Unbonded boats will still need sacrificial zinc anodes at specific spots, such as a zinc collar where a stainless steel propeller shaft interacts with a bronze propeller (we have a variable-pitch propeller on which it is not possible to mount a shaft collar, hence our corrosion) and zincs in the raw-water engine-cooling circuit and any refrigeration condensers. Steel hulls and rudders will need their own zincs.

Unbonded boats are likely to have problems providing adequate lightning protection (see below) and adequate grounding systems for SSB radio and lorans (see Chapter 7).

## Lightning Protection

In some parts of the world lightning is a rarity, but in others it can be quite common—in any given minute, worldwide there are 2,000 thunderstorms in progress, for a total of more than 16 million a year! Parts of the eastern seaboard of the United States are notorious for electrical storms. Since lightning tends to strike the highest object in its vicinity, boats out on the water are peculiarly vulnerable—a sailboat, with its tall mast, is an obvious target! The traditional response to this situation has been to put the mast to use as a lightning rod, conducting a strike "safely" to ground, and so providing a degree of protection for the boat and its occupants; more recently there have been claims that it is possible to prevent strikes altogether. Let's look first at lightning rods.

### The Importance of Grounding

The concept underlying a lightning rod has been understood for some time. When the conditions are right for a thunderstorm—a lot of heat and moisture in the air—the turbulent air strips electrically negative electrons from the moisture molecules, leaving the clouds with a positive electrical charge. The surface of the earth or the ocean beneath the clouds becomes loaded with an abundance of negative electrons. The voltage difference between the cloud and the surface of the earth or water becomes huge, and the pressure to regain an equilibrium enormous. However, air is normally a pretty good insulator, so a charge has to build up to a tremendous intensity before it becomes sufficient to jump the gap from the earth or sea to the cloud above. But once the energy reaches this level the resultant giant spark (actually, a series of increasingly long sparks, known as *stepped leaders*) *ionizes* the path through the air. Ionized air happens to be a good conductor, so now the whole system balances out in a fraction of a microsecond with an enormous current flow (the main lightning strike).

The purpose of a lightning rod is twofold: (1) to bleed off electrons from the surface of the earth to the surrounding air in hopes of dissipating the electrons and so preventing a lightning strike, and (2) if this is not successful, to limit the damage done by a strike by providing a low-resistance path between the two oppositely-charged bodies, thus preventing the lightning from following more hazardous paths. To carry out these tasks, a pointed conductor is raised as high as practicable and connected electrically to the earth or the ocean (Figure 4-21A). Negatively charged electrons from the surface of the ocean are attracted to the positive cloud above, accumulating on the point of the lightning rod. Here the physical constraints caused by the geometry of the point greatly increase the electron density. Since the electrons are all of the same negative charge, and like charges repel one another, there is a pressure to push electrons off into the surrounding atmosphere where they neutralize the positive charge above.

There is a school of thought that holds that this process of attracting charged particles to the lightning rod actually increases the possibility of a strike and that therefore a lightning rod should *not* be fitted to a boat. This position is not supported by the evidence. When the charge density begins to approach the level needed for a lightning strike, electrons will accumulate on the surface of any object in the vicinity, including a mast, and will not care if the mast is grounded or not, or even if it is a poor conductor. Any lightning bolt will then follow the path of least resistance to equalize the points of maximum charge density. *The top of the mast, with or without a lightning conductor, is likely to be one of these points*. At this stage in the cycle, the poorly grounded mast merely offers a greater probability that the strike will be a powerful one since the electrons will not have been bled off by a functioning lightning rod. Damage will be greater than with a lightning rod because of the higher current levels and *the lack of a low-resistance path for the current*.

Failure to provide an adequate path to ground will cause a lightning strike to find its own route.

If this is through people (for example, crewmembers standing close to, or holding, a stay or shroud) it may kill them. If tracking down a wet wooden mast, the resistive path will generate a tremendous amount of heat, explosively boiling moisture in the mast and perhaps blowing its seams wide open. If running to ground through an internal chainplate and then jumping to the ocean outside the boat, it may blow a hole in the boat. If running to a through-hull with an inadequate surface area to dissipate the heat caused by the strike, it will likely blow the through-hull out of the boat, or melt the surrounding resin. And so on—the examples are many. A well-grounded lightning rod will not stop a lightning strike, but it may reduce the chances of a strike, and will tend to lessen the extent of the damage should a strike occur.

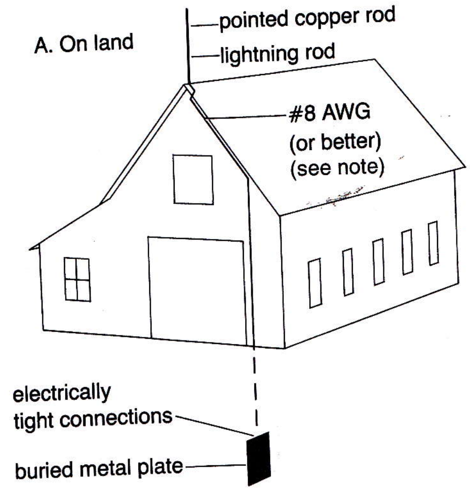


Figure 4-21A. Conventional lightning protection on shore. *(Jim Sollers)*

**The zone of protection.** There is a concept that a well-grounded lightning rod provides a *zone of protection* for an area around its base with a radius equal to the height of the rod (Figure 4-21B and C). Given the height of a sailboat mast, if it is used as a lightning conductor the whole boat will fall within this zone of protection, whereas powerboats need some form of elevated lightning rod to establish such a zone (see below) and even then the whole boat may still not be within the zone of protection (particularly the bow)—the occupants will need to stay clear of these areas during lightning storms.

It should be noted, however, that this zone of protection is by no means absolute. The main conductor from a mast-mounted lightning rod to ground inevitably has some internal resistance. Given a lightning strike, this resistance will encourage part of the strike to follow other paths to ground—what are known as *parallel paths*. In the case of a sailboat, the rigging is one likely parallel path. The extent to which the lightning strike will follow these parallel paths is proportional to the resistance of these paths as compared to the resistance offered by the main lightning conductor. Even if the resistance of the parallel paths is relatively high, given the enormity of the voltages and amperages involved in a lightning strike the parallel paths will still be highly charged—perhaps to tens of thousands of volts. If these parallel paths do not themselves have a low resistance path to ground, the behavior of the strike will become quite unpredictable, passing, for example, through any people bridging the gap between a charged piece of rigging and a grounded fitting on the boat (such as the steering wheel), or generating dangerous *side flashes*.

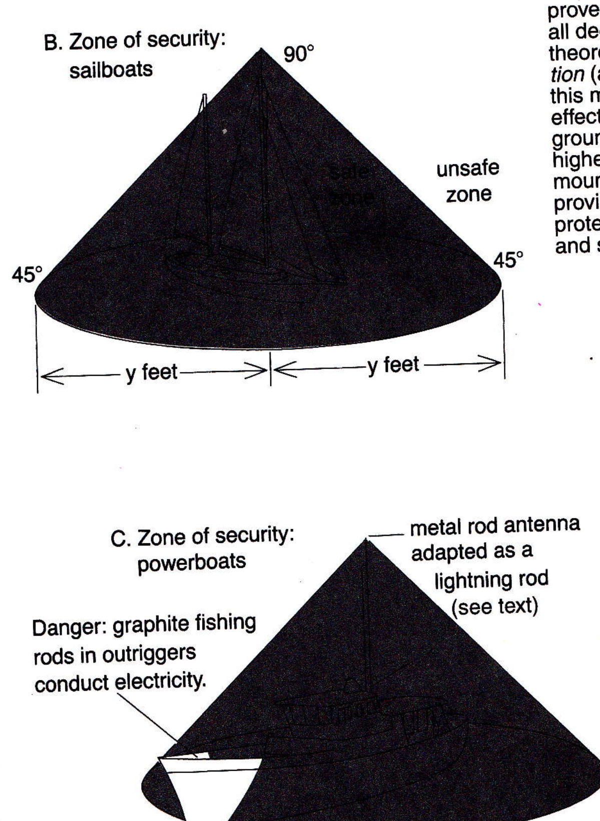


Figure 4-21B and C. Lightning protection. Note that on power boats it may prove impossible to include all deck areas in the theoretical *zone of protection* (and that in any case, this may not be completely effective—see the text). A grounded metal spike higher than any mast-mounted antenna will provide additional protection on both power and sailboats. *(Jim Sollers)*

As a result, the best *people protection* will be had by keeping out of the water and remaining inside a closed boat, so far as this is possible, during thunderstorms. If forced to remain on deck, do not dangle arms or legs overboard, and unless necessary for safe boat handling, avoid contact with any metal objects. *It is especially important not to bridge two such metal items, since in the event of a strike they may be at very different voltage potentials, encouraging the current to run to ground through the bridging body.*