PDHonline Course E131 (2 PDH)

Introductory Lightning Protection Design per NFPA 780-2000

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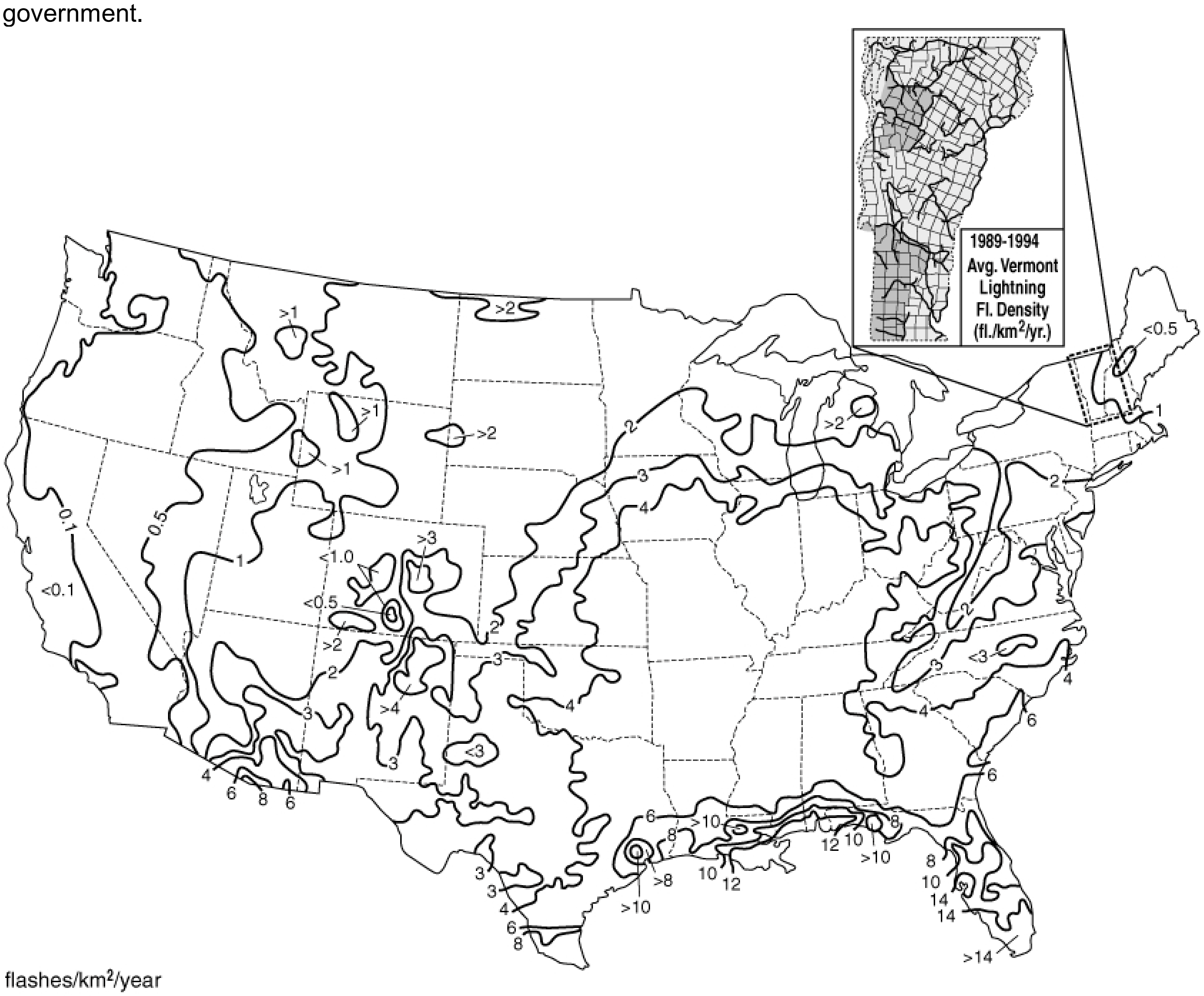
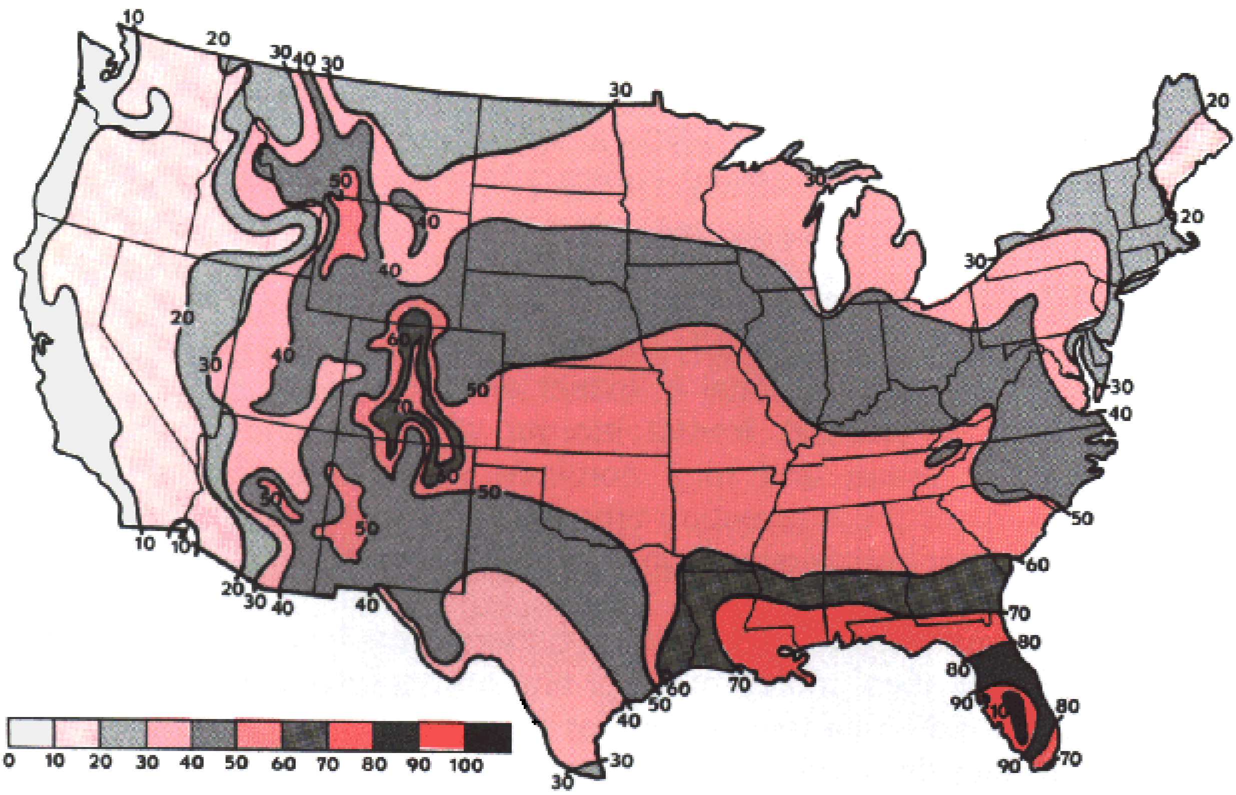
Course Introduction

Lightning is a natural flow of static electricity between the sky and the ground. It strikes buildings, structures, trees, livestock and persons in all parts of the country. It is a severely destructive hazard when it rarely occurs and just as severe where it frequently occurs. The following isoketurdic map displays the frequency of occurrence, based upon a national recording system established by the federal government.



Lightning data provided by the U.S. National Lightning Detection Network™
(Measured lightning flash density corrected for NLDN detection efficiency)

Similar, but not identical, information is reported by the following map, provided by the amateur radio community.



The numbers shown on this map correspond to the color bands and indicate the number of lightning and thunderstorms per year in the indicated area or color band. NOTE: that the largest numbers of lightning storms occur in Florida and in the Midwest.

The destructive force of lightning is beyond human scale. Descriptive numbers commonly used are 100,000 volts, 10,000 amps and temperatures equal to the surface of the sun.

The characteristics of lightning are lawful, but not predictable. The number of strikes per year in a geographic area can be predicted, but not the specific dates or locations. In fact, though lightning is supposed to strike the lightning rods, or air terminals, it often strikes the building adjacent to the terminal or makes a side-strike on the downcomer lead. Current research indicates that the path of a lightning strike follows ionized streamers, with only a +/- 20-ft variability between the streamer and the main strike(s).

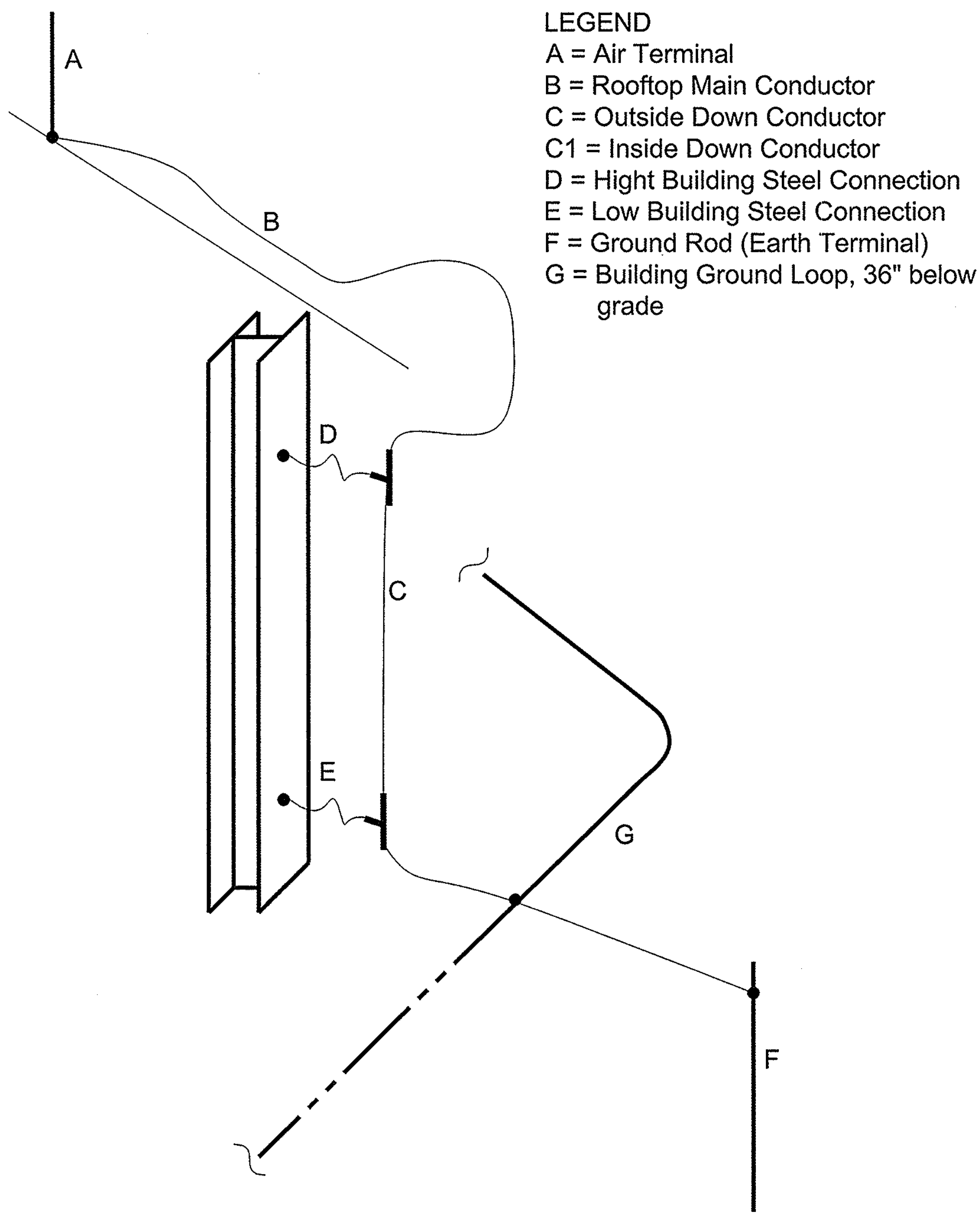
The damage from lightning comes from electrocution, human burns, burning buildings, exploding bricks and mortar, melted electrical equipment, damaged electrical equipment and stresses on electrical equipment that are responsible for failures months later.

However, lightning protection systems work. A broadcast tower will be hit ten or more times during a storm. The current is passed to ground and none of the sensitive electronics are affected.

A conventional Franklin lightning protection system attempts to guide the static electric flow down a preferred path, slightly away from the people, structures and electrical equipment. There are other lightning protection systems, however, which are not addressed in this course. They are not NFPA or UL recognized, but some insurance carriers will accept them as equivalent. This course presents conservative, generally accepted methods. Alternatives not discussed provide opportunities for cost reduction, sometimes with an associated reduction in protection.

It is a common occurrence for a lightning protection salesman to tell the Construction Manager on a project that, “My alternative works just as well as a Franklin system with copper downcomers - and it costs your project only half as much." The justification is of the form, "I have been installing them for 10-years and I'm still in business." Also, "My firm is a member of the Authorized Distributors for XYZ Corp. and certification by Authorized Distributors for XYZ Corp. is the same as UL listing." Construction Managers accept this reasoning and change the specifications in the field. Designers rarely accept this reasoning.

The following graphic emphasizes the grounding portion of a lightning protection system, but shows all parts except rooftop interconnections and bonding.

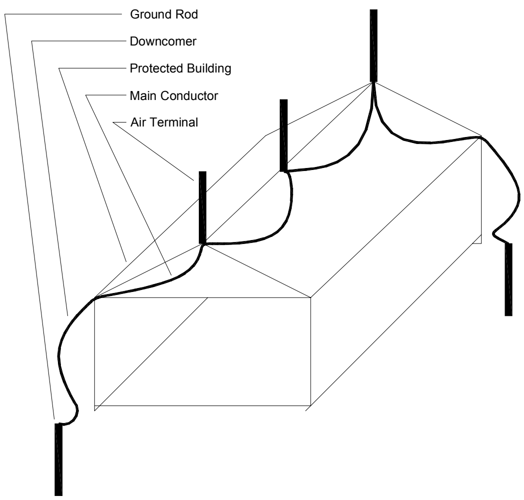


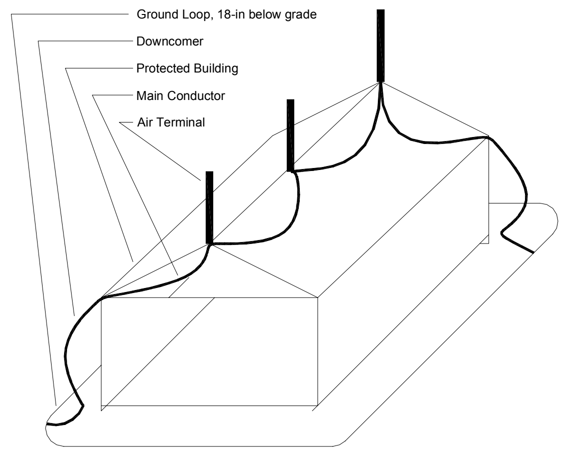
Lightning Protection
Downcomer / Grounding Detail
nts, 9/26/03

Course Content

National Fire Protection Association (NFPA) publication 780-2000, **Standard for the Installation of Lightning Protection Systems**, is a very readable guide to all aspects of lightning, personal protection and the installation of Franklin lightning protection systems. Previous editions were good technically, but the current edition adds narrative discussions which go well beyond the technical content. This course focuses on core principles, but neglects special applications and most of the narrative content. The student is urged to consult the latest edition of NFPA 780 as part of a design for construction.

A Franklin lightning protection system is made up of air terminals, overhead main conductors, downcomers, a ground system and a system of transient voltage surge suppressors (TVSS). (The TVSS is a new requirement, included after substantial lightning related losses that came in on the utility wires.)





Building Ground Loop, Optional Conductive Salts

The following topics are discussed in more detail:

Lightning Rod (Air Terminal) - Install at the highest point and at 20-ft intervals along ridges and parapets. Key tasks are maintaining electrical continuity and roof warranty.

150-ft Rolling Sphere Zone of Protection - Today, NFPA 780 describes the principle of one air terminal protecting another as the Zone of Protection. The model is a rolling sphere with 150-ft radius.

Main Conductor - Every air terminal must have two main conductor connections leading to separate grounds (with exceptions).

Cross-Connector - Large, flat roofs require intermediate air terminals, at 50-ft intervals.

Equipment Bonding - HVAC equipment and antennas on the roof must be electrically connected to the air terminal system. (Why is this so rare in practice?)

Downcomer - An electrical conductor between the rooftop system and the earth must be installed every 100-ft of building perimeter, but not fewer than two.

Ground Rod (Earth Terminal) - Controversy. Ground rods are traditional and good. A ground loop is more expensive, but very attractive theoretically. Rebar in the footer is acceptable.

Ground Loop - Several feet away from the building, a buried conductor at least 18-in below grade, connected to each downcomer and utility service. Optional ground rods and conductive salts.

Building Bonding - This is where judgment comes in. A lightning discharge through the downcomer can induce high voltages on pipes, structural steel and wiring in the building. Intentional grounding of the pipes, steel and wiring to the downcomer eliminates lethal voltages. Try to avoid forcing the main discharge through the pipes, steel and wiring.

Electric Power System Bonding - The National Electric Code (NFPA 70) is adopted by nearly all states and municipalities. It provides extensive details on required electric power grounding, including bonding to the lightning protection system.

Utilities Bonding - By law, each utility entering the building must be electrically connected to the ground system.

Utility Protector - Telephones don't work if you ground both wires where they enter the building. Same for CATV and data. A utility protector is a device, usually provided by the installing contractor, which grounds the leads only when high voltage is present.

Transient Voltage Surge Suppressor (TVSS) - A lightning arrestor is on the utility side of the building main electrical disconnect switch. A TVSS is on the customer side of the building main electrical disconnect switch.

UL Master System Label - The lightning protection industry has grown for two hundred years without regulation. The UL Master System label is as close as we have to a standard and inspection system.

UL 96 Components - Lightning protection hardware and components which carry the UL 96 label have been manufactured to minimum quality standards.

Inspection of Lightning Protection Systems - There is no enforcement of inspection of lightning protection systems, as there is for fire protection systems. Visual inspection annually is recommended.

Lightning Rod (Air Terminal) - What happens at the tip of the lightning rod is not well understood. Or, more accurately, it is well understood by experts who totally disagree with each other. We know that the installation of conductive air terminals usually provides a preferred path for a lightning strike from air to ground. On occasion, the lightning strikes adjacent to the rod and jumps to the downcomer, with damage only on the roof or peak of the structure.

There are four parts to the air terminal, the rod itself, the connection to the main (rooftop) conductor, the physical mounting and the roof installer's acceptance of the physical mounting as not voiding the roof warranty.

The new lightning protection system is of great interest to the Owner for the first six months after installation. He will call the installer if anything is loose and the installer will usually fix it during this period. The key points in design and specification of the system are substantial components - cast bronze rather than stamped steel, and multiple supports – two screws instead of one, double crimp connections, two chimney tie straps.

The air terminals, themselves, are not very interesting. 3/8-in copper is the minimum size. 10-in length is minimum. The mounting details can be very interesting. It is worth a drive around the local area noticing how many buildings have lightning protection systems and how they are installed. It is not the designer's task to specify details of installation. This takes away responsibility from the Contractor and picks up liability for no good reason. Some photographs are included in this course.

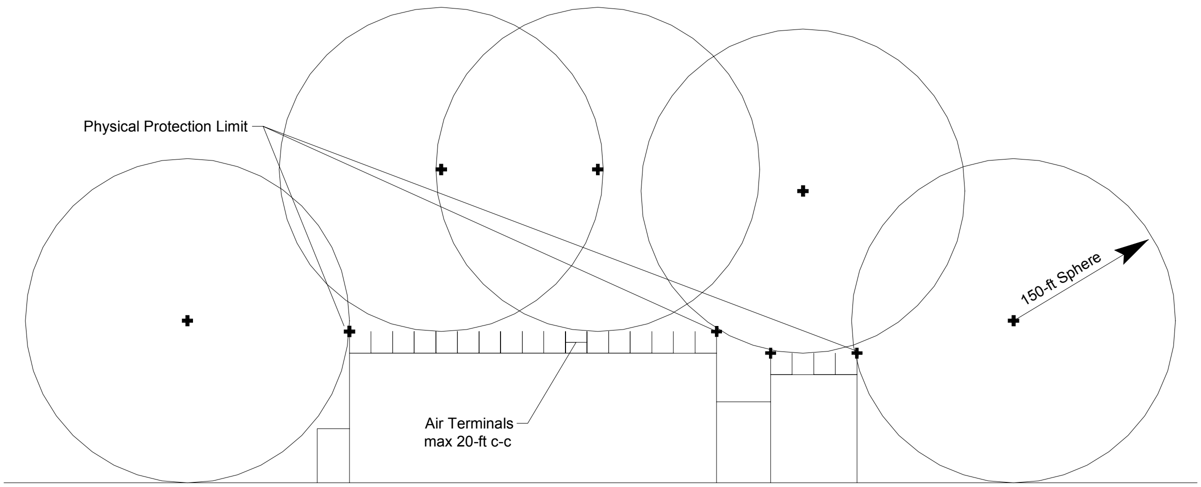
This is a single-story industrial building with a peaked roof. Notice the air terminal on the stack, the bonding to the exhaust fan enclosure and air terminal, the air intake with no protection, because it is within the “cone of protection” of the exhaust fan, and the air terminal on the peak, partially obscured by the tree.

The older design guides for lightning protection used the “cone of protection”, a solid space dropped down from an air terminal, with an angle of 30-degrees from the vertical line. The theory was that conductive objects within the cone were protected by the air terminal. This usually works. The approach, however, is not promoted by the latest NFPA 780. Rather, they speak of a “rolling sphere”, which produces almost the same result and works most of the time, also.

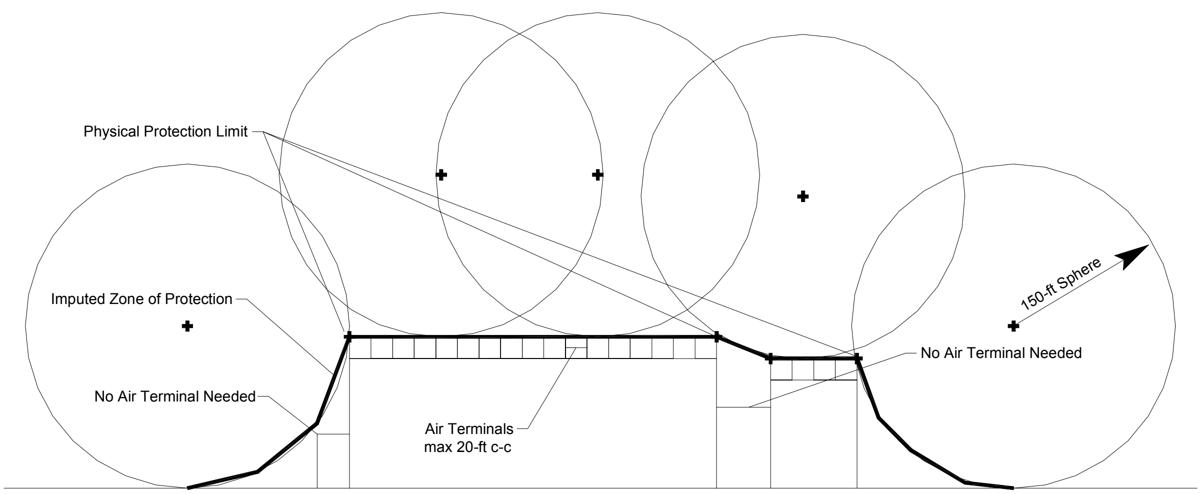
This course focuses more on the design and specification of a functional system likely to be approved by the Authority Having Jurisdiction, on the first submittal. Air terminals must be placed on the highest points of the building and at 20-ft intervals along the ridges and parapets. A few can be omitted if immediately adjacent to a higher air terminal. Lightning rods at 20-ft intervals are a LOT of lightning rods. Usually the designer shows them at 50-ft intervals and includes a note that the installer must “comply with NFPA 780”. The installer knows that they must be at 20-ft intervals and provides them. However, if the installer is not of the highest ethical integrity, the drawing with 50-ft intervals does not warn the Construction Manager or acceptance inspector of the actual needs.

NFPA 780 also requires intermediate air terminals on a flat roof, at 50-ft intervals. Each must have two main conductor connections and separate routes to ground. It is rare to see these actually installed. The terminals are in the way, the main conductors are in the way and a trip hazard and experience of lightning striking a roof drain is almost nonexistent. Similarly, bonding to satellite dishes, LAN repeaters and two-way radio antennas is almost nonexistent. These are required and recommended. A smoked satellite system used for inventory control may be 100x the cost of the bonding strap, main conductor extension and labor.

150-ft Rolling Sphere Zone of Protection - Today, NFPA 780 describes the principle of one air terminal protecting another as the Zone of Protection. The model is a rolling sphere with 150-ft radius, as illustrated by the graphics below.



Zone of Protection, 150-ft Rolling Sphere Model



Zone of Protection, 150-ft Rolling Sphere Model

Main Conductor - 10,000 amps of current flow requires a conductor with a BIG cross-section. The alternative is resistance to flow which makes the lightning want to jump off and go down a better conductor. The listing of main conductors below is from one of the suppliers listed in the link section following the course.

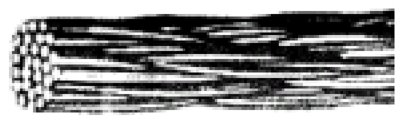
COPPER CONDUCTOR

HB-29-17C Copper Conductor 29 strands of 17 gauge, 59,500 circular mils, net weight 190 lbs. per 1,000 feet (1.150mm, 30mm^2; 278kg/m). Bare only.

HB-32-17C Copper Conductor 32 strands of 17 gauge, 65,600 circular mils, net weight 215 lbs. per 1,000 feet (1.150mm, 33mm^2; 320kg/m). Bare only.

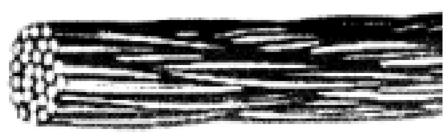
HB-36-17C Copper Conductor 36 strands of 17 gauge, 74,000 circular mils, net weight 240 lbs. per 1,000 feet (1.150mm; 37mm^2; 357kg/m). Bare only.

HB-24-16C Copper Conductor 24 strands of 16 gauge, 61,900 circular mils, net weight 190 lbs. per 1000 feet (1.291mm, 35mm^2, 278kg/m).
Corrosion Resistant also available.



HB-28-16C Copper Conductor 28 strands of 16 gauge, 72,250 circular mils, net weight 225 lbs. per 1000 feet (1.291mm, 37mm^2, 335kg/m).
Corrosion Resistant also available.

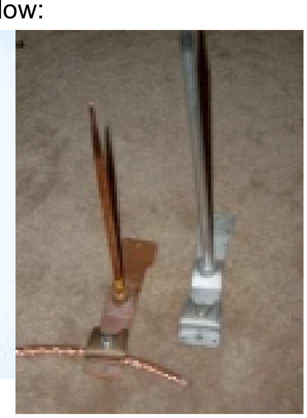
HB-24-14C Copper Conductor 24 strands of 14 gauge, 98,600 circular mils, net weight 328 lbs. per 1,000 feet (1.628mm; 50mm^2, 488kg/m).
Corrosion Resistant also available.



HB-28-14C Copper Conductor 28 strands of 14 gauge, 115,000 circular mils, net weight 375 lbs. per 1,000 feet (1.628mm; 60mm^2 ;558kg/m).
Corrosion Resistant also available.

29 strands of #17 copper is the minimum main conductor. As with the air terminals, the conductor is not very interesting, but the installation details are. The contractor is responsible for selection of the hardware used, but the designer has some responsibility for the acceptance walk-thru and may be sued if the installation results in water damage to the building.

Photos of installation hardware follow:



These are NOT the preferred styles, with multiple physical and electrical connections. Also, aluminum components are not addressed in this course.

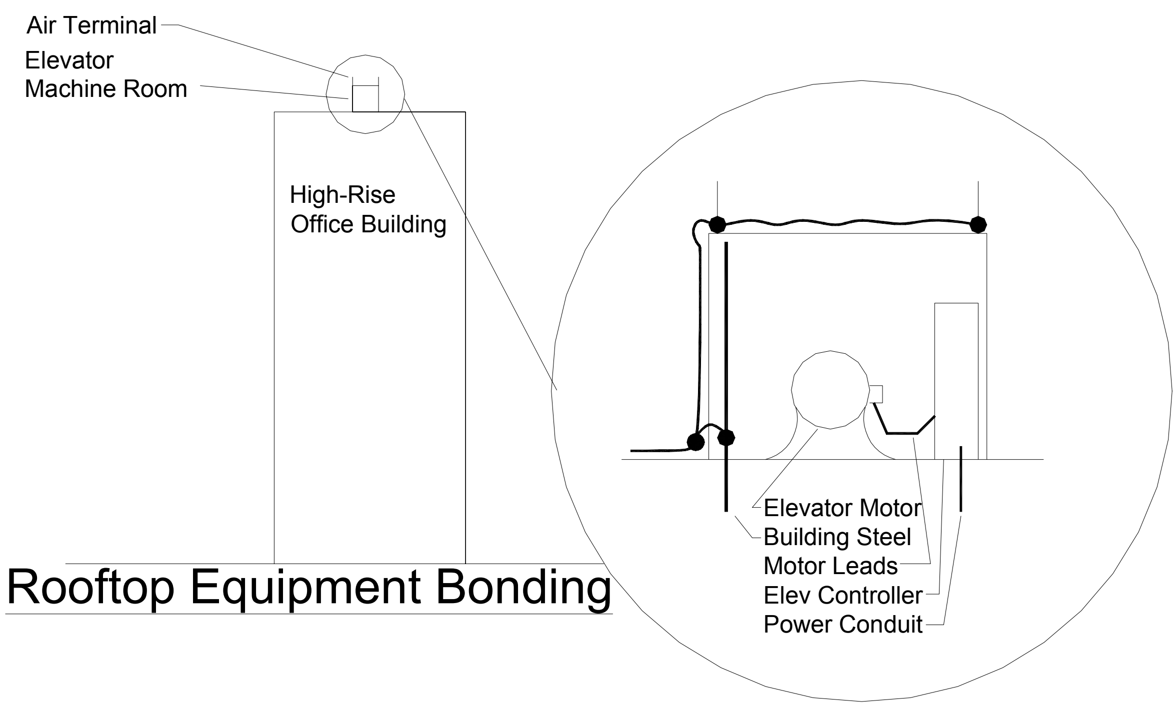
Cross-Connector - A large flat, or nearly flat roof, like an auto plant or shopping mall, is required to have intermediate air terminals every 50-ft. That is, a 50x50 grid can be moved around over the building plan to select an arrangement that includes all perimeter terminals and the additional terminals at the grid intersection points. Terminals on protruding HVAC equipment can replace some grid terminals, following the principles of the 150-ft rolling sphere.

The intermediate air terminals must be grounded by intermediate sections of main conductor, spaced at not greater than 150-ft intervals. Two paths are required for each air terminal. The intermediate sections of main conductor are of the same cross-section and are termed cross-connectors.

Equipment Bonding - DANGER! This requirement is frequently misunderstood, producing hazardous installations.

The NFPA 780 requirement is that rooftop metal equipment be bonded to the rooftop main conductor. The goal is to give the lightning current a preferred path down the heavy copper instead of following the sheet metal, refrigerant lines, power conduit or power wiring. This works. Poor main conductor joints will be identified by arcing and melting during the strike, but massive currents and voltages will not appear on the building HVAC and electric systems.

There is a National Electric Code requirement that all building systems be bonded to power ground. This is to help over current protective devices trip and avoid voltages on equipment to shock people. The hazard is in using the rooftop main conductor to bond inside equipment, as a penthouse motor control center.



In this graphic, a good lightning protection circuit is established for the air terminals, rooftop main conductor and downcomer. A separate ground system is the electric power conduit system and green equipment grounding conductor. The outside ground system carries lightning currents. The inside system carries power fault currents. A low-resistance bonding between lightning and power ground system at the rooftop is bad. It encourages massive lightning currents to follow the power ground.

The proper bonding between lightning ground and power ground at the rooftop is only the incidental common building steel. The lightning ground has an intentional bond, to avoid voltage potential. The conduit is bolted to the steel. The equipment ground is bonded to the equipment enclosure, which is bolted to the steel. Poor bonding inhibits lightning current flow through the power system.

If, however, the lightning main conductor is intentionally bonded to the elevator controller, then, the high quality connection encourages 10,000A lightning current to split between the downcomer and the equipment ground.

Please consider the following example from industrial troubleshooting. The coal processing plant for a surface mine in Indiana suffered regular plc failures in the tipple (tall structure). It had lightning rods bonded to building steel, but no downcomer. The current flow in the steel caused voltage rise at the top of the tipple. The shield on the plc remote input was a better ground, so there was great voltage between lightning ground and signal ground. Installation of a NFPA 780 downcomer eliminated the voltage between top ground and bottom ground. Failures of plc remote i/o ceased. Keep the grounds separate, except at the service entrance main ground connection.

Please consider the following institutional example from a reliability analysis exercise. The research campus in Ohio had several buildings, spread over many acres. (Blow-out walls were required for each laboratory, so wings were separated more than normal for such a campus.) During thunderstorm weather, RS-232 line drivers were blown out on personal computers and communications racks of the campus data communications system. RS-232 operates at nominal +5, -12VDC (though often +5,0). The standard 1488 and 1489 line driver were rated to 35 V. High-withstand chips were available, but not selected for price competitive equipment. Besides, RS-232 is rated for only 50-ft (though being used for 1,000's of feet). Three solutions were applied: keep replacing the drivers (large pc repair group), install data multiplexers with high-withstand drivers, and convert to EtherNet.

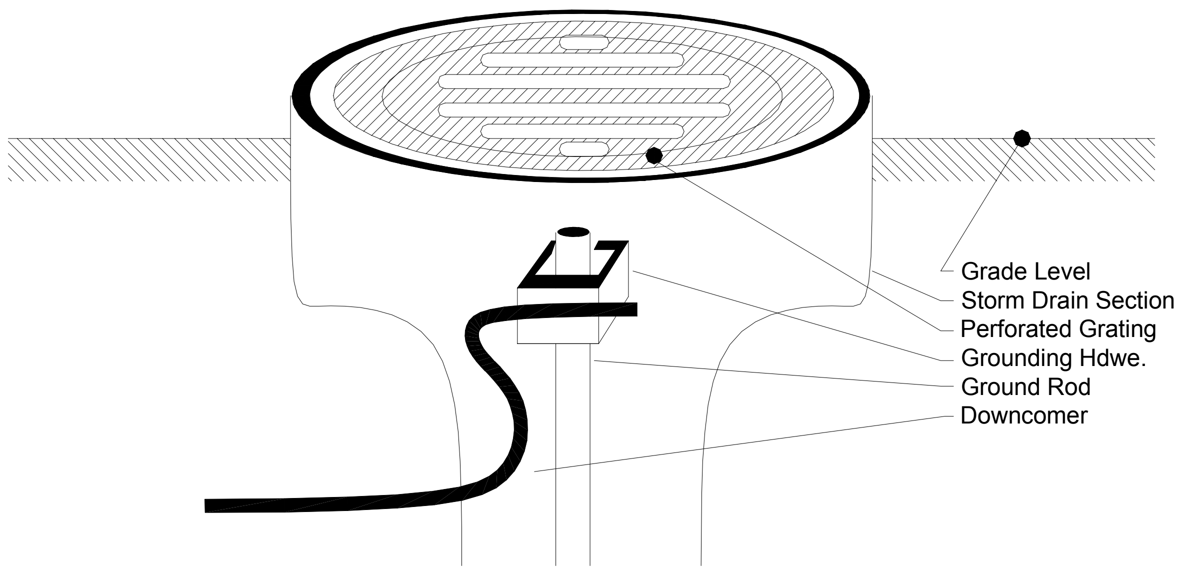
Please consider the following institutional example from an HVAC maintenance department. A large state university in Ohio covered many urban blocks. Each building had separate HVAC equipment, fed from a central steam/chiller plant, through tunnels. When building automation was invented, individual time clocks on the big fans were replaced with a personal computer and a proprietary data communications network with copper conductors through the tunnels. Every time a cloud went over, buildings would start dropping off the HVAC automation system. As with RS-232, the line drivers on the data channels failed, but the data cables were also damaged. The solution was upgrade to a proprietary fiber optic data backbone.

Note that no direct strikes were required for damage to take place. When a highly charge cloud passes over, it induces an opposite charge buildup in the earth below. The local building ground, bonded to the electrical system and the remote HVAC control chassis can easily reach 100VDC above the local building ground and personal computer at the control head-end. 100VDC drives a lot of current through the cable shield. Also, a nearby strike causes a sudden drop in the induced ground voltage. The dv/dt causes driver and cable failures.

Downcomer - An extension of the main conductor, in a wide bend over the eaves, down to grade level and out to a ground rod is the downcomer. It is good design to bond the downcomer to building steel. It is bad design, but permitted, to bond at the top of the steel, bond to the bottom of the steel, and eliminate the downcomer copper. It is much cheaper and more aesthetic. Note the requirement for wide bends. Lightning is a high rise-time pulse. If you make sharp 90-degree bends, the lightning jumps off the end of the wire and back on several inches down. Really. Look at installations in your neighborhood. Look for scorch marks on the siding where the installer thought good workmanship meant tight 90's. Lightning through air creates those temperatures of the surface of the sun. Older downcomer installations used stand-offs for the conductor, for the same reason. Modern installations are tight to the building, but scorch marks have not been noted at downcomers.

The downcomer must be physically protected between grade and 6-ft above grade (rarely observed in field). See photograph below:

Ground Rod (Earth Terminal) - Conventional wisdom is that every downcomer should have a dedicated ground rod to dissipate the lightning discharge. This is pretty much required by NFPA 780 and is good design practice. The ground rod must be min ½-in dia and have 10-ft in contact with earth. This means a 10-ft ground rod, buried to the top. Note, a 10-ft rod with the top exposed for downcomer connections is non-compliant as is a “ground well” with the top exposed for downcomer connection and testing.



Test Well Detail

Present thinking and test data from power ground systems suggest severe limits to the ground rod. Many power grounding specifications today call for three rods, with minimum 10-ft spacing, to provide better earth contact and lower ground resistance. Best practice is a ground loop, as illustrated in the Course Introduction. Reasoning is as follows:

1) A lightning discharge boils out the moisture at a ground rod, radically increasing the ground resistance and voltage rise.

2) A single ground-rod often does not meet numerical ground resistance targets, but they are not enforced through NFPA requirement, specification or acceptance testing.

3) A ground loop is equivalent to a ground rod when 20-ft of bare copper are in contact with soil. A typical ground loop of 200+ ft is a very good earth connection.

4) If a measured good earth connection is required in high-resistance soil, then ground rods with conductive salt release are available or the conductive salts can be spread in the trench with the ground loop installation. Obviously, more surface contact applies to treated-soil ground loop the same way it does to treated-soil ground rod. [Erico, in the Links Section, has excellent discussion of conductive salts.]

The introduction to Ground Rods indicated that they are “pretty much” required by NFPA 780. In fact, the words are, “A ground rod shall terminate each downcomer.” However, the illustrations for earth connections show both ground rods and a ground loop with “optional ground rods”. The descriptive language recognizes the ground loop as acceptable for grounding. This apparent contradiction will be clarified in the next issue of the Standard.

Ground Loop - The ground loop is required to be the size of the rooftop main conductor.

Building Bonding - Please review the previous section on rooftop equipment ground. NFPA 780 requires that electric service, telephone service, antenna system, underground metallic piping, including water service, well casings within 25-ft of the building, gas piping, underground conduits, underground liquefied petroleum gas piping and more - be bonded to the lightning protection system by main conductor size copper. This requirement, also, is rarely seen in the field. See also the electric power system bonding section which follows.

Electric Power System Bonding - For unknown reasons, the installation of electric power systems has recently become an area of interest for Plans Examiners, Building Inspectors and Construction Managers. For a long time, the designs have complied with the Codes, especially “boiler plate” standard details and “canned” specifications. They had been almost universally ignored in the field, however.

Today, bonding the ground connection of the electric power service entrance to incoming utilities, building steel, metal roofs and the lightning protection system is commonly done. #6 AWG is commonly used, though, 4/0 AWG is sometimes specified. These are adequate for personnel protection and electric power system protection. 4/0 is adequate for lightning protection.

The architecture of the electric power system ground system is carefully defined by NFPA 70, the National Electric Code, to meet personnel safety, fire protection, and data communications integrity. Study this Code when questions arise. These are not lightning protection questions.

Utilities Bonding - As indicated previously, all incoming utilities must be bonded to the lightning protection system. Until recently, the natural gas utility fought this requirement, the telephone utility fought this requirement and the water utility wasn’t happy with it. Nobody wants 100,000A imposed upon its components. Installation of the ground loop quiets these fears. The goal is to create a common ground level on all components and try to achieve surrounding earth as the reference.

Utility Protector - The Technology Contractor or supplying data, CATV or telephone utility must be convinced to install lightning protective devices on the incoming data, CATV and telephone lines. The devices are rare in the field and may require special order from a technology supply house. They are not available to a lightning protection contractor or electrical contractor.

Is it worth the trouble? Yes. A lightning protection installation which complies with NFPA 780 has them. The local Authority Having Jurisdiction does not have authority to give a variance. He can only approve additional types.

Additionally, the cost is low, ~$100. It is aggravation to get suppliers to follow specifications and the Codes, but it is the way to get compliance into normal practice and get the suppliers to carry the required components.

Transient Voltage Surge Suppressor (TVSS) - Transient voltage surge suppressors are very simple 10-cent over-voltage control devices. A set costs $10,000 when fuses, a computer, lights and a box are added. Satisfactory, UL-labeled service entrance TVSS devices are available for less than $1,000. Higher priced units carry a much higher quality sales pitch and may last longer.

UL Master System Label - The lightning protection industry has grown for two hundred years without regulation. The UL Master System label is as close as we have to a standard and inspection system.

The UL label does not mean that the installation has been inspected and accepted by UL. It means that the installer has attended UL training and UL has randomly inspected his work and approved it. The acceptance walk-through is the best, perhaps only protection for the Owner.

UL 96 Components - Lightning protection hardware and components which carry the UL 96 label have been manufactured to minimum quality standards. It is an easily enforceable requirement which helps eliminate short-life components. Always be careful with metal compatibility. Aluminum has been used successfully in lightning protection systems and components are available with UL 96 labels, but they still corrode rapidly when in contact with alkaline earth or concrete.

Inspection of Lightning Protection Systems - There is no enforcement of inspection of lightning protection systems, as there is for fire protection systems. Visual inspection annually is recommended. The visual inspection should include an informal pull-out test to confirm the adequacy of connections, poking around vegetation and corrosion to see if the connection is still intact, wrench tighten all clamps and splicers and inspection of all protectors and TVSS (which usually have a "failed" indicator). NFPA 780 recommends annual verification of ground integrity. The 3-point method is extremely time consuming and the non-invasive instrument costs $1500. Ground tests are rarely performed. Visual inspection is rarely performed. (When roofs are replaced, ~every 20 years, the roofing contractor rips off all air terminals and cross conductors. It is not in his contract to replace them. Someone discovers the scrap value of copper and bronze laying loose up there. The lightning protection system is gone! With only a few anchor locations remaining to be identified.)

Sample Specification for Lightning Protection System

SECTION 13100

LIGHTNING PROTECTION

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Air terminals and interconnecting conductors.

B. Grounding and bonding for lightning protection.

1.02 REFERENCES

A. NFPA 780 - Standard for the Installation of Lightning Protection Systems; National Fire Protection Association; 2000.

B. UL 96 - Lightning Protection Components; Underwriters Laboratories Inc.; 1994.

C. UL 96A - Installation Requirements for Lightning Protection Systems; Underwriters Laboratories Inc.; 2001.

1.03 SYSTEM DESCRIPTION

A. Lightning Protection System: Conductor system protecting _________________ consisting of air terminals on roofs; bonding of structure and other metal objects; grounding electrodes; and interconnecting conductors.

1.04 SUBMITTALS

A. See Section 01300 - Administrative Requirements, for submittal procedures.

B. Shop Drawings: Indicate layout of air terminals, grounding electrodes, and bonding connections to structure and other metal objects. Include terminal, electrode, and conductor sizes, and connection and termination details.

C. Product Data: Provide dimensions and materials of each component, and include indication of testing agency listing.

D. Project Record Documents: Record actual locations of air terminals, grounding electrodes, bonding connections, and routing of system conductors in project record documents.

1.05 QUALITY ASSURANCE

A. Perform Work in accordance with NFPA 780 and UL 96A and provide UL Master Label.

B. Maintain one copy of each document on site.

C. Products: Furnish products listed and classified by testing agency acceptable to authority having jurisdiction as complying with UL 96.

D. Manufacturer Qualifications: Company specializing in lightning protection equipment with minimum three years documented experience.

E. Installer Qualifications: Authorized installer of manufacturer with minimum three years documented experience.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Lightning Protection:
   1. _________ (fill in).
   2. _________ (fill in).
   3. _________ (fill in).
   4. Substitutions: See Section 01600 - Product Requirements.

2.02 COMPONENTS

A. Air Terminals: Copper, solid, with adhesive bases for single-ply roof installations.

B. Air Terminal for Chimney: Lead-coated copper.

C. Conductors: Copper cable.

D. Connectors and Splicers: Bronze.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify that field measurements are as indicated on shop drawings.

B. Coordinate work with roofing and exterior and interior finish installations.

3.02 INSTALLATION

A. Submit written approval by the carrier of the current roof warranty that the proposed lightning protection installation will not void the warranty.

B. Install in accordance with NFPA 780 and UL 96A.

C. Connect above ground conductors using mechanical connectors. Protect adjacent construction elements and finishes from damage. Connect below ground conductors using exothermic welding.

D. Bond exterior metal bodies on building to lightning protection system and provide intermediate level interconnection loops 60 feet (18 m) on center.

3.03 FIELD QUALITY CONTROL

A. Perform field inspection in accordance with Section 01400.

B. Obtain the services of Underwriters Laboratories, Inc. to provide inspection and master system labeling of the lightning protection system.

[eof]