Tree Lightning Protection Research at the Bartlett Tree Research Laboratories

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There are many reasons to protect trees from the damaging effects of lightning that are discussed in this proceeding and elsewhere (Smiley et al 2002). It is a fact that tree lightning protection systems are highly effective at protecting trees and the people and property around them. Our challenge, as a commercial installer of tree lightning protection, is to make lightning protection systems as effective as possible while keeping the cost as low as we can so that we may protect more trees.

Research Locations

At the Bartlett Tree Research Laboratories in Charlotte, NC, we have been studying lightning protection systems for over 15 years. One of the problems in our research, as well as others, is the infrequency and unpredictability of lightning strikes. This part of North Carolina is reported to have a strike density of four flashes per square kilometer per year (1.6 strikes per 100 acres per year, Global Atmospherics 1999). The Bartlett Lab is about 1.4 km^2 (350 acres) so we would expect five or six strikes per year. We now have nearly 80 tree lightning protection systems installed on the property. As of August 2007, we have captured four strikes on protected trees and more than that on non-protected trees. A remote site along the coast of Maryland established with the assistance of Tim Zastrow and Joe Bones, has had two strikes. Details of what we have learned from these strikes are presented below.

Lightning Protection Fuses

From a research perspective, our first challenge was to develop a mechanism to alert us when a strike has occurred on a protected tree. Lightning counters are available at a cost of over $100 apiece. Counters would be ideal to detect strikes, however, the cost to install counters on the large number of trees in our research areas was beyond our budget. Instead, we developed an inexpensive fuse system (Smiley and Thompson 2001). For about five dollars per tree we could wrap a coil of wire and attach an automotive fuse to it. This fuse system works by electronic induction. The strike induces a current flow through the coil of wire and blows the fuse. Our first strike to a lightning protected tree with fuses attached, had three fuse systems with different amperage fuses and different numbers of coils. By looking at the fuse amperages and coil numbers of the fuses that blew and those that did not, we were able to calculate how many coils were needed per amp of fuse. We have since installed these fuses on all of our protected trees and have had fuses blow every time a protected tree was know to have been struck.

Conductor Size

The first fused system at our Laboratory that was struck was on an 18 m (60 feet) tall loblolly pine. The conductor in this tree was a 4 mm (0.16 inch, number 6 AWG) diameter, solid copper wire typically used as a house electrical ground. This wire was far smaller than the 11 mm (0.43 inch, 32 strand of 17 gauge wire) diameter, which was the standard for trees at the time of the installation. There was no damage to the wire except at the lightning entrance and exit points. There also was no damage to the above ground portions of the tree, below the air terminal. This told us that the conductor size we were required to use at the time, was far larger than is necessary to protect a tree.

Recommendations from other, non-building lightning protection sources, also required much smaller diameter conductors than were required for trees. In 2000, the American National Standards (ANSI) Committee A300 looked at this research and those recommendations from other industries and decided to propose the use of smaller diameter conductors in trees. They asked the manufacturers of lightning protection conductors and lightning researchers if they had any research that showed smaller conductors were unsafe or ineffective. None was presented to the committee. With this information in hand, the committee did lower the minimum size of conductor required for trees. This continues to provide a significant financial savings for all those who purchase tree lightning protection.

Root Damage

Another part of our research looks at root damage near ground rods and where lightning exits from ground rods. We have now removed four ground rods after strikes and on one tree we were able to air excavate the area around the ground rod to look for root damage. On the root excavated tree we did find extensive root damage within 35 cm (15 inches) of the ground rod. This tells us that if the rod is too close to the trunk, severe buttress root damage is likely to occur. However, there is no compelling reason to run the ground conductor and install the ground rod outside of the tree’s dripline from a root damage perspective.

In two of the four trees that were struck, where we removed the ground rod from the soil for inspection, the lightning left the rod from the bottom tip. This is the point where departure is least likely to cause tree damage so is therefore most desirable. In the third case the ground rod was located within 60 cm (two feet) of PVC irrigation pipe and control wires. The lightning departed from the ground rod at the exact depth of the buried utilities, lightning sideflashed to the utilities causing an explosion of the pipe and melting of the control wires. The lightning followed the wires to the control box causing extensive damage to the controls. In the fourth case, the lightning departed from the conductor at a side-by-side finger type splicer that was installed just above the soil line. The lightning sideflashed to the root system of the tree. When the ground rod was pulled from the soil it was found that the soil was dry the entire depth of the 2.4m (8 foot) ground rod due to an extensive drought. Apparently, the water in the root was more conductive to the lightning than the ground rod.

Root Damage Near Ground Conductors

This study was conducted to determine if roots near ground conductors are damaged when lightning protection systems are struck. Ground conductors are copper cables that connect the primary down conductor on the tree trunk to the ground rod. Ground conductors are often installed very close to tree roots. It was not known if roots growing near ground conductors are damaged when the system is struck. If they are damaged as extensively as those around a ground rod, then there is no reason to move the ground rod away from the trunk. Therefore, determining if roots near ground conductors are damaged is important in determining the location of ground rods in relation to the trunk and determining how close the ground conductor can be installed near major roots.

This research was conducted at locations near Middleburg, Virginia working in cooperation with arborist Tom Armstrong. The strike density in this area is approximately four flashes per square km per year (Global Atmospherics 1999), but tends to be more common on hilltop properties.

Trees in this study did not have fuses installed on the lightning protection systems so we relied on eyewitness to the strikes and physical damage to the soil to determine which trees were struck. Five trees with lightning protection systems that were reported to have been struck by lightning were located. Ground conductors were excavated to a distance about 2m (7 feet) from the tree trunk on April 2, 2002. Roots within 10 cm (four inches) of the ground conductor at the time of the strike were located and examined. The portion of the root closest to the conductor was cut to determine if decay or damage was present in the phloem and sapwood. Roots were rated as healthy or injured.

On the five study trees, 10 roots were located within four inches of the conductor. None of the roots had injury consistent with lightning damage (Table 1).

Table 1. Roots that were inspected for damage near the ground conductor on trees that have lightning protection systems that were known to have been struck by lighting. All farms were near Middleburg, Virginia.

Location	Species	DBH in inches	Yrs since strike	Number of known strikes	Distance from Trunk (inches)	Distance from Conductor (in.)	Damage
Dundrillin Farm	White oak	50	7	≥ 1	10	1	none
	White oak	36	6	5	22	3	none
					30	0	none
					51	3	none
Huntlend Farm	Tulip poplar	24	4	≥ 1	8	0	none
Dinwiddle Farm	Black locust	16	3	≥ 1	8	2	none
					20	0	none
	Red maple	34	5	≥ 1	17	1	none
					28	1.5	none
					63	0	none
					73	0	none

With the soil texture and moisture conductions present in northern Virginia, it was apparent that no root damage occurs near ground conductors when systems are struck by lightning. This is very different than from the extensive damage found near a severed conductor and a ground rod that were struck. This lack of damage indicates that no significant heating or electrical damage occurs between the trunk and ground rod.

We concluded that when installing lightning protection systems, the location of the ground rod is more important than the route of the ground conductor from a tree health perspective. If the ground rod is located at the edge or beyond the root plate, in accordance with the ANSI A300 standard (ANSI 2002), little significant root damage would be expected. If the ground rod is located close to a buttress root or the trunk, damage can be expected if a strike occurs.

Air Terminal Comparison

The work of Dr. Charlie Moore and Dr. Bill Rison (Moore et al 2000) has brought attention to the blunt air terminal for use in lightning protection system. It is hypothesized that the better receptor an air terminal is, the less likely lightning damage will occur at or above the air terminal and the large area of protection around the air terminal.

We have looked at the air terminal on most of our lightning strikes. At our Annapolis, Maryland site, we set up the trees to compare the different types of terminals. There in 2003 we installed three different air terminals on each protected tree connecting all three to one down conductor and ground rod. One sharp Franklin point, one blunt Moore terminal, and one frayed terminal were installed per tree. Due to the size of the tree crown, the lightning should have a nearly equal chance of striking any of the three terminals. One of these experimental trees was struck in 2004, as indicated by the blown fuse. It was the blunt tip that was struck.

Two of our other trees that were struck at the Bartlett Lab site were near the straight cut or bent tip primary conductor. On both of those trees there was lightning damage above the air terminal.

While one strike does not make an experiment, when combined with the research done by Moore and Rison, it does indicate that blunt terminals will be more effective than the other types of air terminals and could improve tree protection.

Conclusion

Lightning protection research will continue at the Bartlett Tree Research Laboratories to increase our number of data points and try to find trends with the effects of lightning on tree lightning protection systems. We would like to collect more data on the effects of connectors, conductor’s ability to channel lightning and to determine if old abandoned drive fasteners affect the direction of lightning, as well as confirming what we know about root damage and terminal efficacy. Due to the unpredictable nature of lightning, these studies may take many years to complete. As we go along, we plan to propose incremental improvements to lightning protection system designs and installation practices so that we can protect more trees and the people who live around them.

Literature Cited

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