Lightning and Gunpowder in the 18th Century

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1.0 Introduction

Because explosions of gunpowder have many similarities to thunder and lightning – extremely loud and bright, and often unexpected - there were many analogies drawn between these phenomena after the introduction of gunpowder into Europe in the 14th century. On or before June, 1751, experiments and observations of electricity by Benjamin Franklin and co-workers[1] showed that gunpowder could be ignited by a small spark,[2] and lecturers and demonstrators used gunpowder to enhance the explosions of "thunder houses" to emphasize that grounded metallic rods might protect structures from lightning damage. Almost immediately after the sentry box and kite experiments proved that thunderclouds contain electricity and that lightning is an electrical discharge,[3] Franklin published a short note entitled "How to secure houses, etc. from Lightning" in *Poor Richard's Almanack* for 1753.[4] The basic idea was that a tall, well-grounded conductor with a sharp point at the top will either prevent a discharge by silently discharging the thundercloud so that it can do no harm, or if a discharge does occur, at least the tall rod will provide a preferred place for the lightning to strike, and then the associated grounding conductors will guide the current into the ground and prevent damage.

In modern terminology,[5] the three key elements of Franklin's design are: (1) one or more metallic *air terminals* are mounted on the roof of the structure, and (2) horizontal *roof conductors* and vertical *down conductors* connect these terminals to (3) a *grounding system* that provides an electrical connection to earth. Since Franklin initially thought that silent, point discharges might provide protection, the first air terminals were thin, sharp needles inserted into the end of iron bars, and the first down conductors were chains of nail rods, each several feet long, that were mechanically linked or hooked together. These elements would work well at the low current levels of point discharges, but they were not adequate at the very much larger currents that flow in direct lightning strikes.[6]

By 1762 enough experience had been gained through practice for Franklin to make the following recommendations for an improved system: [6]

- the air terminals should be one-inch diameter, steel rods, 5 to 6 feet long and tapered to a sharp point. If the building had any dimension larger that about 100 feet, a pointed rod should be mounted at each end and that there should be a conductor between them.
- All roof and down conductors should be continuous, at least half an inch in diameter, and they should be mounted on the outside of the building. If any links or joints must be made in these conductors, the links should be filled with lead solder to maintain electrical continuity.
- The grounding conductor should be a one-inch diameter iron rod driven 10 to 12 feet into the earth, and if possible, this conductor should be kept at least 10 feet away from the foundation. Franklin also stated that the ground rods should be painted in order to minimize rust, and that connecting them to the water of a well was best, if a well was nearby.

2. Protection of Gunpowder

In August, 1769, lightning struck the tower of the church of St. Nazaire in Brescia, Italy, and the current passed through vaults where 207,000 pounds of gunpowder had been stored for safe-keeping; [7] the resulting explosion killed about 3000 people and destroyed one-sixth of the city. In response to this disaster, the British parliament passed two acts establishing standards for the manufacture and storage of gunpowder in private hands, and in May 1772, the Board of Ordnance asked Benjamin Wilson and later Franklin to make recommendations for protecting the new arsenal at Purfleet from the effects of lightning.[8] This request was the beginning of a long controversy between Wilson and Franklin about whether the air terminals should be tall and have sharp points, as recommended by Franklin, or whether they should be mounted just below the roof in the form of round balls, as recommended by Wilson. Further review of the Purfleet arsenal by a committee of the Royal Society (both Wilson and Franklin were members of that committee) and a large experiment with model structures eventually led to a recommendation to protect gunpowder magazines using Franklin's scheme. Franklin also recommended that the following specific improvements be implemented at Purfleet:[8]

- Eliminate all vertical bars of iron that had been installed in the roof because these together with the copper hoops on the barrels of gunpowder might form an incomplete conductor between the roof and the ground;
- Tall rods (at least 10 feet long), 1 inch in diameter, should be mounted at each end of the building, and these should be connected to the lead coping that covered the ridge of the roof and to the grounding conductors; and

- Improve the grounding system by keeping the down conductors continuous and connected to wells that went below the water table.

In 1776, Franklin went to Paris as a minister to the court of France to solicit aid for the American revolution (including gunpowder). While he was in Paris, he attended meetings of the Royal Academy of Sciences and, because of his background and experience with lightning, he participated on several committees that reviewed the protection of special structures such as cathedrals and powder magazines.

In May, 1780, Franklin received the following request from his friend Jan Ingenhousz, physician to the court of Austria and the discoverer of photosynthesis:

> "If you could communicate to me some short hints, which may occur to you about the most convenient manner of constructing gun powder magazines, the manner of preserving the powder from moisture and securing the building in the best manner from the effects of lightning, you would ablidge me." [9]

Franklin's reply is of particular interest because it represented a radically new approach, and it did not depend on any lightning rods or even grounding conductors:

"With regard to Powder Magazines

> My idea is,
>
> That to prevent the Mischief which might be occasion'd by the Stones of their Walls flying about in case of accidental Explosion, they should be constructed in the Ground; that the Walls should be lined with Lead; the Floor Lead; all ¼ Inch thick & the Joints well solder'd; the Cover Copper; with a little Scuttle to enter, the whole in the Form of a Canister for Tea. If the Edges of the Cover scuttle fall into a Copper Channel containing Mercury, not the smallest Particle of Air or Moisture can enter to the Powder, even tho' the Walls stood in Water or the whole was under Water." [10]

It is noteworthy that 96 years later (in 1876) the famous Scottish physicist, James Clerk Maxwell, made almost the same recommendation for protecting powder-mills:

> "What we really wish to prevent is the possibility of an electric discharge taking place within a certain region – say, in the inside of a gunpowder manufactory. If this is clearly laid down as our object, the method of securing it is equally clear."
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> "It would, therefore, be sufficient to surround our powder-mill with a conducting material, to shield its roof, walls, and ground-floor with thick sheet-copper, and then no electrical effect could occur within it on account of any thunderstorm outside." [11]

Today the modern lightning literature[12] terms the method of protecting explosive devices or facilities by completely surrounding them with a metal sheath a "Faraday

cage," and the effect of such a cage is the reason one is generally safe inside an airplane or an automobile during a lightning storm. What we have seen here is that this important idea was first introduced by Benjamin Franklin in 1780 and then forgotten until it was re-introduced by Maxwell who apparently had no knowledge of Franklin's priority.

3. Notes and References

[1] Cohen, I. Bernard, *Benjamin Franklin's Experiments: A New Edition of Franklin's Experiments and Observations on Electricity*, Harvard Univ. Press, Cambridge, MA, 1941.

[2] Franklin references are taken from The Papers of Benjamin Franklin, Ed. By L. W. Labaree, W. B. Wilcox, C. A. Lopez, B. B. Oberg, E. R. Cohn et al., Yale University Press, New Haven, CT, Vol. I, 1959 to Vol. 36, 2001 with some capital letters suppressed to conform with modern usage. In the following notes, these volumes will be referred to as BF Papers; the volume number will be in italics, and the page numbers will be inclusive. The detonation of gunpowder by electricity is described in *BF Papers, 4*, 145.

[3] Cohen, I. Bernard, *Benjamin Franklin's Science*, Harvard Univ. Press, Cambridge, MA, 1990, Chapter 6.

[4] *BF Papers, 4,* 408-409.

[5] Krider, E. Philip and Martin A. Uman, "Cloud to ground lightning, lightning protection, and lightning test standards," *Encyclopedia of Electrical and Electronics Engineering*, John Wiley & Sons, New York, *11,* 350-357, 1999.

[6] Krider, E. P., "Benjamin Franklin and the First Lightning Conductors," The Bakken conference on the "History and Cultural Meaning of the Lightning Rod," November 4-6, 2002.

[7] Harris, W. S., *On the Nature of Thunderstorms; and on the Means of Protecting Buildings and Shipping Against the Destructive Effects of Lightning*, John W. Parker, London, 1743. p.163.

[8] See Headnote to BF letter to Richard Dawson, *BF Papers, 19*, 153-154 and also 244-265.

[9] BF Papers 32, 341-346.

[10] *Ibid.* 346-349.

[11} Maxwell, J. C., Report for the British Association for the Advancement of Science, 1876; Quotations taken from *Lightning Conductors, their history, nature, and mode of operation*, 3rd Edition, by Richard Anderson, E. and F. N. Spon, London, 1885, pp. 257-262.

[12] Golde, R. H., *Lightning Protection*, Chemical Publishing Co., New York, 1975, p. 60.