# Lightning Protection:

## Optional or Recommended?

*BY KEITH LANE, P.E., RCDD/NTS SPECIALIST, TPM, LC, LEED AP*
*Lane Coburn & Associates, LLC.*

**Through a few basic calculations, an engineer can gain a better understanding of the order of magnitude of lightning risk faced by a commercial building.**

A lightning protection system, first and foremost, provides safety to a commercial building and its occupants. But it also increases electrical service continuity by eliminating damage to the structure from a lighting strike.

How does it work? A lightning protection system for a commercial building provides the means for the lightning strike to pass through an area without damaging non-conductive parts of a building or causing a power outage and insulation damage. The system does not prevent a strike from occurring. Rather, it is a method of controlling lightning by channeling it along a low-resistance path.

The main components of a lightning protection system are air terminals, down conductors and ground rods. And all of this equipment should be installed per NFPA 780.

An engineer can use a risk assessment calculation based on NFPA 780, I*nstallation of Lightning Protection Systems*. The analysis below, based on NFPA 780-2000, uses a handful of criteria including:

1. Height, length and width of the building.
2. General location of the building (within the United States).
3. Environmental coefficient.
4. Building and roof structural material.

## What is Lighting?

**What exactly is lightning? It is the visible discharge of static electricity. It can occur between clouds, or between a cloud and the earth. During a lightning event, positive charges move to the top of the cloud and negative charges move to the bottom.**

**Lightning will typically discharge at the highest object in an area—i.e., a tall building or structure.**

**5.** Structural content coefficient.
**6.** Occupancy coefficient.
**7.** Lighting consequence coefficient.

It is important to work with the architect and the structural engineer to thoroughly understand all components of the building to accurately assess the lightning risk based on the design criteria noted above. Also, the general geographical location of the building is an important criterion.

In NFPA 780-2000, a map of the United States is laid out with contour lines indicating the average lightning flash density in flashes per $km^2$ per year. For the far West, the figure is 0.1 per year, while at the south end of Florida, it's more than 14.0 per year.

As for building type, the risk associated with large gathering areas such as stadiums, theaters and large retail stores or malls can include loss of power, fire, panic and potentially loss of life. The risk associated with offices, banks and data centers can be from loss of power to the computers and potentially lost critical data. An industrial, manufacturing and pharmaceutical lab facility can incur lost production time as a result of a loss of power. Even a brief loss of power in a data center, greater than the time allowed in the CBEMA curve, can cause computers to restart.

NFPA 780-2000 determines a *lightning strike frequency* (Nd) based on the yearly strike frequency, which is in turn based on the average flash density, the collective area and an environmental coefficient:

$$Nd = (Ng) * (Ae) * (C1) \text{ where}$$

Ng = yearly average flash density in a region
Ae = equivalent collective area of the structure in $km^2$, or $LW + 6H(L+W) + \pi 9H2$
C1 = environmental coefficient

The NFPA 780 risk analysis also determines the *tolerable lighting frequency* (Nc), which is a measure of the damage risk to the structure or building:

$$Nc = (1.5x10^{-3}) / C \text{ where } C = (C2) * (C3) * (C4) * (C5)$$

C1 is the environmental coefficient, which deals with the buildings height and proximity to other tall structures and can range from 0.25 to 2.0.

C2 is the structural coefficient, from 0.5 to 3.0 and based on the contents of the structure (metal, nonmetallic or flammable) and the content of the roof (metal, nonmetallic or flammable)

C3 is a coefficient based on the value of the contents in the structure, their flammability and whether they are replaceable. This value can range from 0.50 to 4.00.

C4 is the coefficient of the occupancy of the structure. The choices for this value are unoccupied, normally occupied and difficult to evacuate or risk of panic. These values can range from 0.5 to 3.00.

C5 is the coefficient of the consequence of a lightning strike. This value has to do with the requirement of continuity and the consequence to the environment if power is lost. These values can range from 1.0 to 10.0.

In this analysis, if the final calculated number for Nd is greater than the final calculated number for Nc, then lighting protection is recommended. Otherwise, protection is optional.

The engineer can also look at the relative difference between Nd and Nc to get a better understanding of the order of magnitude of risk. In "Optional or Recommend?" on p. 30, two sample buildings are described and analyzed in terms of a lightning risk analysis. Increasing the building height from 200 ft. to 400 ft. means that lightning protection is no longer optional; it's recommended.

Any requirements for a lightning protection system from the authority having jurisdiction (AHJ) or other regulatory requirements should be evaluated over and above the risk assessment as illustrated in NFPA 780. This risk assessment should be a guide only; the final decision to use a lightning protection system should be made by the building owner. There also needs to be a real assessment of the potential cost of downtime for critical facilities.

### GETTING DOWN TO DESIGN

Once it is determined that lightning protection is required—whether by the owners, as a result of risk analysis, or by the AHJ—the installation of the system should follow the practices as defined in NFPA 780.

A lightning strike can cause a higher voltage level on the incoming utility power lines. This higher voltage is transformed to a higher serving voltage than the building's electrical service was designed for. This damaging overvoltage can cause insulation breakdown in conductors and switchgear and in sensitive electronic equipment. At very high voltages, the surge can flash over and cause an extensive breakdown of the main electrical service.

The lightning system designer should also provide a means to reduce step voltage and contact voltage, restrict fire from spreading, reduce induced voltages and reduce the effects from surges induced from lightning to sensitive electronic equipment. The electrical engineer should be consulted to provide appropriate surge protection and transient voltage surge protection at the main electrical service and on the secondary side of 120/208-volt stepdown transformers feeding sensitive electronic equipment. See UL 1449 for standards for transient voltage surge protectors and the *National Electrical Code* Article 280 for surge arrestors.

There are products on the market that offer combined lightning protection and transient voltage surge suppression (TVSS) in one package. This device is installed on the secondary side of the distribution transformer at the main electrical service gear. These devices use a spark gap to prevent the high voltage surges resulting from a lightning strike from entering the building's electrical service. The device also contains TVSS to diminish any residual surge let through from the surge arrestor. Additional transient voltage surge protection should be coordinated downstream in front of critical loads to ensure service continuity.

Critical facilities like data centers, banking facilities and hospitals should evaluate the real cost of downtime or threat to human life from a lightning strike. If it is determined that a lightning protection system is going to be employed in a facility, the installation should follow the practices spelled out in NFPA 780. Additionally, coordination with the electrical engineer is critical to ensure that proper surge arrestors and TVSS are installed in a coordinated manner to protect the main electrical service and the sensitive electronic equipment from damage and downtime. ⒺⓃⒹ

## Lightning Protection: Optional or Recommended?

A comparison of two sample buildings demonstrates that when it comes to lightning protection, all other variables being equal, height matters. Risk analysis calculations based on NFPA 780, *Installation of Lightning Protection Systems*, demonstrates that when building height increases, the protection threshold passes from optional to recommended.

### BUILDING ONE

Assume a building that is 100 ft. long (L) by 100 ft. (W) by 200 ft. high (H) in Seattle, where the yearly average flash density (Ng) is 0.1.

Ae is the equivalent collective area of the structure in $km^2$. It is equal to the ground area with the same yearly lightning flash probability as the structure. This value increases with increased height of the building:

***Ae*** = LW + 6H (L+W) + π9H2 = **0.0232**

**Ng = 0.1**

**C1** for this example will be **0.5**. The structure is surrounded by smaller structures within a distance of 3H.

**Nd** (lighting strike frequency) = (Ng) (Ae) (C1) = 0.1 * 0.0232 * 0.5 = **0.0012**

**C2** assumes that it is a metal structure and a nonmetallic roof with a resulting coefficient of **1.00**.

**C3** assumes that the contents of the building are of standard value and are nonflammable, resulting in a coefficient of **1.00**.

**C4** assumes that the building is normally occupied, resulting in a value of **1.00**.

**C5** assumes that electrical system continuity is not required, and that there would be no environmental impact if the electrical system were shut down by a lightning strike. This will result in a value of **1.00**.

**Nc** (tolerable lighting frequency) = ($1.5x10^{-3}$) / C where C = (C2) * (C3) * (C4) * (C5); in this example, C = 1 * 1 * 1 * 1 = 1

**Nc** = (1.5x10-3) / 1 = **0.0015**

Because Nd (0.0012) is less than Nc (0.0015), in this example, lightning protection is optional, based on NFPA 780 risk analysis.

### BUILDING TWO

Now, assume almost the same building in Seattle, but with double the height—400 ft. instead of 200 ft.

**Ae** = LW + 6H (L+W) + π9H2 = **0.0455**

**Ng** is the same as for Building One: **0.1**.

**C1** for this example again will be **0.5**.

**C2** through C5 will also be the same as before: **1.00**.

**Nd** = (Ng) (Ae) (C1) = 0.1 * 0.0455 * 0.5 = **0.0023**.

In this example, Nc still equals 0.0015, but Nd is now greater at 0.0023. As a result of this risk analysis, lightning protection is recommended.