LightningMaster®
Corporation

LightningMaster Corporation

1770 Calumet Street – Clearwater, FL 33765 – 1.800.749.6800 – www.lightningmaster.com

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Lightning Master is a full service, full spectrum static solutions and lightning and transient protection company, **serving the oil and gas and chemical industries since 1984**. Our complete line of products and systems is backed by our worldwide support and customer service. Lightning Master has become recognized internationally as the industry leader in lightning and static protection.

Serving North America from Canada's Oil Sands to the Eagle Ford in Texas, Lightning Master Corporation can provide top notch customer support across the continent. With joint ventures in Asia and Singapore, and a presence in Africa and the Middle East, Lightning Master Corporation is the worldwide authority on static and lightning protection.

Lightning Master principals actively participate in furthering the industry through principal membership on national code writing committees including:

- National Fire Protection NFPA 780, Committee on Lightning Protection
- National Fire Protection Association NFPA 781, Committee on Lightning Protection using Early Streamer Emitting Air Terminals
- IEEE 1576, Working Group, Standard for Lightning Protection Using Charge Transfer System
- American Petroleum Institute API 545, Working Group, Standard for Lightning Protection for Hydrocarbon Storage Tanks

Unparalleled Customer Service - We're with you every step of the way

Site survey and evaluation

- Our experienced field engineers create detailed report of the safety requirements of your site
- Elite team of experienced engineers who perform forensic analysis of lightning and static damage

System design

- We custom-tailor protection strategies that meet your site-specific needs
- We've worked in conjunction with the top companies in the industry to write specifications that meet and exceed industry standards

Products

- Bonding and Grounding
- Transient Voltage Surge Suppression
- Structural Lightning Protection
- Streamer Delaying technologies
- LMC In-Tank Static Dissipaters – patent pending

Installation

- We offer turn-key installation by Lightning Master-employed crews
- Training, supervision, and ongoing support of Customer personnel or contractors
- Lightning Master approved installation contractors (in selected areas)

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The White Papers - Introduction

Creating a Safe Environment for Your Critical Equipment

In today's world, we use microprocessor based equipment to help make our operations faster and more efficient. It is difficult to find a toaster, let alone a sophisticated control system, that is not microprocessor based. This technology has revolutionized the way the world does business, allowing us to handle information at an ever accelerating rate.

However, with the advent of micro-processors, it has become apparent that the same environment which was adequate for equipment based on older technology, (take, for example, vacuum tubes), may not be adequate to allow new technologies to operate at their maximum reliability.

The newer technologies are much more susceptible to damage from all types of transients. Electronic equipment is susceptible to transients all the time, which can cause damage ranging from catastrophic failure to minor damage which eventually accumulates to the point of unreliable or random operation or ultimate failure. And, as devices operate faster, the problems become worse. It is not possible to make electricity travel faster. So, in order to make a device operate faster, the distances which the electricity must travel is reduced. As the distances and clearances are reduced, arc-over voltages become lower, exacerbating vulnerability to damage from transients.

When developing a system, the primary objective is to make it work to further its specific goals. You do not necessarily consider the environment in which it will operate.

At Lightning Master, we approach the situation differently. We are not specifically concerned with what your equipment does; whether it operates a cell site, wastewater treatment plant, nuclear reactor or petroleum refinery. We are specifically concerned with the environment in which it operates.

We optimize that environment to enhance the reliability and longevity of your equipment. It makes little sense to buy state-of-the-art equipment for your business or operation and install it in an environment where it will be subject to transients which may damage the equipment, cause data problems and shorten its useful life.

The Lightning Master approach:

To that end, Lightning Master Corporation has developed a systems approach to help you solve your equipment reliability problems by creating safe environment in which it may function. We offer services and equipment ranging from that needed to address a specific problem to turn-key optimization. Lightning Master will:

- survey and analyze your existing environment
- provide a written report of findings and recommendations
- design your protection system
- write your specification
- manufacture and supply all required parts and equipment
- provide turnkey system installation or supervise installation by others
- provide continuing customer upgrade and warranty support

We provide protection in the highest lightning incidence areas of the US and other parts of the world where securing maximum personnel safety, reducing downtime, increasing reliability and optimizing equipment utilization through maximum availability is of critical concern.

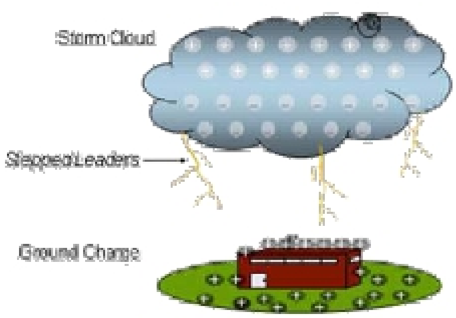
The Lightning Phenomenon

As an electrical storm builds, various mechanisms create a stratified charge within the storm cloud, with an electrical charge at the base of the cloud. Since we are mostly concerned with cloud-to-ground lightning, we are concerned primarily with the charge on the base on the storm, as that charge induces a "shadow" of opposite charge on the surface of the earth beneath it.

As the storm charge builds, so does the cloud base charge. Since like charges repel, and opposite charges attract, the cloud base charge induces an opposite charge on the surface of the earth beneath it - it pushes away the same charge and pulls in the opposite charge. The cloud base charge attracts, or pulls, on the ground charge, trying to pull it off the surface of the earth. It is this tendency for the storm base charge and the ground charge to equalize through the intervening air which causes cloud-to-ground lightning.

As the storm cloud travels over the earth's surface, it drags this ground charge along beneath it. When the ground charge reaches your facility, the storm cloud charge pulls it up on, and begins concentrating ground potential on your facility. If, before the storm cloud travels away, it manages to concentrate enough ground potential on your facility so that the difference in potential between the storm cloud base charge and the charge on your facility exceeds the dielectric strength, or resistance, of the intervening air, the air breaks down electrically, and a potential equalizing arc occurs; a lightning strike.

Since we are concerned with lightning strikes to objects and structures on the surface of the earth, and some 95% of all ground strikes are negative cloud-to ground lightning, for the purpose of this discussion we will describe negative cloud-to-ground lightning.



When the intervening air breaks down, the strike itself begins with the propagation of stepped leaders. Stepped leaders originate within the cloud charge, and extend in jumps of a hundred and fifty feet or so at a time towards the surface of the earth. These are the wispy, downward reaching branches of light you see in a photograph of a strike.

We see a lightning strike in two dimensions. Actually, the area of stepped leaders also has depth, so there is a field of stepped leaders working their way down toward the surface. When the stepped leaders reach to within about five hundred feet of the surface, the attraction between the stepped leader charge and the ground charge becomes so strong that objects on the surface of the earth begin to respond by releasing streamers of ground charge upward toward the stepped leaders. Streamers form off of various objects on the surface: utility poles, fence posts, antennas, building edges, etc.

When a streamer and a stepped leader meet, the ionized channel becomes the path for the main lightning discharge. The other stepped leaders and streamers never mature. Occasionally, two or more will meet simultaneously, and forked or branched lightning will occur.

Once the ionized path is completed, the current discharge occurs. Although a lightning strike appears to be a single flash, it is actually a series of flashes. Lightning flashes on for approximately one one-thousandth of a second then shuts off for about two one-hundredths of a second, flashes on for one one-thousandth of a second then shuts off for about two one- hundredths of a second, repeating the process multiple times. When the potential difference is no longer sufficient to continue the discharge, the lightning strike ends.

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Lightning Damage

There are four basic types of lightning damage: physical damage, secondary effect damage, electromagnetic effect damage, and damage caused by changes in ground reference potential.

Physical damage is caused by current flow and heat. A typical lightning strike in the United States conveys between 25,000 and 45,000 amps, with the higher amperage strikes occurring in the south, where the storms build higher. Lightning is high current flowing over a short period of time.

The core temperature of a lightning channel is approximately 50,000 degrees Fahrenheit, or about five times the surface temperature of the sun. During a strike, the temperature rises from the ambient temperature to a temperature approaching 50,000 degrees over a very short rise time. It is this heat which causes the sap in a tree struck by lightning to turn to steam and expand, splitting the tree. Concrete never quite dries out; there is always latent moisture in concrete. When a concrete structure is struck, the latent moisture turns to steam, expanding and damaging the concrete structure. When the air surrounding the lightning channel is heated this rapidly, it expands in a shock wave. This shock wave can damage a structure. This is why lightning rods have a minimum length – to top lift this shock wave off the roof of the protected structure.

The ***secondary effect*** of a lightning strike can cause arcing and induced currents. During a lightning strike, the point at which the strike occurs is relatively vacated of ground charge. The area surrounding the point of the strike remains highly charged, causing an almost instantaneous potential gradient across the area. The surrounding area releases its charge to the point at which the strike occurred, causing a flow of current. This current flow can arc across any gaps in its path. If that arc takes place within a flammable material, it can cause a fire or explosion. If the arc takes place within a bearing, such as in a pump in a treatment plant, it can scar the bearing and cause premature wear. If it takes place on a circuit board, it can damage the circuit board.

The ***electromagnetic field effect*** is similar to nuclear blast EMP, and can induce currents in nearby wires or other conductors. The on-off-on-off action of a lightning strike causes the electromagnetic field surrounding the strike to expand and collapse with the series of flashes. This electromagnetic field motion can induce electrical currents in nearby conductors, including wires and electrical equipment.

Older vacuum tube equipment is operated on relatively high voltages. Therefore, the vacuum tube was able to absorb a much higher voltage surge without damage. When a vacuum tube which operates on a few hundred volts sees a one hundred volt surge, it is no big deal. When a microprocessor which operates on only a few volts sees a one hundred volt surge, it is a big deal. The current induced by electromagnetic effect can easily be sufficient to cause damage. In fact, microprocessors can be damaged by a nearby strike even if they are not in use or even connected to a power source.

This effect explains why lightning may strike a few hundred feet away from a structure and the telephone system in the structure stops working. Why? Obviously, the lightning energy did not enter the structure. The electromagnetic pulse from the strike induced current into the telephone wiring, both into and within the building, damaging a microprocessor within the system and causing a system failure.

When the ***ground reference potential changes*** across a site, it can cause current flow through grounding systems. Assume that the AC power service enters a structure at one location and is grounded at that location. The telephone service enters the same structure and is grounded at a different location. Both feed into a computer. The AC power service ground establishes the potential of the motherboard, and the telephone service ground establishes the potential of the modem board. Current divides and takes all paths - the amount of current flowing over any one path is proportionate to the surge impedance of that part vis-à-vis the surge impedance of all paths. If lightning strikes near the structure closer to one service ground than the other, there will be a difference in potential between the two grounds. This difference in potential will produce current flow. Most of the current will flow through the ground under the structure (the lower impedance path). However, some current will flow from one service ground, through the modem and computer, to the other service ground. This current flow can damage the computer.

Lightning Protection: A Three Pronged Attack

Integrated Three-Step System:

Based upon our experience, we have developed an integrated systems-approach to environment optimization which may be tailored to any type of facility or operation. The Lightning Master approach consists of three steps:

- **Bonding and Grounding**
- **Transient Voltage Surge Suppression**
- **Structural Lightning Protection**

As you read through the various sections, you will notice that it is based upon the three step program. To implement our solutions-based approach, Lightning Master personnel will conduct a survey of your facility, provide you with a written report of our findings, design and recommend the optimum system solution, and, should you prefer the turnkey approach, provide and install the system we recommend.

We can also help you write specifications to assure effective and uniform practices at and between your facilities. Whatever you need, we can provide in a prompt, cost-effective package.

After you read through our information, please call us with your specific questions regarding our approach and how we would apply it to your type of application. We will be happy to discuss any aspect of our program, and, if you would like, meet with you at your convenience for an in-person presentation.

Bonding & Grounding

Bonding is simply a matter of taking all of the electrical and metallic masses in a facility and connecting them with conductors, bringing them to the same electrical potential. The primary reason for bonding is personnel safety, so someone touching two pieces of equipment at the same time does not receive a shock by becoming the path of equalization if the two pieces of equipment happen to be at different potentials.

For the same reason bonding protects people, it also protects equipment, by reducing current flow on power and data conductors between pieces of equipment at different potentials.

Grounding is a matter of bringing the bonded equipment mass to the potential of the surface of the earth which it occupies. Again, the primary reason is personnel safety, and the secondary reason is equipment protection. When it comes to grounding, we need to consider two types of grounding: low-impedance grounding of structures, and single-point ground potential referencing for services and equipment

Low-Impedance Structural Grounding

A structure is anything that is likely to be struck by lightning. Multiple low-impedance paths to the grounding system transfer lightning energy off of the structure and into ground as quickly as possible. Since lightning is very high frequency, low-impedance, they key to grounding is not just low-resistance, but the paths themselves. The higher the impedance the lightning energy "sees", the greater the voltage increases. The higher the voltages, the more likely the energy will arc or take unwanted paths to ground.

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Therefore, it is important to provide multiple paths with good geometry directly to grounding electrodes within the grounding system.

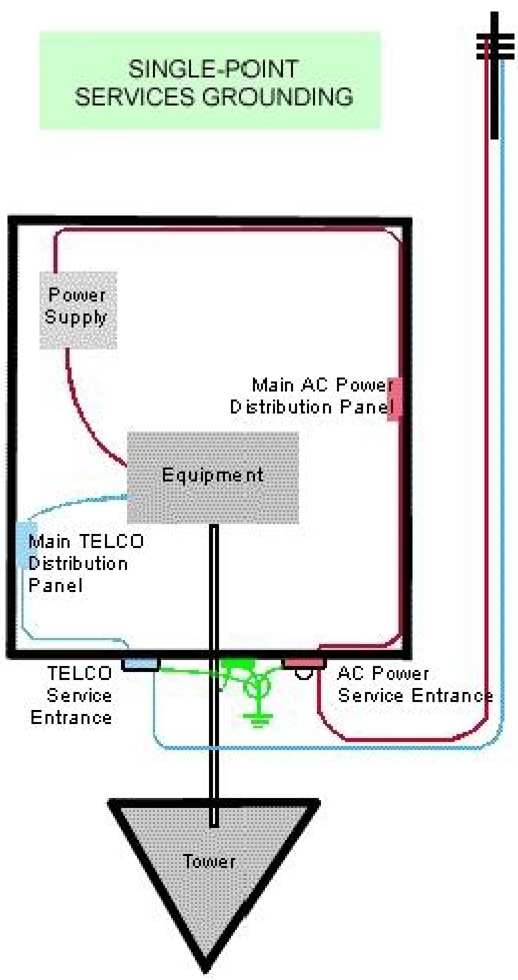
Single-Point Services And Equipment Ground Potential Referencing

Why is it that direct lightning strikes at two similar facilities can leave one undamaged and the other virtually destroyed?

Among all the variables involved in system design, we have found the single most important factor in effective lightning protection to be not simply bonding and grounding of equipment and services, but proper connection of the services and equipment bonding sub-system to the grounding system.

A change in potential per se, does not damage equipment. It is a difference in potential across your equipment causing current flow through your equipment which causes damage. If the potential of the entire system changes at the same time and rate, and the equipment does not have any other source of ground potential reference, there is no current flow and no damage occurs.

Current divides and takes all paths. The proportion of the current flowing on any one path is proportional to the surge impedance of that path relative to the total surge impedance of all paths. Even if heavy duty bonding straps are provided between grounds as the primary intended path of equalization, some of the current flow will be through unintended paths; through other conductors and equipment.

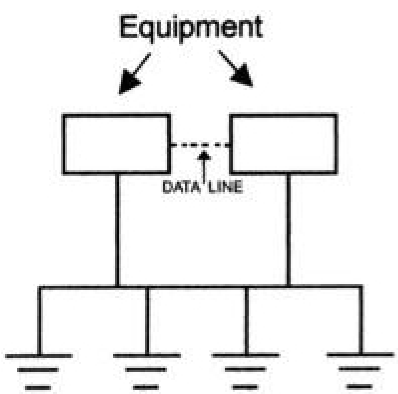


Therefore, it is critical to bring all services and equipment grounds within a facility to the same potential before they connect to the grounding system, eliminating the possibility of current flow.

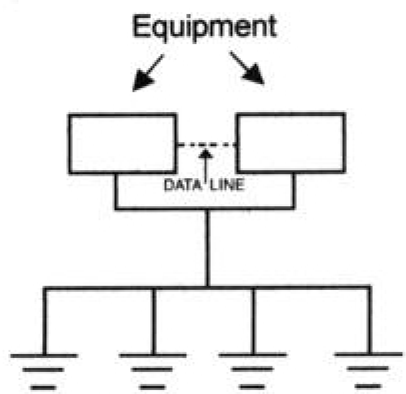
In a typical facility, we must be concerned with several different ground potentials.

The first set of ground potentials is associated with the services to the site, i.e., AC power, TELCO, data and RF transmission lines from antennae. If a piece of equipment is connected to both a data line and to a power supply, and there is a difference in ground potentials between those two service grounds, that difference in potential can equalize within the equipment, causing damage or accelerated wear.

The second set of potentials is associated with the various electrical and electronic equipment chassis grounds. If two pieces of equipment are communicating with one another through a data line, and if there is a difference in potential between the two pieces of equipment, that potential can equalize through the data lines within one or both of the pieces of equipment, (see illustration below)



Mutiple-point ground potential referencing (can cause current flow through equipment)



Single-point ground potential referencing (prevents current flow through equipment)

When we refer to the facility equipment, it is important to note that we are referring only to electrical or electronic equipment, not door frames, air conditioning ducting, miscellaneous masses of inductance, etc.

To perhaps oversimplify the concept, envision an imaginary plane at or just below the floor level of the facility. All of the site equipment and services should be appropriately bonded together above this plane, and an appropriate grounding system established below this plane. All services and equipment grounds should pass through one and only one hole through that plane. Therefore, all equipment within the site will be at the ground potential of that single-point. This concept is commonly referred to as "single point grounding", or, more accurately, "single point ground potential referencing".

Transient Voltage Surge Suppression

The energy and raw power contained in a lightning strike are truly awesome. It is easy to imagine the havoc which a direct strike to your facility can cause. However, the majority of electronics damage is not caused by direct lightning strikes, but is rather the result of transient voltage and current surges induced on power, telecommunications or RF transmission lines by the strong electromagnetic fields created during a lightning strike, and by more mundane causes such as power company switching, nearby heavy loads, traffic accidents involving utility poles, etc.

These surges can propagate for miles on metallic conductors, ending up at your facility service entrances retaining sufficient energy to damage or destroy electronic equipment. If you do not take steps to stop them, power surges can enter your facility and damage or upset your equipment. These transients were

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not so much of a problem in the days of vacuum tubes which operated on high internal voltages. However, with the introduction of microprocessors which operate on very low internal voltages, they have become a very real problem.

Every day, transients of all types are causing wear and tear on your equipment. With the move toward faster digital equipment, the problem will become more noticeable and expensive. The faster the electronic device, the more susceptible it is to transients. It is not possible to make electricity travel faster. Therefore, if you want to make a device operate faster, the distance which the electricity travels must be reduced. When you reduce the distance, the arc-over voltage becomes lower. Therefore, the device is more susceptible to a transient. So there is a need for some type of device to stop power surges before they enter your facility, and to stop internally generated transients before they are distributed to your equipment.

A transient voltage surge suppression (TVSS) device simply limits the voltage to a value slightly above the nominal operating value of the system to allow normal operations, yet below a value which will allow damage to connected equipment. Lightning Master offers a full line of transient voltage surge suppression (TVSS) equipment for all types of services designed to provide the most efficient and cost-effective protection possible.

All-Mode Protection

Here are two types of transients: common mode and transverse mode.

To illustrate, let us examine the simplest type of system, a two wire 120 volt circuit. One wire, the line wire, is nominally at 120 volts compared to the electronic device. The other wire, the neutral or return wire, is nominally at zero volts compared to the equipment. As long as the difference in voltage is 120 volts, the electronic device is happy.

However, there are two types of transients which may appear on these wires. The first type is a transient on one wire. Say the line wire suddenly momentarily jumps from 120 volts to 2,120 volts with a 2,000 volt transient. The electronic device is straddling the two wires looking for 120 volts. If it suddenly sees 2,120 volts, it may sustain damage.

The second type is a transient on both wires. With the same 2,000 volt transient, the potential, or voltage, on the line wire jumps to 2,120 volts, and the potential of the neutral wire jumps to 2,000 volts relative to the electronic device. In this case, the excess voltage may cause arcing between the electronic device and the chassis in which it is contained, which nominally remained at zero volts.

Therefore, in a two wire system, two modes, or legs, of surge suppression are required; one mode between the line and neutral wires and a second mode between the neutral wire and the equipment chassis or ground. The same principle applies to multiple wire systems; the more wires, the more modes of surge suppression required.

AC POWER

High voltage, high amperage transients may enter your facility on the AC power service. Therefore, it is important to employ a robust TVSS device at your AC power service entrance. Lightning Master offers the highest quality main panel devices to prevent transients from entering your facility from the outside. However, power company studies have revealed that the majority of the transients seen by your equipment do not come from outside your facility, but rather are generated inside your facility by motors and other loads.

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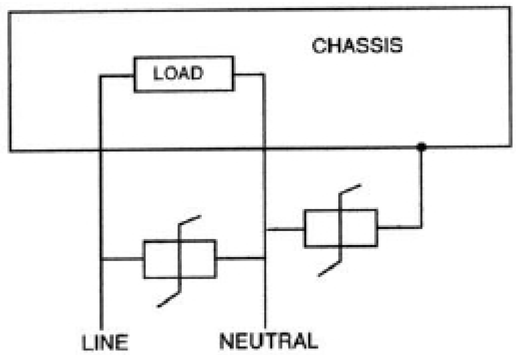
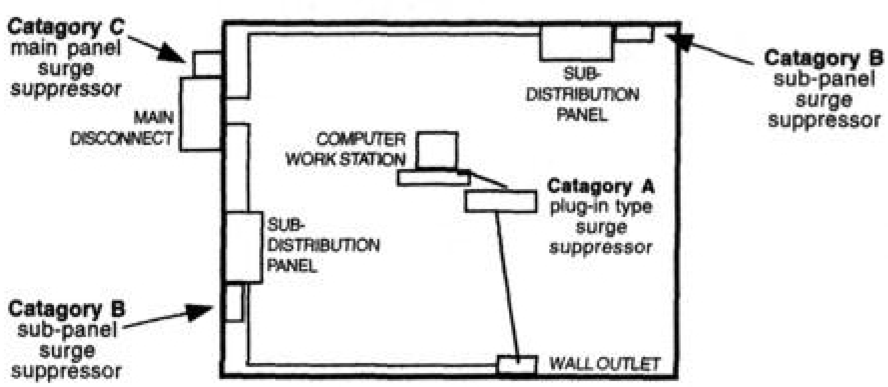


Lightning Master also offers a full line of sub-panel TVSS devices to limit the "sharing" of internally generated transients. These devices are installed on your sub-panels, so that when a transient originating on one circuit travels back to its sub distribution panel, the TVSS device limits it before it can be redistributed onto other circuits within the panel, including circuits feeding your sensitive equipment. This approach of installing multiple TVSS devices in series is called "staged protection", and is particularly effective in limiting damage from both externally and internally generated transients.

Telephone and Data

Telephone and data line transients may be high voltage, but are usually relatively low amperage, the current being ultimately limited by the wire size. However, telephone and data devices tend to be very susceptible to damage or interruptions caused by transients.

Therefore, high speed, tight clamping value TVSS devices should be employed at your telephone and data service entrances. Lightning Master offers a full line of TELCO and DATA TVSS devices for all applications, including POTS lines, T-1, and computer networks.



RF Transmission Line

Since RF transmission lines are connected to antennas which are often the highest structure in the area, they are capable of delivering high voltage, high amperage transients to your facility. Since DC power may be fed up a transmission line to power equipment near the antenna, TVSS devices for this application may have to be designed to allow DC power to pass unobstructed. Conventional devices employing internal RF coupling and gas tubes wired at a right angle to the main path through to the equipment are no longer capable of protecting modern equipment.

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State-of-the-art devices, devices in which the low impedance path leads to ground, and the higher impedance path leads to the equipment, need to be employed to secure maximum protection. Therefore, Lightning Master offers a full line of gas tube and one-quarter wavelength shunts.

Installation considerations: When planning system layout, it is important to install surge suppressors to achieve maximum performance while avoiding situations which could compromise their performance.

During installation, avoid routing unprotected and ground wires adjacent and parallel to protected wires, where transients can be inductively coupled from the unprotected and ground wires onto the protected wires downstream of the surge suppressor. This also applies to routing protected wires from one type of service, particularly a low-voltage service such as telephone or data, adjacent to the unprotected or ground conductors of another service, such as AC power or radio frequency (RF) coaxial cables. A transient on either the unprotected or ground conductors of one service may be inductively coupled onto the protected conductors of the other service. Often we will see surge suppression elements installed directly on the circuit board they are intended to protect. This is less than optimum placement, as once the transient is on the board, it is generally too late to limit its propagation across the board.

Avoid locating a surge suppressor inside a metal enclosure containing the protected equipment. When a surge suppression element reacts to a transient, it emits an electromagnetic pulse (EMP). If the surge suppressor is located within the same metallic enclosure as the protected equipment, the Faraday cage effect of that enclosure will tend to contain the emitted EMP within the enclosure where it may be inductively coupled onto conductors within the protected equipment. Therefore, the surge suppressor should be located outside the enclosure containing the protected equipment, using the Faraday cage effect to keep the EMP out of the enclosure.

Long conductors and bends in the conductors between a parallel TVSS device, such as an AC power surge suppressor, and the load it protects can dramatically affect surge suppressor performance. At a 3 kA, 8 X 20 microsecond pulse (IEEE standard pulse), each foot of conductor length can produce in an increase in clamping voltage of 150 to 200 volts. Therefore, in the case of a surge suppressor connected to a load with three feet of conductor, the inductive reactance of the conductor can increase the clamping voltage of the surge suppressor by 900 to 1200 volts (three feet in each direction between the surge suppressor and the load). Also, the travel time along the longer conductors can delay surge suppressor response time.

To address these and other problems, Lightning Master developed the services vestibule concept. As the name implies, a services vestibule is a separate enclosure through which all service conductors (AC power, telephone, data, RF, etc.) enter a site or remote equipment cabinet. Each service is grounded to a main ground bus within this vestibule. The main ground bus is grounded to an appropriate site ground, and bonded to any structural lightning protection system. A surge suppressor installed on each service conductor, and grounded to the main bus. No conductor enters the site or equipment cabinet until it has been grounded and surge suppressed in this separate, adjacent vestibule. This approach keeps all the "bad" things, such as grounding, surge suppression, and EMP, outside of the site or remote equipment cabinet. Only grounded, protected conductors are allowed inside.

Lightning Master will be pleased to assist you with your system layout to eliminate problems and to optimize surge suppressor performance.

Structural Lightning Protection

The third step in securing effective lightning protection is generally referred to as structural lightning protection. This term describes what is most readily recognized as the traditional lightning rod (air terminal) system, with its associated bonding and grounding systems.

It is important to note that the purpose of a lightning rod system is to keep the protected structure from burning down. That is why lightning rod systems are covered under National Fire Protection Association standards. That was fine back in the days of barns filled with hay and horses. Lightning would strike the

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lightning rod on the barn and be conveyed to ground. The barn would not burn down, and everyone would be happy, particularly the horses.

However, we have now taken the hay and horses out of the barn and installed computers. Lightning now strikes the structure, and the energy is conveyed to ground. The barn does not burn down, but now, none of the computers in the barn work. So everyone is not happy.

Since we cannot, with currently available technology, influence the formation of cloud charge or of stepped-leaders, if we want to influence the attachment of cloud-to-ground lightning, we must influence the formation of ground charge and of streamers. Hence, the introduction of streamer- influencing technology.

A good illustration of the general principle is found in the debate between the relative merits of a sharp lightning rod versus a blunt lightning rod. Please refer to the lightning propagation section (next) of these white papers for a review of lightning strike mechanism. Assume we have a sharp rod and a blunt rod side-by-side with the axis between them perpendicular to, and directly facing, an oncoming electrical storm. As the ground charge reaches the two rods, the potential rises on both. The sharp rod will tend to break down into corona under a relatively low potential, leaking off some of the ground potential to the atmosphere. The blunt rod will hold its charge, with ions accumulating on the blunt end.

As the ground potential builds, the corona builds around the sharp rod, while the blunt rod still tends to retain its charge. When the ground potential becomes very high, as when stepped leaders are on their way down from the cloud and there is going to be a strike in the immediate vicinity, the corona will build in density and elevation around the pointed rod. When the blunt rod finally breaks down, it breaks down catastrophically, and the accumulated charge jumps off of the blunt rod in a streamer extending well upward toward the stepped leaders.

Since the object on the ground that throws off the best streamer is the one most likely to be struck, the blunt rod is more likely to trigger a strike than is the sharp rod. Streamer-influencing technology uses this principle to influence strike termination likelihood. If you want to direct lightning to a preferred attachment point, do so with an early streamer emitting (ESE) air terminal. If you want to discourage lightning from attaching to a protected structure, use streamer-delaying air terminals. If you merely want to intercept a close proximity lightning strike, use a conventional lightning rod system. Lightning Master Corporation offers all three technologies, based upon the requirements of our Customers.

Turn the page

To read the section on lightning propagation

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Lightning Strike Completion Mechanism

Various mechanisms create a stratified charge in a storm cloud. The charge on the base of the cloud induces an opposite charge on the surface of the earth beneath it. (Remember playing with magnets as a kid? Like charges repel and opposite charges attract.) As the storm cloud builds, it increases the potential difference between the cloud base charge and the ground charge, with the cloud base charge trying to pull the ground charge off the surface of the earth.

As the charged storm cloud travels through the atmosphere, it drags its ground charge along beneath it. When the ground charge reaches a structure, the attraction of the cloud charge pulls it up onto the structure, and concentrates the ground charge on the structure. If, before it moves away, the charge on the cloud base manages to concentrate enough ground charge potential on and around the structure beneath it to overcome the dielectric of the intervening air, an arc, or lightning strike, occurs.

When the dielectric of the air is overcome and lightning is going to strike, the process begins with the formation of stepped leaders branching down from the cloud. These stepped leaders propagate in jumps of about one hundred and fifty feet. The next set of stepped leaders propagate through the first set and jump another hundred and fifty feet, and so on towards the ground. These stepped leaders are the tendril-like branches extending down from the cloud which are visible in a photograph of a lightning strike. We see a lightning strike in two dimensions, but the field of stepped leaders is three dimensional, it has depth too.

When the stepped leaders are within five hundred feet or so of the ground, the electric field intensity on the ground becomes so strong that objects and structures on the ground begin to break down electrically and respond by shooting off streamers up toward the stepped leaders. When a streamer connects with a stepped leader, the ionized path becomes the channel for the main lightning discharge. The other streamers and stepped leaders never mature.

For the purposes of this discussion, it is not critical whether the cloud base charge is positive or negative. Indeed, it can vary, and the entire process can occur in the opposite direction.

Change in streamer initiation time, is a concept describing the influence air terminals have on the formation of streamers. ΔT is the change in time, as compared to a conventional lightning rod, of the release of the streamer from a particular air terminal. ΔL is the change in length, or more importantly height, of the streamer, and is derived from ΔT. The earlier a streamer is emitted, the longer it is relatively, and the more of a head start it has over other streamers from the same area. Therefore it has a better chance of reaching the stepped leaders first, and completing the strike to the air terminal. This positive ΔT is the basis of early streamer emitting technology, technology designed to attract lightning to a preferred point. Conversely, an air terminal that delays the formation of streamers, or exhibits a negative ΔT and ΔL, is less likely to complete the strike to itself.

Streamer Influencing Technology

Early Streamer Emitting Technology

Early streamer emitting air terminals are designed to emit a streamer early in the streamer- formation phase of a lightning strike, thereby becoming the preferred lightning attachment point.

As the ground charge builds immediately before the lightning strike, the ESE air terminal accumulates ground charge. In the instant before the strike, when the stepped leaders are branching down from the cloud, the ESE terminal emits a series of pulses of ground charge, forming a streamer from itself before streamers emit from other structures. In theory, its streamer reaches the stepped leaders before competing streamers, thereby winning the competition.

Ground charge accumulation and streamer triggering may be either by air terminal geometry (shape) alone, or by electronic triggering in an electronically activated streamer emitting (EASE) air terminal. Lightning Master offers electronically activated ESE air terminals. Lightning Master ESE air terminals combine a US manufactured UL Listed air terminal with a triggering device designed by Laboratories de Physique des Gaz at des Plasmas, the French national laboratories.

STREAMER-DELAYING TECHNOLOGY

Lightning Master brand Streamer Delaying structural lightning protection technology is essentially an outgrowth of, and an improvement upon, conventional lightning protection technology. It employs the basic conventional system with modified air terminals which are designed to reduce the incidence of direct strikes to the protected structure. All of the components used in this type of system are UL Listed, and the system is designed to meet UL 96A and NFPA 780. As such, the completed system is eligible for a UL Master Label or Letter of Findings.

With the advent of microprocessors, it has become necessary to reduce the incidence of lightning strikes to protected facilities.

Lightning Master streamer-delaying technology secures the desired result by reducing the accumulation of static charge, and by retarding the formation of lightning-completing streamers from the protected structure.

This technology is not new. Patents covering the technology go back as far as 1839, with most progress on the subject reflected in patents issued in the late 1920's and early 1930's. The patents referenced in Lightning Master's patent on the PP series products are those on aircraft static wicks. Static wicks are an option available with an aircraft's avionics (radio) package, and have been in general use for many years.

Next time you board an airplane, look at the trailing edges of the wing and tail, and observe this technology in its aviation application. In its structural lightning protection application, it works as follows.

The operation of a Lightning Master ¨ brand Streamer-Retarding technology is based upon the point-discharge principal. The principal, as illustrated in this formula, holds that the smaller the radius of a dissipating element, the greater the electric field intensity.

Point-Discharge Formula

The relationship is not direct, but an inverse square relationship. If one point is half the radius of another, the electric field intensity is not just doubled, but quadrupled. That is why Lightning Master employs the smallest radius dissipating elements feasible. Point radius is the most important factor in product performance.

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$$\mathcal{E} = \frac{Q}{4\pi \epsilon r^2} \qquad D = \frac{Q}{4\pi \epsilon r^2}$$

where:

$\mathcal{E} = electric\ field\ intensity$

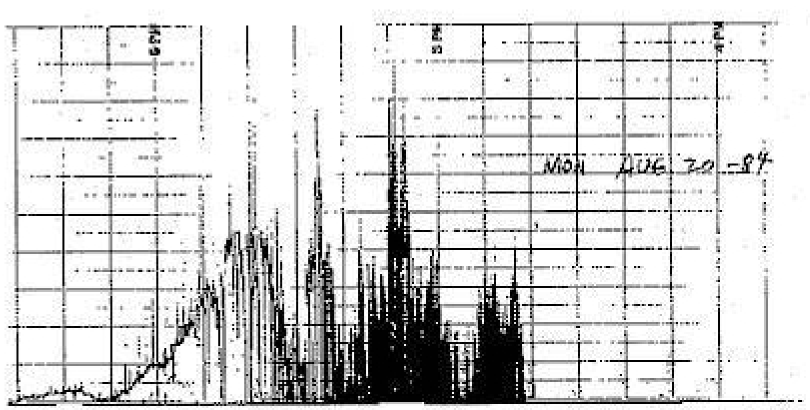
$Q = charge\ (in\ coulombs)$

$\epsilon = permittivity\ of\ space$

$r = radius$

Since charge accumulates, on and streamers tend to form from, a structure predictably - according to the principles of point discharge, a structure properly blanketed by air terminals designed to delay the formation of streamers is thus protected, since streamers tend not to form from that structure.

This graph shows the current flow through a Lightning Master LS series dissipater installed on the WTOC-TV 425' self-supporting STL tower in Savannah, Georgia. The dissipater was isolated from the tower with insulators, and a twelve gauge copper wire run from the dissipater, through a 500 ohm resistor, to ground at the base of the tower. This graph, generated on August 20, 1984, shows time from 4 PM to 6 PM, right to left along the horizontal axis, and current on a fifty microamp scale on the vertical axis.

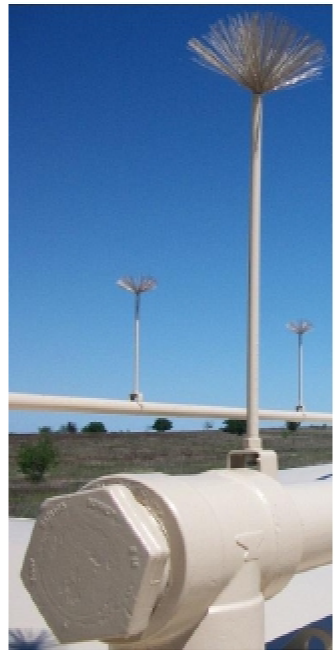


All objects have natural dissipation points. On a structure, charge tends to gather at, and streamers form from, the top of the structure (the ultimate point) and from edges and corners. The most effective way to mount a streamer delaying system, in terms of structure, weight, wind loading, cost and aesthetics, is to enhance this natural tendency by supporting the system from the structure itself at these natural charge accumulation points. In other words, the installation of the system should be tailored to the structure, not vice versa. How does a system enhance natural charge accumulation and dissipation? Keep in mind the nature of the static ground charge. Perhaps it is an oversimplification, but one way to envision system design is to imagine taking the structure, inverting it, and dipping it into syrup. When the inverted structure is raised from the syrup, the points from which the syrup drips will be analogous the charge accumulation and streamer formation points. These are the points at which the streamer delaying components should be mounted.

Streamer Delaying Air Terminals

Lightning Master uses NFPA 780 and UL 96A as its design and installation standard. Lightning Master products are designed for ease of installation. A variety of factory designed and supplied installation systems make it possible to easily tailor the Streamer Delaying system directly to the protected structure. Lightning Master designers will be happy to tailor a system design to your structure.

On a building or other structure normally protected by lightning rods and the associated bonding and grounding system, existing industry accepted lightning rod system design provides an adequate and proven method and arrangement for mounting Lightning Master ® brand Streamer Delaying air terminals. One may enhance a conventional system by installing dissipaters in place of the conventional air terminals. Lightning Master PP-30 series products are Underwriters Laboratories listed air terminals, additionally offering streamer delaying properties.



Now a user can enjoy both the benefits of a "Master Label" and insurance carrier requirements, and the benefits of a system.

Installing a Streamer Retarding lightning protection system upon one structure does not make another nearby object or structure more likely to be struck by lightning. Since a static dissipation system functions by delaying the formation of streamers from one structure, it has no effect on the formation of streamers from any other structure.

How well do the technologies really work? We sometimes hear comments from the pseudoscientific community that streamer-influencing technology does not work. However, remember what we are trying to do. We are not attempting to stop or redirect all lightning. We are only trying to influence the likelihood of a direct lightning strike to one relatively small geographical area on the surface of the earth. Therefore, we do not have to influence charge accumulation and streamer formation entirely. We only have to influence the behavior of the ground charge a very small percentage to affect streamer formation a fraction of a second from that specific point, so a competing streamer will be, or will not be, the first to complete the strike.

Hybrid Systems

An understanding of streamer influencing technology opens the door to many possibilities, including hybrid systems. Several years ago, Lightning Master was asked to design a lightning protection system for the new Advanced Launch System (ALS) at Cape Canaveral. There were several design constraints which made the use of a conventional system or a static dissipating system impractical. One of the options we suggested was a perimeter of early streamer emitting air terminals surrounding the complex to lower the overall ground charge making it onto the site by triggering strikes to the perimeter protection. This was to be complimented by a matrix of Lightning Master Streamer Delaying air terminals inside the perimeter to retard the lightning process in the protected site area itself. Working in conjunction, the two systems offered the possibility of a practical and effective solution, without compromising the ALS system design limitations. This approach highlights that one type of system is not necessarily better than another. Each has its applications, and there are applications which are best served by a combination, or hybrid, approach.

Lightning Protection - Conclusion

Structural lightning protection is the third leg of the three-part tripod of effective transient protection. By influencing the incidence of direct lightning strikes to the protected structure, you can reduce the incidence of stress on the bonding and grounding system and on the transient voltage surge suppression system. By doing so, by employing all three sub-systems in a complementary overall system, you can secure the maximum in personnel safety and optimize the environment in which your equipment operates.

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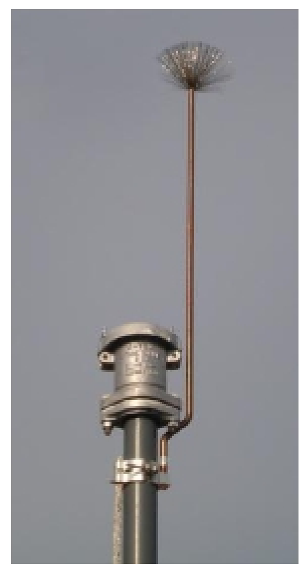
Streamer Delaying Products

Streamer Delaying Air Terminal

Multipurpose spot dissipator - Lightning Master straight air terminals can be mounted wherever traditional lightning rods would be mounted. Made in stainless steel, copper, aluminum, or tinned copper for site specific customization, and can be attached to any Lightning Master base. Lengths vary based on site and application. For a description of how these terminals reduce the incidences of lightning, please see the Streamer Influencing Technology section of the White Papers on page 14.



Enardo Valve (off-set) Streamer Delaying Air Terminal

Lightning Master Inardo Valve solutions are oriented to provide clearance when valve opens during operation. This 36” spot dissipator installs on an Enardo Valve riser pipe. FRP pipes requires a down conductor cable (shown in photo), attached to the pipe at 3’ intervals, and grounded at the base. Steel pipes do not require a down conductor cable.

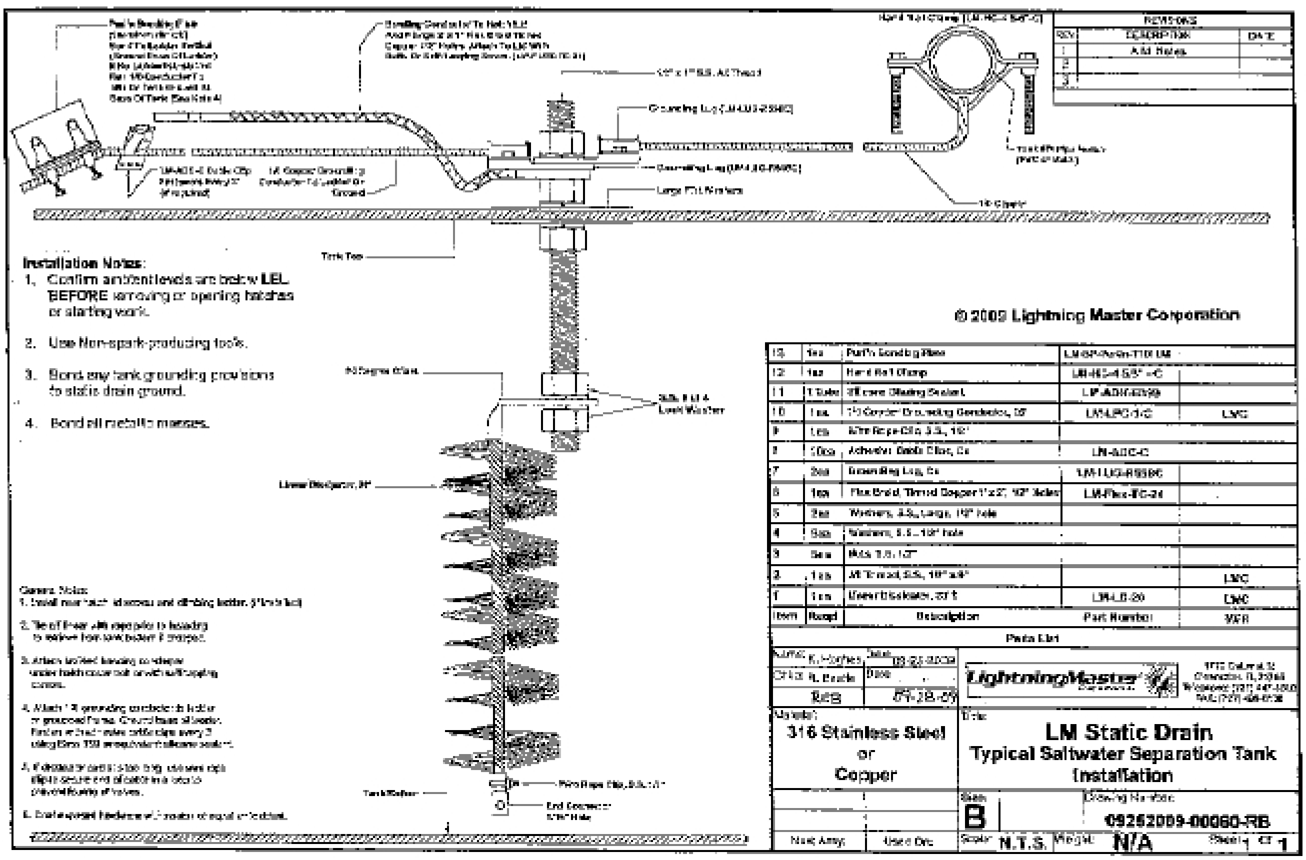
Candelabra Air Terminal

For use in place of standard air terminals in a structural lightning protection system installed to UL-96A and NFPA 780 specifications. Standard Elevation conductor: 5/8”x18”, ½” thread (unless otherwise specified).

Lightning Master Static Solutions

In-Tank Static Drain

Lightning Master offers a complete static and lightning protection system for steel and fiberglass storage and process tanks. The system addresses dissipation of static and bound charge (potential) on the stored product, direct lightning attachment to the tank or tank battery, and bonding of all masses of inductance on the tank and battery.   In the sections that follow there is a comparison of methods and systems, demonstrating the need for static solution technology, and an article explaining the detail and methodology of Lightning Master static solutions. The article was coauthored by Bruce Kaiser, President of Lightning Master Corporation, and Alan Roachell, of Rosewood Resources, and was published in Tank Storage Magazine, January 2012.



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Comparison of Methods and Systems

Static and Lightning Protection for Storage and Process Tanks

Lightning Master offers a complete static and lightning protection system for steel and fiberglass tanks. They system addresses dissipation of static and bound charge (potential) on the stored product, direct lightning attachment to the tank or tank battery, and bonding of all masses of inductance on the tank and battery. Alternatice solutions offered do not address all three problems, and offer partial solutions of only limited effectiveness. Below is a discussion of the alternatives available, their design intent, and performance limitations, and a summary of the advantages of the Lightning Master system and philosophy.

Carbon Veil is a conductive strip woven into a fiberglass tank with a grounding lug provided near the base of the tank. The intent is to dissipate static charge from the stored product onto the strip.The drawback of this system is that it presents a flat surface to the stored product. Charge more readily dissipates off of small radius electrodes than off of flat surfaces – this limits the effectiveness of the veil. If adjacent wraps of the veil do not overlap, it presents the possibility of arcing between wraps during a lighting strike or ground fault. Additionally, the carbon veil does not provide bonding to miscellaneous masses of inductance on the tank, nor does it provide air terminal or a full-size conductor to ground.

Chain or other appliance suspended in the tank is also intended to dissipate static charge from the stored product onto the chain or other appliance. The limitation of this system is that it presents a flat (curved) surface to the stored product. Charge more readily dissipates off of small radius electrodes than off of flat surfaces – this limits the effectiveness of the appliance. Additionally, the suspended chain or appliance does not provide bonding to miscellaneous masses of inductance on the tank, nor does it provide air terminal or a full-size conductor to ground.

Conductive paint only coats the outside of the tank. Therefore, it cannot dissipate static charge from the stored product within the tank. Conductive paint may help by providing a path for energy from a direct lightning strike down to the tank exterior, however this division of current over the face of the painted surface is compromised, as there is only one or two ground lugs providing a path to ground at the base of the tank. Aditionally, the painted surface will be only marginally effective in serving as a lightning attachment point. If lightning attaches to the tank, the paint will probably not the thick enough to prevent the melting-through of the fiberglass, since it does not meet lightning protection code requirements NFPA 780-3.6.1.3.

Catenary systems consist of grounded masts or poles supporting a wire or wires over the site. This type of system is primarily intended to protect electric power utility company transmission and distribution lines by intercepting what would otherwise be direct strikes to the phase conductors. The overhead wires have no effect on streamer formation from the tanks, and therefore do not affect the likelihood of a direct strike to the tanks. They are merely intended to “get in the way of a direct strike,” intercepting and conveying it to ground. When used to protect tanks or other structures, this system cannot mitigate secondary effect arcing, which is the primary cause of ignition. In fact, if a catenary system performs exactly as designed and intercepts a direct strike, it maximizes the likelihood of secondary effect arcing across the tank and appurturences by bringing the lightning energy to ground near the base of the tank. The catenary system also has no effect on the static charge on the stored product, does not provide bonding to miscellaneous masses of inductance on the tank, and does not provide pupose-designed air terminals on the tank or tank battery.

Conventional lightning rod systems use Franklin-type lightning rods arranged on the tanks and battery. The conventional lightning protection model is based on attracting lighting to the lightning rod, then conveying it to ground. While this is fine on a wooden house or barn (the type of structure this systems was designed to protect), it is not appropriate for use on tank batteries. Lightning attachment is not the primary cause of tank ignition, the primary cause is secondary effect arcing. The conventional lightning rod systems is designed to attract lightning to itself – which causes maximum secondary effect current flow at the site, introducing the primary cause of ignition instead of preventing it.

Early streamer emitting systems use a small number of air terminals, usually a single air terminal, to protect an extended area. This type of air terminal works by emitting a streamer early in the streamer formation phase of a lightning strike. This assures that its streamer will reach the downward reaching stepped leaders before any others, thereby becoming the preferred lightning attachment point. They are often labled with names inferring that they protect the area by keeping away direct lightning strikes, but actually the opposite is true. Lightning will tend to attach to the ESE air terminal rather than to a tank, or other structure, but since lightning direct lightning attachment is not the primary cause of ignition, the primary cause is secondary effect arcing. An ESE system is designed to attract lightning to itself – which causes maximum secondary effect current flow at the site, introducing the primary cause of ignition instead of preventing it.

Turn the page to read the full article from:

TANK STORAGE magazine

A new way to dissipate **electrical charge**

On a fairly regular basis, certain types of tanks explode or catch fire, sometimes, but not always, during electrical storms. This is a recurring industry problem without a reliably effective solution.

There are two possible causes of this type of incident: a direct or proximate lightning strike,

to build in the vapor space.

A secondary source may be bubbling of the air/gas mixture. This leads to a suspicion that the boundary layer between the liquid and gas may play an expanded role in this problem. There are also miscellaneous sources, such as clothing on people. This factor is humidity sensitive similar to

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One common solution to lightning risks may actually be making the problem worse

A new way to dissipate electrical charge

On a fairly regular basis, certain types of tanks explode or catch fire, sometimes, but not always, during electrical storms. This is a recurring industry problem without a reliably effective solution.

There are two possible causes of this type of incident: a direct or proximate lightning strike, or static discharge.

Direct attachment may be the cause of some incidents, but it is not the likely culprit in most cases. There have been many incidents that occurred when lightning was not present in the area. Additionally, there have been many incidents involving steel tanks. It is unlikely that lightning attachment caused burn-through or heating ignition of vapor in these tanks. Therefore, the most likely cause ... static discharge. The source of static may be the result of normal operations, such ... or draining, or it may be secondary effect from a direct or nearby lightning strike. Secondary effect arcing is also static discharge, albeit high energy and occurring over a very short time frame. This arcing is produced by the inrush of ambient ground charge toward the point of a lightning strike. The inrushing charge can arc across gaps in its path, thus providing both a static charge and a static discharge.

Therefore, the ideal protection system would address both causes. Fortunately, the solution is the same. A system that protects against lightning strikes, both direct and nearby, will also protect against static discharge ignition.

Probability versus consequences

The probability of this type of incident is unpredictable. It could be ... years between incidents or years without incidents, followed by a series ... catastrophic events. On the other hand, one north Texas operator lost two batteries in one day.

The consequences of this type of incident include lost production, the cost of replacing the damaged facility, environmental impact and clean up, and bad press, especially if the subject tanks are located in a populated area or a local fire company responds.

Conditions leading to ignition

According to API 2003; A.7, in order for an electrostatic charge to become an ignition source, four conditions must be met:

1. a static charge must be generated,
2. the charge must be accumulated to the level at which it is capable of producing a incendive spark (A.6.2), that spark ... with adequate energy to ignite,
3. ... across which ... accumulated charge may arc (source of ignition),
4. an ignitable gas mixture must be present around the source of ignition.

Sources of static charge (Rub two molecules together)

The primary static charge appears to be turbulence from mixing fluids, either from pumping, particularly through non-metallic pipe or from filling, splash filling, with the falling fluid penetrating standing fluid. Air/foam injection to increase flow rates may also be a primary source. The tiny droplets of fluid above the product are separated by the dielectric gas or air, allowing the charge to build ... the vapor space.

A secondary source may be bubbling of the air/gas mixture. This leads to a suspicion that the boundary layer between the liquid and gas may play an important role in this problem. There are also miscellaneous sources, such as static on people. This factor is humidity sensitive similar to touching a doorknob on a dry day, and the charge does not usually build to the level where it becomes incendive.

Accumulation of static charge

Charge dissipates from a fluid into points and sharp edges, not flat surfaces. That is why charge does not readily dissipate into the shell of a metal tank – it is flat. This allows the charge to accumulate at a rate faster than it dissipates. The presence of a carbon veil in a fibreglass tank does not accelerate charge dissipation. It still presents a flat surface to the bound charge on the liquid. An epoxy-lined steel tank is similar to a fibreglass tank regarding static charge dissipation.

Because the static charge eventually relaxes, an incendive spark is most likely while the charging mechanism is active.

Source of ignition (Sparking)

When the static charge exceeds ... the medium breaks down and a potential equalizing arc occurs. The arc may occur between masses of inductance, such as piping, fittings, the thief hatch and its collar (if it is loose enough to rattle, it is loose enough

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Streamer Delaying Products

Streamer Delaying Air Terminal

straight air terminals ... Multipurpose ... would be mounted. Made ... in stainless ... Master base ... cast ...

Lengths vary based on site and application. For a description of how ... see the Streamer ... Influencing Technology section of the White Papers page 14.

Enardo Valve (off-set) Streamer Delaying Air Terminal

Master Enardo ... are oriented ... Lightning ... opens during operation. This 36" spot dissipator installs on an Enardo Valve riser pipe. ... FRP pipes requires ... attached to the pipe at 3' ... grounded at the ... Steel ... not require conductor cable.

Candelabra Terminal

... of air terminals use in place ... standard ... to UL-96A specifications. Standard Elevation ... conductor: 5/8"x18", ½" thread (unless otherwise specified).

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Streamer Delaying Products

to arc), electronic sensors on the tank, and vacuum trucks, or between the bound charge on the stored protect and any of the above.

Ignitable mixture

The likely source of gas is the 'Coca Cola' effect. Gas is suspended in the fluid underground. When it reaches the wellhead, the reduction in pressure allows the gas to escape, much like carbon dioxide escapes from Coca Cola when the can is first opened.

The turbulence involved with further handing allows more gas to escape, much like drinking Coke through a straw, then blowing it back into the can and drawing it out again. Splash filling, while helping to accelerate molecular breakdown and speeding the separation process, also allows additional gas to escape. Air/foam injection to increase flow rates also generates gas.

To allow combustion, oxygen must be available in sufficient concentration. Oxygen may enter the tank from atmospheric vents or from a thief hatch left open, a common practice. Oxygen may be introduced to prevent a vacuum in the tank during the process of emptying. Therefore, the conditions for combustion may be high when filling an empty tank, as static has been generated by the flowing liquids and oxygen is present in the tank.

Lightning caused ignition

Ignition due to lightning is caused by the ground charge induced by the cloud base charge on the surface of the earth beneath the storm. The storm cloud generates charges within the cloud, and a charge on the base of the cloud. This charge induces an opposite charge on the surface of the earth beneath it. The attraction of opposite charges attempts to pull this ground charge off the surface of the earth, so it is dragged along the surface of the earth beneath the cloud.

When lightning strikes the surface of the earth, it relatively vacates the ground charge at the point of the strike. The surrounding area remains highly charged, so

Picture caption to come

Streamer Delaying Air Terminal

Multipurpose spot dissipator - Lightning Master straight air terminals can be mounted wherever traditional lightning rods would be mounted. Made in stainless steel, copper, aluminum, or tinned copper for site specific

these terminals reduce the incidences of lightning, when used to protect tanks

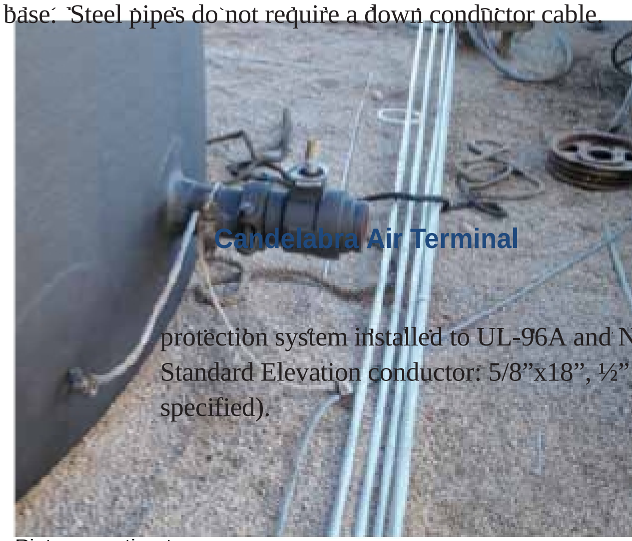
Valve (off-set) Streamer Delaying Air Terminal

Lightning Master Inardo Valve opens during operation. This 3... installs on an Inardo Valve riser pipe.

requires FRP pipes

intervals, and grounded at the base. Steel pipes do not require a down conductor cable.

Picture caption to come



Candelabra Air Terminal

protection system installed to UL-96A and NFPA 780 specifications. Standard Elevation conductor: 5/8"x18", ½" thread (unless otherwise specified).

Picture caption to come

the remaining ground charge flows toward the point of the strike. If this inrush of charge crosses a gap, it may arc. This all happens very quickly, with the storm cloud providing the source of the charge and a sufficient accumulation of charge to form an incendive spark. The tank structure provides the source of ignition and the ignitable mixture.

Solutions

The most common lightning fix is a catenary (overhead wire) system. This system consists of grounded masts or poles supporting a wire or wires over the site. Based upon the above description of the problem, this system is far from ideal. The catenary wire is intended to get in the way of a lightning strike and convey it to ground. When used to protect tanks and similar structures, this system cannot mitigate secondary effect arcing, the primary cause of ignition. In fact, if a catenary performs exactly as designed, it brings the lightning energy to ground near the base of the tank, thereby maximizing the likelihood of secondary effect arcing across the tank and appurtenances.

The catenary system has no effect on the bound charge on the stored product, does not provide bonding to miscellaneous masses of inductance on the tank, and does not affect the likelihood of a direct strike by influencing streamer formation.

Additionally, several options have been employed to control the conditions necessary for an electrostatic charge to become an ignition source.

Condition 1: the generation of a static charge. Among the solutions suggested and tried are employing piping of successively increasing diameter to reduce the flow rate, and locating fill pipe discharge near the bottom of tank. Although they do reduce the rate of charge accumulation, they are only partially effective, as turbulence still creates static.

Condition 2: the charge accumulation to the level at which it is capable of

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producing a incendive spark. Among the solutions to this is inserting a metallic rod or similar conductor into the tank to increase the rate of discharge, as recommended by API 2219, 5.4.1.2. However, this is not optimally effective, as the inserted item still constitutes a flat or curved surface.

Condition 3: an appropriate source of ignition. This is commonly accomplished by bonding all masses of inductance. In addition to tank battery appurtenances, vacuum trucks must be bonded to the system. This bonding conductor may be a simple flexible cable, which is just as effective and not as expensive as retractable reel system, or as complex as a conductive hose, which may be difficult to test on a regular basis and to maintain. Any system used should provide strain relief for the driver who forgets to unhook truck before driving away.

API 2219 allows grounding of a truck to a ground rod separate from the site ground. As this ground rod may be at a potential substantially different from that of the remainder of the site, particularly that of the stored product, this technique may be inadequate.

These steps are moderately effective, but fail to address the bound charge on the stored product.

Condition 4: the presence of an ignitable gas mixture. Normal maintenance should include the dump valve, and operating practices include close thief hatch and controlling the rate of filling and emptying a tank.

New approach

The wild card in tank protection has always been equalizing the bound charge on the stored product. Charge dissipates from a liquid onto points and edges. Even in a steel tank, there are none to help dissipate the bound charge on the stored product. The liquid simply lies against the side if the tank, and the charge is inductively couple onto the flat surface. It takes time for the potential to relax, allowing the static charge to accumulate faster than it dissipates.

Lightning Master designed an in-tank static drain consisting of a stainless steel cable with stainless steel electrodes inserted into the wind of the cable. This drain, installed through the thief hatch and secured to the top of the tank, introduces thousands of electrically sharp points into the stored product, offering a low-resistance path for bound charge to leave the liquid and vapor space. It sucks the charge out of the product, allowing it to relax much more quickly. This allows the charge to dissipate faster than it accumulates.

On a steel tank, the only additional bonding required is a jumper between the thief hatch and collar (if it is loose enough to rattle, it is loose enough to arc).

On a fibreglass tank, a conductor system is installed bonding the top vent pipe or manifold, the in-tank static drain, thief hatch collar, walkway handrail system, and tank conductive elements such as a carbon veil, and the drain pipe at the base of the tank.

The bonded mass of the tank system is then bonded (grounded) through existing electrically continuous metallic piping or dedicated conductors on non-conductive piping to the injection well, truck load-out, and on-site and service ground. This brings all site components and structures to the same potential as the ground potential, thus reducing the possibility of arcing. Truck drivers should be trained to bond their trucks to the site bonding system without exception. The truck bonding system may consist of a retractable reel grounding wire, or may be as simple as a flexible cable with a spring pressure clamp attached to its end. In either case, a means of strain relief must be provided to compensate for the driver who drives away with the grounding clip still attached to the truck.

To provide direct lightning strike protection, streamer-delaying air terminals (lightning rods) are installed atop the tank, vent or vent manifold piping and handrail structure. These air terminals are UL Listed lightning rods, and also retard the formation of lightning completing streamers from structures, thereby reducing the likelihood of a direct lightning attachment.

These systems are simple, lightweight, and easy to install, and have been employed successfully on hundreds of fibreglass tanks throughout the US and overseas. Each system must be site specific, system designed in accordance with the standards contained in NFPA 780, and approved by the city of Ft. Worth and many other municipalities for the installation of tanks and batteries within city limits.

It costs less than commonly used systems, such as the catenary system, and is more effective at controlling the conditions that constitute the proximate cause of tank incidents.

For more information:
This article was written by Alan Roachell, Rosewood Resources and Bruce Kaiser, Lightning Master Corporation, http://www.lightningmaster.com/

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Streamer Delaying Products

Streamer Delaying Air Terminal

Multipurpose spot dissipator – Lightning Master® air terminals can be mounted wherever traditional lightning rods would be located. Made with copper, stainless steel, aluminum, or tinned copper to site specific customization, and can be attached to any Lightning Master base. Lengths vary based on site electrical application. For a description of how these terminals reduce the incidences of lightning, please see the Streamer Influencing Technology section of the White Papers on page 14.

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Lightning Master Surge Protective Devices

Necessity For Critical Load Lightning Arrestors

As recently as a few years ago, lightning damage to a motor or other critical load was considered to be an unpreventable act of God. In today's world, lightning damage to a motor is considered to be poor preservation of a critical asset. When a large motor goes down, it usually takes an appreciable portion of systems or processes down with it. They system remains down until the motor is repaired or replaced. Time is money, especially down time.

Often times, most companies do not maintain an inventory of spare motors, so replacement time becomes critical. You do not send out two guys with a pickup truck to change a large motor. Extensive mobilization may be involved, as well as the expense and delay of locating a replacement or arranging motor rewinding or other repair. All told, the cost of an appropriate arrestor is many times less than the cost of down time and equipment replacement.

Lightning Master has recently introduced arrestors for 4,160V, 2,400V, 660V, and 480V applications. These rugged units are small, lightweight, and easy to install in the most challenging environments. Best of all, they are reasonably priced, making them very cost effective.

The use of these devices is recommended by motor manufacturers, as they are designed to provide dielectric protection for the motor and insulation system. Because Lightning Master arrestors employ MOV technology, they negate the need for surge capacitors.

Therefore, we suggest a program to secure protection for your valuable assets by installing these arrestors on a progressive basis. Based upon our experience, you may want to consider protecting assets based on the following priorities:

1. **Critical facilities** – These constitute facilities in your system that are critical to your overall operation, and could include pipeline junctions, stations that can pump in both directions, stations without backup, etc.
2. **Facilities subject to performance penalties** – These constitute your facilities providing service to an outside customer imposing a performance penalty in the event your service is unavailable.
3. **Sites at the end of electric utility transmission or distribution lines** – These are subject to excessive power company transients.
4. **Remote sites** – These are sites that may be difficult to access, particularly during winter or rainy season.
5. **Sites subject to past damage** – Lightning does strike twice in the same place. If a site has a history of lightning damage, such damage will likely continue.

Programmed protection entails acquiring a number of arrestors each month, and distributing them to sites based upon priority and described above. Over time, critical sites are protected first, with all sites protected eventually. Protect your valuable assets and enhance reliability now with Lightning Master surge arrestors.

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Lightning Master Surge Products

Medium Voltage Arresters (660V-4160V)

The custom designed Lightning Master® series of robust medium voltage surge protection devices are unparalleled in the SPD industry. Massive MOV assemblies are attached to a large ground plane to provide the lowest impedance path to ground as possible, for maximum protection of your valuable equipment, negating the need for surge capacitors.

This series of surge arresters was designed with the heavy-duty industrial user in mind. It will provide surge and transient protection in the harshest of environments for your motors in process control, mining, pumping, and on shore / offshore drilling applications.

Critical Load Lightning & Surge Arrester	
LM-660V-3PD-70	660V Three □ 4 Wire Delta
LM-2400V-3PD-70	2400V Three □ 4 Wire Delta
LM-4160V-3PD-70	4160V Three □ 4 Wire Delta
Surge Rating ((8/20 µS))	70 kA nominal, phase-to-phase & phase-to-ground
SCCR	Dependent on external OCP device
IMAX	70 kA
Design Standard	IEEE C62.11
Status Monitoring	None – Failed Arrester trips OCP overcurrent device to alert operations
Dimensions (in)	15 W x 15 H x 8.5 D Compact Design
Shipping Weight (lb)	30 - Light Weight for easy installation
Enclosure	NEMA 4 Stainless Steel w/ external mounting flanges, safety locked continuous hinge cover
Accessories Included	18" #12 AWG 40kV rated - 3 wires plus ground; 1" Myers Hub or offset fitting with nuts included

Low Voltage Surge Suppression Devices (120V-600V)

Lightning Master manufactures a full line of AC power surge suppressors for industry and commercial applications. Most manufacturers offer specific units for each voltage. This creates an installation problem, as few end users know the actual voltage they need. A Customer may say he has 480V service, when he actually has 277/480V 3ø Y service. If the installer shows up with a 480V surge suppressor, he cannot complete the installation. Lightning Master solved that problem by addressing all operating voltages with only three different series, plus two additional snap-in modules for high-leg services.

All models are ETL Listed to UL 1449, Third Edition, for both the US and Canada	
240 Volt Basic Series 120/240 & 120/208	120 V Single□, 120/240 V Single (Split) □, 120/208V 3 □ Y, 240V 3 □ D, and 240V 3 □ D Corner Grounded
480 Volt Basic Series	277/480V 3 □ Y, 480V 3 □ Delta, 277V Single □, 480V Single □
600 Volt Basic Series	347/600V 3 □ Y & 600V 3□ D
Dimensions (in)	6" X 8" X 4"
Shipping Weight	5.1 lbs
NEMA Rating	4X
Temperature Rating	-30C to +65C
Surge Rating	50 kA/Phase
Connection	18" #12 AWG 4 - 3 wires plus ground; 1" Offset fitting with nuts included
Features	Protection Indicator, Isolated Form C Contact

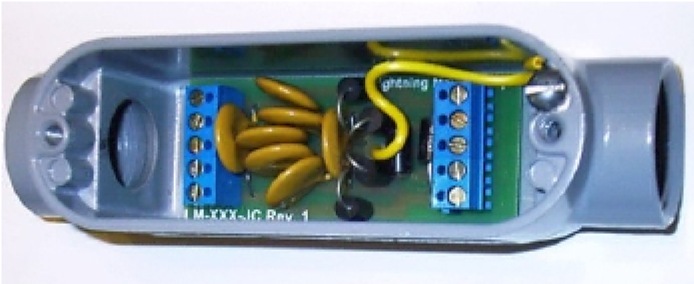
Measurement, Control, and Data Surge Protection

TS-12

The TS-12 is a 12-line Transient Voltage Surge Suppressor designed for a wide variety of current loop applications for commercial and industrial process control protection. This product protects the connected devices from over-voltage transients, which can be very damaging or cause anomalies in the data – it provides signal noise reduction.

This product compliments the Pipe Cleaner	
Surge Rating	20 kA (8/20uS)
Type Designation	12 Terminal Data Protector, Automatic Recovery
Fast Response Time	<5nS
MCOV	30VAC & 150 VAC
Electrical Specifications	30V and 120V Nominal Voltage, All 5kA, Nominal Discharge Current 8/20 Impulse
Operating Temperature	-20C to +85C
Dimensions	6 7/8” L x 3 1/8” W x 2 5/8” H
Enclosure	Protects against water, dust and oil intrusion

Pipe Cleaner



Lightning Master Pipe Cleaners are dual-circuit in-line, multi stage, parallel devices designed to protect 4-20mA data and 5V, 24V, 110V/120V control wires in process control applications. Designed to stop transients before they reach the device under protection, these units can be used in DC data and AC control applications. They are designed to be installed in series with your existing conduit wiring. The LM-PC fits standard ¾ inch metal conduit, and PVC versions available.

This product compliments the TS-12	
Surge Rating	10 kA (8x20 waveform)
Type Designation	Automatic Recovery
Fast Response Time	<5nS
Series Impedance	1 Ohm
Standard Voltages	5, 24, 110/120 VDC
Operating Temperature	-20C to +85C
Design Features	Protects 2, Same Voltage Circuits Per Package

Specialty Surge Protection Devices

Load Cell Protector

The Load Cell Protector services your sensitive and valuable load cells and weighing systems from transient surge events. These surge suppressors install easily at load cells, summing boxes and control computers, protecting both four and six wire systems. They work on both digital and analog systems, and do not affect scale system calibration. Surge suppressor geometry combines a low-impedance transient (surge) path through surge suppression elements with a high impedance transient path to the device under protection.

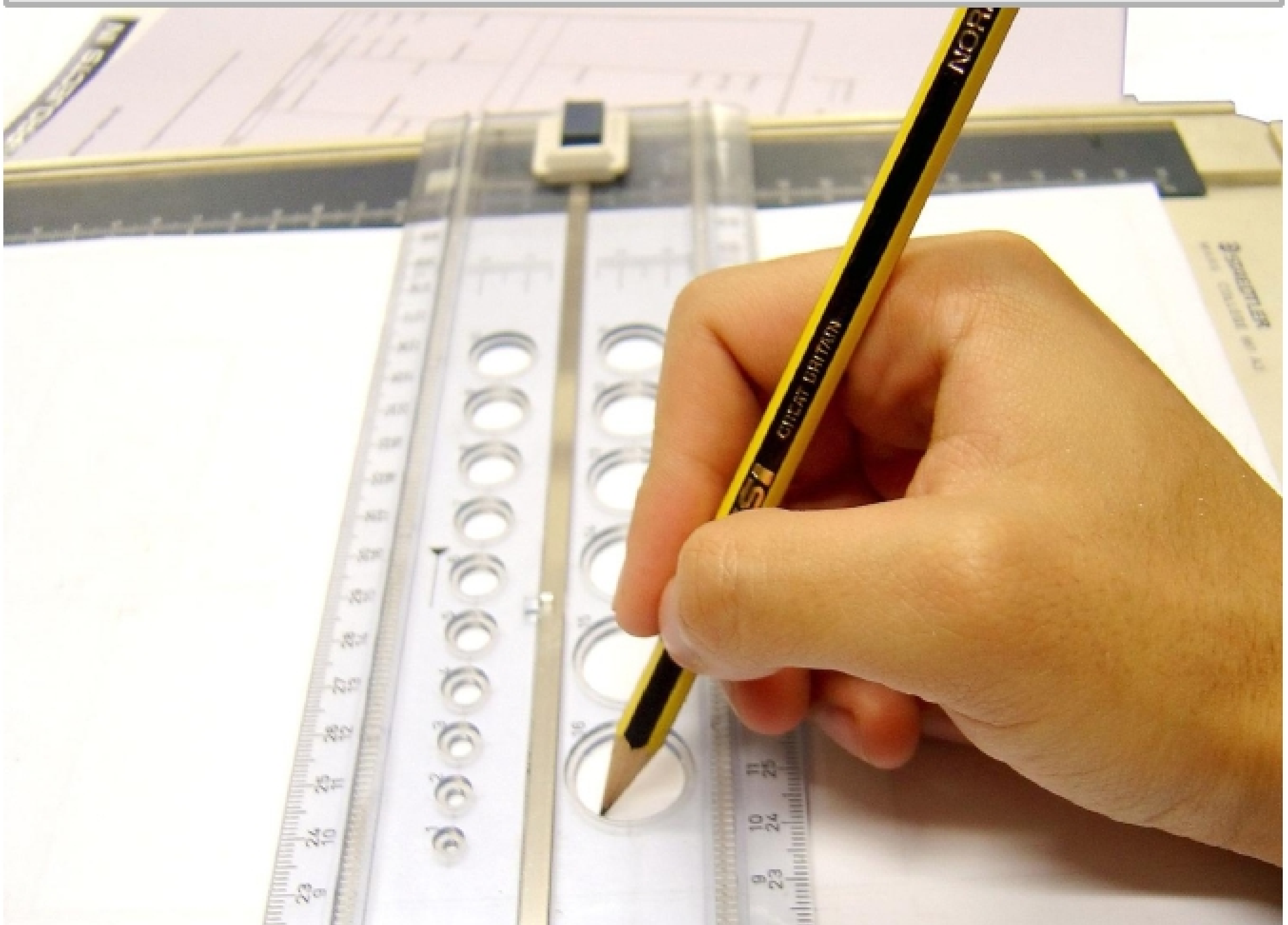
Automatically returns to a passive state after a transient passes	
NEMA Rating	4X
Type Designation	Automatic Recovery
Enclosure	6.3” L x 6.3”W x 3.5” H
Signal-To-Shield	30V Clamping Voltage
Surge Capacity	10kA
Shield-To-Ground	75V Clamping Voltage
Surge Capacity	100kA All Components

Ground Wire Filter

The Ground Wire Filter™ (GWF) effectively eliminates “sneak path” transients from entering sensitive electronic equipment through the ground wire. The GWF is a specially designed and wound toroidal choke/filter that presents an extremely high impedance path to high frequency transients. It absorbs and blocks their passage along the ground wire feeding into your sensitive electronics equipment, reducing downtime and damage.

This product complements all other types of previously installed surge/noise suppression devices	
Installation Features	12”-#12 AWG Wire Leads For Universal Installation
Type Designation	Automatic Recovery
Dimensions	4”L x 2”W x 2 ½”H
Enclosure	Sealed to protect from water, dust, and oil
Transient Frequency Response	1 Hz – 200 MHz
Applications	120/240/480/600V 50/60 Hz 1 or 3 Phase

Our engineers work with you to design a system, or custom spec that meets your needs.



CALL US: 1-800-749-6800

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