# Lightning prevention systems for paper mills

**Roy B. Carpenter, Jr.**

*Several mills use this lightning-prevention system to protect their overhead power-distribution lines from lightning strikes and insulator flashover.*

Paper mills are increasingly relying on sensitive electronic equipment to control their operations. However, the sensitivity of these devices has made mills vulnerable to the effects of lightning strokes. An interruption in the power supply or the destruction of delicate microcircuits can have devastating effects on mill productivity.

Lightning strokes can be prevented by a Dissipation Array® system (DAS®). During the past 17 years, the concept has been applied to a host of applications in regions with a high incidence of lightning activity. With nearly 700 systems now installed, more than 4000 system-years of history have been accumulated. Areas as large as 1 $km^2$ and towers as high as 2000 ft have been protected and completely isolated from lightning strokes. There have been very few failures, and in every case, the cause of the failure was determined and corrected.

The interest in this technology has increased with the industry's expanded use of automated process controllers. Within the past three years, several paper mills have used various forms of dissipation-array technology for partial or complete protection of their facilities. The most common application has been the isolation of overhead power-distribution lines from lightning strokes and associated insulator flashover, which can cause the lines to trip out.

## Charge dissipation

### The concept

Lightning strokes occur when there is a sufficiently large charge differential between a storm cloud and the earth. These charge differentials are neutralized by lightning strokes, which transfer a deluge of electrons within a span of microseconds. Lightning strokes can be prevented by allowing this transfer of electrons to proceed slowly over a period of several minutes. The gradual dissipation of the electric charge on the earth prevents buildup of the large charge differentials that can initiate a lightning strike.

Charge-dissipation systems utilize a phenomenon known as point discharge or corona discharge, which causes the bluish electrical glow that sailors call St. Elmo's fire. This electrostatic phenomenon encourages the transfer of a charge from a charged body (the earth) to the surrounding air molecules. The charged air molecules are acted upon by the electrostatic field created by the storm, which carries the charge away. The resulting corona current continues to discharge the site throughout the storm. A detailed description of these operating principles is provided in the literature (*1*).

### The equipment

The charge-collection and -dissipation equipment are the key factors in preventing the occurrence of lightning strokes. The charge-collection system—the ground-current collector (GCC)—must provide an effective interface with the earth so that it can receive the earthbound charge. The system must also provide an efficient path for the transfer of that charge from every location or facility within the protected site to the charge-dissipation device. This device, called the ionizer, must in turn provide an effective interface with the air so that it can efficiently transfer the earthbound charge to the air molecules. The DAS concept is illustrated in **Fig. 1**, along with a conventional collector-diverter system known as the lightning-rod system (LRS).

While both concepts provide three subsystems or functional components, their functions are vastly different. The LRS concept includes single-point air terminals whose function is to collect and divert any strike moving within their predefined spheres of influence. In contrast, the DAS air terminal provides thousands of points whose function is to dissipate the positive charge that builds up on the surface of the earth during a storm. Each point ionizes adjacent air molecules, making them positive ions in a negative electrostatic field. The resulting ion mobility facilitates charge dissipation at the protected site.

Lightning rods must be capable of carrying surge currents of 2,000-400,000 A for an average of 20$\mu$s. The length of a lightning conductor often exceeds 100 ft. In contrast, the DAS service wiring can carry no more than 0.5 A, with currents typically on the order of a few hundred microamperes. While lightning conductors have diameters at least 0.5 in., DAS service wires have diameters no more than 0.1 in. Lightning conductors exert an impedance of up to 1000$\Omega$ for high structures, such as power-

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plant stacks.

The LRS grounding system must provide a low-resistance interface with the earth. For each ohm of resistance, a difference in potential of more than 20,000 V will normally be developed across that interface. In contrast, the resistivity of the GCC to earth is not important. It simply surrounds the site and is connected to each element in the protected area, providing a large surface area for the collection function. It is recommended that the GCC be constructed of copper tubing because of the tubing's low surge impedance and greater soil contact per unit weight. Additional details of the GCC are provided in the literature (*1*).

### The major cause of downtime: lightning-induced transients

The use of sensitive electronic equipment in paper mills is becoming increasingly common. The sensitivity of these control systems has made mill operations vulnerable to the effects of lightning. Downtime resulting from interruption of the power supply is seldom the result of a direct strike. More often, it is the result of secondary effects such as:

- Electromagnetic pulse
- Electrostatic pulse/atmospheric transients
- Earth currents and related transients
- Bound charges/secondary arcs.

These phenomena induce transients in data and power lines. The resulting voltage spikes can range in value from less than a volt to many thousands of volts, with pulse durations ranging from nanoseconds to several hundred microseconds. The use of any form of LRS protection can increase the risk of these secondary effects (*1*). A thorough description of transient phenomena is provided in the literature (*2*).

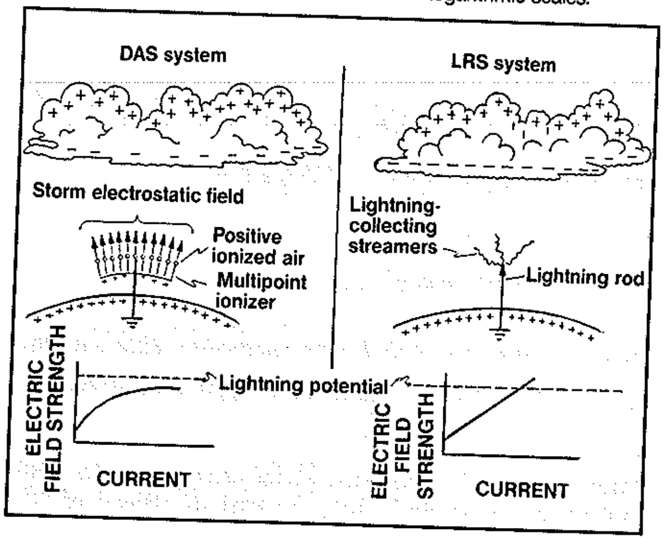
Protection from the effects of these transient phenomena can be obtained by:

- Protecting each vulnerable interface with some form of electronic device (*3*) or
- Preventing any lightning strike from terminating where it can produce damaging transients.

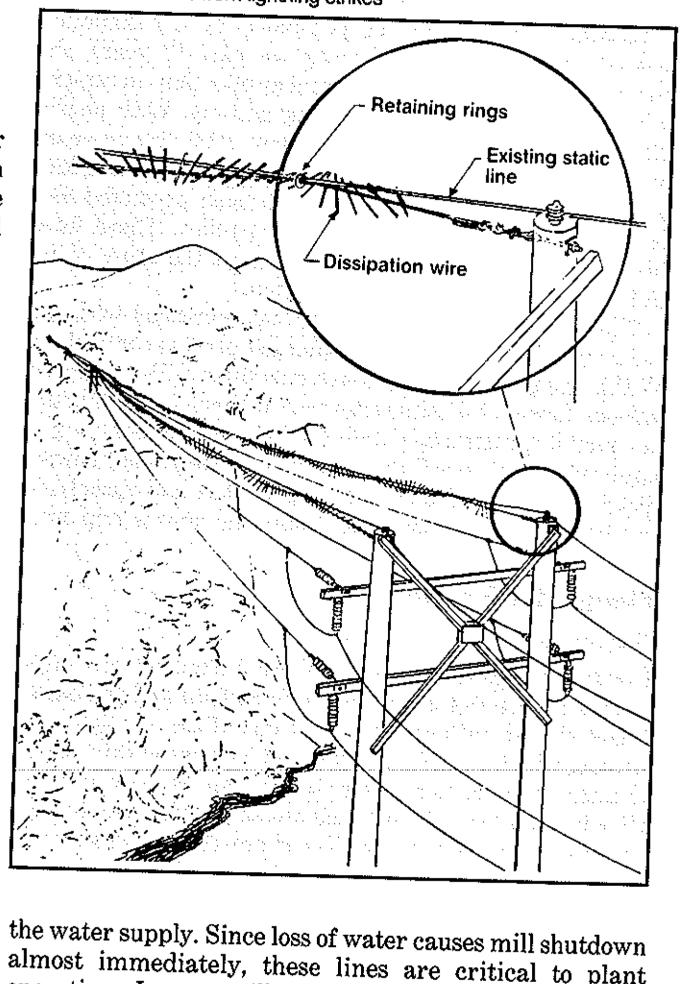
The latter concept is recommended for automated processes, where there are many data points being monitored and numerous related control lines. By eliminating the source of transients, you also eliminate the need to define and protect each of these potentially vulnerable interfaces within the protected area. This article discusses the application of this approach in a mill environment.

Incoming power lines must also be appropriately protected. A thorough discussion of this subject is available in the literature (*3*).

**1.** Charge dissipation via ionization vs. charge collection and diversion with a lightning rod. The graphs are based on logarithmic scales.




**2.** Installation of dual strands of dissipator wires to protect power-transmission lines from lightning strikes

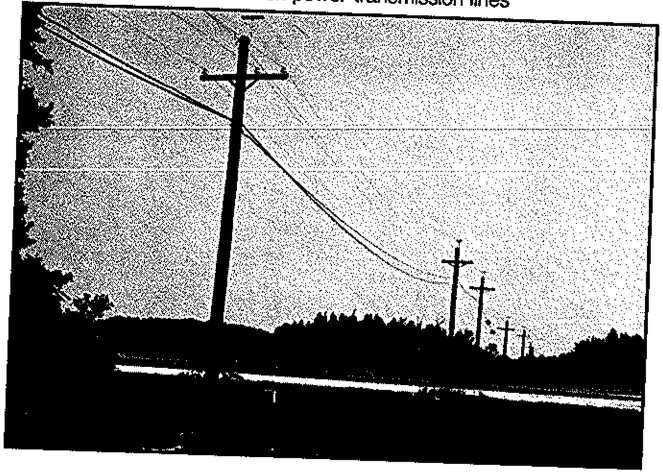



## Mill applications

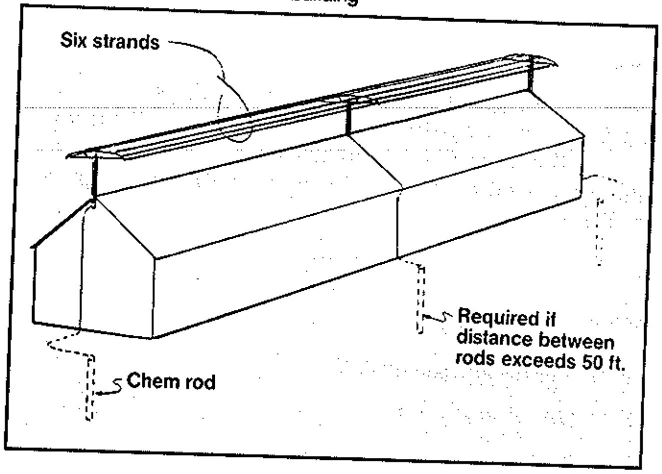
### Protection of overhead power-distribution lines

The distribution of power throughout a paper mill mandates long runs of distribution lines throughout the plant. The outdoor portion of the power-distribution system usually consists of overhead lines. Most often, the mill's greatest exposure involves disruption of power to the water supply. Since loss of water causes mill shutdown almost immediately, these lines are critical to plant operations. In some mills, prevention of a single shutdown can more than pay for a system capable of protecting the entire mill. Even a momentary loss of power can have a significant impact on mill operations. Thus the most popular DAS application in paper mills is the protection of overhead power lines from lightning strokes and from

3. Typical DAS installation on power-transmission lines



4. Typical DAS installation on building




insulator flashover caused by nearby strikes.

**Figure 2** illustrates application of the DAS concept to overhead power lines. Two dissipation wires are deployed about 2 ft above the topmost phase conductors. The dissipation wire is a stainless-steel carrier wire with uniformly deployed stainless-steel points attached to it. The wire is supported by tee bars at each utility pole, which in this case are connected to individual ground rods. A detailed description of the dual-dissipator system (DDS) is provided in the literature (*4*).

The conventional form of protection involves the use of an overhead ground wire. Lightning strokes are diverted to the ground wire instead of striking the phase conductor. However, even if the ground wire functions as planned, there is always the possibility of insulator flashover as a result of the transient created by the electrostatic field. Such transients can easily reach potentials of up to one million volts during the stroke process. The occurrence of flashover usually trips the power line, even if the phase conductors themselves are not struck. Insulators for a given distribution line are chosen based on their ability to resist flashover: the higher the insulator rating, the lower the incidence of flashovers.

The dissipation wires not only prevent lightning from striking either themselves or the phase conductors; they also reduce the electrostatic field around the phase conductors to such a level that flashover is not possible. The absence of an electrostatic field means no transients. **Figure 3** illustrates one possible installation of dissipator wire on a power-transmission line.

### Protection for the process control buildings

Many mills operate under the mistaken notion that process controllers inside buildings are safe from the effects of lightning strikes. While they are safe from the effects of a direct stroke, they are vulnerable to the resulting side effects. Most problems are caused by the effects of electromagnetic pulse (EMP), but sometimes the electrostatic pulse (ESP) can be the offender. These secondary phenomena penetrate the building walls and are mutually coupled to the intra-building wiring. If the coupling is close enough, the transients induced in these wires can destroy electronic equipment or cause it to malfunction.

Anything that attracts lightning to the building (lightning rods, square corners or sharp points on elevated buildings) can proliferate the problem. The relative proximity of a lightning stroke to these areas assures close coupling of the EMP and the ESP (for other-than-steel buildings). The most vulnerable wires are those in or near the outer walls of these buildings.

**Figure 4** illustrates one application of dissipation-array technology to protect a paper machine building. Deployment of such a system prevents lightning from striking the building or from terminating closely enough to cause the EMP damage that accompanies the average lightning stroke. Many buildings are protected with such systems.

### Protection for log-yard cranes

The height of log-yard cranes makes them likely targets for lightning. They are also vulnerable to surges on power lines, which can damage their power control and distribution systems. Some crane control systems are more vulnerable than others, particularly those that use silicon-controlled rectifier switches or other sensitive electronics.

**Figure 5** illustrates a typical DAS installation for protecting the crane and surrounding area from lightning strokes. Such a system protects the crane, the operator, and workers supporting crane operations. Different crane designs require slightly different DAS configurations.

The DAS constantly discharges the crane, maintaining a safe environment for personnel and equipment. A large crane can act as a giant capacitor with respect to earth or a cloud. Even though the crane is on earth and grounded, the surge impedance of that ground can be high enough to allow the crane to hold a charge for a short time. If a worker on the ground were holding a part of the crane when a stroke occurred nearby, the worker would become part of the crane discharge path and receive an electrical shock.

### Protection for open yard areas

Most lightning-related deaths are caused by the first strike. Open areas where workers and equipment are active during the day can pose a problem during marginal weather conditions. Since these areas are usually well lighted, the light poles provide an excellent location for DAS ionizers.

**Figure 6** illustrates one such application. The GCC is recessed into the ground surrounding the area to be protected and tied directly into every fixed facility in the immediate area. This approach has been used to protect coal yards, chip yards, and log yards.

**Protection for power plants**

Most power-generating plants are equipped with high stacks for venting flue gasses. The height of these stacks makes them excellent locations for a DAS ionizer, since the electrostatic potential increases with height, as seen in Eq. 1.

$$E = FH \qquad (1)$$

where

$E$ = electrostatic potential, V

$F$ = field strength, V/m

$H$ = height of the ionizer, m.

As height increases, there is an exponential increase in the average dissipation current and thus the efficiency of charge dissipation.

**Figure** 7 is a photograph of a DAS system on a stack in a mill power plant. This ionizer is more than 35 ft in diameter and provides over 3500 dissipation points. The inner ring rests on top of the stack, and the dissipation surface droops below it. The existing lightning conductors were used as service wires. The grounding configuration for the lightning conductors satisfied the requirements of a GCC because it surrounded the plant.

To be completely effective, the GCC must surround both the power plant and the stack and be tied into the steel framework of all facilities within the protected area. These connections promote the slow discharge of the included facilities, even if some parts are higher than the ionizer.

**Completing the protection package**

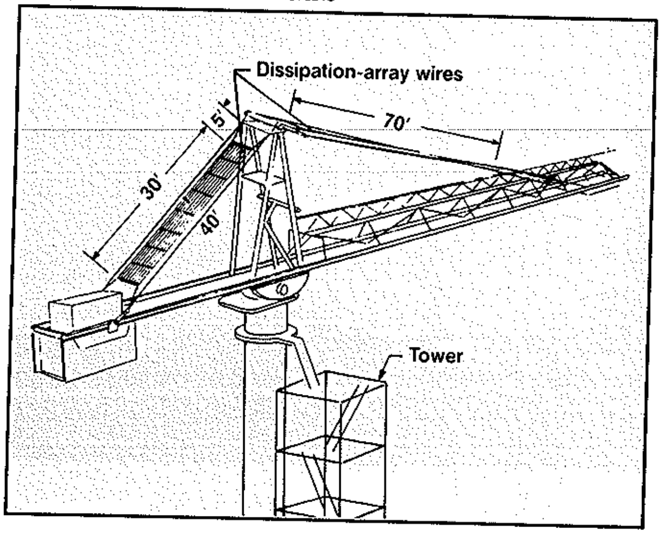
To complete any facility protection package, it is necessary to add electronic circuit protectors to all circuits that pass beyond the DAS sphere of influence. Special protectors are available that will prevent the passage of any form of transient voltage into the protected area without adversely affecting any circuit parameter. The search for a specific protective device begins with the identification of the appropriate family of circuit protectors. The specific device is then selected from among the members of that family (*5*).

## Conclusion

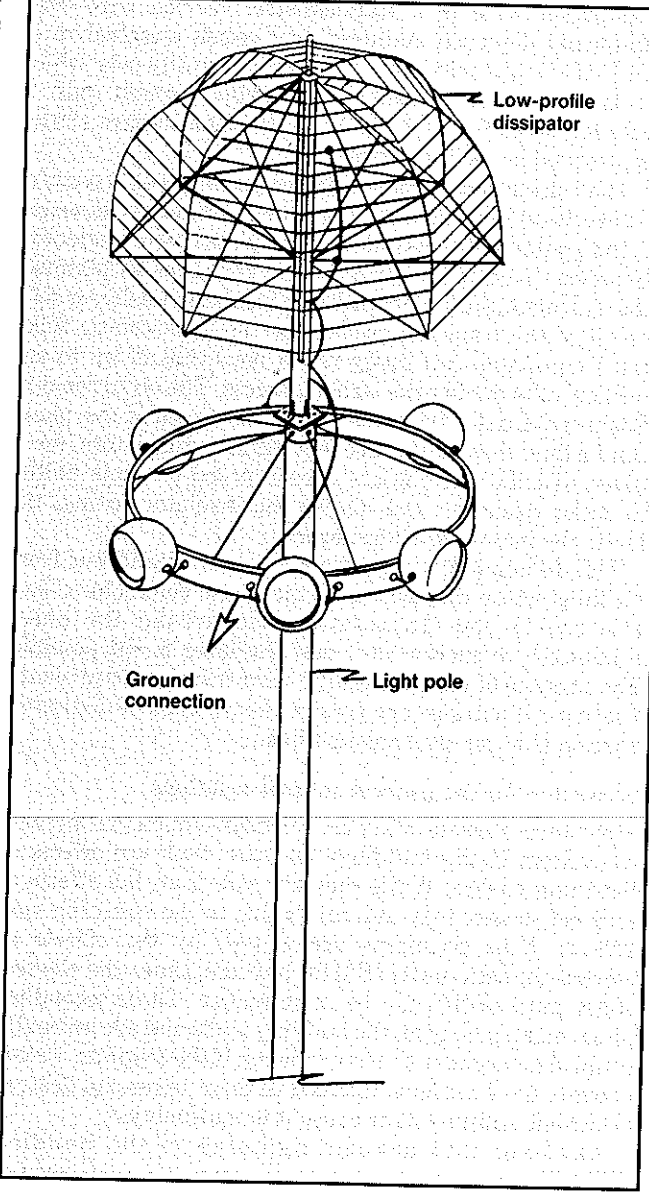
It possible to eliminate any reasonable risk of damage to equipment or power interruption from lightning strokes. The dissipation-array system described in this article is not offered as a panacea for all lightning problems. However, it has proved to be an effective building block in programs designed to provide positive lightning protection.

The system does prevent lightning strikes, and it can be a cost-effective alternative to the installation of multiple circuit protectors.□

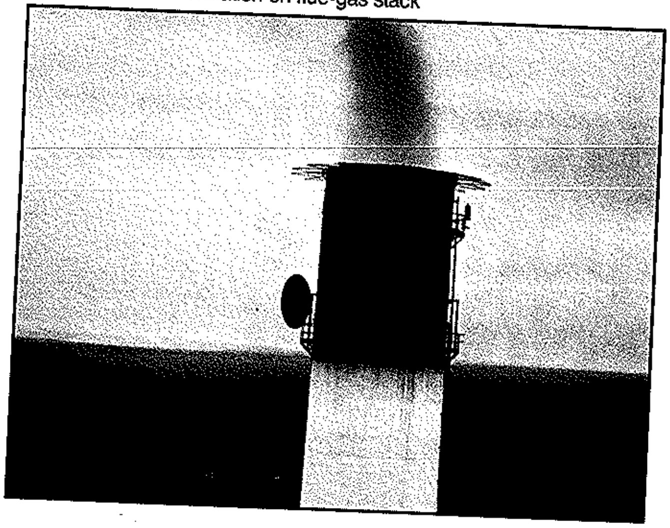
**5.** Typical DAS installation on crane




**6.** Typical DAS installation on light pole



**7.** Typical DAS installation on flue-gas stack



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