LIGHTNING PROTECTION INSTITUTE

BUILD& PROTECT

Lightning Protection Frameworks for Resilient Design & Construction

Build and Protect: Lightning Protection Frameworks for Resilient Design and Construction

Abstract

Lightning is a photogenic natural phenomenon that is the result of violent electrostatic discharge that occurs when two electrically charged atmospheric regions are temporarily equalized. The visual energy discharge – often accompanied by significant auditory stimulus (thunder) – invokes powerful responses in humans and animals.

Despite the innate beauty associated with lightning storms, their energy can produce significant damage in the natural and built environment: deaths, injuries and fires often accompany lightning events. Fortunately, of the estimated 8 million lightning strikes that occur worldwide every day, not all are lethal or cause damage (Thompson, 2014).

> Lightning is not only spectacular, it's dangerous. About 2,000 people are killed worldwide by lightning each year. Hundreds more survive strikes but suffer from a variety of lasting symptoms, including memory loss, dizziness, weakness, numbness, and other life-altering ailments. Strikes can cause cardiac arrest and severe burns, but 9 of every 10 people survive. The average American has about a 1 in 5,000 chance of being struck by lightning during a lifetime. (National Geographic, n.d.)

Severe thunderstorms and convective weather[1] were responsible for a record-breaking $5.7 billion costs in insurance losses in the first quarter of 2017. Previously, "homeowners insurers nationwide paid out $826 million to help more than 100,000 policyholders recover economically from lightning-caused property damage in 2016," said Michael Barry, Head of Media and Public Affairs at the Insurance Information Institute (Lightning Protection Institute, May 7, 2018).

[1] "Convective weather" describes an unstable weather pattern caused by air mixing at different temperatures resulting in dangerous air current uplifts.

This paper addresses efforts to increase lightning protection in the built environment by resilient design and construction through consensus-based building and safety codes.

Problem Statement

While regrettably the global and national lightning data are inconsistent, there are some similarities among reliable sources. Lightning continues to cause significant property damage in a variety of properties throughout the US. In just a few short weeks in the summer of 2019**,** lightning-caused fires damaged or destroyed hundreds of properties, among them:

- On May 2, 2019, a mid-day lightning strike hit a multi-story senior living complex in Prince George's County, Maryland, resulting in a two-alarm fire. Although no one was injured in the attic fire, about 75 residents had to be evacuated (Kubota, S. May 2, 2019).
- A wood beam and roofing material were destroyed by a lightning strike July 24, 2019 at historic McKnight Hall at Gettysburg College in Pennsylvania. The building, constructed in 1898, suffered minor damage (Naylor, S. July 24, 2019).
- More than 4,400 acres of high desert scrub burned from a lightning strike July 26, 2019 northeast of Las Vegas, Nevada. The fire on federal Bureau of Land Management property had to be controlled by four hand crews, three engines and three helicopters that ferried water from nearby Lake Mead (Haas, G. July 26, 2019).
- Four middle school classrooms and adjacent workspaces were destroyed by a July 20, 2019 lightning strike in Brandon, Florida (Sokol, M. July 23, 2019).
- A Folkston, Georgia, furniture store was destroyed by a lightning strike and subsequent fire July 21, 2019. "It took 18 trucks and dozens of firefighters to fully extinguish the fire, which was monitored overnight for hot spots. No injuries were reported but the building may not be structurally sound," according to local news services. (Harding, A. July 21, 2019).

Lightning-caused property losses do not discriminate among occupancy types. Table 1 reflects loss data based on different property uses.

Table 1.

Lightning-Caused Property Loss Data by Occupancy

Occupancy or Use	Estimated Losses
Storage facilities	$ 28 million
Churches, restaurants, gymnasiums	$22 million
Hotel and motels	$19 million
Industrial and manufacturing	$15 million
Outdoor properties	$ 3 million
Educational and health care	$3 million

Source: Lightning Protection Institute https://lightning.org/lightning-is-your-home-business-or-community-in-the-line-of-fire/

In 2016 there were 38 lightning deaths in the United States (about 0.1 per million), compared with 26 in 2015 and 2014. From 2006 to 2016 on average about 31 people died each year from lightning strikes in the United States, according to the National Weather Service. The significant decline in lightning deaths is due to fewer farmers working in fields, along with technological advances, better lightning protection and awareness of lightning safety. (Insurance Information Institute, n.d.) However, although advances in lightning protection have reduced the number of deaths, first responders still are at great risk of injury or death in the aftermath of lightning storms. In 2018, a Howard County, Maryland, fire fighter was killed in a 7-alarm house fire that was suspected to have been caused by a lightning strike (Fox4DC.com. July 23, 2018).

To provide a sense of the frequency of U.S. lightning strikes, Figure 1 is a screen-capture selected to solely illustrate one 24-hour period of lightning strikes in central Nebraska.

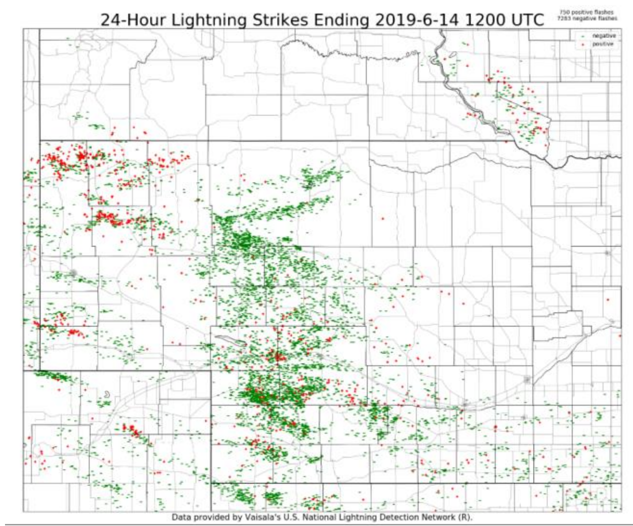

Figure 1.
Screen Capture of One 24-hour Period of Lightning Strikes in Central Nebraska
Source: U.S. National Lightning Detection Network

An average lightning strike can carry as much as 30-50 kA[2] of destructive electric energy, which can rip through roofs, explode walls of brick and concrete, ravage circuitry, perforate gas piping and ignite deadly structural fires. Compared to a household electrical circuit of 120 volts, a single lightning strike can carry up to 300 million volts of electrical energy, which can pack a powerful punch. (Lightning Protection Institute, 2019).

The highest lightning strike ever recorded was 200 kA, but it is unlikely any single person will ever experience anything of this magnitude. In a storm, recorded lightning strikes appear as a bell curve with 200 kA as the extreme high-end value but a very small incidence, just like the beginning of the bell curve is about 8 kA, the smallest amount of energy that can overcome the insulating value of air. This lower value is not recorded often either. The greatest incidence of lightning occurs in the 30-50 kA range (top of the bell curve) and that is a more average range for design requirements. Surge protection devices are generally tested to 30 kA. Lightning protection components in the international standards are tested to 50 and 100 kA. Overall system design provides for splitting of attachment current along multiple grounded paths.

[2] kA = kiloAmps. One kiloAmp equals 1,000 amps, a measure of electrical current flow. Most single family residential electrical services are rated at 200 amps.

The National Fire Protection Association (NFPA) collects and evaluates fire and other hazard data. Its most recent survey (2013) of U.S. lightning-caused fire losses reported that from 2007 to 2011, U.S. fire departments responded to an estimated annual average of 22,600 caused by lightning. Additionally, Federal and state wildland fire fighters reported an estimated 9,000 annual wildland fires to the National Interagency Fire Center (NIFC) in Boise, Idaho, where wildland fire coordination and resources are maintained. NIFC statistics show that in 2004-2008, an average of 11,400 (14%) of reported wildland fires were started by lightning per year. However, wildland fires caused by lightning led to much more average damage per fire (500 acres vs. 40 acres) than fires caused by humans. (Ahrens, M. 2013).

According to the paper, only 19% of reported lightning fires occurred in homes, but these accounted for 86% of the associated lightning fire civilian deaths, 76% of the associated injuries and 68% of the direct property damage. (Ahrens, 2013, p. iv).

From 2003 through 2012, 42 U.S. firefighters, in total, were killed as a result of lightning caused fires. NFPA collects data about every firefighter fatality in the US. These numbers are totals, not averages for the period. Four of the fire fighters died during structural events while the remaining 38 died in wildland fires.

From a social perspective, the US leads the world in reducing the number and frequency of lightning caused deaths. According to one study, lightning death rates in India are about 2 persons per million and parts of Asia and Africa can be 100 times more: especially affecting poor populations (Phippen, J.W., 2016). In 1997, Lopez and Holle identified the downward trends in US lightning deaths from 1900 to 1991 (Figure 2).

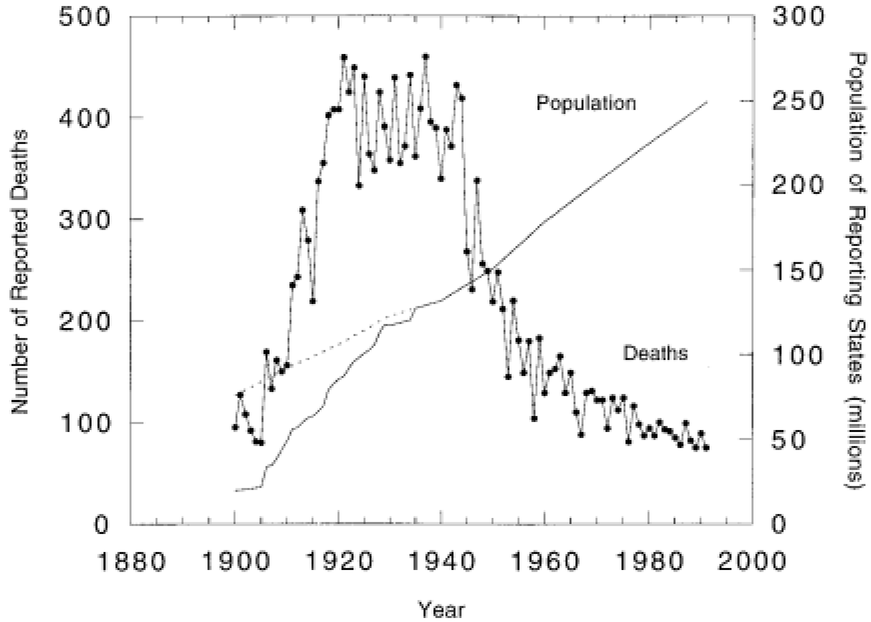

Figure 2.
Annual Lightning Deaths reported to Bureau of Census and Public Health Service (1900 to 1991) Source: Lopez and Holle (1997)

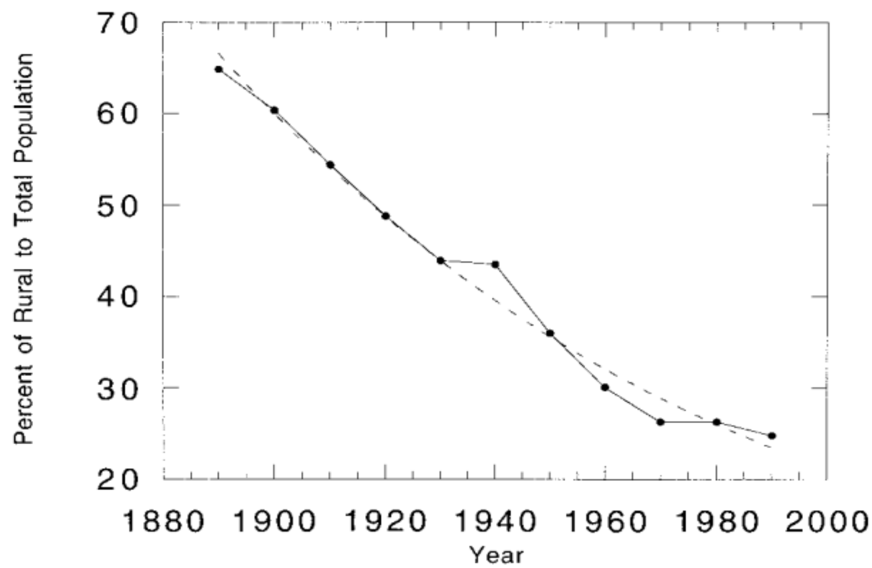

Figure 3.
Percent of Total Rural Population (1800 to 1991)
Source: Lopez and Holle

While the NFPA fire data are six years old, there are additional contemporary climate issues that bring the topic to the forefront. According to Aich, et.al.

> . . . Scientists are starting to recognize that lightning has a broader story to tell. Lightning frequency is changing, as climate is changing. For example, lightning's close relationship to thunderstorms and precipitation makes it a valuable indicator for storminess, which makes lightning a particularly useful means of observing a variable and changing climate [Price, 2013; Williams, 2005].
> What's more, lightning is not only an indicator of climate change; it also affects the global climate directly. Lightning produces nitrogen oxides, which are strong greenhouse gases [Price et al., 1997].

Furthermore, Thompson (2014) reports the problem will only get worse as global warming increases, "the studies that have been done to date estimate the increase in lightning to be anywhere from 5 to 100 percent per degree Celsius rise — a strikingly wide range".

Climate Change Impacts

The topic of climate change – also called "global warming" -- is a political hot potato. While people may argue legitimately over its causes, the data that substantiate its occurrence are compelling. According to the National Aeronautics and Space Administration (NASA):

> The planet's average surface temperature has risen about 1.62 degrees Fahrenheit (0.9 degrees Celsius) since the late 19th century, a change driven largely by increased carbon dioxide and other human-made emissions into the atmosphere.
> Most of the warming occurred in the past 35 years, with the five warmest years on record taking place since 2010. Not only was 2016 the warmest year on record, but eight of the 12 months that make up the year — from January through September, with the exception of June — were the warmest on record for those respective months. The oceans have absorbed much of this increased heat, with the top 700 meters (about 2,300 feet) of ocean showing warming of more than 0.4 degrees Fahrenheit since 1969. Global sea level rose about 8 inches in the last century. The rate in the last two decades, however, is nearly double that of the last century and is accelerating slightly every year (NASA, June 13, 2019).

News media accounts of flooding, wildfires, wildland-urban interface fires and concomitant landslides, lead government and private sector policy makers to address how to make communities more resilient from these sorts of disasters. If climate change affects lightning and vice versa, it can be expected there will be an increase in public discussion around ways to mitigate the consequences of lightning.

Resilience

Hurricane Katrina in 2005 was the tipping point in the country's response to the consequences of weather-related disasters on the built environment. Furthermore, it invigorated public discussion on climate change. Katrina was responsible for 1,833 deaths and damage estimated at $151 billion, including $75 billion in the New Orleans area and along the Mississippi coast. According to the Property Casualty Insurers Association of America, Katrina resulted in insurance claims worth $41.1 billion that were paid to 1.7 million policyholders, with 98 percent of claims settled within a year. (Johnson, D. 2015)

As a result of this disaster, politicians and policy makers began a robust public discussion on the topic of "resilience": the ability to weather a catastrophic event and recover quickly to previous status and functionality. According to Hassler and Kohler,

> The concept of resilience offers a means to address the long-term evolution of the built environment and to explore implications of changing conditions on the efficacy of different approaches to planning, design, operation, management, value and governance. Potential threats appear both as disruptions (over short time horizons) and slow moving, diffuse threats (over longer time spans). An effective response may need to include a combination of anticipation (precaution) measures and resilience heuristics. However, the evolution and interaction of multiple and largely unknown threats makes it extremely difficult to develop proactive interventions with regard to exposure, sensitivity and adaptive capacity. (Hassler & Kohler, 2014)

The community-wide resilience discussion eventually must trickle down to the topic of lightning-resistant design and construction. While lightning strikes are ubiquitous in nearly all parts of the US, the frequency and consequences are most notable in the Midwest and Southeast (See Figure 4).

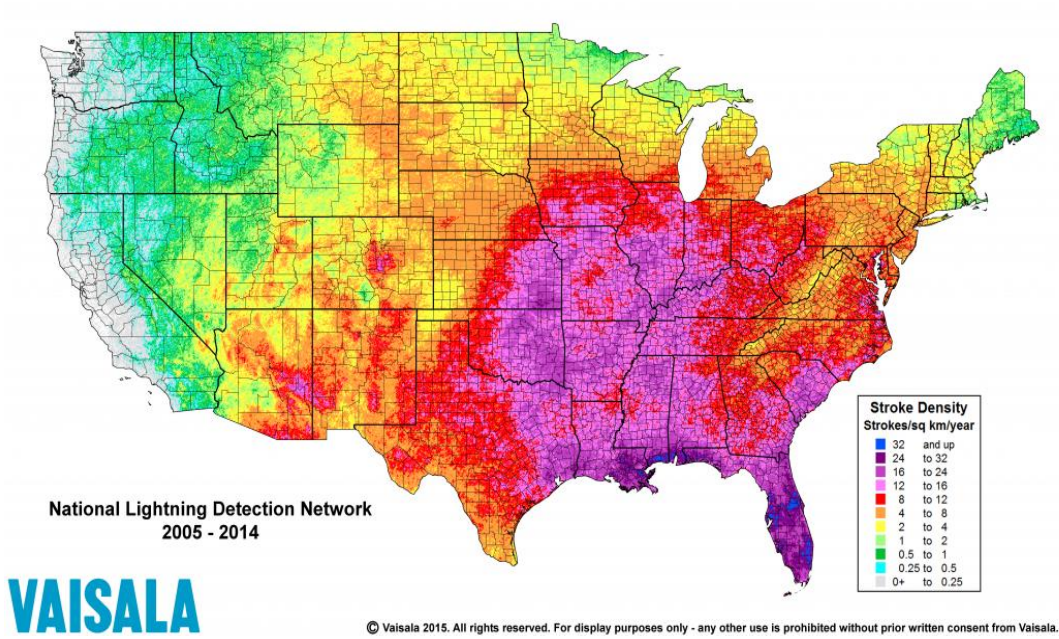

Figure 4.
US Lightning Stroke[3] Density 2005-2014
Used by permission. © Vaisala 2015. All rights reserved.

Table 1 extracts lightning-caused fire data from NIFC's National Interagency Coordination Center that is derived from its regional collections (see Figure 5). The data do not discriminate among wildland, wildland-urban interface or structural fires.

[3] The term lightning "flash" is used to describe the entire discharge, which takes on the order of 0.2 seconds. But a flash is usually made up of several shorter discharges which last less than a millisecond and which repeat rapidly enough that the eye cannot resolve the multiple events. These individual discharges are called strokes. Source: http://hyperphysics.phy-astr.gsu.edu/hbase/electric/lightning2.html

Figure 5.
National Interagency Fire Center Geographic Areas and Coordination Centers.

Table 2.
Extract of Lightning-Caused Wildland Fires by National Interagency Coordination Center Data

Year	Southern	Eastern	Rocky Mountain	Southwest	Northern Rockies	Total
2010	1,068	169	941	947	633	3,758
2009	557	62	1,090	1,546	1,212	4,467
2008	1,706	171	941	1,027	679	4,524
2007	2,578	330	1,672	1,869	1,363	7,812
2006	1.457	256	2,479	3,220	1,970	7,926
Regional Total	5,910	988	7,213	8,609	5,857	28,487
Pct. of Total*	**20.7**	**0.34**	**25.3**	**30.2**	**20.5**	

May not total 100% due to rounding.

Source: Lightning-caused Fires by Geographic Area, 2001-2010. Retrieved from *http://www.nifc.gov/fireInfo/fireInfo_stats_lightng.html*.

The data imply there is ample opportunity to reduce the number of built-environment fires in these lightning-prone regions through engineered solutions that include lightning protection systems. Reducing fire losses enables home and business owners and tenants the ability to "weather a catastrophic event and recover quickly to previous status and functionality."

Role of Code and Standards

Unlike other developed countries, construction safety codes are not mandated by federal or national authorities. Construction safety codes in the US are developed through a consensus-based process: anyone with an interest in improving health, safety and welfare in the built environment can participate in the process to develop and amend the codes. Likewise, industry standards for the design, installation, testing and maintenance of building sub-systems are accomplished through consensus. It is up to state or local jurisdictions to elect to adopt and enforce codes while also having the freedom to select which code and edition[4].

In the US, there are two organizations that have a significant influence on the development of these documents: the International Code Council (ICC) and National Fire Protection Association (NFPA). While there are many other standards development organizations (SDO) that produce documents supporting the built environment, these two entities produce the most widely used building, fire, plumbing, mechanical, electrical and fuel gas codes and standards.

Anyone with an interest in health, safety and welfare for the built environment may submit proposals to add or amend these codes and standards. The SDO have processes in place for three- to five-year update cycles depending upon the topic. The purpose of these regular updates is to assure code and standards remain current and relevant with changes in design, technology and the marketplace. Both NFPA and ICC have online systems for submitting, reviewing, substantiating and approving code and standard changes. The two associations have slightly different final voting policies: any NFPA member may vote on a code change proposal; at ICC only those who are "designated governmental representatives" (i.e. code officials and their staff) may vote on the outcome.[5] Both organizations' processes comply with Federal or American National Standards Institute (ANSI) guidance for SOs to assure public and private interests are represented fairly and with due process.

Once developed, the codes and standards become "model" documents that state, local and Federal entities can adopt by transcription to give them legal powers. The model codes and standards also

[4] Construction fire safety codes and standards typically are under constant modernization and revision, with new editions published every three years.

[5] For information on each organizations' code change process, visit www.nfpa.org or www.iccsafe.org.

can be modified by the users to address local conditions and concerns. Local code officials – who go by a variety of titles from "code official" to "authority having jurisdiction" – are responsible for enforcing the rules and regulations spelled out in these documents. This is most often accomplished through a process of municipal or third-party construction permitting, plan review, inspection and issuance of a "certificate of occupancy" that allows the project developer to assume possession and use of a structure that is deemed compliant with the codes and standards. Code officials not allowed to prescribe rules and regulations on construction projects unless those measures have been lawfully adopted by the jurisdiction they represent.

The codes prescribe the minimum levels of construction for public health, safety and welfare, and the accompanying standards describe how to achieve those minimums. The ICC, for example, references more than 1,300 standards in its codes, and NFPA produces more than 300 consensus codes and standards, including NFPA 780, *Standard for the Installation of Lightning Protection Systems.*

In terms of lightning protection for the built environment, there is a gap in the model construction codes. Neither the *International Building Code®* nor the *International Residential Code®* (the predominantly-used codes in the US[6]) require or refer to lightning protection systems. The *International Fire Code®* -- used in all 50 states -- but the predominant fire code in 42 – regulates hazards materials, storage, processes and operations. It includes several references to lightning protection for petroleum bulk facilities and fireworks displays but provides little design guidance. This results in a shortcoming for code officials who have no legally adopted standard to reference when lightning protection is required or wanted.

NFPA 1 *Fire Code*, includes a reference to the 2017 edition of NFPA 780 as a mandatory reference standard. It is the predominant fire prevention code in New England, a handful of Mid-Atlantic states and Florida --- the latter two being high lightning strike areas -- but mandates lightning protection only in relation to aircraft fueling operations (NFPA 1, 2018, p.1-75).

These gaps suggest a significant opportunity to promote the inclusion of lightning protection systems in current construction through modern safety codes.

[6] The *International Residential Code®* applies to one- and two-family dwellings and townhouses, the *International Building Code®* regulates all other construction. NFPA promulgates NFPA 5000 *Building Construction and Safety Code*, but it is adopted in fewer than 1% of US jurisdictions.

Lightning Protection Design

There are five elements needed to provide an effective lightning protection system. *Strike termination devices* (lightning rods) must be suitable to accept direct lightning attachment and patterned to accept strikes before they reach insulated building materials. *Cable conductors* route lightning current over and through the construction, without damage, between strike terminations at the top and the grounding electrode system at the bottom. The below-grade *grounding electrode system* must efficiently move the lightning to a destination away from the structure and its contents. *Bonding or the interconnection* of the lightning protection system to other internal grounded metallic systems must be accommodated to eliminate the opportunity for lightning to side flash[7] internally.

Finally *surge protection devices* must be installed at every service entrance to stop the intrusion of lightning from utility lines, and further equalize potential between grounded systems during lightning events. When these elements are identified properly in the design stage, incorporated into a neat workmanlike installation, and no changes to the building occur, the system will protect against lightning damage. Elements of this passive grounding system always serve a similar function, but the total design is specific for individual structures.

Lightning protection components are made from materials that are resistant to corrosion and they must be protected from accelerated deterioration. Many system components will be exposed to the atmosphere and climate. Combinations of materials that form electrolytic couples in the presence of moisture shall not be used. Current carrying system components must be highly conductive. Prevailing site soil conditions will impact in-ground system components. The system life and maintenance/replacement cycle is dependent on material choice and the local environment. System materials must be coordinated with the structural materials in use – including flashings, copings, ventilator housings, various roofing systems – to maintain the moisture envelope for the intended life of the building.

Third-party service providers exist to monitor lightning protection inspection, certification, specification, design consulting and review, interpretation and other services to meet the needs of

[7] A side flash or flash over occurs when lightning jumps to another grounded system from the lightning protection system, either through air or nonconductive building materials. This will normally happen when lightning finds a less resistant path to ground, thus bonding helps eliminate or equalize potential between grounded building systems.

property owners, architects, engineers, general contractors and homeowners. The Lightning Protection Institute Inspection Program (LPI-IP) provides system certifications with a three-year expiration date to complement the NFPA three-year code and standard review process and keep pace with new technology.[8] Table 3 describes the services available to evaluate lightning protection system design and performance.

Table 3.

LPI-IP Inspections and Applications

Certificate or Service	Description
Master Installation Certificate Inspection	General certificate that covers lightning protection systems for single structures, certifying compliance with the specified standards.[9]
Extended Master Installation Certificate Inspection	Inspection that includes all aspects of the Master Installation Certificate Inspection. Additionally, it includes ground electrode resistance testing and continuity testing per specified military standards.
Reconditioned Master Installation Certificate Inspection	General certificate covering systems previously certified with the LPI-IP Master Certificate or equivalent level. [10]
Limited Scope Inspection	Partial system inspection limited to a specified scope of work. Inspecting entity does not certify an entire system or structure complies with any national standard.
Deviation Appeal	Technical support appealing deviations received during the jurisdictional inspection process.
Formal Interpretation	Review and analysis of design proposals in accordance with nationally recognized codes and standards.

Source: "A Step Forward" LPI-IP. Retrieved from https://lpi-ip.com/media/2019/04/LPI-IP_Services.pdf

[8] More information about the inspection service is available at the LPI-IP web site at www.lpi-ip.com.

[9] A single structure encompasses all its connected parts, including common walls, firewalls, walkways and other elements.

[10] Structures having undergone alteration to square footage and/or footprint are ineligible for the reconditioned certificate and require a new LPI-IP Master Certificate or Limited Scope Inspection.

According to UL,

> Determining the correct methodology for designing a system of protection is critical to its efficiency and functionality. An average size structure, with a simple roof type, one roof elevation, no uneven vertical changes, and the protection techniques can be rather straightforward and easy to design.
>
> However, if the building structure becomes complex with changes in roof elevations such as a multi-story section, defined shapes such as dormer projections, or tall objects such as stacks, it will require different considerations for design to afford proper protection of the entire structure. (UL July 2016).

The United States standards for complete lightning protection systems include:

- NFPA 780, *Standard for the Installation of Lightning Protection Systems*
- UL 96, *ANSI/CAN/UL Standard for Lightning Protection Components* & 96A, *Standard for Installation Requirements for Lightning Protection Systems*, and,
- LPI 175, *Standard for the Design – Installation – Inspection of Lightning Protection Systems* (2017).

These standards are based on the fundamental principle of providing a reasonably direct, low-resistance, low impedance metallic path for lightning current to follow, and making provisions to prevent destruction, fire, damage, death, or injury as the current flows from the roof levels to below grade. The Standards represent a consensus of authorities regarding basic requirements for construction and performance of qualified designs and products.

For those areas that are susceptible to infrequent lightning strikes, or where lightning is prevalent but a designer is not certain it is recommended, NFPA 780 includes a "Simplified Risk Assessment" tool[11] to establish if lightning protection is appropriate.

The NFPA 780 risk assessment tool uses a mathematical analysis that compares common environmental factors to tolerable risk factors. "The lightning risk assessment should take into account parameters associated with the structure and its surrounds, the lightning flash density of the location,

[11] Several proprietary but free versions of the tool are available online using the phrase search "NFPA 780 Risk Assessment Guide." The author makes no warranty or recommendation to any tool other than that found within the most current edition of NFPA 780.

and the importance of the facility and its processes to the business, the community, and the environment". (Cole, May 5, 2011).

Typical risk factors include:

1. The structure size: length, width and height.
2. Whether the structure is the tallest structure in the vicinity, and whether it is isolated or among a cluster of other buildings.
3. Whether the site is flat or hilly, and where the critical structure sits in relation to elevation.
4. What the regional flash density is (See Figure 4: US Lightning Stroke Density 2005-2014).
5. Whether the structure is metal with a metallic roof
6. The inherent hazard of the building (e.g. flammable or non-flammable contents, high-, medium- or low-value products, irreplaceable cultural items).
7. The human occupancy of the building (e.g. unoccupied, normally occupied or difficult to evacuate).

Using mathematical formulae in NFPA 780, the analyst can make an informed recommendation regarding the need for a lightning protection system and develop a cost-benefit evaluation for its suitability.

Lightning Protection Effectiveness

The science of lightning protection has evolved since Ben Franklin invented the lightning rod in 1752. While the principles behind the science of lightning protection remain the same, today's structures and their amenities have presented several challenges that the lightning protection standards have needed to address.

NFPA 780 has been in existence for more than a century. The standard is routinely updated and edited to incorporate improvements in technology and new scientific findings. The Federal Aviation Administration, NASA, Dept of Energy and Department of Defense routinely specify NFPA 780-compliant lightning protection for their structures. Federal agencies rely heavily on nationally recognized specifications of the Lightning Protection Institute (LPI), NFPA and UL and consider lightning protection systems as critical in protecting our national infrastructure. Today's lightning protection systems provide practical and tested solutions for the interconnection of grounded building systems, surge suppression requirements for electrical communication and data lines and their coordinated bonding.

Conclusion and Recommendations

As research continues and new products are developed, undoubtedly there will be changes to the standards as knowledge increases and is shared among the construction safety community. In the meanwhile, science and industry can continue to rely on the existing consensus standards to design and install lightning protection systems.

In order to improve survivability and enhance resilience, building designers, architects and owners need to evaluate the value-added engineering of lightning protection systems, especially in those portions of the world where lightning frequency is common.

According to the Lightning Safety Alliance, there are five important reasons lightning protection systems should be incorporated into building design:

- Affordability – Pricing for lightning protection systems typically is less than 1% the value of a structure, making it less expensive than security systems, generators and specialty lighting.
- Safety Requirements – Insurance, OSHA and risk management authorities are increasingly citing lightning protection measures in their hazard mitigation plans. As lightning-caused damage, fires, injuries and deaths continue, it is likely the model code-promulgating organizations will add lightning protection mandates to building and fire safety codes.
- Fortifies Technology – Automated building systems and smart structures rely on lightning protection to prevent surge interruptions and costly downtime.
- Improves Sustainability – Lightning protection systems frequently are included on Green and LEED structures as a building resilience measure against a common and highly destructive weather threats.
- Hazard Analysis -- Lightning protection is increasingly required when a NFPA 780 Risk Assessment determines a structure's vulnerability to lightning is greater than its tolerable risk. (Lightning Safety Alliance, April 16, 2019).

Safety standards are designed to ensure the safety of products, activities or processes. When it comes to lightning protection, the difference between "safe and effective" lightning protection and "unsafe and ineffective" lightning protection is ultimately related to which guidelines are implemented.

> Often considered the grandfather of lightning protection, NFPA 780 provides valuable resource information for AHJs, project designers, engineers, insurance professionals and anyone responsible for the protection of lives and property from dangers associated with lightning. NFPA also serves as the basis for the LPI-175 *Standard of Practice for the Design-Installation-Inspection of Lightning Protection Systems* reference document, which is commonly used by LPI-certified designers and installers and LPI-IP inspectors.
>
> NFPA 780 covers lightning protection system installation requirements for structures, watercraft, wind turbines, industrial stacks and other special occupancies. Lightning protection guidance for new construction and building trends (including solar systems, arrays, catenary systems, airfield lighting, rooftop equipment) are also addressed, with new information and sections added to the Standard in conjunction with the three-year review process. (LPI, August 18, 2016).

One intermediate solution is to submit to the International Code Council a code change proposal that would include NFPA 780, *Standard for the Installation of Lightning Protection Systems* as a *mandatory* reference standard for lightning protection system design. This would provide local code officials a nationally recognized standard to reference when permitting and reviewing lightning protection system design.

A second --- longer-term -- solution is to propose an appendix[12] to one or more of the model codes that includes the NFPA 780 "Simplified Risk Assessment" tool as a non-mandatory guide and references the remainder of the prescriptive NFPA 780 requirements as a recommendation. Appendices in the model codes are optional unless legally adopted and often act as a "test bed" for ideas that may not be ready for the entire membership to accept or may not affect all portions of the country. For example, the *International Fire Code* included an appendix on ozone generation equipment until it was finally added to the main code text. An appendix on lightning protection systems could be adopted for enforcement by those jurisdictions that need it and left as reference material for those that think it is unnecessary.

[12] NFPA refers to appendices as "annexes."

A third but less desirable solution would be to propose mandatory lightning protection requirements at the state and local level with a focus on those regions of the nation where the lightning stroke density is the highest. This could include the states in the "Southern" region in Figure 5. above. The specific language for these proposals could be modeled after the current lightning protection requirements included in the 7th Edition (2020) Florida Building Code.

Given the frequency of lightning-caused fires in the built environment and wild-urban interface, the increasing risk of lightning damage that could accompany climate change, and the historic reliability of lightning protection systems based on national consensus standards, the opportunity is ready for bringing this important topic into the national discourse on resilience and public protection from weather-related threats.

About the Author

Rob Neale is the owner and principal of Integra Code Consultants, a Maryland-based firm that provides construction code consulting, plan review and training.

Previously, he was the International Code Council's Government Relations Vice President for National Fire Service Activities where he coordinated efforts to get the US fire service more engaged in the code development and enforcement process. Rob also served as the Deputy Superintendent for the United States Fire Administration National Fire Academy in Emmitsburg, MD. He was responsible for development of curriculum aimed at improving the professionalism of America's fire service.

Rob for six years managed the National Fire Academy's Technical Fire Prevention curriculum; including fire inspection techniques, prescriptive and performance-based fire and building code interpretation and application, fire protection systems function, design, installation and standards, and plan review for fire inspection personnel.

Rob represented the United States Fire Administration in an analysis of the Fire Department of New York's "Comprehensive Building Inspection and Data Analysis System" in 2009, and the Federal Emergency Management Agency World Trade Center Building Performance Assessment Team in 2001.

He served as charter member of the National Fire Protection Association Technical Committee No. 1037 for "Professional Qualifications for Fire Marshal," and represented the United States Fire Administration and International Code Council on the Underwriters Laboratories Fire Council. He has more than 30 years' experience in Washington state municipal fire protection as a fire chief, fire marshal, and fire fighter.

Rob graduated from the Center for Homeland Defense and Security master's degree program at the Naval Postgraduate School. He holds a bachelor's degree in Liberal Studies from Western Washington University.

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How lightning enters a structure:

Through a direct strike that can ignite fires or explode roofing, brick, wood, mortar or concrete

Via roof projections like antennas, architectural ornaments, vent fans and satellite dishes

Through a strike to a chimney, dormer, cupola or metal roofing accessory

Via telecommunications, utility lines, and electronics

Via surges or side flash delivered through a nearby tree or pole

Through wiring, electronics, cable lines and data systems

Through irrigation systems, invisible fences, security systems and electric gates

Through metallic lines, piping or CSST gas piping

All of the above can create a pathway for lightning's extreme electricity and destructive energy.