IMAGE: ©Justin Maconochie

At Oakland University's Human Health Building (see "How to 'Top'…," page 24), air terminals are installed at roof high points and corners, along parapets and on rooftop equipment.

Lightning Protection and the Building Envelope

By Jennifer Morgan, CSI and Michael Chusid, RA FCSI

A building enclosure includes "all materials, components, systems and assemblies intended to provide shelter and environmental separation between [an] interior and exterior."[1] Although enclosures should withstand wind, blast, fire, heat exchange, moisture and other phenomena, one of nature's most-frequent and destructive forces is frequently overlooked—lightning.

Lightning strikes 23 million times a year in the lower 48 states[2] and causes nearly $1 billion (US) a year in property insurance claims.[3] Deductibles, uninsured losses, injuries, deaths, power outages, travel interruptions and wildfires raise the economic impact.

Lightning surges also can destroy electronic devices controlling environmental and security systems; communication and computational equipment; and other devices that make high-performance buildings operational. When damage is discovered, facilities professionals may not recognize its link to a lightning strike that may have occurred when their building was unoccupied or a strike outside their building that sent a surge through wires or pipes penetrating the building envelope.

As isolated events, only the local news media reports lightning damage and, even then, only if it results in a dramatic event like fire. Regardless, a single lightning strike can be a disaster for individuals and businesses.

National Fire Protection Association (NFPA) 780, *Standard for the Installation of Lightning Protection Systems:* Annex L (2014) provides methods for assessing whether a structure's vulnerability to lightning is greater than its tolerable risk:

- Vulnerability is determined by lightning density (frequency/area/year, based on weather maps), as well as a structure's area and height, topography and proximity to taller structures or trees.
- Risk is affected by conductivity and combustibility of the roof and structural systems; value and combustibility of contents; ease of evacuation; owner's attitude toward operational continuity; and environmental hazards.

Regardless of calculations, NFPA recommends a lighting protection system (LPS) if any of the following are present: large crowds, continuity of critical services, high lightning flash frequency, tall isolated structures, explosive or flammable content, irreplaceable cultural heritage or regulatory or insurance requirements. Recently introduced online tools have simplified such assessments.[4]

Resilience takes on urgency as climate change spawns more-frequent and severe thunderstorms. Lightning also accompanies floods, tornados, hurricanes and volcanic eruptions. Using an LPS for emergency operation centers, hospitals, storm shelters, schools and infrastructure must be part of disaster-preparedness planning.

An LPS also contributes to sustainability. Indeed, durability and operational integrity are fundamental to sustainability. An LPS has outstanding life-cycle performance since most components last indefinitely and can be reused or recycled

without loss of metallic value. In addition, an LPS can be incorporated into the new Pilot Credits addressing resilience in the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) certification.[5] The credits include:

- Credit IPpc98—*Assessment and Planning for Resilience*, which requires project teams to "identify the potential high risks associated with natural hazards affecting the project site(s) and building function."
- Credit IPpc99—*Design for Enhanced Resilience*, which states an intent to "design and construct buildings that can resist, with minimal damage, reasonably expected natural disasters and weather events ..." It references FORTIFIED for Safer Business standards that recommend using an LPS.[6]
- Credit IPpc100—*Passive Survivability and Functionality During Emergencies*, which has options requiring back-up generators or photovoltaic collectors—systems vulnerable to lightning unless protected.

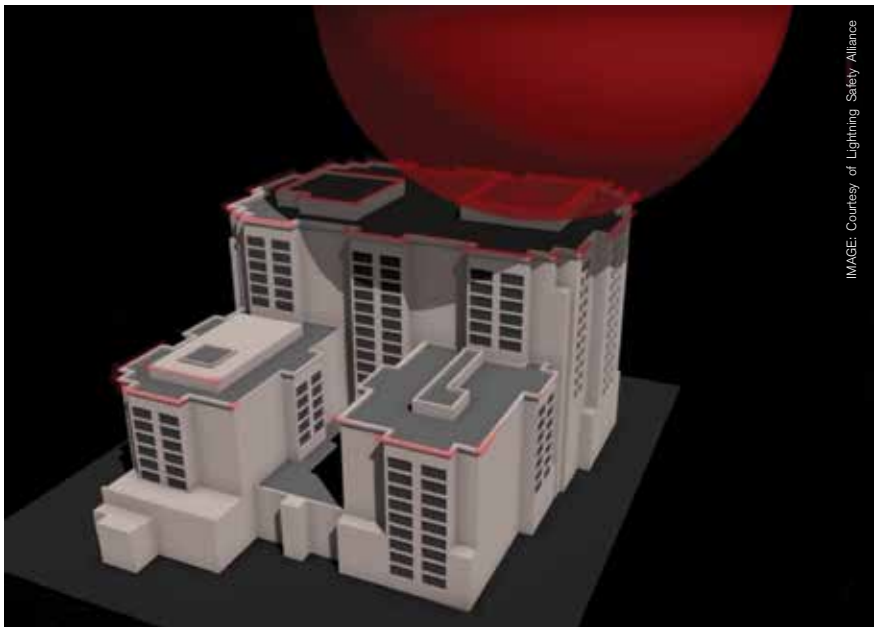
IMAGE: Courtesy of Lightning Safety Alliance

Figure 1: A 300-foot-diameter sphere is rolled across a building to model where lightning can strike (shown in red) unless air terminals are provided.

It Takes a System

An LPS provides an electrically continuous, low-resistance path between sky and earth. From top to bottom, principal components consist of strike termination devices, conductors and ground electrodes, plus connectors, fasteners, welds and accessories. Do not assume a building's electrical grounding system will protect against lightning damage; electrical grounding is designed for 120/240 volts, not lightning's three million volts. LPS components must comply with UL 96, *Standard for Lightning Protection Components* and usually are made of highly conductive copper, bronze or aluminum; plated finishes can be used for aesthetic reasons and increased corrosion resistance.


IMAGE: Emily Strieter / Oakland University

Figure 2: Air terminals are mounted on the back of a parapet to minimize visibility; conductors lead to through-roof penetrations.

Strike termination devices create zones of protection that intercept atmospheric electrical charges. The charged field is usually modeled as a 300-foot-diameter sphere rolled over a building *(see "Figure 1," above)*, and strike termination devices are placed wherever the sphere contacts the structure.[7] Most strike termination devices are air terminals, formerly called "lightning rods." They can be as small as 3/8-inch-diameter by 10-inches-tall on buildings. Air terminals are located at roof high points and corners, 20-foot-maximum-on-center spacing at the roof perimeter and as required at intermediate locations and on top of rooftop equipment. They can be set in 24 inches from roof edges to minimize visibility from the ground *(see "Figure 2," left)*. Elements, such as railings and screens, also can be used as strike termination devices if they are metal at least 3/16-inch thick. Avoid using "early streamer emission" or "charge dissipation" devices that claim to prevent lightning strikes or to protect entire buildings with just a few devices.

Conductors interconnect strike termination devices with other system components. Installers often use multistrand cables due to their flexibility and current-carrying capacity. Metal framing elements at least 3/16-inch thick and electrically continuous can serve as conductors and reduce LPS-associated costs in steel-framed buildings. Conductors can be installed adjacent to or concealed within combustible materials; they are sized so brief bursts of current do not encounter sufficient resistance to get hot. Standards require at least two widely separated down conductors; structures with perimeters exceeding 250 feet require additional conductors. Other requirements apply to structures taller than 75 feet. Installers can use through-structure penetration devices where conductors pass through the building envelope and then seal these devices with flashings or sealants.

Ground electrodes are designed according to soil conductivity. *Surge protective devices* are required on power and communication lines penetrating the envelope. *Bonding* is required between lightning conductors and other grounded building systems to equalize

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electrical potential and prevent side-flashing (arcing) from an LPS to other systems.[8]

The Envelope, Please

Project specifiations typically delegate LPS design to qualified lightning protection firms and require compliance with industry-accepted standards, certification programs and third-party inspection programs.[9] NFPA 780 and UL 96 coordinate with other UL and Lightning Protection Institute (LPI) standards. LPI has three levels of personnel certification, culminating in a Master Installer/Designer qualified to design installations. Inspection services, offered by UL and the LPI Inspection Program (LPI-IP), issue certifications if an LPS meets standards.

Maintenance staff and service vendors must avoid damaging or disconnecting components while performing their work; any incurred damage should be promptly repaired by lightning protection specialists. Surge protective devices must be checked periodically to assure they have not been damaged by lightning or other electrical anomalies. New service entries and rooftop equipment must be integrated into the LPS. Inspection certificates expire after three or five years, and building owners should have their structures reinspected and repaired to obtain recertification.

NFPA/UL/LPI standards are based upon two centuries of scientifically proven performance that has been vetted by many governmental and research organizations. Recent advances include: satellite and ground-based systems that identify lightning strike locations with ever-increasing precision; 3-dimensional (3D) modeling that helps explain how lightning propagates; rocket-triggered lightning strikes that test components and systems; and protocols that protect crowded outdoor venues. While nature cannot be controlled, the tools to prevent lightning-related failures are in the hands of building designers and specifiers. JNIBS

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How to "Top" a LEED Platinum Building?

For the new Human Health Building at Oakland University, the answer is a "no brainer," according to Siraj Khan, PE, campus engineering director. "We installed [an] LPS to assure the safety of our buildings and people using them," he says. "A lightning surge could damage electrical and electronic systems, computers, equipment, appliances and clinical apparatus and disrupt research our students and faculty are doing."

The 160,000-square-foot building in Rochester, Michigan, designed by SmithGroupJJR, utilized large arrays of photovoltaic (PV) panels and solar hot water heaters. According to LPS installer, Philip Youtsey of Guardian Equipment Co., "We had to mount air terminals directly to solar collectors and bond the racks and hydronic piping to the grounding system. The building's steel columns are used as down conductors and we installed a counterpoise loop around the building for enhanced grounding." The project was inspected and certified by LPI-IP.

Most buildings on the campus are lightning protected. John Harmala, AIA, senior project manager for the school's Capital Planning & Design, explains: "An LPS is a sensible precaution and a negligible expense considering the overall cost of construction."

Kahn agrees the system has been reliable and cites a lightning strike on a power company's substation 88 feet from a campus building. He says, "Power was temporarily knocked out but the LPS worked as expected. There was no damage to campus buildings."

IMAGE: ©Google

The footprint of the Human Health Building plays a major role in determining its vulnerability and the cost of a lightning protection system.

References:

[1]ASTM E2813-2e1, *Standard Practice for Building Enclosure Commissioning*.

[2]Vaisala, Inc. Average, 1996 to 2008, **www.lightningsafety.noaa.gov/stats/96-08Cloud_to_Ground.pdf**.

[3]According to the Insurance Information Institute (**www.iii.org**), insurance companies paid $739 million on nearly 100,000 residential claims in 2014. Lightning fires in nonresidential properties caused an average of $108 million in direct property damage each year from 2007 to 2011.

[4]Morgan, Jennifer; Chusid, Michael. "Lightning Protection: The Architect's Standard of Care," *Architectural Products*, March 2016, **ecle.biz/standardofcare**; also see **ecle.biz/riskcalculator**.

[5]U.S. Green Building Council, **www.usgbc.org/articles/leed-pilot-credits-resilient-design-adopted**.

[6]Insurance Institute for Business & Home Safety, **disastersafety.org/wp-content/uploads/FFSB_Volume_I_Standards-2014.pdf**.

[7]View an animation showing the rolling sphere method at **ecle.biz/rollingsphere**.

[8]For more information, visit the Lightning Protection Institute at **www.lightning.org**, or "Lightning Protection and the Building Envelope," *Construction Specifier*, 2015-08, **ecle.biz/constructionspecifier**.

[9]A non-proprietary guide specification can be downloaded from **www.constructionspecifier.com/lightning-specs**.

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