



Tree Lightning Protection Systems (part one)

By E. Thomas Smiley, A. William Graham Jr., and Scott Cullen

Objectives

- Describe the various forms of lightning discharges and their effect on trees
- Summarize the criteria for recommending trees for installation of a lightning protection system
- Identify the materials typically used in a lightning protection system
- Understand the components of a lightning protection system

CEUs for this article apply to Certified Arborist, Climber Specialist/Aerial Lift, and BCMA practice category only.

Lightning is an extremely powerful and pervasive force of nature. There are an estimated 100 million lightning strikes annually in North America. Those strikes result in the death

of 20 to 35 people each year in the United States. In addition, lightning strikes damage property, injure livestock, and start structural and forest fires. The resulting estimated annual property losses are in the range of USD \$5 billion per year.

Thousands of unprotected trees are struck by lightning in urban and suburban settings every year. Damage and injury to trees from lightning varies greatly. Some lightning-struck trees will exhibit no signs or symptoms of damage. Others will display various levels of damage. Some trees will die within a short time, while others will linger for years before succumbing to secondary pests. Some trees may survive with appropriate treatment. Relatively few struck trees will be completely shattered or blown apart. When this severe damage does occur, parts of the tree can be thrown



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hundreds of yards/meters, potentially causing personal injury or property damage. Struck trees that survive the short term can have an increased risk of structural failure in the long term due to initial wounds and subsequent wood decay.

Lightning

Physics of Lightning

A basic understanding of how lightning works will aid in understanding tree lightning protection system (TLPS) design and components. Lightning is a high-current, transient, atmospheric discharge with a path length measured in miles/kilometers. A strike begins with a charge separation in clouds. While pockets of charge actually occur throughout a cloud, in general, positive charges concentrate in the top of the cloud and negative charges in the lower portion, with additional positive charge pockets imbedded in the lower part of the cloud. Depending on the position and proximity of these charge pockets, several kinds of lightning discharges can occur:

- Intra-cloud discharges within the same cloud between positive and negative charge pockets.
- Cloud-to-cloud discharges between a charge pocket of one polarity in one cloud and a charge pocket of opposite polarity in another cloud.
- Cloud-to-ground discharges between a positive or negative charge pocket in the cloud and the earth or objects on Earth.



Figure 1. Cloud-to-ground lightning discharge. Tree lightning protection systems are generally limited to protecting trees from these types of discharges.

The concern with trees is generally limited to cloud-to-ground discharges (Figure 1).

The lightning strike process is initiated by the generation of a stepped leader from the cloud. As the stepped leader gets longer and approaches Earth, objects above the surface, such as trees, initiate upward 'streamers.' When contact is made between an upward streamer and a downward stepped leader, a return stroke begins. The upward streamer and one branch of a downward stepped leader typically meet 33 to 330 feet (10 to 100 m) above the object or tree that initiated the streamer.

A typical lightning strike has three or more upward and downward strokes. Each stroke lasts about 0.0001 to 0.0002 seconds, and each strike (or flash) 0.1 to 0.2 seconds. The current in a stroke averages between 30,000 and 50,000 amps, with voltages ranging from hundreds of thousands to tens of millions of volts, or 10 to up to 300 coulombs. Approximately 30 percent or more strikes contain 'continuous current,' where there is a continuous flow of current (100–500 amps for up to half a second). These strikes are more likely to start fires.

Definition of Electrical Terms

Ampere (amp, A): The unit expressing the rate of flow of an electric current. One ampere is the current produced by a difference in potential of one volt across a resistance of one ohm.

Conductivity: The capability of a material to conduct electricity. It is the reciprocal of resistivity.

Continuity: A state of an electrical circuit being able to conduct current between two points.

Coulomb (C): A unit of electrical charge. The quantity of charge transported by a constant current of one amp for one second.

Current: The movement of electrons in a conductor measured in amperes.

Impedance: The measure of the forces opposing the flow of current. It is composed of a combination of resistance and reactance, and is generally expressed in ohms.

Ohm (Ω): A unit of electrical resistance defined as the resistance of a circuit with a voltage of one volt and a current flow of one ampere.

Resistance: The opposition to current flow, expressed in ohms.

Volt (V): The electrical potential needed to produce one ampere of current through a resistance of one ohm.



Sideflash

A lightning strike often results in sideflash. Sideflash occurs when a portion of the electrical current jumps from a struck tree or other object to another nearby object, such as a person, tree, or structure. Sideflash can cause serious damage to structures, potentially starting fires or damaging electrical systems and appliances. It can also cause personal injury or damage to other trees. Sideflashes are most likely to occur within two feet (60 cm) of the object that was struck.

Sideflash can also occur within a protected tree if the TLPS was not correctly installed or maintained. This occurs most often when conductive objects, such as a tree support system, were not connected or 'bonded' to the TLPS.

Step Voltage

Another phenomenon associated with a lightning strike is the dissipation of the electrical current in the earth.

Once lightning contacts the earth, the charge spreads out from the point of contact in all directions. The current is greatest on or near the surface, called a "skin effect." Step voltage is the difference in electrical potential between two points, such as a person's feet (their 'step') along that surface. If the voltage difference is great enough, current will flow through a person or animal, potentially causing great harm.

Step voltage occurs near both protected and unprotected objects and accounts for a significant percentage of lightning-related injuries, typically within 50 feet (15 m) of the strike. Step voltage in the earth should not be confused with the stepped leader, in the sky, that initiates a lightning strike.

Objectives of Tree Lightning Protection Systems

Tree lightning protection systems are intended to provide a preferred point for lightning attachment and a preferred path to ground for lightning strike currents. This path will reduce the risk of damage to struck trees, damage to adjacent trees and structures resulting from sideflash, or property damage or personal injury from debris thrown from a lightning-struck tree. Correctly installed and maintained systems are extremely effective at preventing serious lightning damage to trees (Figure 2).

TLPS Limitations

TLPSs do not ensure safe havens for people during storms. They are not intended to protect people from direct lightning strikes or step voltage. In addition, TLPSs will not protect electrical or electronic systems within or outside adjacent structures. These include computers, cameras, HVAC, communications equipment, electronic controls for irrigation systems, landscape lighting, and well pumps.

Tree lightning protection systems require maintenance. While the working life of conductors and major components can exceed 50 years, TLPSs need to be inspected on a periodic basis. If component parts deteriorate, they should be replaced to maintain an effective system. As the tree starts to overgrow the TLPS, new fasteners or other components need to be replaced, repaired, or extended. As a tree grows in height, the TLPS needs to be extended to remain most effective.

Deciding Which Trees Should Be Protected

The National Fire Protection Association's Standard 780 (NFPA780, § F-1) and the American National Standards Institute (ANSI A300 Part 4 §A-1.1) recommend installation of a TLPS in trees that are within 10 feet (3 m) of a structure. When trees are taller than adjacent structures, the upward streamers produced from the trees will be more likely to intercept a downward stepped leader than streamers from the lower structures. If the tree is protected



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Figure 2. A red maple (*Acer rubrum*) destroyed by lightning. Correctly installed and maintained TLPSs are extremely effective at preventing serious lightning damage to trees.

by a TLPS, the risk of damage to the tree, as well as side-flash damage to an adjacent structure, are reduced. The risk of property damage or personal injury from the flying debris of a splintered tree is also reduced.

The Tree Care Industry Association recommends also protecting trees of historical interest; trees of unusual value; tall trees in recreational or park areas; and trees in susceptible locations, such as isolated trees on a hill, on a golf course, or in a pasture. When deciding which trees should be protected with a TLPS, it is appropriate to perform a basic (Level 2) tree risk assessment (see ISA's *BMP Tree Risk Assessment*). Trees determined to have unacceptable levels of risk or those in poor health are unsuitable candidates for a TLPS.

Lightning-Strike Susceptibility

The risk of lightning damage is a function of the probability of a direct strike to the tree and the expected damage to the tree resulting from the strike. Arborists should recommend protection for trees that have a high risk of a strike and high value damage.

Location and Size

Susceptibility to lightning strikes is most related to tree location and size (Figure 3). Trees considered more susceptible to a direct strike include:

- trees close to water
- trees on hilltops or on slopes facing the direction of approaching storms
- the tallest tree in a group
- trees growing in the open or in small groups
- trees that border woods or line a street
- trees in local areas or geographic regions with a history of numerous lightning strikes

Species

Some tree species are considered more likely to be damaged, if struck by lightning, than others. This may be because of their electrical conductivity as it relates to tree moisture content. Lists of species susceptibility to lightning damage vary among authors. Table 1 provides a summary of susceptibility to damage in the northeastern United States. This table is presented to aid the arborist in establishing the priority of trees to be selected for protection. For example, if a client has three trees of different species of equal height and importance, and can only afford to protect one tree, it is preferable to protect the tree that has been rated at a higher level of species susceptibility to damage.

TLPS Components

Materials Specification

Before installing a TLPS, a qualified arborist or certified lightning protection system installer will need to inspect the tree, site, and soil in order to develop specifications for installation. (Note: There is no certification for tree



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Figure 3. Susceptibility to lightning strikes is most related to tree location and size. This tree is much taller than both the surrounding structures and trees and may make a good candidate for installation of a TLPS.

lightning protection system installers, only for *structural* lightning protection system installers.) The specifying arborist should be sure all components that will be used are of compatible sizes and materials, and designed for use in TLPSs. Since most key components are not found in hardware stores, they will need to be obtained from a lightning protection or arborist supply company in advance of scheduling installation.

Materials

All components used in TLPSs should be made for this use or compliant with national standards for TLPSs. These materials are composed of, or clad with: commercial, electrical-grade copper; copper alloys, including brass or bronze; or stainless steel. Specific metals are required for certain portions of a TLPS. Aluminum and unclad steel components are not acceptable in the functional part of a TLPS, but may be used as non-functional



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Table 1. Trees in the northeastern United States and their susceptibility to damage from lightning strikes.^z

Tree genera	Common name	Susceptibility to lightning damage
<i>Acer</i>	maple	moderate
<i>Aesculus</i>	horsechestnut	low
<i>Betula</i>	birch	moderate to low
<i>Catalpa</i>	catalpa	moderate
<i>Fagus</i>	beech	low
<i>Fraxinus</i>	ash	high
<i>Ilex</i>	holly	low
<i>Liriodendron</i>	tulip poplar	very high
<i>Picea</i>	spruce	moderate
<i>Pinus</i>	pine	moderate
<i>Platanus</i>	sycamore	moderate
<i>Populus</i>	poplar	moderate
<i>Quercus</i>	oak	high
<i>Robinia</i>	black locust	very high
<i>Tsuga</i>	hemlock	moderate
<i>Ulmus</i>	elm	moderate

^z This table is presented as a guide to selecting trees for lightning protection. If all other factors (e.g., height, location, distance from house) are equal, trees rated as high or very high should be protected before trees of low or moderate susceptibility.

components, such as the fasteners that attach PVC conduit to protect a system from vandalism.

To avoid galvanic corrosion, TLPS components should not directly contact greatly dissimilar metals that would form an electrolytic couple. For example, copper conductors should not directly contact galvanized steel support cables.

Components

Conductors

Conductors are the main wire or cable component of a TLPS. They are made of copper and can be a single solid wire or multi-stranded cables in rope-lay, smooth-twist, or loose-weave configurations made specifically for this use (Figure 4). While aluminum conductors are used in structural lightning protection systems, they are not compliant with A300 (Part 4 §43.5.1.1) and therefore are not permissible in a TLPS in the United States. If aluminum conductors are allowed in TLPSs by other national standards, copper grounding conductors are preferred because of corrosion problems that occur when aluminum is in contact with soil. In such systems, aluminum and copper conductors must be joined using specialized dielectric connectors at a sufficient height above grade to avoid soil contact.

In order to direct the electrical current from a lightning strike, copper TLPS conductors need to have a minimum total cross-sectional area of at least 0.022 in² (14.2 mm²).



Figure 4. A multi-stranded cable affixed to the tree with a hammer-driven fastener.

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This is equivalent to a 1/4-inch or 6.4 mm diameter cable composed of 14 strands of 17 AWG (American Wire Gauge) copper wires, or a single 3/16-inch or 4.1 mm diameter, 6 AWG solid conductor. Conductors of this size have been found to be adequate for TLPSs and significantly reduce material cost compared to larger sizes required in older TLPS standards.

Larger diameter conductors, such as 32 strands of 17 AWG copper wires (15/32-inch or 11.9 mm diameter), required by older TLPS standards, or a single 2 AWG (1/4-inch or 6.4 mm diameter) solid copper conductor may still be used in a TLPS when a lower impedance conductor is desired. Some property owners or managers require the use of these larger diameter conductors in new TLPSs. The specifying arborist should carefully read and understand bid or contract specifications when planning and pricing a TLPS.

Conductors are classified based on their location in the system:

- Primary conductors run from near the top of a tree to a grounding electrode.
- Branch conductors run from a branch top to a primary conductor, rather than directly to a grounding electrode.
- Ground conductors are the continuation of a primary conductor running from the base of the trunk to the grounding electrode.
- Bonding conductors connect metal objects in the tree (such as a support system cable) to primary or branch conductors.

Connectors

Conductor connectors are used to connect conductors to each other, to other system components, or to other metallic objects. They are also called splicers or cable splicers.

Conductor connectors are classified by how they secure the connection:

Clamp-type connectors use bolts to secure the connection between conductors or other components or metallic objects. Clamp-type connectors attach more tightly than crimp-type connectors, so there is less likelihood of loosening over time. Installed within three feet (1 m) of the soil surface.

Crimp-type connectors are used to join conductors and are available in end-to-end, side-by-side, and “Y” configurations (Figure 5). They have fingerlike projections that are bent over onto the conductor and have at least two 1/8-inch (3 mm) projections inside that penetrate the conductors upon closing. Crimp-type connectors must be sized to match the conductor. When installing this type of connector, the fingers must be crimped very firmly over the conductor. The connection strength is often tested by pulling on the conductor below the connector with the full weight of the installer.

If a TLPS is specified with a larger diameter primary conductor (e.g., 32 strands of 17 AWG wire) and smaller diameter branch conductors (e.g., 14 strands of 17 AWG wire) and a crimp-type connector is used to join them, it must be specifically constructed for different size conductors.

Bonding connectors are clamp-type connectors made of bronze or consisting of two or more types of metals (bimetallic), to reduce the likelihood of forming an electrolytic couple. Specialized bonding clamps are used for bonding to large-diameter conduits or pipes [greater than 0.75 inch (2 cm)].

Both crimp-type and clamp-type connectors are constructed so that 1–1.5 inches (3.8 cm) of conductor overlap and can be secured within the connector. When installed correctly, both types support at least 200 pounds-force (890 newtons).



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Figure 5. This crimp-type connector is being used to connect the TLPS to a cabling system in the tree crown.

Air Terminals

The air terminal is the uppermost, aboveground component of a TLPS, located near the top of a tree, and is intended to provide a lightning strike attachment point.



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Figure 6. A tree lightning protection system is not required to be terminated with a manufactured air terminal, but the use of a manufactured blunt air terminal is preferred because they are more effective at attaching the strike to the TLPS.

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A TLPS is not required to be terminated with a manufactured air terminal, but the use of a manufactured air terminal is preferred because they are more effective at attaching the strike to the TLPS (Figure 6). If manufactured air terminals are used, blunt terminals (Moore, Bartlett) are preferred over sharp terminals (tree points, Franklin points).

If no manufactured air terminal is installed, the end of the conductor should be cleanly cut, with all strands in contact. Fraying the ends of the conductor is not recommended.

Fasteners

Fasteners are used to secure conductors to the tree (Figure 6). They are also called 'stand-offs' because they separate the conductor from the surface of the tree. Fasteners are sized to match the conductor and are of substantial construction so that they can be anchored into wood. Fasteners are designed to be either hammer-driven or screwed into the tree. Hammer-driven fasteners are also known as 'drive fasteners.' Screw fasteners are either single-use fixed-length,

or extendable. Both types are pinched tightly onto the conductor either before or after installation.

Grounding Electrodes

Grounding electrodes (formerly called a grounding system) provide electrical contact with the earth. They consist of the ground conductor and either of two types of terminations:

Ground rods must be no less than one half-inch (13 mm) in diameter and eight feet (2.4 m) long (Figure 7). Slightly larger-diameter [5/8-inch (16 mm)] rods are more resistant to bending and therefore are preferred in hard or rocky soil. Ground rods are made of copper-clad steel, stainless steel-clad steel, solid copper, or solid stainless steel. The typical ground rod has a steel core for strength and is clad in copper for conductivity and corrosion resistance. Solid copper is expensive and may be too soft to drive in hard soils. Solid stainless steel is stronger than solid copper, but is less commonly available and more expensive than copper-clad steel.

When longer ground rods (more than 8 feet or 2.4 m) are required or when shorter ground rods are all that are available (such as in parts of Europe and the United Kingdom), multiple ground rods with machine thread on each end can be used. They are connected with a double female-threaded connector. To prevent damaging the machine thread when driving the rod, a threaded cap is fastened to the top threads. Compression fittings that have a smooth, slightly tapered interior can be used to connect non-threaded ground rods in a similar fashion. Compression fittings are not crimped onto the ground rod, they join two rods as they are driven into the soil and have at least 1–1.5 inches of overlap.

Ground rods are connected to ground conductors using ground-rod clamps.

Ground plates are copper sheets at least 0.032-inch (0.8 mm, 20 gauge) thick with a surface area of at least 2 ft² (0.19 m²). The plates typically used in a TLPS are 18 inches × 18 inches or 2.25 ft² (46 cm × 46 cm or 0.21 m²).

Ground plates are connected to ground conductors using a minimum of two connectors that are permanently attached to the ground plate when it is manufactured. The two crimp-type or clamp-type connectors must each apply pressure to a ground conductor over a minimum length of 1–1.5 inches.

Ground rod clamps are used to connect a ground conductor to a ground rod. They should have a minimum contact length for both the rod and conductor of 1–1.5 inches. The inside width of the clamp should match the ground rod diameter [one half or five-eighths inch (13 to 16 mm) diameter].

Straight ground rod clamps should be heavy-duty and have at least two screws or bolts to fasten to the ground



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Figure 7. Ground rods must be no less than one half-inch (13 mm) in diameter and eight feet (2.4 m) long. The typical ground rod has a steel core for strength and is clad in copper for conductivity and corrosion resistance.

rod. Shorter, light-duty single-bolt clamps commonly used in electric system grounds are not acceptable in a TLPS. When installing straight ground rod clamps, the bolts must seat onto the rod rather than the ground conductor. The conductor should enter from the top of the

clamp. Right-angle (crossover) ground rod clamps are preferred when installing more than one ground rod in an in-line configuration.

The December 2015 CEU article will cover planning and installing tree lightning protection systems.

CEU QUESTIONS

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If you prefer to use the paper answer sheet for home study of this article, darken the appropriate circles on the answer form of the insert card in this issue of the magazine. A photocopy of the answer form is not acceptable. A passing score for this test requires sixteen correct answers. ISA will be phasing out the magazine's paper answer sheets in 2016.

Please also complete the registration information on your answer form, including your certification number, and mail the form to: ISA, Certification, P.O. Box 3129, Champaign, Illinois, 61826-3129, U.S. Answer forms for this test, **Tree Lightning Protection Systems (part one)**, may be sent for the next twelve months to obtain one continuing education unit (1 CEU).

If you do not pass the quiz, ISA will send you a retake answer sheet. You may take the quiz as often as is necessary to pass. If you pass, you will not be notified; rather, you will see it credited on your CEU report (available online). Processing CEUs manually takes four to six weeks.

CEUs for this article apply to Certified Arborist, Climber Specialist/Aerial Lift, and BCMA practice category only.

- Which of the following represents the electrical potential needed to produce one ampere of current through a resistance of one ohm?
 - conductor
 - coulomb
 - volt
 - impedance
- Sideflash occurs when
 - the electrical impedance of the lightning strike is greater than the air's resistance
 - there is a continuous flow of current from the cloud to the ground
 - the lightning strike moves horizontally across the sky instead of vertically to the ground
 - a portion of the electrical current jumps from a struck tree or other object to another nearby object
- Which of the following is *not* an acceptable material for the construction of tree lightning protection system functional components?
 - commercial, electrical-grade copper
 - copper alloys, including brass or bronze
 - lead-infused structural steel
 - stainless steel
- Once lightning contacts the earth
 - the charge spreads out from the point of contact in all directions
 - sideflash creates an electrical hazard up to 50 feet (15 m) from the strike
 - the amperes in the cloud and on the ground are in equilibrium
 - no further damage can occur to surrounding objects
- What is the minimum length a ground rod should be?
 - 6 feet (1.8 m)
 - 8 feet (2.4 m)
 - 10 feet (3 m)
 - 12 feet (3.7 m)
- Which of the following trees are candidates for installation of a lightning protection system?
 - trees of unusual value or historic interest
 - trees within 10 feet (3 m) of a structure
 - tall trees in recreational or park areas
 - all of the above
- Tree lightning protection systems should be installed in trees in poor health to ensure a lightning strike does not kill the tree.
 - True
 - False
- The risk of lightning damage is a function of the
 - consequences of tree failure and the amperes conducted through the strike
 - likelihood of tree failure in the absence of a lightning strike minus the likelihood of failure from a strike
 - tree's height in relation to nearby structures and the probability of sideflash from a lightning strike
 - probability of a direct strike to the tree and the expected damage to the tree from a strike
- According to Table 1, if all other factors are equal (e.g., height, location, distance from structure), which tree species is most susceptible to damage from a lightning strike?
 - beech (*Fagus*)
 - black locust (*Robinia*)
 - catalpa (*Catalpa*)
 - elm (*Ulmus*)



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10. Copper grounding conductors are preferred over aluminum ones because
 - a. aluminum does not conduct electrical current underground
 - b. of corrosion problems when aluminum is in contact with soil
 - c. copper is cheaper and therefore a more economical choice
 - d. as sunlight degrades aluminum, it loses its conductivity
11. Tree lightning protection systems are intended to
 - a. prevent trees from any damage that may occur from a cloud-to-ground lightning strike
 - b. provide a preferred point for lightning attachment and a preferred path to ground for lightning strike currents
 - c. deflect lightning strike currents to nearby structures or the ground, away from susceptible plant tissues
 - d. all of the above
12. Bonding conductors connect
 - a. metal objects in the tree to primary or branch conductors
 - b. a primary conductor and the grounding electrode
 - c. the primary conductor to the tree
 - d. all of the above
13. What type of conductor connector is recommended for bonding metallic objects within three feet (1 m) of the soil surface?
 - a. bimetallic bonding connector
 - b. crimp-type connector
 - c. clamp-type connector
 - d. air terminal connector
14. Which of the following trees are generally *not* considered more susceptible to lightning strikes?
 - a. trees on slopes facing away from approaching storms
 - b. trees that border woods or line a street
 - c. the tallest tree in a group
 - d. trees close to water
15. A manufactured air terminal is not required in tree lightning protection systems, but they are recommended because they are
 - a. more visually appealing than a simple, wire-ended system
 - b. less likely to break in a storm than a homemade air terminal
 - c. more likely to fray the end of the conductor, helping to attract a lightning strike
 - d. more effective at attaching the strike to the tree lightning protection system
16. Fasteners are used to secure conductors to the tree by
 - a. affixing to the bark
 - b. being driven into the wood
 - c. wrapping around the trunk
 - d. screwing into decayed sapwood
17. What is the purpose of grounding electrodes in the tree lightning protection system?
 - a. they diffuse protons from the air into the ground
 - b. they provide electrical contact with the earth
 - c. they ensure power outages don't disrupt the system
 - d. all of the above
18. Which of the following terms is defined as the discharge between a charge pocket of one polarity in one cloud and a charge pocket of opposite polarity in another cloud?
 - a. cloud-to-ground
 - b. cloud-to-cloud
 - c. intra-cloud
 - d. inter-cloud
19. All the materials needed for a tree lightning protection system can be obtained at local hardware stores.
 - a. True
 - b. False
20. Right-angle (crossover) ground rod clamps are preferred when
 - a. installing more than one ground rod in an in-line configuration
 - b. attaching a grounding rod and conductor made from different materials
 - c. using a ground plate instead of a grounding rod
 - d. only two-screw type straight ground clamps can be found

Arborist News CEU Quiz Answer Sheets Going Digital-First

Next June, ISA will be transitioning the answer sheet submission process for CEUs submitted for articles published in *Arborist News* to a digital-first policy. Here's what that means:

- *Arborist News* quizzes are available online through the ISA webstore (www.isa-arbor.com/store)
- CEUs submitted electronically are processed faster (two business days)
- The paper answer sheet is slowly phasing out

After roughly two years of implementation and continuous tweaking, we are confident in pursuing a digital-first approach to accepting/grading the answer sheets associated with CEU article quizzes published in each issue of *Arborist News*. (Rest assured, the CEU articles and the quiz will still appear in print; this merely refers to the submission of the CEU quiz answer sheet.) The digital-first approach will significantly reduce grading inconsistencies, and new features will allow quiz takers the opportunity to see which questions were answered incorrectly.

For readers unable to go full-digital, paper answer sheets will be made available upon individual request. ISA is currently developing a new video tutorial to assist those new to the ISA webstore interface.