nal symptoms. Lightning or electrical current passes from the trunk of the tree through the roots and dissipates in the ground. Major root damage from electricity may cause the tree to decline and die without significant aboveground damage. If the tree is in leaf, the leaves wilt and the tree will probably die within a few days. If the tree survives long enough to leaf out the following spring, then the chances of recovery are much greater. Watering and fertilization are suggested to reduce tree stress.

Generally, when lightning damage has created hazardous broken branches, corrective pruning should be done. However, waiting two to six months is recommended before doing major and expensive corrective pruning to assess whether the tree will recover. If during this waiting period, the tree shows no obvious signs of decline, then the pruning is probably worth the expense. Consult with a certified arborist for recommendations concerning the health of your damaged tree. Commonly prescribed practices are water management, bark repair, pruning, fertilization, pest management and tree monitoring. Expensive treatments should not be taken until the tree appears to be making a recovery. Otherwise, when it becomes obvious that the tree will not recover from the lightning strike, the tree should be removed.

Lightning damage in trees is much more effectively prevented than repaired and is often less costly. Qualified arborists can recommend the installation of lightning protection systems where appropriate or the proper course of action if a tree has been struck by lightning.

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NOAA

Lightning striking a tree.

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Lightning Protection for Trees

David S. Vandergriff, UT Extension
Urban Horticulture & Forestry

Wayne K. Clatterbuck, Associate Professor
Forestry, Wildlife & Fisheries

Lightning is one of nature's most powerful forces. Lightning can have devastating effects on people, property and trees. Each strike of lightning can reach more than five miles in length, and produce temperatures greater than 50,000 degrees Fahrenheit and an electrical charge of 100 million volts. At any given moment, there are 1,800 thunderstorms in progress somewhere across the earth. Lightning detection systems in the United States sense an average of 25 million lightning strikes per year.

Lightning is the second leading cause of weather-related deaths, killing an average of 73 people (more than tornados and hurricanes combined) and injuring an additional 300 persons in the United States each year. Of those struck by lightning, 10 percent of the strike victims die and 70 percent of those who survive are left with serious long-term effects. The most deaths, injuries and damage reports from lightning are recorded during the summer months (Table 1). About a third of all lightning injuries occur during working hours, another third during recreational and sporting events, and the final third occur in a variety of settings. Since people are outdoors more in the summer months, the odds of exposure to lightning strikes are increased.

About one-third of the lightning deaths in the United States occur under or near unprotected trees (Lightning Protection Institute, 1999). A person does not have to be in direct contact with a tree that is struck to be injured or killed. The total energy of a lightning bolt is equivalent to two tons of TNT as it travels from the strike point. As the current travels down a tree it can "jump" to a more conductive tree, person, animal or structure, since the current follows the path of least resistance. This phenomenon is called "side flash." As the current flows down a tree and moves from the roots into the adjacent soil, a great difference in electrical potential exists as the charge disperses through the soil. This electrical differential is called "step voltage." People or animals standing in the area may conduct this potentially deadly flow of electricity through their bodies, flowing up one leg and down the other. Tree lightning protection systems reduce step voltage. However, step voltage

Wayne Clatterbuck

Lightning scar on an eastern white pine tree.

Table 1. Summary of casualties (death and injuries) and damage to property from lightning for Tennessee by season, 1959-1994. *(Curran and others, 1997)*

State	Casualties				Damage Reports			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Tennessee								
	107	318	46	2	178	501	73	12

THE UNIVERSITY of TENNESSEE

can still occur as the current leaves the ground-system component of a tree lightning-protection system.

Trees occupy a particularly susceptible position in the landscape, since they are often the tallest objects. Tall trees are the most vulnerable, especially those growing alone in open areas such as on hills, in pastures or near water. Many of these trees line our community streets and surround our homes, schools and businesses.

Lightning Protection for Trees

Properly installed, tree lightning protection systems are relatively inconspicuous, non-injurious to the tree, permanent and very reliable. In areas frequented by people or animals during storms, tree lightning protection systems should be considered. Other trees to consider for lightning protection systems are trees of historical significance, high-value trees and trees in recreational areas, golf courses and parks. *The Standard for the Installation of Lightning Protection Systems* (National Fire Protection Association, 2004) recommends installation of tree lightning protection systems in trees that are within 10 feet of a structure, are taller than the adjacent structure or with limbs overhanging the structure.

Tree lightning protection systems are a risk management tool that can minimize tree damage, reduce collateral damage around a tree and provide a preferred path for electrical charges to the ground. **These systems are not designed to directly protect people from lightning strikes or step voltage and should never be viewed as making a protected tree a safe haven during an electrical storm**. Lightning protection systems control the path of the lightning after it hits. They do not prevent or reduce the risk of lightning striking a tree. Also, lightning protection systems will not protect electronic systems inside a structure or its components outside the structure, such as irrigation systems and well pumps.

Tree lightning protection systems must be installed and maintained by a qualified arborist. Qualified arborists can be identified by looking for a professional certified by the International Society of Arboriculture (ISA) at the following Web site: *www.treesaregood.com*. Several search options are provided, including by zip code, city or state. Since specialized knowledge and training specifically in lightning protection systems are essential, be sure to ask about the arborist's training and experience with these systems.

All lightning protection systems should be installed in compliance with safe arboricultural work practices as set forth by the Occupational Safety and Health Administration (OSHA), ANSI Z133 standards (National Arborists Association, 2001) and other applicable safety standards. Design standards for lightning-protection systems are governed by the standards set forth in ANSI A300, Part 4 (National Arborist Association, 2002).

Since lightning protection system components are excellent conductors of electricity, they must not be installed over utility lines where contact is possible and must comply with the minimum distance restrictions set forth in ANSI Z133.1. The ground conductor components should not cross underground utility or communication cables. Before installing a lightning protection system, consider the periodic inspection and maintenance of the lightning protection system. This is critical for maintaining the functionality of the system. Be sure to locate underground utilities before installing the lightning protection systems by calling Tennessee One Call System, Inc. 800-351-1111.

All materials used in lightning protection systems should be made specifically for those system applications. The working life of the major components can be as long as 50 to 100 years. If component parts become damaged or deteriorate, they can be easily replaced. All materials used in tree lightning protection systems are made of or clad with commercial electrical grade copper, similar copper alloys, bronze or stainless steel. Specific metals are required in specified components of the lightning protection system. Lightning-protection system components include:

Conductors – Electrical conductive cables made in a rope-lay, smooth-twist or loose-weave design of at least 14 strands of 17 AWG copper wire.

Fasteners (also known as drive fasteners or stand-offs) – Used to attach conductors to the tree by driving them through the bark and into the tree.

Air terminal – Located near the top of the tree and attached to the end of the conductor to intercept lightning strikes.

Cable splicers and clamp-type connectors – Used to connect lengths of conductors. Available in end-to-end, side-by-side and "Y" configurations.

Bonding clamps – May be required if large diameter conduits or pipes are installed in the tree.

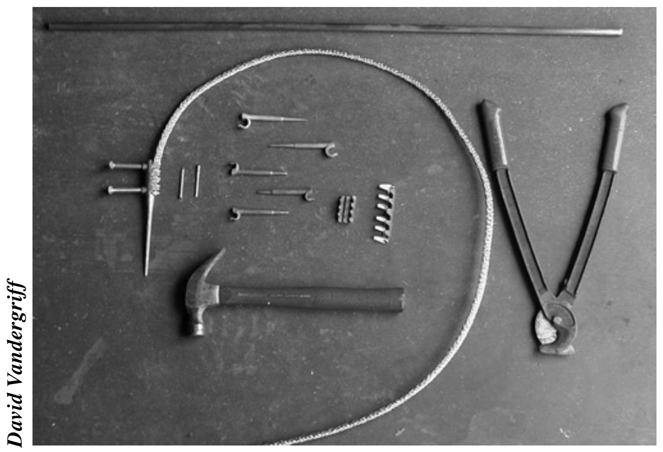
Ground rods – A steel core rod clad in copper that is at least ½ inch in diameter and 8 feet in length.

Ground rod clamp – A clamp used to connect the conductor to the ground rod.

Ground plates – Copper sheets at least 0.032-inch thick with a surface area of at least 2 square feet used in shallow soils where ground rods cannot be installed.

Tree protection systems have flexible cables that allow for the swaying of the trunk and branches as well as adjustable units to allow for the growth of the tree. Air terminals are attached to the highest point of the tree, which in turn is connected to copper conducting cable. The conducting cable is fastened along the trunk and extends to the ground. The cable is attached to a ground rod that is generally 8 feet in length and driven vertically and countersunk into the ground at least 10 feet from the trunk of the tree (Figure 1).

The design of the lightning protection system using the components listed above is tree- and site-specific. Lightning damage to trees is extremely variable and appears to be influenced by the voltage of the charge, species of the tree, tree height, geographic location, proximity to structures and the moisture content of the tree and surrounding area. A qualified arborist has the knowledge and skills to design the system that best fits your situation using the criteria established in the ANSI standards.



David Vandergriff

Lightning protection components and installation tools.

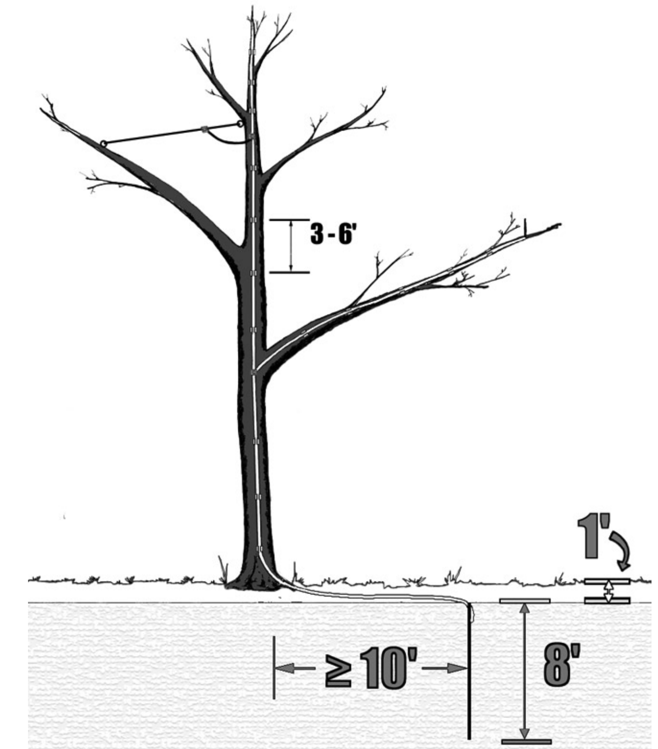


Figure 1. A typical tree lightning-protection system. Fastener spacing is 3 to 6 feet. Ground rods (at least 8 feet long) should be driven in the ground at least 10 feet from the trunk. The top of the ground rod should be at least 1 foot deep.
Credit: Bartlett Research Laboratory

Although the working life of a lightning protection system can be 50 to 100 years, periodic inspection and maintenance are crucial for the system to remain in proper working condition. Inspection should be done annually on fast-growing trees and every two to three years on slower-growing trees. Regular inspection of urban trees is a good practice, even if lightning protection systems are not present. The inspection of lightning protection systems should include:

- Check the air terminals for location near the top of the tree. As the tree grows, the terminals must be moved up.
- Check for fasteners being overgrown by the tree.
- Check the connectors for tight connections and presence of corrosion.
- Verify that the conductors are free of breaks, nicks or pinches.
- Verify that ground conductors are intact. Inspect for trenches that may have severed the conductors.
- Verify that the bonding conductors are tight and free of corrosion.

Electrical conductivity testing may be done with an ohm meter. Ground resistance may be checked with a specialized ground resistance meter.

Always follow standard arboricultural practices for tree work. These include not using climbing spurs when installing and maintaining lightning protection systems to avoid damage to the bark, cambium and other live tissue. Cutting roots greater than 2 inches in diameter should be avoided in the installation process. If pruning is needed on the tree having a lightning protection system installed, the pruning should be done prior to the installation of the system.

Response of Trees to Lightning

A tree's biological functions and/or structural integrity are affected by lightning strikes. Along the path of the strike, sap boils, steam is generated and cells explode in the wood, leading to strips of wood and bark peeling or being blown off the tree. If only one side of the tree shows evidence of a lightning strike, the chances of the tree surviving and eventually closing the wound are good. However, when the strike completely passes through the tree trunk, with splintered bark and exploded wood on each side, trees are usually killed.

Many trees are severely injured internally or below-ground by lightning despite the absence of visible, exter-