A BRIEF HISTORY OF LIGHTNING PROTECTION

Norman L. Fowler
HQ AFCESA/ENE
Tyndall AFB, Fl. 32403-6001

ABSTRACT

Over the past several years considerable interest has been given by various agencies of the federal government to lightning protection. The lightning protection systems and underlying principles used today have evolved slowly over the 200 plus years Ben Franklin invented the first lightning rod. As knowledge of the lightning phenomenon expands, these principles and systems will continue to evolve. This paper presents a very brief history of this evolution.

BRIEF HISTORY

There has recently been much Department of Defense interest in lightning protection systems. Most of this attention has centered on the adequate safeguarding of conventional and nuclear weapons from the effects of a lightning strike. Some attention has also been given to the use of systems designed to dissipate or prevent lightning. This particular concept has actually been around since Ben Franklin first proposed it in the 1700s.

Most people know of Ben Franklin's kite experiment, but less well-known is the fact that this experiment was the result of his active experimentation with what was then known as "electrical fluid." By extensive experimentation, Franklin had observed that static electricity could be conducted away from a charged sphere by a nearby sharp, iron needle. Noticing the physical similarities between this static electricity and lightning, he wrote the following in 1749." The electrical fluid agrees with lightning in these particulars:

1) Giving light
2) Color of the light
3) Crooked direction
4) Swift motion
5) Being conducted by metals
6) Crack or noise in exploding
7) Subsisting in water or ice
8) Rending bodies it passes through
9) Destroying animals
10) Melting metals
11) Firing flammable substances
12) Sulphureous smell

Franklin further wrote "The electrical fluid is attracted by points. We do not know if this property is in lightning. But

Report Documentation Page

Report Documentation Page	*Form Approved OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **AUG 1992**	2. REPORT TYPE	3. DATES COVERED **00-00-1992 to 00-00-1992**
4. TITLE AND SUBTITLE **A Brief History of Lightning Protection**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **HQ AFCESA/ENE, ,Tyndall AFB,FL,32403-6001**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA260986, Volume III. Minutes of the Twenty-Fifth Explosives Safety Seminar Held in Anaheim, CA on 18-20 August 1992.

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

since they agree in all particulars wherein we can already compare them is it not probable they agree likewise in this? Let the experiment be made." Whereupon in 1750 he flew a kite in a thunderstorm and produced a spark to his hand from a metal key tied to the string. Having proved lightning is a form of electricity, he suggested that thunderstorms could be discharged by elevated, pointed iron rods connected to earth in the same manner as a sharp iron needle conducts electricity away from a charged sphere. After a few trials he proposed another concept for lightning rods. He suggested that if the rods did not discharge the thunderstorm, one of them might intercept a stroke and conduct it safely to earth, thereby protecting the building. Franklin never pursued this second theory and recommended that all rods have sharp points to prevent lightning. It is interesting to note that Franklin's rods were simply long iron rods driven about 3 feet into the ground, stapled to the end of a house and projected 6 or 8 feet above the ridge. Given the average height of houses back then this would make the rod 35' to 40' long (Fig.1). In comparison, modern rods are rarely over 10" long and are connected to cables for grounding purposes.

Almost immediately a disagreement arose in England over the use of sharp rods. King George III equipped his palace with blunt rods in the belief that "sharpened rods might attract lightning and thus promote the mischief that it was hoped to prevent." Controversy continued until by 1878 lightning protection practices were so diverse that the British Meteorological Society (BMS) called an international meeting of engineers and scientists to review existing knowledge and to formulate general rules for the erection of lightning rods. The report issued in 1881 covered current American practices, among them was Joseph Henry's advice that the upper part of the rod should be terminated in a single point, the cone of which should be encased with platinum not less than 1/20" in thickness." Another American advocated the use of cast iron caps on chimneys and other protuberances. The formal position of the report on sharpened rods was the following equivocation: "...it seems best to separate the double functions of the point...beveling it off so that if a disruptive discharge does take place, the full conducting power of the rod may be ready to receive it... At the same time we suggest that at one foot below the extreme top of the upper terminal that there be firmly attached...a copper ring bearing 3 or 4 copper needles, each 6 inches long.." Needless to say, these recommendations did nothing to end the controversy over the best method to protect against lightning.

In 1901, the British Lightning Research Committee was formed to again address the issue. Oddly, this committee devoted little time to the shape of the upper part of rods. Instead it gave more attention to down conductors, the problem of making better contact with the earth, and the area of protection. In a classic bit of equivocation, the committee seemingly endorsed a cone of protection where the base of the protected cone has a radius equal to the height of the rod above ground when it wrote "though this may be sufficiently correct for practical purposes, it cannot always be relied on." Other cones of protection, such as 1:1 3/4 and 1:2, where flatly rejected. Sir Oliver Lodge was a major contributor to the report issued by this committee. Among the ideas that he mentioned in the report and which still form the basis of modern protection are the following:

1) The effect of down conductor self induction needs to be accounted for.

2) Lightning will distribute itself over "such conductors as may be present" with little regard to resistance.

3) Lightning finds "no great difficulty" in traveling great distances through air or any "other medium of rather better conductivity."

4) It prefers to move in a straight line and that "sharp turns bends, or spiral windings in conductors" may lead to side flashes.

Much progress was made, but the configuration of rods remained predictably diverse.

In America in 1904 the National Fire Protection Association (NFPA) adopted the first edition of NFPA #78, The National Lightning Protection Code. This was the first American national concensus standard. While not specifically addressing point discharge controversy, its advent paralleled the rapidly growing electrical industry. Miles and miles of overhead lines were being strung. Metallic conductors installed to bring electricity into buildings also brought lightning. The lightning induced power outage thus came into being. Surge arresters were developed as knowledge of lightning protection struggled to keep up with technology.

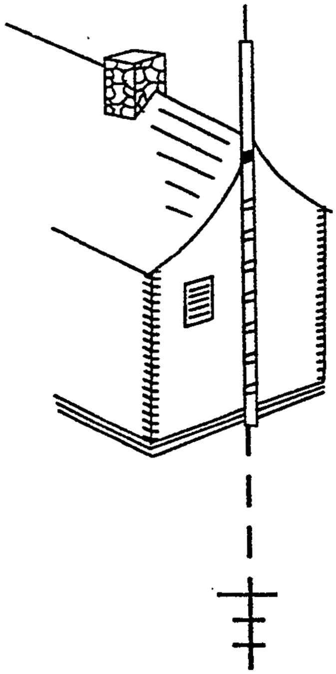
Beginning in 1926, the US government became interested in lightning protection. In the summer of that year, lightning initiated a devastating series of explosions at the Lake Denmark munitions depot in New Jersey. Over a million pounds of explosives were detonated and 19 lives were tragically lost. This catastrophy resulted in the formation of the DOD Explosives Safety Board which still functions today with the charter to oversee and provide guidance and regulations to insure the safety of all US titled munitions. From 1941 through the second world war, much effort was expended protecting arsenals, defense plants, munitions dumps, and related government facilities. The basis of this protection was NFPA #78.

In the late 1970s, a new "zone of protection" concept was introduced - the rolling ball concept. Experience had shown that traditional straight line "cones of protection" from the tip of the lightning rod to some distance on the ground could not always be depended upon to provide full protection. The rolling ball concept has proven to be effective because lightning advances from cloud to earth in discrete distances or steps of about 150 ft. Only when a downward stroke reaches a distance of about 150′ above the earth will it be positively attracted to a point to be struck. This concept of area of protection is easiest to understand by visualizing a weightless ball (or sphere) with a 150 ft radius rolling over the surface of the earth and up and over all projections above the earth's surface (Fig 2). Anything touched by the ball is susceptible to being struck by lightning, while all objects not touched by virtue of the ball being lifted over them by higher objects are protected.

Presently, some of the more interesting (and DOD pertinent) research is being conducted by Mr Marvin Morris of Sandia National Laboratories in Albuquerque, NM. By using modern instrumentation and rocket-triggered lightning, Mr Morris and his associates have been able to measure the voltage, electric, and magnetic fields generated inside an earth covered munitions igloo during a lightning strike. Current densities in the various paths to ground were also measured. This research has turned up some surprising data which may eventually change lightning protection on DOD munitions facilities. Electric and magnetic fields were measured below harmful levels while voltage levels were low enough to permit a minimum 12 inch separation from walls and metal masses without causing a flash over. One of the most interesting findings was that most of the current from the lightning stroke was conducted through the structure re-bar system to the floor and foundation and then to earth. A very small percentage of current actually passed through the down conductors to the ground rods and earth. This, of course, is because the massive re-bar system in a typical igloo has much less inductance than the down conductors. A very significant discovery is that rise time (the amount of time it takes the lightning induced impulses to reach maximum value) is 3 times faster (.3 micro seconds) than previously thought. This has implications in DOD munitions maintenance and inspection building where a faster rise time can more easily induce current into weapons open for maintenance. This research is continuing and hopefully will result in DOD components being able to spend their lightning protection design and maintenance money more wisely.

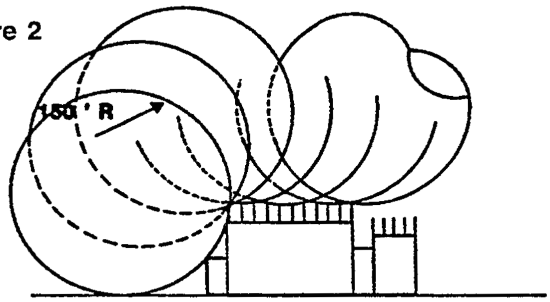
But what about the controversy of sharp points either attracting lightning on bleeding the charge from a cloud? It is now well known that sharpened rods do not sufficiently dissipate electrical charges in active thunderclouds overhead, nor do they attract lightning. Nature is full of these point discharge sources which disprove the dissipation/attraction theory. A pine forest has literally millions of point discharge sources (pine needles) yet lightning does strike it and at a rate well within statistical bounds. Notwithstanding this and other scientific data, systems are still being sold today based on their ability to prevent lightning strikes. In the late 1980s, the Federal Aviation Administration (FAA) installed lightning dissipation systems at the Orlando and Tampa airports for the

Figure 1



BEN FRANKLIN'S LIGHTNING ROD
(ADAPTED FROM LIGHTNING PROTECTION INSTITUTE STUDY COURSE)

Figure 2



ROLLING BALL CONCEPT OF AREA PROTECTION
(ADAPTED FROM NFPA #78)

purpose of testing the effectiveness of these systems. The systems were monitored closely for 2 years. In 1991, the FAA gave Congressional testimony that these systems were not anymore effective against lightning than conventional systems. In other words, they did not prevent lightning strikes. This is ironic since the inventor of the lightning rod, Ben Franklin, invented it for the purpose of slowly and silently drawing "the electric fire from the cloud."

CONCLUSION

As we move into the 21st century lightning protection will become more important. Many of the technological devices commonplace today are more susceptible to lightning damage that their "low tech" predecessors. Smaller, faster, more sensitive computers and composite materials for aircraft are examples of technologies which will challenge modern lightning research. Today's rapidly changing technologies and the attending research will surely effect how DOD operates. It appears that the history of lightning protection has just begun.

References:

[1] C.B. Moore, M. Brook, E.P. Krider, A Study of Lightning Protection Systems, The Atmospheric Science Program of The Office of Naval Research, Oct 1981.

[2] Ralph H. Lee, Protection Zone for Buildings Against Lightning Strokes using Transmission Line Protection Practice, IEEE Transactions on Industry Applications, Vol IA-14, No. 6, Nov/Dec 1978.

[3] Home Study Course, School of Lightning Protection, 1985.