By Don Kimberlin, NCE

Goodness! Gracious! Great Balls of Fire!

The scene of this "low-tech" article on lightning is in the late 1950s, in a time and place before solid-state electronics and EMI or EMP was a studied science…but also a time and place before remotely controlled, unattended electronic installations. As well, the story tells a bit about why, when the era of space flight occurred, and NASA opened its space center in Florida, that NASA had to become a leading force in developing lightning protection.

It might explain my lifelong interest in the phenomenon, in which Florida is exceeded in lightning strike frequency only by Amazonian Brazil, Central Africa, Southeastern Asia, and some parts of Austrailia.

Also, it tells a bit about a first work experience for someone who never knew of lightning's frequency or ferocity before it became a part of the workplace.
(Don Kimberlin)

Shuttle pad strike photo above by NASA. Lightning photograph next page courtesy Michael Bath, Jimmy Deguara and David Croan, Australian Severe Weather. http://.www.australiasevereweather.com/

(LANDIS, North Carolina - August 2003) Long before there was Disney World, life as an AM transmitter operator in Florida's Tampa Bay included a live daily electrical show—you could set your watch to it at 3PM. The breezes would slow to a stop; the semi-tropical humid air would boil up into anvil-shaped cumulous clouds. And then the heavens would open up into a combination of blindingly thick walls of water and multifold lightning bolts!

When I took the job, the wizened souls who already worked there seemed completely blasé and took it in their stride. No way would Florida Power be able to keep the juice flowing, so cranking the generator, shortly after the clouds were seen moving in from the Gulf of Mexico, was routine. In fact, we would often switch to generator power during a station or commercial break, simply to avoid a program disruption.

When the clouds arrived, the show would begin. Perched along the Gandy Causeway, WTSP (5 kW DA-N) had a 455 foot, 225 degree central member, and two 90 degree members added for night operation, which of course floated in the daytime. It was not unusual for the tall tower to take 25 hits or so during the half hour of violent weather each day! The thunder was deafening, largely because the base of the 455-foot tower was just 50 feet from the open back door of the transmitter building.

. . . As I asked him what was wrong, he pointed at a blue fireball rolling across the floor and exclaimed, "What happens if you touch one of those things?" My candid and truthful answer was, "Golly, I really don't know. I never tried to touch one."

Both the AM and FM transmitters cycled off and on repeatedly, sometimes in step with the repetitive pulses of the instant lightning bolt. Those strikes were often so strong that they would divide into several forks and repeatedly hammer all three towers for 5 or 10 seconds.

Over the course of years of experience, the wily WTSP crew had reworked and overworked the bonding and grounding in and around the whole building, to the extent that most of the lightning had a place to go outside the building. Unfortunately, that did not keep some from getting into the AM transmitter's RF amplifier cubicle, where a buzzing volume of ionized air emitted a nasty atomic-like pulsating purple-blue glow.

Occasionally, the entire cubicle would fill, and a buzzing ball of blue fire would emit from the crack of the door closure, rolling across the asphalt tile floor, spitting and buzzing until it hit the far wall and burst into nothing with a sort of "pifft" sound.

At the time, there was a Western Union clock on the wall opposite the transmitter control desk above the FM transmitter's face. When lightning hit the telegraph line that brought in time setting pulses, the entire clock would take on a buzzing blue glow of ionized air. Its appearance was like some fiendish device in Doctor Frankenstein's Laboratory.

Photo by Steve Baynham (copyrighted)

SPARE PARTS

Parts failures? By the dozens. Parts that never seemed to fail in other areas of the nation: Like rectifier filament transformers, control relay coils, heavy 1940s-50s steel boxed, iron-cored power supply chokes and blower motors. The loss of chokes, transformers and motors was so common at our plant and all the others in Florida, that the vendor we all relied on, Tampa Armature Works, kept a stock of rewound units on hand for the broadcasting stations of the state. We lost mica transmitting capacitors and 200-watt resistors by the boxfull, and vacuum capacitors really were not much relief. (Blown-up Faraday capacitor filler was really messy, sticky stuff to clean up, let me tell you!)

Yet, so far as I knew, this was normal life for everyone with a similar job nationwide. Only after WTSP was sold to some Northerners, and their VP of Engineering came to town, did I begin to realize Tampa Bay was in the lightning epicenter of the United States. He was in town one August afternoon and happened to be in the transmitter building with me when the show began. I was, of course, seated behind the steel transmitter control desk, pushing reset switches and scribbling transmitter log entries. I eventually noticed he had backed himself up on tiptoe into the steel cabinet racks behind the desk, and that all his color had drained to his feet. As I asked him what was wrong, he pointed at a blue fireball rolling across the floor and exclaimed, “What happens if you touch one of those things?” My candid and truthful answer was, “Golly, I really don’t know. I never tried to touch one.”

Now, if you live in coastal California, you might say, “Don, your imagination is working overtime.” That is because the US West Coast has one of the lowest incidences of lightning in the world—an average of only 5 days per year with any lightning. But Tampa Bay has more than 100 lightning days a year.

Later, when I changed careers to go to work for AT&T’s (then monopoly) Long Lines Department, I saw a US map called an isokeraunic chart. In the years before weather radar and lightning detection networks, one of the records weather observers kept was a notation if thunder was heard that day. Since the sound of thunder typically can be heard up to about ten miles from its source, it meant the charts had large blank areas for places in which there were no weather observers within ten miles. Isokeraunic charts have obviously become much more detailed and accurate since then. They used to show a line that encompassed Interstate Highway 40 from Tampa Bay to Daytona Beach as having more than

Continued next page . . .

100 thunderstorm days a year. That line is more detailed today, but Tampa Bay remains as the Lightning Capital of the US.

RISK FACTORS

There are several factors to consider about lightning risk, and frequency of activity is but one of them. If you look northward on the charts from Tampa, the entire Southeastern US steadily trends down in frequency until a level of about 50 days per year is reached in the Carolinas. However, the soil conductivity up there is something like 30 micromhos, giving that lightning far less “drain” to dissipate itself. The net result is a similar potential damage risk for the entire Southeastern region.

And tropical weather is not the only cause. Dry air can sometimes cause incredibly high static buildup. There is an area in Arizona where isokeraunic charts show 60 days of activity per year. I have been told engineers there commonly see balls of St. Elmo’s Fire atop towers, and arcs approaching 150 feet in length between towers have been seen. When a spark gets that much voltage behind it, damaging currents can be induced in wires for a large nearby area. True, the Arizona lighting arcs may not build to the monstrous 200 kiloamps of a large Florida bolt, but their effect can be just as destructive.

Why? Because soil conductivity is what controls the quantity and rate at which the earth can dissipate the lightning. It is a whole lot easier to get a 5,000-micromho southeastern saltwater swamp to dissipate lightning than 10-micromho desert sand or Vermont granite. Thus, even though the lightning might be less frequent and even smaller, its damage can easily be as large, simply because at best it has nowhere to go.

All of this makes understanding how to avoid damage a complex and variable picture. It is clear the primary defense is bonding and grounding. If lightning hits, your best defense is the lowest impedance path to earth you can provide for it. Lacking that, the lightning will create its own path—usually by destroying something you did not want destroyed. The damage might appear to have been capricious, but if you really understand the issues and investigate what happened, you probably can devise a change that will offer the lighting a less harmful way to dissipate itself.

DE-FENSE! DE-FENSE!

Still, that is only part of the story. It can be just as important to make your plant less attractive to lightning in the first place. Over the past half-century, many studies and improvements have been made to the understanding of just what attracts lightning, and lightning avoidance can in many cases be very effective. A special separate Lightning Code, Part 78 of the National Electrical Code, has existed for some years. It offers descriptions of how to handle lightning and how to minimize exposure by placing “air terminals” on buildings. You will see these on the roof parapet of new buildings these days.

There have been a number of significant proofs of the effectiveness of air terminals. Perhaps most spectacular is the dissipation array festooning the 13 story-high Space Mountain at Disney World right in Florida’s lightning alley. If you had not been told about it, you would probably never notice the carpet of spikes atop Space Mountain. While Disney’s Fairy Tale castle a short distance away gets its pointed spires blasted regularly, Space Mountains’ grounded, many-spiked dome has never been hit. It simply offers no single point to attract a hit. Similarly, during testing of the efficacy of air terminals some years ago, direct comparison of lightning hits to the twin towers of the World Trade Center showed no hits to the tower with air terminals installed, while the unprotected tower took multiple hits.

AM broadcasters have some very simple first lines of defense to employ. You should have some form of series reactance, even down to a one-turn loop in the tower RF feed, in every wire going onto the tower. And, you should have a spark gap across the tower base set nice and close. Some broadcasters set their gap by modulating the transmitter 100% with tone, tapping the base gap together until it arcs over from the transmitted signal, then tapping it open enough to break the arc. Those operators also polish the gap (with the transmitter off, of course!) to keep it from growing “whiskers” which would close the gap. The overall result will be a tower base gap much closer than any textbook setting you were taught.

Lightning avoidance techniques may well have a place in your plan for protection against lightning damage or interruption. But, let us look at a different line of defense that many people mistakenly think is the first and only one—surge suppressors.

Surge suppressors are used to reduce the pulses conducted into facilities on power and phone lines. (If lightning actually hits the power or phone lines near your plant, the conducted pulse will likely be so huge it will probably destroy the wire itself as well as any surge suppressor.) You can really only expect surge suppressors to be capable of conducting pulses induced into the wire by nearby strikes.

Worse, if you do not or cannot give the surge protector a low-impedance path to ground, its effectiveness can be reduced to worthlessness. Fight off the obsessive tidiness of coiling up surge suppressor power cords. If the only ground path you can provide is a power receptacle’s AC power ground filled with twists and turns, safely housed in nice steel tubing or BX that makes it into a nice series inductor, you can forget what suppressive value your “surge protector” might have!

IN THE INTERVENING YEARS SINCE THE START OF THIS STORY, I have seen a panoply of test and measurement methods developed to evaluate and quantity the risk of lightning damage at any given location. Indeed, one can spend many thousands of dollars for a lightning risk audit. That would be prudent. But, by learning just a few simple precepts about the nature of lightning, you can reduce the potential or the recurrence of lightning damage where you work.

WHAT LIGHTNING IS

Basically, lightning is simply a giant Low-Frequency flow of pulsating Direct Current electricity. Where an engine starter motor may draw 500 Amps at 12 Volts and melt connectors with the slightest resistance, a small lightning bolt is probably a current of 10,000 Amps at several million Volts. In other words, even the smallest lightning bolt is gigantic. And the "big" ones? They have been calculated to run up to 200,000 Amps.

Impossible to handle, you say? No more so than handling an 800 pound gorilla. It will go where it wants to go, but *if you give it an easy path to take, it will choose that path*. The lesson: Make ground wires short, straight if possible. Leaving a drip loop in an outdoor ground wire is lighting suicide. The lightning will not go around the corner. It will simply jump to some other nearby convenient path, and usually do some damage while doing so.

The simple way to understand what happens is to follow the principles we all learned from Michael Faraday and others: There is a magnetic field that surrounds a wire conducting electricity. When that electricity is lightning, the field is enormous—for an instant. The wire has incredible amounts of self-inductance—for an instant.

The enormous magnetic field surrounding the wire induces large currents in everything else near it, so everything in the vicinity is suddenly charged. Since the amount of current induced in all those nearby things—even electrical power boxes themselves—varies widely from device to device. All manner of secondary arcs can occur in devices that were not even hit. That is why a massive, low inductance ground is essential for lightning protection. Your objective is to try to get and keep everything at the same low potential. Perhaps a short "war story" will illustrate.

INSTALL A GOOD GROUND

One location I was called to had a computer RS-232 line run from its newswire satellite receiver in one building to its printer in another a few hundred feet away. (Yes, 1200 bps async data can be run for significant distances—possibly as far as a mile—using RS-232 interfaces.) The problem was that the connection kept blowing up the little IC chip driver/receivers used in RS-232 interfaces. "Why?", asked the locals, "Did the interface cable not have a common ground wire in it?" Yes, it did. But that wire was only a 24 gauge solid copper conductor, and any currents induced in it would drain to earth through the chips. They could really only handle about 50 milliamps of current to ground. The actual devices never got hit. All the lightning in the area hit other things, but it blew those chips due to currents induced in the signal return "ground" wire of the RS-232 cable.

The solution was to bond the power ground terminals of the two buildings together with a Number 8 AWC wire to meet the National Electrical Code. Lo and behold, after that wire was installed, not only did the RS-232 failures cease, but a variety of other strange failures ended, too—like light bulbs that burned out when lightning was in the vicinity.

Tidy electricians, and even tidy engineers cause one lightning bugaboo that is often seen. They will dress wiring and power ground wires with nice, square bends along walls. If you have seen much lightning damage, you have seen the burns where lightning jumped across the square bend, or even jumped off the wire onto a nearby wire to change its path to ground. It usually causes some damage in the process. So, undo those nice, tidy square bends. Change them into nice, gradual turns with very large radii. The larger the radius, the less likely you are to have lightning damage where you least expect or want it.

Therefore, keep an eye out for tidy but long extension and power cords. Neatniks will obsess over messy cords and coil them up out of the way. It is possible to create a reactance of one Ohm in a coiled up cord that is 50 feet long. A simple Ohm's Law calculation shows that one-Ohm of reactance to just 10 Amps of induced current can produce 10 Volts for a few microseconds. How long would you expect a microphone to survive if you plugged it into 10 Volts? One microsecond? Ten microseconds? Does it matter? The microphone died and nobody knew why, because the lightning hit the next building—or "the tower took it."

Finally, if your protective ground system has been doing its job, its connections will actually get heated, and will develop a carbon layer in the joints that must be cleaned. So, all the connections and joints of your protective grounds need regular inspections, with cleaning if carbonized joints are found. This might best be done with a megger or similar device, just for the sake of an accurate test.

While not every transmitter site gets to experience the 3 PM Great Ball of Fire, there still are plenty of potential dangers to equipment and to people. So, to repeat the bottom line: Make all paths to ground as straight and short as possible, and then keep them that way. That is what those wise old owls in Tampa Bay were doing a half century ago, and it still works today. **Ω**

Don Kimberlin is a NARTE Certified Engineer, based in Landis, NC. He has written on many technical topics, both current and historical, and loves to go hunting for history. You can reach him at: donkimberlin@earthlink.net

(Reprinted courtesy of *Radio Guide* – www.radio-guide.com)