Pipes Organs and Lightning

By Arthur E. Schlueter, Jr.

While not all inclusive, this document serves as a general statement on lightning and its affect on pipe organ relays, combination actions, MIDI devices, and amplifiers, as well as associated digital voice generators and power sources of DC (direct current) rectifiers.

Millions of dollars worth of damage, and in some cases complete loss of equipment and structures, are a result of lightning in public assembly buildings. Much research has been conducted on ways to lessen the effects of lightning, as well as the effects of Electromagnetic Interference (EMI), to the electronic systems that may be utilized in the modern pipe organ.

Lightning is a natural event. The lightning bolt appears to be indiscriminate in nature and can choose to strike anything at random. However, it only takes one strike in the vicinity to create havoc within today's pipe organs.

Each damaged instrument can be subject to both immediate documented problems, and conditions where components are weakened but may not cause immediate problems. Failure can occur up to a year after the lightning or EMI event. It should be noted that any semi-conductor that lightning comes close to can be affected. Lightning is always seeking ground to complete the circuit. Conductive material such as a copper roof, bell tower, and conductors in the attic will act as a lightning rod, particularly if it is connected to anything which may provide a path to earth ground.

Lightning strikes, effects of EMI, and electromagnetic pulses resulting from airborne radiation, can effect nearby semi-conductor components. The results of damage are usually immediate, but may become evident anytime within up to one year of the event. Damage can vary greatly from a few components, to the destruction of every component within a relay, combination system or any electronic system or subsystem.

The following list, while not complete, describes ways that lightning damage occurs:

1. **In rare instances, the organ is directly hit at the console, organ cables, power supply, amplifier, or any associated electronic unit connected to the organ.**

   This is the most devastating to an organ. The direct hit results in physical damage, as well as the electrical damage. An organ taking a direct hit will normally display charring at the point of entry and exit, and along the path in between. The natural result is cabinet damage as well as electrical damage. The resulting damage to the cabinet is immediately obvious, and the appropriate corrective action would be equally obvious.

   What is not obvious is the resulting electrical damage, which is usually invisible to the eye, and is only displayed by the effects on the organ performance, if it is able to perform. Normal electrical damage results in the destruction of semiconductors, particularly chips. Capacitors and other devices may also be affected.

   The components that fail immediately are the easiest to correct because they can be tracked down by normal troubleshooting techniques. The negative side of this, however, is the damage to the remaining components which do not result in immediate failure. These damaged components are referred to as "the walking wounded." Ultimately, they always fail, but it is impossible to predict when. Experience has taught us that these walking wounded components can continue to function for 1-4 years after the strike. Normally when this happens the organ works fine after being restored for a few weeks, months, or even a year. Then a few more components fail, causing symptomatic behavior in the organ. After being repaired again, more failures occur again shortly. This continues until virtually all components have been replaced. This situation occurs with all types of lightning damage.

2. **A lightning strike in the general area with pulses entering through the power lines.**

   This is the most common type of lightning damage. The organ is plugged into a power outlet. Lightning strikes close by ((one or two miles away is very common) and manages to get on the power line. By the time the lightning pulse gets to the organ, it is attenuated to probably less than 100,000 volts. Even if the organ is off, this voltage is sufficiently high to bridge the power switch and randomly damage components throughout the organ. We call these "transients" or "spikes." Considering that all semi-conductors are designed to operate in a 5-volt or 12-volt environment, it comes as no surprise that several thousand volts wreaks havoc.

   It is very common for failure to occur in components following this type of strike. Usually about 40% fail immediately. The remainder fail as walking wounded over the next 1-4 years.

3. **Similarly, pulses can enter through organ cabling, such as an pipe division, or speaker wire.**

   This type of lightning damage usually results in the least amount of damage, but is still traumatic to the organ. Normally, it occurs when speakers are mounted high in the church. The speaker wire acts as lightning rods and attract a strike. The lightning travels down the speaker wires into the power amplifiers and enters the organ backwards through the circuitry. The net result is usually significantly less damage to the digital logic and computer circuitry, however analog circuits are devastated. The amplifiers take the brunt of the strike.

   Most of the time this is the easiest to repair because the amplifiers can be replaced as modules. It also helps that the logic circuits remain functional and can help with the troubleshooting of the audio circuits.

   Remember though that the damage can be as destructive as any other strike, effecting components throughout the organ, depending on the strength of the strike.

4. **EMI and Electromagnetic pulse damage through airborne radiation.**

   It is commonly believed that leaving an organ unplugged during an electrical storm will protect it from damage. Not true! Many cases have been documented where close proximity hits have caused over one hundred failures in an organ that was unplugged during the storm. These organs were working perfectly prior to the storm.

   Accompanying the lightning strike is a phenomenon called an electromagnetic pulse. This pulse can be of sufficient magnitude to generate many thousands of volts of static electricity, all of which is seeking a ground. An unplugged organ in the vicinity will be subject to the same forces as though it were plugged in.

   Again, if the above damage conditions exist, immediate failures, followed by "walking wounded" failures over the months and years will likely occur. In rare cases the organ can be restored to its condition prior to the strike, but this is generally the exception.

Although the major focus of this document is lightning, the effects of lightning are often similar to the effects of electrical (AC or DC) surges of power and amplified signals associated with the transmission of energy, i.e. surge.

The modern pipe organ is supplied DC current from a rated and listed rectifier that is over-current protected. Providing protection from lightning and power surges can be quite challenging, as 220V or 220/440V three-phase power supplies are the source of AC current for many larger systems.

Some churches and public assembly places have installed line voltage conditioners, which have fail-safe engineering to restructure the line voltage for the organ.

These devices can provide a higher level of protection against the power line pulse that can occur from a lightning event. This is very expensive and has proven to be only marginally effective, because lightning does not affect the pipe organ from only the power source.

Considerations in Repairing Lightning Damage

In repairing a damaged pipe organ, reference should be made to the International Electrical Code/National Electrical Code, which is a division of the National Fire Protection Association, to assure that all repairs, wiring and over-current protection is in compliance with these codes. The repairs should also be in compliance with all local, county, or state agencies which have jurisdiction for the installation or modification of low-voltage 0-50 volt AC or DC, and AC or DC power circuits for 50 volts or higher. Any work on the high or low voltage circuits that require modification, change, or servicing of such circuits, should only be carried out with whatever permits or licenses are required from the city, county, or state which has jurisdiction.

Although the NEC pipe organ code (Article 650 Pipe-Organ) does not give specific information on lightning/electrical surges, the National Electrical Code does provide guidance in Article 285, Article 640 and Article 501, as well as articles dealing with low-voltage and general conductor and wiring practices. Although Article 650 deals specifically with the wiring of a pipe organ, it should be noted that all other articles of the code also apply, depending on the circumstances, such as in electronic sound generating equipment, speakers, amplifiers, etc., per Article 640, as well as the installation within a Public Assembly Place, Article 518.

The pipe organ code (Article 650) is very explicit about the installation of power signal circuits and wire size, as well as over-current protection and installation of rectifiers and blowers. The use of electronic equipment, such as MIDI equipment, electronically generated organ sounds, amplifiers, speakers, and associated wiring, is to comply with Article 640.

This document is not a substitute for a review of each institution, and compliance with its code. However, listed below are a few of the items that should be reviewed.

◊ Organs installed prior to 1990 may have their existing electrical wiring, relays, and associated electrical systems covered by the code dated prior to the 1990 code.

◊ Low voltage signals or electromagnetic valve supply circuits that electrically connect to an antiphonal division should be installed in a metallic conduit or raceway. In the case of multi-signal process data, approved listed shielded cabling can in some applications be utilized.

◊ Long cable runs, including, but not limited to, pipe signals, pipe data cable, pipe

valve supply circuits, audio lines, and zimbelstern cables, are susceptible to picking up the electromagnetic interference (EMI) pulse from nearby lightning events, even those not directly physically affecting the structure or high voltage wiring.

◊ As a general rule, all cabling from the organ console to the organ should be in a metal or shielded conductor. This is especially important in modern electronic process data signal systems.

◊ Generally, internal organ wiring within the organ chamber does not require shielded cables.

◊ In using electronic sound producing devices, all data cabling should be kept as short as possible and all cables should be shielded and if possible, grounded at both ends.

◊ Speaker wires are susceptible to picking up EMI. When installing speakers and amplifiers, locate the amplifiers as close as possible to the speakers, and protect amplifiers with a surge protector.

◊ If a metal conduit is not installed, and installation of a conduit is impractical, then the data and/or audio cable should be double-shielded.

◊ Electronic equipment used in a pipe organ must have a ground conductor.

For assistance with possible lightning damage to a pipe organ, call 800-836-2726 or 770-482-4845.

About the Author

Arthur E. Schlueter, Jr., founder and CEO of A.E. Schlueter Pipe Organ Company, has extensive experience writing and developing standards, guidelines and codes. He was the Associate Executive Director of the Southern Association of Colleges and Schools responsible for setting standards for higher education. For nine years he has served as a committee member of the National Electrical Code Panel 12 and was the principal submitter of Code 650 - Pipe Organs, and Code 640 which includes electronic organs. He is licensed in multiple states as a low-voltage electrician, has earned B.A., M.Ed., and Sp.Ed. degrees ,and is a doctoral candidate.

NOTE: This document has been compiled for reference purposes using information from public domain sources, and Code material from the National Electrical Code. The author of this document, Arthur E. Schlueter, Jr. is a member of Panel 12 of the National Electrical Code.