applications employing equipment that communicates over telephone lines, a lightning arrester **must be** provided. For indoor equipment the lightning arrester must be installed at the point where the communication line enters the building as shown in Figure 3-6. The ground terminal of this arrester must connect to a ground rod and/or a buried ground bed.

Gas lines also require special grounding considerations. If a gas meter run includes a thermocouple or RTD sensor installed in a thermowell, the well (not the sensor) must be connected to a gas discharge-type lightning arrester as shown in Figure 3-7. A copper braid, brazed to the thermal well, is dressed into a smooth curve and connected to the arrester as shown. The curve is necessary to minimize arcing caused by lightning strikes or high static surges. The path from the lightning arrester to the ground bed should also be smooth and free from sharp bends for the same reason.

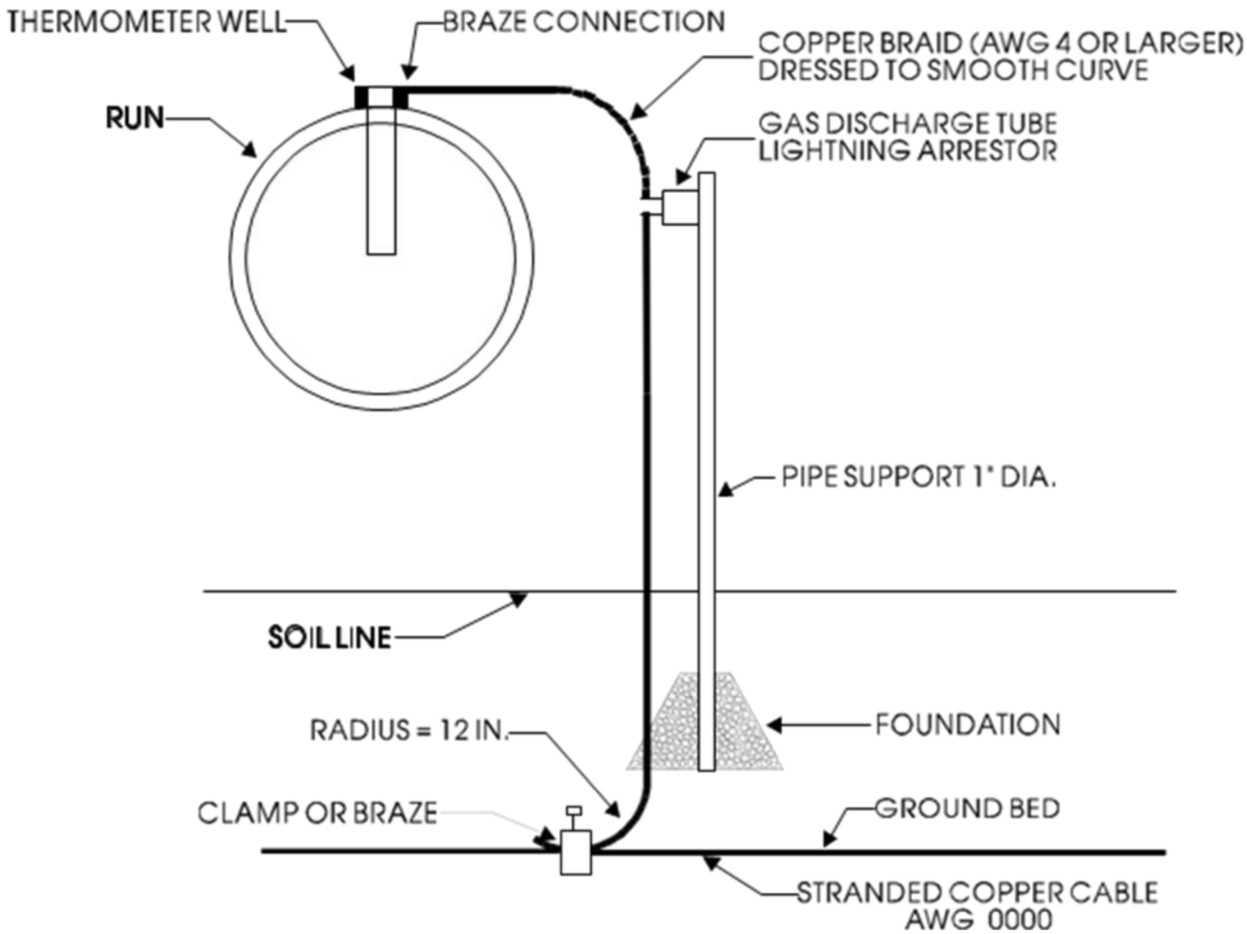

Figure 3-7. Grounding of Thermometer Well in Gas Line

3.4 Isolating Equipment from the Pipeline

3.4.1 Meter Runs Without Cathodic Protection

Some (but not all) flow computers may be mounted directly on the pipeline. For example, the FB1100/FB1200 can be mounted directly using the traditional mounting kit or a coplanar mounting kit but only if the pipeline includes a process manifold. If direct mount is not allowed or supported (for example in the FB2100/FB2200) the flow computers may be mounted remotely on a vertical stand-alone two-inch pipe (see Figure 3-8). The earth ground cable is to run between the flow computer's Ground Lug and Earth Ground (rod or bed) even though the flow computer's Multivariable Transducer may be grounded to the pipeline. If any pressure transmitters or pulse transducers are remotely mounted, connect their chassis grounds to the pipeline or earth ground.

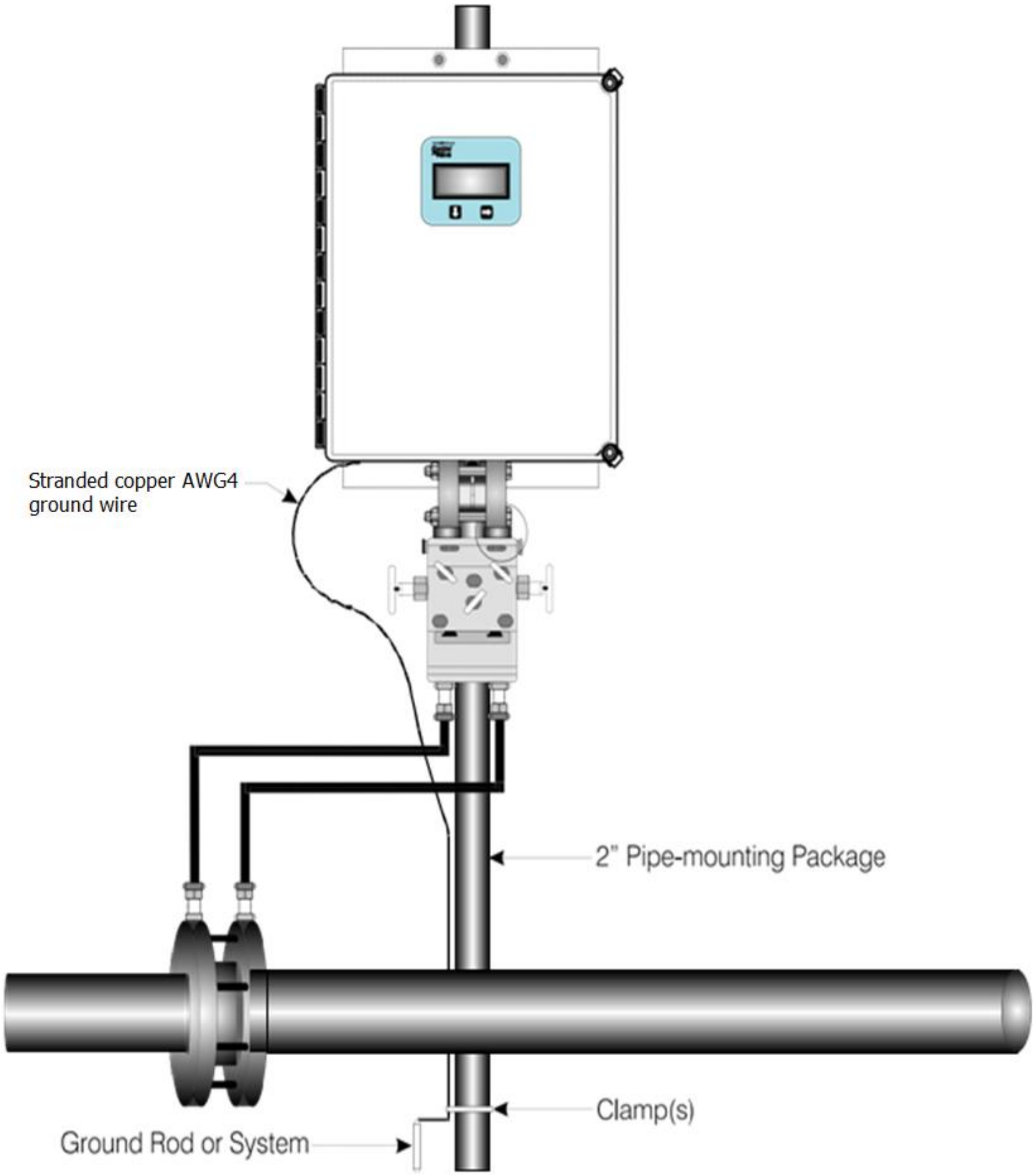

Figure 3-8. Remote Installation without Cathodic Protection

3.4.2 Meter Runs With Cathodic Protection

Dielectric isolators are available and are always recommended as an added measure in isolating the flow computer from the pipeline even though the flow computer does provide 500V galvanic isolation from the pipeline and should not be affected by cathodic protection or other EMF on the pipeline. Some (but not all) flow computers may be mounted directly on the pipeline (see Figure 3-9) or remotely on a vertical stand-alone two-inch stand-pipe (see Figure 3-10). It is recommended that isolation fitting always be used in remotely mounted meter systems. An isolation fittings or gasket should be installed between the following connections:

- All conductive tubing that runs between the pipeline and mounting valve manifold and/or the unit's multivariable pressure transducer.
- All conductive connections or tubing runs between the flow computer and turbine meter, pulse transducer, or any other device that is mounted on the pipeline.
- Any Temperature Transducer, Pressure Transmitter, etc. and their mount/interface to the pipeline.

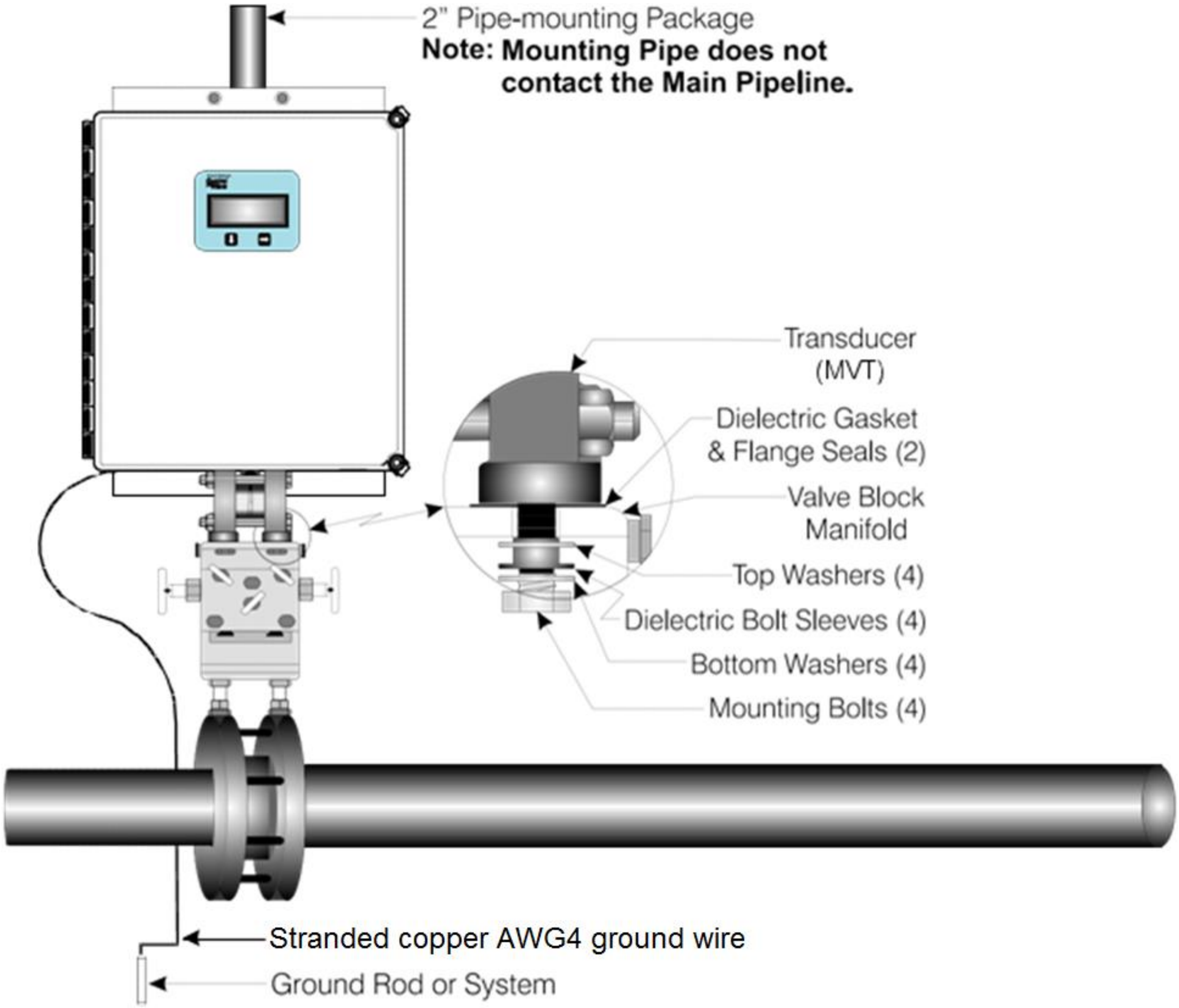

Figure 3-9. Direct Mount Installation (with Cathodic Protection)

The ground conductor connects between the Ground Lug and a known good earth ground. Connect the cases of Temperature Transducers, Pressure Transmitters, etc., to the known good earth ground. If the mounting 2-inch pipe is in continuity with the pipeline it will have to be electrically isolated from the flow computer. Use a strong heat-shrink material such as RAYCHEM WCSM 68/22 EU 3140. This black tubing will easily slip over the 2-inch pipe and then after uniform heating (e.g., with a rose-bud torch) it electrically insulates and increases the strength of the pipe stand.

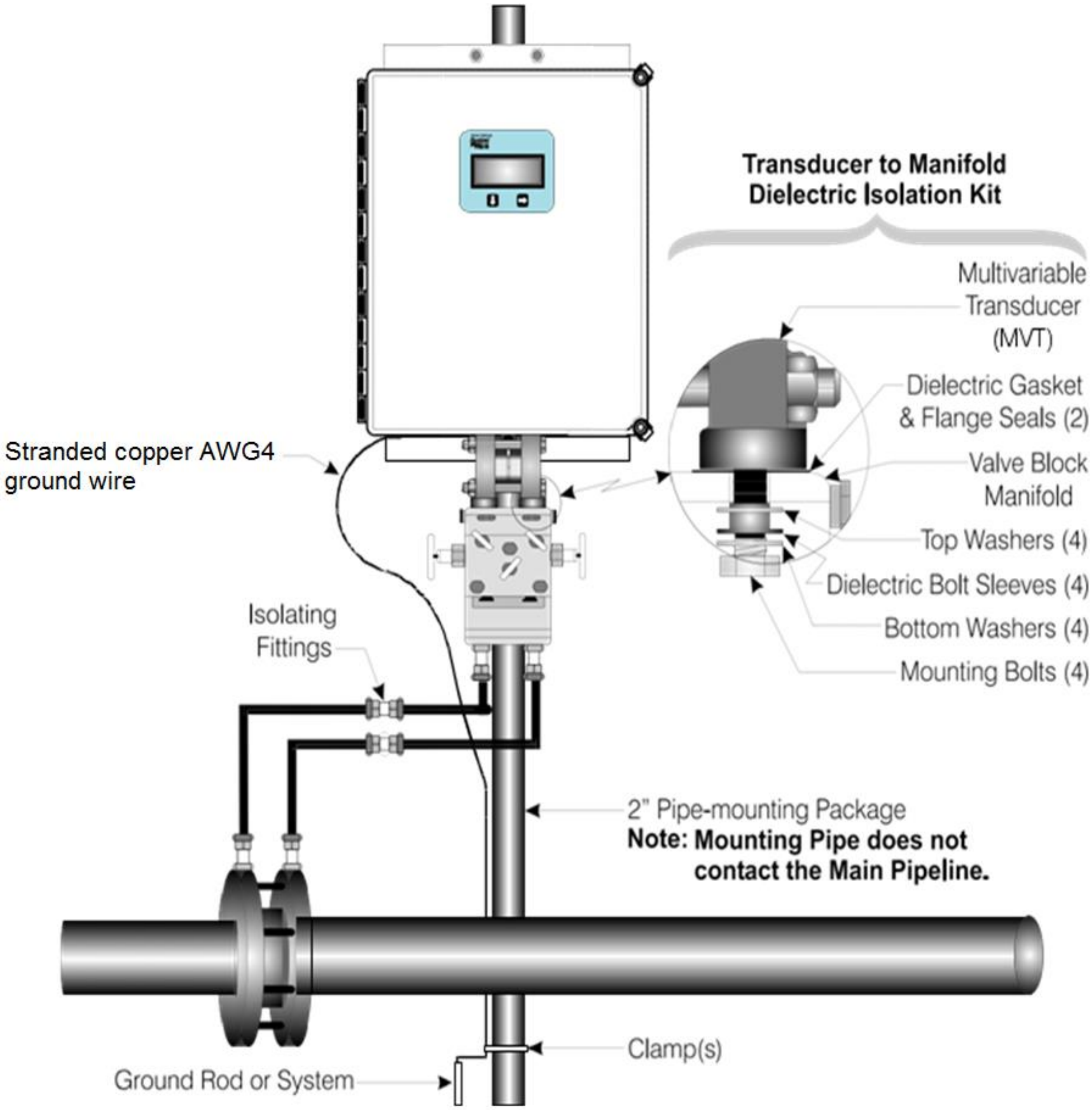

Figure 3-10. Remote Installation (with Cathodic Protection)

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Chapter 4 – Lightning Arresters and Surge Protectors

In This Chapter

4.1 Strokes and Strikes

Lightning takes the form of a pulse that typically has 2 µS rise and a 10 µS to 40 µS decay to a 50% level. The IEEE standard is 8 µS by 20 µS waveform. The peak current will average 18 KA for the first impulse and about half of that for the second and third impulses. Three strokes (impulses) is the average per lightning strike. The number of visible flashes that may be seen is not necessarily the number of electrical strokes.

A lightning strike acts like a constant current source. Once ionization occurs, the air becomes luminous conductive plasma reaching up to 60,000° F. The resistance of a struck object is of little consequence except for the power dissipation on the object (I^2 x R). Fifty percent of all lightning strikes will have a first impulse of at least 18 KA, ten percent will exceed the 60 KA level, and only about one percent will exceed 120 KA.

4.1.1 Chance of Being Struck by Lightning

The map of Figure 4-1 shows the average annual number of thunderstorm days (Isokeraunic level) for the various regions within the continental U.S.A. This map is not representative of the severity of the storm or the number of lightning strikes since it does not take into account more than one lightning strike in a thunderstorm day. The Isokeraunic or Isoceraunic number provides a meteorological indication of the frequency of thunderstorm activity; the higher the Isokeraunic number the greater the lightning strike activity for a given area. These levels vary across the world from a low of 1 to a high of 300. Within the United States the Isokeraunic level varies from a low of 1 to a high of 100.

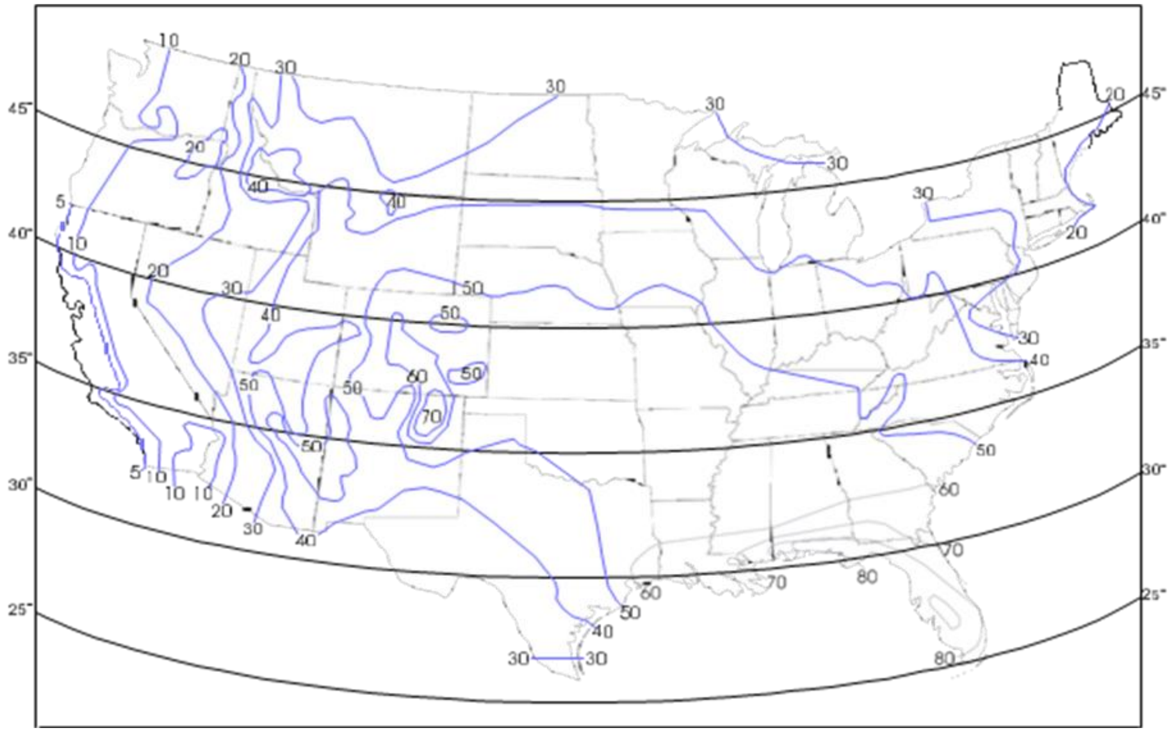

Figure 4-1. Chance of Being Struck by Lightning

Thunderstorms are cloud formations that produce lightning strikes (or strokes). Across the United States there is an average of 30 thunderstorm days per year. Any given storm may produce from one to several strokes. Data on the subject indicates that for an average area within the United States there can be eight to eleven strokes to each square mile per year. The risk of stroke activity is increased for various areas such central Florida where up to 38 strokes to each square mile per year are likely to occur.

To determine the probability of a given structure (tower, building, etc.) (within your location) being struck, perform the following computation:

1. Using the map of Figure 4-1 (or a comparable meteorological map for your location), find the Isokeraunic level (I) for your area. Then using Chart 1, find “A” for your area.
2. Refer to Figure 4-1 to find the latitude. Then using Chart 2, find “B” for your latitude (Lat.°).
3. Multiply “A” x “B” to get “C”.
4. To calculate the number of lightning strikes per year those are likely to strike a given object (tower, mast, etc.), use the equation that follows (where “C” was calculated in step 3 and “H” is equal to the height of the object.

   Strikes Per Year = (“C” x H^2) ÷ (.57 x 10^6)

Chart 1

I	"A"
5	8
10	26
20	85
30	169
40	275
50	402
60	548
70	712
80	893
90	1069
100	1306

Chart 2

LAT.°	"B"
25	.170
30	.200
35	.236
40	.280
45	.325

Note for these charts:

I = Thunderstorm Days Per Year (Isokeraunic Number)

A = Stroke activity for associated Isokeraunic Area

B = Height/Stroke coefficient for associated latitude

For Example: On Long Island, New York (Isokeraunic number 20), Chart 1 gives "A" to equal 85. The latitude is approximately 40°. Referring to Chart 2, "B" is found to be equal to .28. "C" for this example is equal to 23.80. Using the equation for strikes per year, it is determined that a 100-foot tower has .4 chances per year of being struck by lightning.

Assuming that no other structures are nearby, the tower will more than likely be struck by lightning at least once in three years.

Note: The Isokeraunic activity numbers connoted as "I", "A" and "B" in Charts 1 and 2 above are provided for the continental United States. Isokeraunic data for various countries is available from various federal or state Civil Engineering or Meteorological organizations. This information is typically available from manufacturers of lightning strike protection equipment (such as Lightning Arresters).

Since controllers and flow computers use DC operated systems that are isolated from AC grids, they are typically immune to lightning strikes to power lines or power equipment (except for inductive flashover due to close installation proximity). However, once a radio or modem has been interfaced to the controller or flow computer, the possibility of damage due to a lightning strike on power or telephone lines or to a radio antenna or the antenna's tower must be considered. It is recommended that the additional lightning protection considerations listed below be followed for units installed in areas with a high possibility or history of stroke activity.

Units interfaced to a modem: In series with the phone line (as far away as possible from the equipment) - for indoor installations the lightning arrester should typically be located at the point where the line enters the structure.

Units interfaced to a radio: Mount antenna discharge unit (lightning arrester) as close as possible to where the lead in wire enters the structure. See Antenna Caution below.

4.1.2 Antenna Caution

Each year hundreds of people are killed, mutilated, or receive severe permanent injuries when attempting to install or remove an antenna or antenna lead. In many cases, the victim was aware of the danger of electrocution but failed to take adequate steps to avoid the hazard. For your safety, and for proper installation maintenance, please read and follow the safety precautions that follow - they may save your life.

- When installing or servicing an antenna:

  DO NOT use a metal ladder. DO NOT step onto or touch an antenna mast while power is applied to an associated radio unless the radio is a low power (low current) type.

  DO NOT work on a wet or windy day, especially during a thunderstorm or when there is lightning or thunder in your area. Dress properly; shoes with rubber soles and heels, rubber gloves, long sleeve shirt or jacket.
- The safe distance from power lines should be at least twice the height of the antenna and mast combination.
- Antenna Grounding per National Electrical Code Instructions:

  A. Use AWG 10 or 8 aluminum or AWG 1 copper-clad steel or bronze wire, or larger as ground wires for both the mast and lead-in. Be mindful of dissimilar metals resulting in a corrosion problem. Securely clamp the wire to the bottom of the mast.

  B. Secure lead-in wire from antenna to antenna discharge (lightning arrester) unit and the mast ground wire to the structure (building, shed, etc.) with stand-off insulators spaced from 4 feet (1.22 meters) to 6 feet (1.83 meters) apart.

C. Mount antenna discharge unit as close as possible to where the lead-in wire enters the structure.

D. The hole drilled through the wall for the lead-in wire should be just large enough to accommodate the cable. Before drilling this hole, make sure there are no wires or pipes, etc. in the wall.

E. Push the cable through the hole and form a rain drip loop close to where the wire enters the exterior of the structure.

F. Caulk around the lead-in wire (where it enters the structure) to keep out drafts.

G. Install lightning arresters (antenna discharge units). The grounding conductor should be run in as straight a line as practicable from the antenna mast and/or the antenna discharge units to grounding electrode(s).

H. Only connect the antenna cable to the radio after the mast has been properly grounded and the lead-in cable has been properly connected to lightning arresters which in turn have each been properly connected to a known good earth ground.

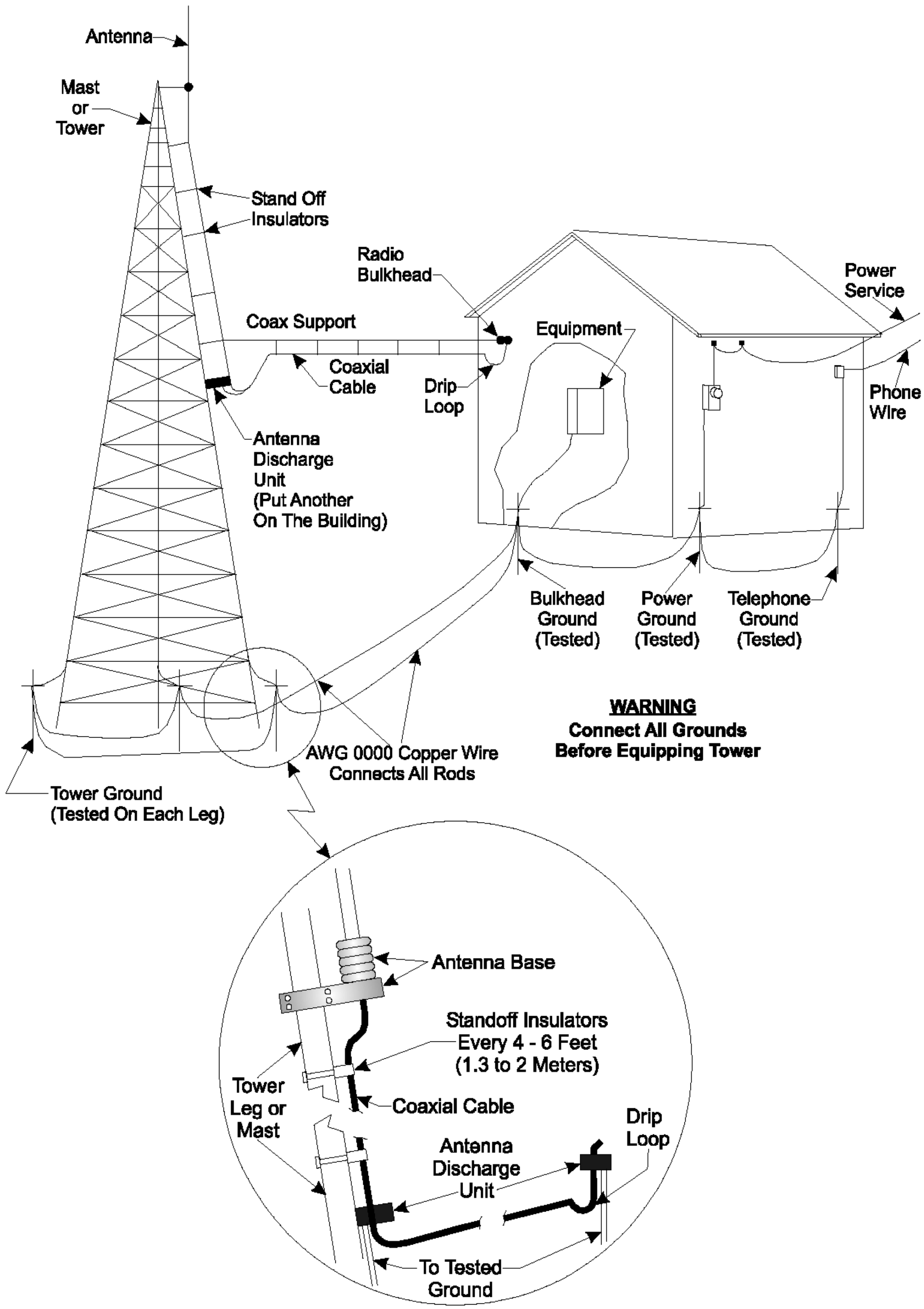

Figure 4-2. Radio Antenna Field Installation Site Grounding Diagram

For all systems it is best to have all communication equipment input/output grounds tied together. In the case of ControlWave units, this is accomplished via the unit's chassis ground (Typically at a ground lug, ground bus or ground plate). However additional communication equipment lightning arresters and surge protectors should be tied to the same system ground. System ground consists of the tower leg grounds utility ground and bulkhead equipment ground stakes that are tied together via bare copper wire.

4.1.3 Ground Propagation

As in any medium, a dynamic pulse, like R.F., will take time to propagate. This propagation time will cause a differential step voltage to exist in time between any two ground rods that are of different radial distances from the strike. With a ground rod tied to a struck tower, the impulse will propagate its step voltage outwardly from this rod in ever-expanding circles, like a pebble thrown into a pond. If the equipment house has a separate ground rod and the power company and/or telephone company grounds are also separate, the dynamic step voltage will cause currents to flow to equalize these separate ground voltages. Then if the coax cable (associated with a radio) is the only path linking the equipment chassis with the tower ground, the surge can destroy circuitry.

4.1.4 Tying it all Together

To prevent this disaster from occurring, a grounding system must be formed which interconnects all grounds together. This will equalize and distribute the surge charge to all grounds, and at the same time, it will make for a lower surge impedance ground system. This interconnection can be done as a grid, where each ground has a separate line to each other ground, or by using a “rat race” ring which forms a closed loop (not necessarily a perfect circle) which surrounds the equipment house completely.

By making this interconnection, it will be necessary to use proper I/O protectors for the equipment. Of course, these should be a requirement regardless of whether this grounding technique is used. I/O protectors are used for power lines (even those these don’t feed into a controller/flow computer), telephone lines, and also to minimize EMI pick-up from a strike. Ideally it is best to place all I/O protectors on a common panel that has a low inductance path to the ground system. The controller/flow computer would then have a single ground point from its chassis ground terminal/ground lug to this panel. In lieu of this, the controller/flow computer in question should be tied to a ground rod that in turn is connected to the earth/system ground created for the site.

Your protected equipment connected to a common single ground system, will now be just like a bird sitting on a high tension wire. When lightning strikes, even with a 50 ohm surge impedance ground system, the entire system consisting of equipment, ground system, building, etc., will all rise together to the one million volt peak level (for example) and will all decay back down together. So long as there is no voltage differential (taken care of by protectors and ground interconnections, there will be no current flow through the equipment and therefore no resulting equipment damage.

4.1.5 Impulse Protection Summary

- Use more than one ground rod.
- Place multi-ground stakes more than their length apart.
- Tie Power, Telco, Tower, Bulkhead and equipment ground together.
- Make all ground interconnect runs that are above ground with minimum radius bends of eight inches and run them away from other conductors and use large solid wire or a solid strap.
- Watch out for dissimilar metals connections and coat accordingly.
- Use bare wire radials together where possible with ground stakes to reduce ground system impedance.
- Use I/O protectors (Phone line, Radio) with a low inductance path to the ground system.
- Ground the Coaxial Cable Shield (or use an impulse suppressor) at the bottom of the tower just above the tower leg ground connection.

4.2 Use of Lightning Arresters and Surge Protectors

Units equipped with radios or modems use lightning arresters and surge protectors to protect equipment from lightning strikes, power surges and from damaging currents that have been induced onto communication lines.

The first line of defense is the Lightning Arrester. These devices typically use gas discharge bulbs that can shunt high currents and voltages to earth ground when they fire. The high current, high voltage gas discharge bulb has a relatively slow response time and only fires when gas has been ionized by high voltage.

The second line of defense is the Surge Protector, which is made of solid state devices, fires very quickly and conducts low voltages and currents to ground. Surge protectors are built into some modems.

Lightning Arresters are applied to circuits as follows:

- Equipment or circuits that can be exposed to lightning strikes, falling power lines, high ground currents caused by power system faults, by operational problems on electric railways, etc.
- Equipment installed in dry, windy areas, such as the Great Plains and the Southwest Desert in the United States. Wind and windblown dust can cause high voltages (static) to appear on overhead wires, fences, and metal buildings.

Note: Lightning Arresters may explode if a lightning strike is very close. Mount lightning arresters where flying parts won't cause injury to equipment or personnel.

4.2.1 Installation of Lightning Arresters and Surge Protectors

1. Install lightning arresters external to equipment cabinets, racks or buildings.
2. Each lightning arrester requires a separate ground connection to the nearest available earth ground. Use the manufacturer's specified wire size.

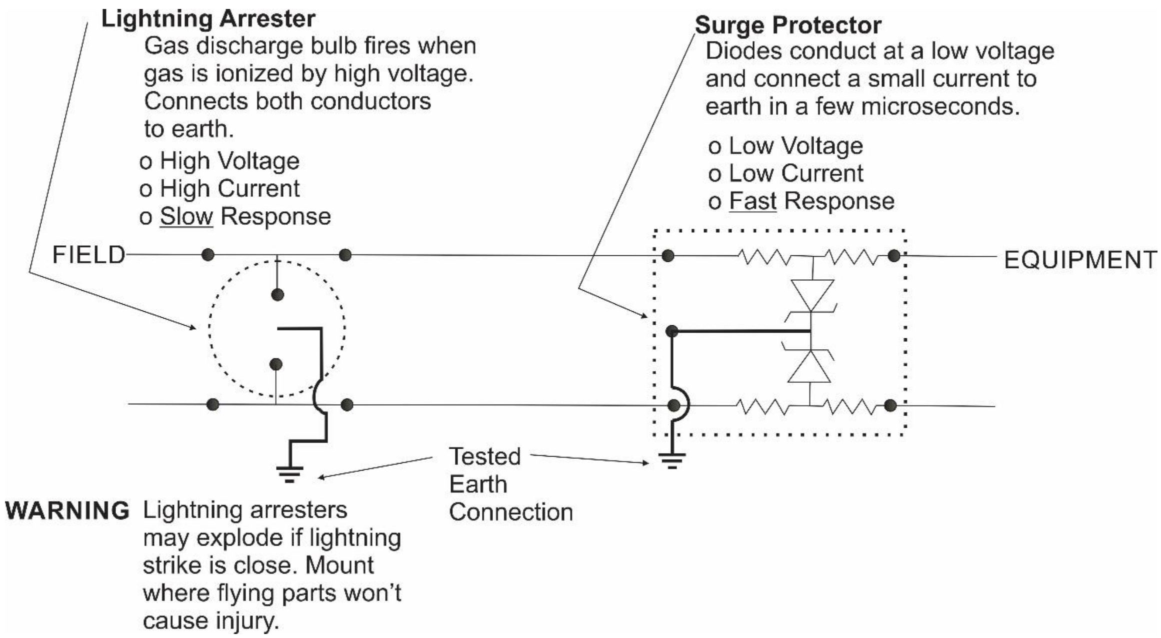

Figure 4-3. Lightning Arresters and Surge Protectors

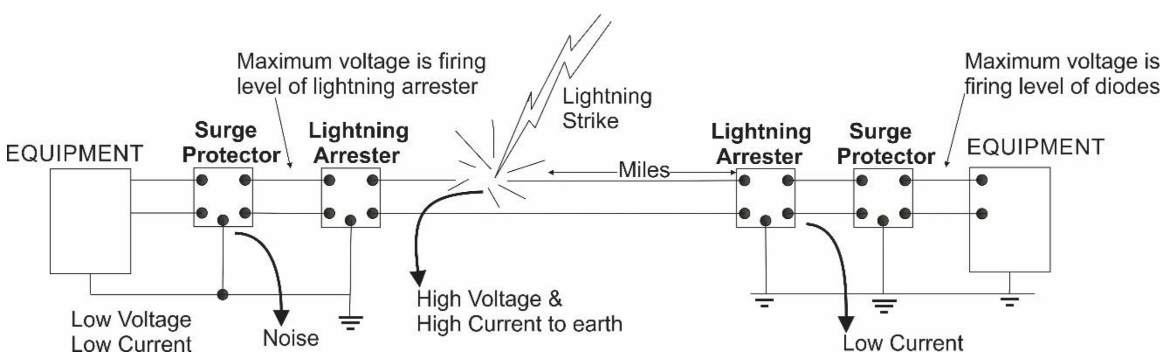

Figure 4-4. Protecting Equipment with Lightning Arresters and Surge Protectors

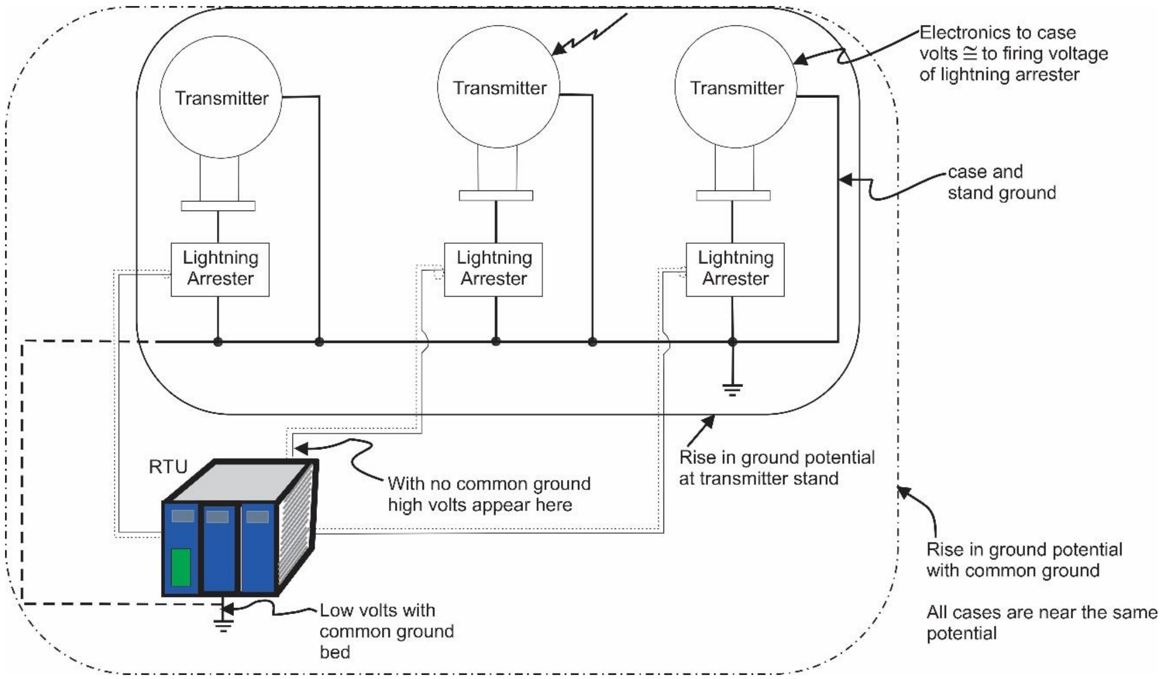

Figure 4-5. Protecting Equipment with Lightning Arresters

Chapter 5 – Wiring Techniques

In This Chapter

5.1 Overview

This section provides information pertaining to good wiring practices. Installation of Power and "Measurement & Control" wiring is discussed. Information on obscure problems, circulating ground and power loops, bad relays, etc. is presented. Good wire preparation and connection techniques along with problems to avoid are discussed.

5.2 Instrument Wiring

Each of the rules listed below is briefly discussed; the emphasis herein is placed on the avoidance of problems as well as equipment safety.

- **Rule 1** – Never utilize common returns.
- **Rule 2** – Use twisted shielded pairs (with overall insulation) on all Signal/Control circuits.
- **Rule 3** – Ground cable shields at one end only.
- **Rule 4** – Use known good earth grounds (Rod, Bed, System) and test them periodically,
- **Rule 5** – Earth connections must utilize smoothly dressed large wire.
- **Rule 6** – Perform all work neatly and professionally.
- **Rule 7** – Route high power conductors away from signal wiring according to NEC Rules.
- **Rule 8** – Use appropriately sized wires as required by the load.
- **Rule 9** – Use lightning arresters and surge protectors.

- **Rule 10 –** Make sure all wiring connections are secure.

5.2.1 Common Returns

Use of common returns on I/O wiring is one of the most common causes of obscure and difficult to troubleshoot control signal problems. Since all wires and connections have distributed resistance, inductance and capacitance, the chances of a achieving a balanced system when common returns are present is very remote. Balanced systems (or circuits) are only achieved when all currents and voltages developed in association with each of the common returns are equal. In a balanced system (or circuit) there are no noise or measurement errors introduced due to by "sneak circuits."

The illustration of Figure 5-1 shows the difference between testing an I/O circuit that is discrete and has no sneak circuits and one that utilizes common returns. Common sense tells us that it is tough to mix up connections to a twisted shielded pair (with overall vinyl covering) to every end device. Do yourself a favor; to make start up easier, **DON'T USE COMMON RETURNS!**

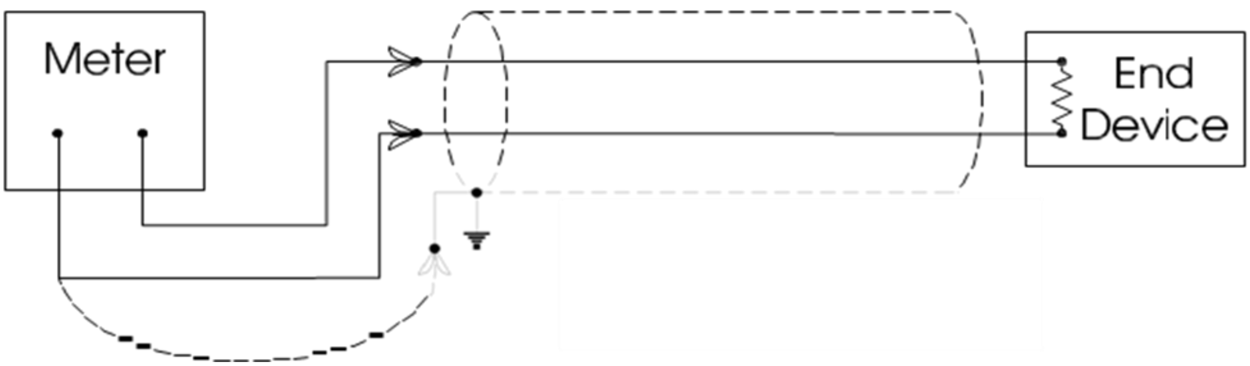

Figure 5-1. Field Wired Circuit Without a Common Return

Note: Without a common return, there are no sneak circuits and testing is easy.

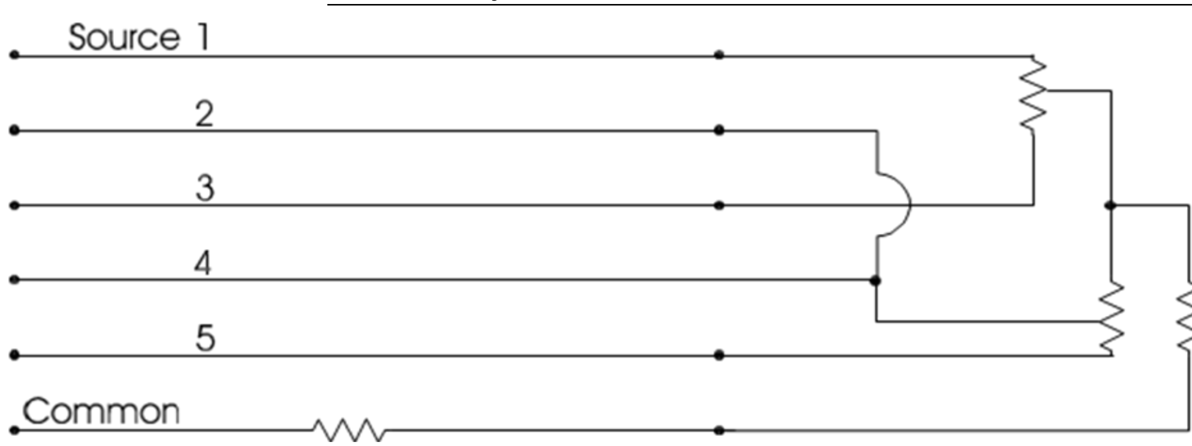

Figure 5-2. Field Wired Circuit with a Common Return

Note: With a common return, sneak circuits are created! A lot of equipment must be disconnected to find a sneak circuit!

5.2.2 Use of Twisted Shielded Pair Wiring (with Overall Insulation)

For all field I/O wiring the use of twisted shielded pairs with overall insulation is highly recommended. This type of cable provides discrete insulation for each of the wires and an additional overall insulated covering that provides greater E.M.I. immunity and protection to the shield as well.

5.2.3 Grounding of Cable Shields

DO NOT connect the cable shield to more than one ground point; it should only be grounded at one end. Cable shields that are grounded at more than one point or at both ends may have a tendency to induce circulating currents or sneak circuits that raise havoc with I/O signals. This will occur when the ground systems associated with multipoint connections to a cable shield have a high resistance or impedance between them and a ground induced voltage is developed (for whatever reason, i.e., manmade error or nature produced phenomena).

5.2.4 Use of Known Good Earth Grounds

Controllers/flow computers should only have one connection to earth ground; this connection is provided via the Ground Lug. Since these units are DC-based systems, grounding does not take into account AC power grounding considerations. Earth grounding the unit is absolutely necessary when the unit is equipped with a radio or modem. Additionally, these units should be connected to earth ground when they are installed in areas that have frequent lightning strikes or are located near or used in conjunction with equipment that is likely to be struck by lightning or if struck by lightning may cause equipment or associated system failure. Earth Grounds must be tested and must be known to be good before connecting the controller/flow computer. Earth grounds must be periodically tested and maintained (refer to Chapter 4).

5.2.5 Earth Ground Wires

Earth connections must utilize smoothly dressed large wire. Use AWG 3 or 4 stranded copper wire with as short a length as possible. Exercise care when trimming the insulation from the wire ends. Twists the strands tightly, trim off any frizzes and tin the ends with solder. The earth ground wire should be clamped or brazed to the Ground Bed Conductor (that is typically a standard AWG 0000 copper cable. The earth ground wire should be run such that any routing bend in the cable is a minimum 8-inch radius above ground or a minimum 12-inch radius below ground.

5.2.6 Working Neatly and Professionally

Take pride in your work and observe all site and maintenance safety precautions. After properly trimming the stranded pair wire ends, twist them in the same direction as their manufacturer did and then tin them with solder. Install the tinned wire end into it's connector and then secure the associated connector's clamping screw. Remember to check these connections for tightness from time to time. If solid copper wire is use (in conjunction with the DC Power System or for Earth Ground) make sure that the conductor is not nicked when trimming off the insulation. Nicked conductors are potential disasters waiting to happen. Neatly trim shields and whenever possible, coat them to protect them and prevent shorts and water entry.

Remember loose connections, bad connections, intermittent connections, corroded connections, etc., are hard to find, waste time, create system problems and confusion in addition to being costly.

5.2.7 High Power Conductors and Signal Warning

When routing wires, keep high power conductors away from signal conductors. Space wires appropriately to vent high voltage inductance. Refer to the National Electrical Code Handbook for regulatory and technical requirements.

5.2.8 Use of Proper Wire Size

ControlWaves utilize compression-type terminals that accommodate up to #14 AWG gauge wire. FB1100/FB1200/FB2100/FB2200 flow computer terminal blocks accept 28-12 AWG gauge wire. A connection is made by inserting the bared end (1/4 inch max.) into the clamp beneath the screw and securing the screw.

Allow some slack in the wires when making terminal connections. Slack makes the connections more manageable and minimizes mechanical strain on the PCB connectors. Provide external strain relief (utilizing tie wrap, etc.) to prevent the loss of slack at the controller/flow computer.

Be careful to use wire that is appropriately sized for the load. Refer to equipment manufacturer's specifications and the National Electrical Code Handbook for information on wire size and wire resistance. After installing the field wiring, test each load to determine if the correct voltage or current is present at the load. If you know the resistance of the field wires (Circular Mills x Length) you should be able to calculate the load voltage. Conversely, if you know the minimum load voltage and current, you should be able to derive the maximum voltage loss that is allowable due to line resistance and then the correct wire size. Referring to Figure 5-2, a relay that is picked by 100 mA, with a loop supply voltage of 24V
and a total line resistance of 20 ohms, the load voltage (voltage across the relay) should be:

$$V_L = V_S - (V_C + V_C) \quad \text{where } V_C + V_C = (R_C + R_C)\ I$$

$$22 = 24 - 2 \quad \text{where } 2V = (20\ \Omega) \times 0.1\ A$$

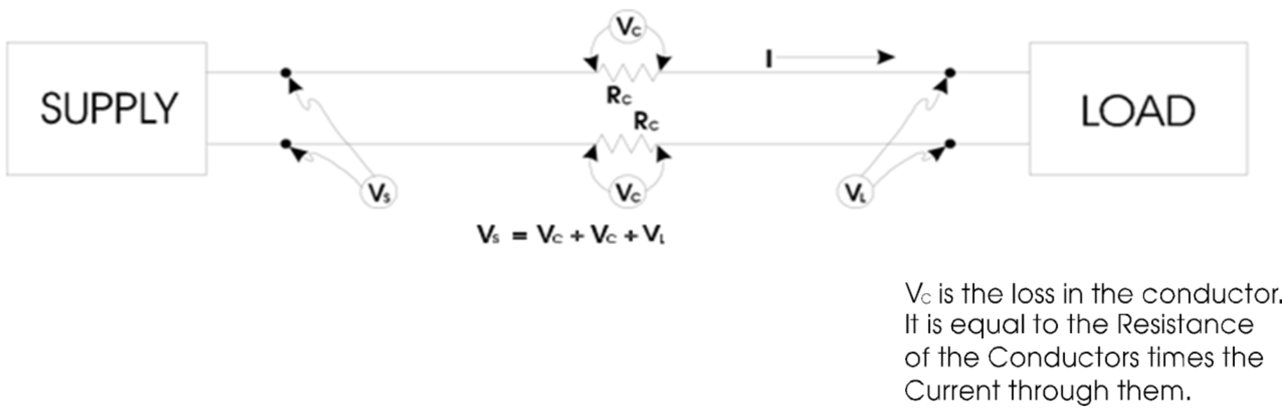

Figure 5-3. Calculating Load Voltage due to Line Resistance

5.2.9 Lightning Arresters & Surge Protectors

Use lightning arresters in association with any radio or modem equipped unit. Some modems are equipped with surge protection circuitry. Lightning arresters or Antenna Discharge Units should be placed on the base of the antenna and at the point where the antenna lead (typically coax) enters the site equipment building. When a modem is used, a lightning arrester should be placed at the point where the phone line enters the site equipment building. If you use a modem that does not include surge protection circuitry it is recommended that you also install a surge suppressors or lightning arrester on the phone line as close to the modem as possible. *Any unit interfaced to a radio or modem must be connected to a known good earth ground.*

5.2.10 Secure Wiring Connections

Make sure that all wiring connections are secure. In time wires that were once round will become flattened due to the pressure applied by screw compression type terminals and site vibrations. After a while these compression screws have a tendency to become loose. Part of a good maintenance routine should be to check and tighten all screws associated with wiring terminal connections. Avoid nicking the wire(s) when stripping insulation. Remember, nicked conductors will lead to future problems. Also remember to provide some cabling slack and strain relief.

If installing stranded or braided wiring that has not been tinned, be sure to tightly twist the end (in the same direction as manufactured) and then trim off any frizzed wires.

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