



# Property Risk Consulting Guidelines

## LIGHTNING PROTECTION

### INTRODUCTION

Lightning is an electrical discharge occurring in nature. Electric charges build naturally within a cloud, between clouds, and between clouds and the earth. Storm conditions increase these potential differences. The voltage between a cloud and the earth can exceed 30 MV.

The atmosphere is a dielectric. It provides electrical insulation between objects having different electrical potentials. When the potential difference between any of these objects becomes too great, the insulation breaks down and lightning results. Taking place within a fraction of a second, this discharge of electrostatic energy produces a large, visible spark; a sound called thunder; and heat. "Thunderstorm" refers to weather conditions during which lightning discharges occur.

The visible discharge of lightning is commonly called a lightning bolt, strike or flash. Current in the flash can exceed 25 kA. Flashes above 200 kA have been reported. The path of the discharge between a cloud and earth can cause extensive property damage and death.

Lightning is thought to travel the path of least impedance through the air, along conductive items, and to ground. However, winds, electric fields and other factors can cause unexpected hits. Lightning strikes have different sizes, shapes and strengths. No one can reliably predict the time, path, point of termination, size or strength of a strike. One theory in the science of lightning is "Lightning will do whatever it wants to do."

Traditional lightning protection systems are special electrical systems designed to capture and control lightning. These systems attempt to intercept lightning strikes and carry the strike current safely to earth. They protect buildings and other structures using strike termination devices (receptors), main conductors and ground terminals. The traditional lightning protection system contains at least one of the following:

- A strike termination device (receptor) that "attracts," "takes" or attempts to "intercept" lightning strikes. The placement of the receptor(s) is designed to shield a "protected area" from direct strikes. Air terminals, formerly called lightning rods, are common receptors. Any substantial electrically conductive structural or ornamental component can serve as a receptor.
- A buried ground terminal, typically a ground rod or ground plate, provided specifically for grounding of lightning strikes.
- A main conductor designed to safely carry the strike current from the strike termination device (receptor) to the buried ground terminal. Structural steel members and heavy, stranded cable are commonly used as main conductors.

Traditional lightning protection systems usually also contain one or more bonding conductors. As a lightning discharge passes through a lightning protection system, its current flow causes different

components of the system to reach different voltages. These differences occur because of resistance and impedance in the circuit. Too high an electrical potential difference between nearby parts can cause arcing as the air dielectric breaks down. The bonding of system components lowers impedance and thus limits potential differences. Similarly, bonding nearby conductive objects to a lightning protection system equalizes voltages between connected points and prevents arcing between them. Thus, bonding prevents electrical breakdown and helps control the discharge path.

Because traditional lightning protection systems uses strike termination devices (receptors), conductors and grounds, this section refers to them as RCG systems. RCG systems are common throughout much of the world. NFPA 780 is an installation standard describing one RCG approach to lightning protection. This standard defines terms, contains drawings of system components, and depicts typical installations.

Underwriters Laboratories produces a lightning protection standard, UL 96A, which is similar to NFPA 780. The Lightning Protection Institute (LPI) also publishes a comparable standard, LPI-175.

Nontraditional “lightning protection systems” include one type system based on charge dissipation, and another based on early streamer emissions. Charge dissipation systems actually attempt to dissipate cloud charges over a protected area, and thus, to prevent lightning from occurring in that area. Early streamer systems are superficially based on the traditional RCG philosophy, but they use specially designed air terminals to trigger “early streamers” to initiate and attract lightning strikes over larger distances. Theoretically, early streamer systems allow a wider spacing of strike termination devices (receptors) than do traditional systems. Radioactive lightning rods are among the group of special air terminals used in early streamer systems.

AXA XL Risk Consulting does not recommend charge dissipation or early streamer lightning protection systems. NFPA installation standards do not exist for these systems. Controversy concerning their effectiveness persists. In contrast, traditional RCG systems have a long record of success.

No one lightning protection philosophy fits all loss experience. Although RCG systems establish areas that are “substantially immune” (NFPA 780 definition – zone of protection) to lightning strikes, these protected areas are not invulnerable. Even underground bunkers have been struck and damaged by lightning. In general, people involved in property loss control and safety believe NFPA 780 and similar RCG protection systems provide a reasonable, though imperfect, level of protection.

## POSITION

Install lightning protection to protect buildings and structures meeting these three criteria:

- Located where there is a known history of thunderstorms.

- NOTES:**
- 1) The need for protection should not be rejected because an area has a low thunderstorm frequency. Even a relatively low exposure of five thunderstorm-days per year does not assure a facility will not be hit.
  - 2) An existing structure may not require additional protection if its history suggests locale, topography and nearby permanent structures afford natural protection. However, the addition of a new structure may affect what was natural protection. A new, prominent structure is likely to attract lightning.
- Occupied by hazardous materials or hazardous operations, or otherwise occupied such that lightning endangers safety or high property values.
  - Designed without natural means to control lightning discharges. For all-metal buildings, bonding and grounding of structural steel components can reduce or eliminate the need for separate lightning protection systems.

Protect buildings and structures from direct lightning strikes by installing lightning protection systems meeting the requirements of NFPA 780, UL 96A or LPI-175. Use components listed to UL 96. Use listed or certified installers. As an example, a “UL Master Label” certified lightning protection system is

a system designed to meet UL 96A criteria, installed by UL listed installers, constructed with UL listed components, and covered by the UL re-examination service.

Protect buildings and structures from lightning induced surges traveling along incoming electric power and communications lines by installing surge arresters at electrical service entrances to divert these surges to earth.

Protect electric equipment from lightning induced surges by following the recommendations in PRC.5.2.2 and NFPA 70 (NEC). Article 280 of the NEC describes general requirements for surge arresters in premises wiring systems.

Refer to NFPA 780 for acceptance of structural components as components of lightning protection systems. Structural metal framing may be used as conductors where framing members are electrically continuous and adequately sized. Metal railings and even the metal skin of a building may be used as strike termination devices (receptors) if adequately sized and properly bonded to this protective, grounded metal framing. Architects, engineers, designers, installers and inspectors involved in lightning protection systems may evaluate the use of structural components for lightning protection as outlined in NFPA 780.

Install static wires above all outdoor power lines on the plant property. Position, size and ground the static wires to shield the power lines against direct lightning strikes.

Electrically interconnect grounding mediums and large conductive objects in, on and near each structure. Use recognized low-impedance bonding and grounding techniques that follow the lightning protection standard. For increased reliability, encircle the protected structure with an in-ground loop conductor that connects all grounding systems to thus form a single earth system. Electrically interconnect lightning conductors; arrester grounds; electrical service grounds; secondary circuit grounds; telephone system grounds; equipment grounds; building steel; metal towers, fences and gates; large metal objects; and, where practical, metallic underground water mains. Aboveground continuity should be verified annually. Where an isolated grounding system is required by an equipment manufacturer, such as where electrical noise will be especially disruptive, it should be well-separated from the lightning protection grounding system to minimize the potential for arcing (flashover) between systems. IEEE Standard 142, IEEE Standard 1100, NFPA *Fire Protection Handbook*, NFPA 70 and NFPA 780 provide detailed guidance on grounding and bonding.

Prohibit noncurrent-carrying metallic parts of electric equipment, e.g., metal raceways and panel enclosures, and ungrounded conductive materials, within 6 ft (1.8 m) of a lightning down conductor unless bonded to the lightning protection system in accordance with NFPA 780.

Provide a surge arrester at each transformer primary and secondary line-connection where any segment of either line runs outdoors and is exposed to lightning surges.

Test new grounding systems as the temperatures and ground moisture conditions change throughout the year. Generally, for the first 2 yrs, test grounding systems no less than quarterly. Establish a history of test results. Then, test ground resistance at least annually during the period having the greatest soil resistivity. Maintain ground resistance at 5 ohms or less. Testing should use the 3-Terminal, Fall Of Potential test method and may need to have their testing frequency increased to semi-annually if resistance levels cannot be maintained. Corrective action should be scheduled and be completed by UL listed or manufacturer qualified installers recognized in the industry.

As most RCG systems employ their receptors along roof lines, management of change (MOC) practices should be fully enforced per PRC.1.0.2 when special or new equipment are installed in the area. PRC.5.2.2. and the specific sections of NFPA 780 relating to Photovoltaic (PV) solar arrays should be used when planning such systems to assure proper design and integration with existing, modified or new RCG systems.

## DISCUSSION

### Two Common Protection Methods

A direct lightning strike can destroy any property in its path. Electrical power and communications equipment could be damaged by lightning even if the lightning strike occurs miles away. This damage can result when the utility distribution system carries the lightning induced electrical surge to the customer's site. Customers install surge arresters to protect their equipment from such events. Utility switching and load-changing surges can also be controlled by these same surge protection devices.

Therefore, protection against lightning employs two distinct loss control methods. These are:

- RCG lightning protection systems to protect structures and enclosed equipment from direct strikes. Typical RCG lightning protection schemes are shown in NFPA 780.
- Surge protection devices to protect power, manufacturing and communications equipment from induced voltage surges traveling in electrical conductors and caused by "nearby" or indirect strikes, as described in PRC.5.2.2.

Most lightning protection schemes employ both RCG protection and surge protection. Both RCG lightning protection systems and lightning surge protection devices attempt to provide safe paths for discharging the electrical surges caused by lightning. Figure 1 is an example of direct lightning and indirect lightning surge protection.

RCG systems can also employ surge arresters at service entrances to protect structures from the lightning surges that travel along power and communications lines. These arresters protect structures. They do not serve the same purpose as arresters provided near utilization equipment to protect it from lightning. See NFPA 780.

### When Protection Is Needed

In general, AXA XL Risk Consulting recommends the installation of an RCG lightning protection system in any locale known to have a history of lightning strikes and wherever safety or high property values can be compromised by a lightning strike. See NFPA 780 Appendix L "Lightning Risk Assessment" for description of their review system to determine if lightning protection system is needed or optional based on site specific factors.

Similarly, AXA XL Risk Consulting recommends surge protection where safety, high equipment values or serious exposures are jeopardized by lightning strikes.

### Protected Area

No protection system can guarantee that lightning will not strike in the protected area. See NFPA 780 for an explanation of striking distance. NFPA 780 bases most of its protection requirements on a striking distance of 150 ft (46 m). NFPA 780, Chapter 7 "Protection for Structures Containing Flammable Vapors, Flammable Gases, or Liquids That Can Give Off Flammable Vapors" is more conservative. It uses a 100 ft (30 m) striking distance. As the designed striking distance decreases, the protection needs increase. However, striking distances reportedly can be 50 ft – 700 ft (15 m – 213 m), depending on the strength (amperage) of the discharge. In general, the NFPA 780 approach to protecting structures is considered appropriate until such time as loss experience dictates changes are needed.

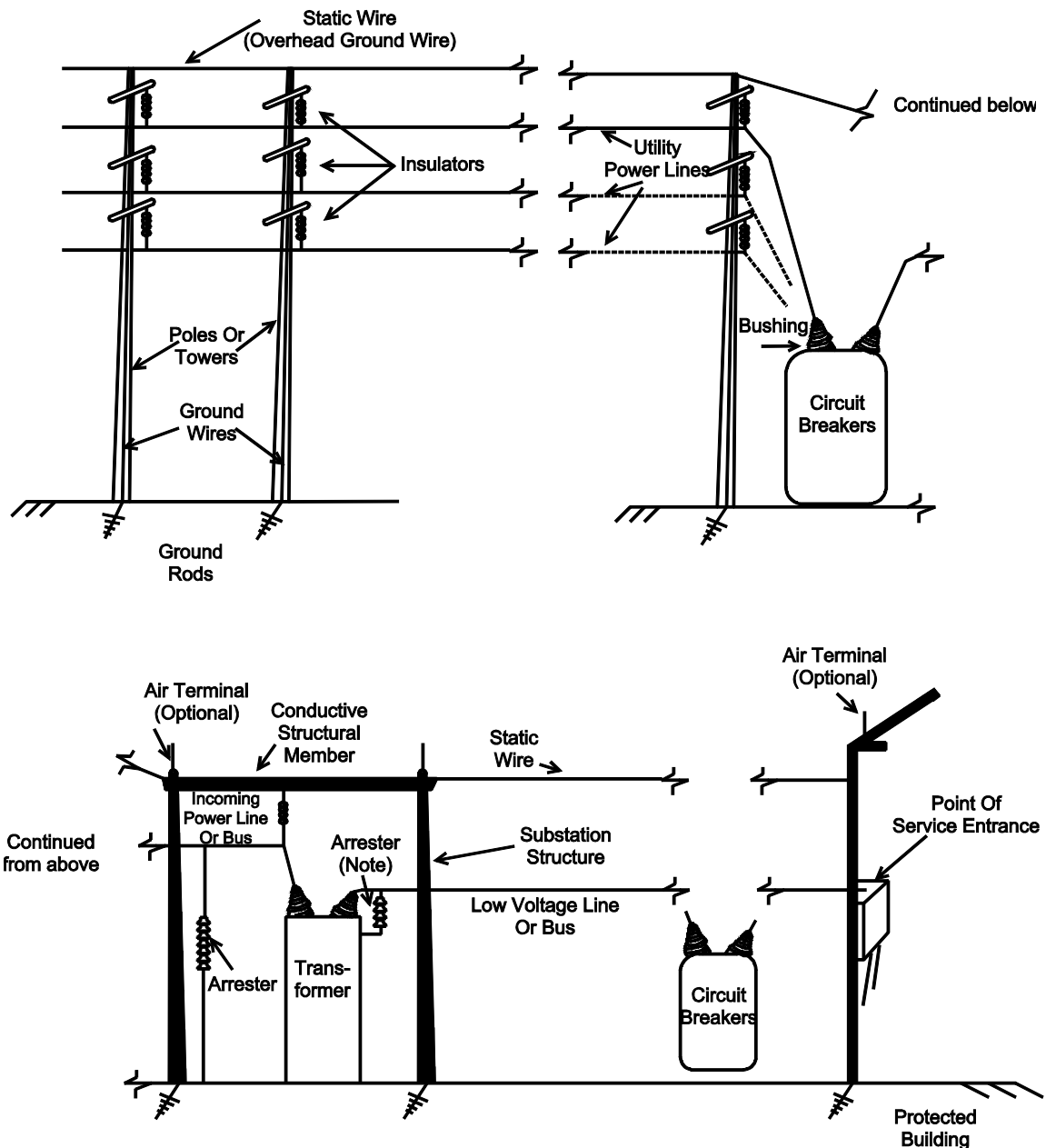


Figure 1. Example Of Electric Distribution Lightning And Surge Protection.

**NOTE:** The low voltage arrester may use a ground conductor or may be bolted to tank.

### Codes And Jurisdictions

Many countries have developed their own RCG system standards. Some are considerably different from NFPA 780. Instead of lightning rods, conductive cables supported above a roof might serve as strike termination devices (receptors). Or, specially shaped air terminals might be used.

This document is not intended to replace local codes, standards or requirements. It describes NFPA 780 type RCG systems that are internationally recognized as providing a substantially reliable approach to lightning protection for structures. Other RCG systems required by local jurisdictions can be equally effective.

### **Comments On “Franklin Rod” And “Faraday Cage” Type Systems**

NFPA 780 describes an air terminal as a rod of specified construction and size. But such a device is only one of the permitted strike termination devices (receptors) in RCG systems. Another strike termination device (receptor) allowed by NFPA 780 is an exposed metal structural part having a thickness of at least  $\frac{3}{16}$  in. (4.8 mm). Modern steel-frame buildings can be protected against lightning without the use of air terminals or lightning rods. Thus, describing RCG systems as “Franklin Rod” type systems is misleading.

A “Faraday Cage” is an enclosure whose construction precludes entry and exit of undesired electromagnetic disturbances. Typically, this is a double-walled screen room whose conductive construction intercepts air borne signals and noise to prevent their passage through the cage. A lightning protection system is loosely described as a Faraday Cage because the system intercepts lightning and protects a specified zone from a lightning strike. However, a lightning protection system is not a Faraday Cage. Describing an RCG system as a Faraday Cage type system is inaccurate.

### **Protecting Electrical Distribution Systems**

Outdoor electric power distribution systems use poles and towers to carry one or more elevated power lines. These structures, and the electrical distribution systems they support, require protection against lightning. A direct strike to a wood pole can ignite the wood. A strike to a metal tower can heat its members and weaken its support capabilities. A direct strike into an electrical system can put such a large current surge into the system that the withstand capacity of connected equipment and protective devices is exceeded.

The protection of electric utility distribution systems is not within the scope of NFPA 780. Often, however, an RCG-type system is installed for such protection. Many employ masts, air terminals, overhead wires and down conductors as described in NFPA 780. The overhead wire is called a shield, ground or static wire. The wire is grounded to attract the lightning, and thus shield or protect the electric distribution system components, including power lines, poles, substations and towers, located below. When lightning strikes an air terminal or shield wire, current is carried to ground through the high ampacity protective system. Generally, only an induced voltage from this “nearby” strike affects the power system.

Many utilities develop their own lightning protection guidelines. Because the direct property loss potential to a utility is low, major portions of many systems go unprotected. To provide a reasonable level of reliability to utility users, public utility lines near customers are shielded using static wires. Usually grounded by connection to a down conductor at each pole, these static wires run above the utility power lines. They extend at least 2000 ft – 2500 ft (600 m – 760 m) out from the customer’s connection. The static wire normally terminates above the facility connection at the point of building entry, at the facility switchgear station, or at a transformer. Within a building, shielding is normally satisfied by a metal building frame, or by the exterior or integral lightning protection system.

RCG protection does not protect against induced voltages in electrical systems. As described earlier, electrical equipment is protected using surge protectors. See PRC.5.2.2.

### **Other Considerations**

NFPA 780 requires a dedicated ground terminal for the lightning protection system. Often, grounding electrodes or ground rods are buried in the earth for this purpose. This lightning system ground is electrically connected to other grounding systems, such as electric power system grounds and telecommunication system grounds, using a bonding conductor to limit potential differences between wiring systems.

A poor grounding system will make lightning and surge protection ineffective. The resistance of a grounding system is influenced by the soil conditions, including moisture content, temperature and chemical makeup. The deeper the installed ground rods or grids, the less of an effect climate will have on the system.

Chemically treating the soil with salts may be needed to obtain the low resistance required, especially where usable soil depth is limited by rock formations. However, chemical dilution and spread into the environment can be problems. Chemical treatments should be used only where more permanent and less labor-intensive means of reducing ground resistance cannot be used.

The UL Electrical Construction Equipment Directory provides guidance on the selection of lightning conductors, air terminals, fittings, and grounding and bonding equipment, and lists contractors who install "UL Master Label" certified lightning protection systems for structures.