REPORT OF THE THIRD-PARTY INDEPENDENT EVALUATION PANEL ON THE EARLY STREAMER EMISSION LIGHTNING PROTECTION TECHNOLOGY

BY

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Submitted to the National Fire Protection Association Standards Council on September 1, 1999

EXHIBIT E

OBTAIN FROM MARY MAYNARD, #001

PREFACE

This report is the result of the collaborative and cooperative efforts of the three independent evaluators in reaching a complete and full consensus on the content of the report and the recommendations to the National Fire Protection Association Standards Council. Each evaluator certifies as to his full and complete agreement with the report as prepared and submitted to the National fire Protection Association Standards Council on September 1, 1999.

Name _____

Date 8-14-99

Name _____

Date August 19, 1999

Name _____

Date AUGUST 23, 1999

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I. INTRODUCTION

A. Purpose of Panel

The third-party independent evaluation panel was created by the legal Agreement of Settlement and Release between the National fire Protection Association and the National Lightning Protection Corp., Heary Bros. Lightning Protection Co., Inc. and Lightning Preventor of America, Inc. (297) The agreement was accepted by the National fire Protection Association Standards Council on October 8, 1998 (296) as follows:

> At its meeting on October 8, 1998, the Standards Council considered the request of Linda Joseph, representing Heary Bros. Lightning Protection Co., Inc., Lightning Preventor of America, Inc. and National Lightning Protection Corp. The request asks the Council to reopen the proceedings for issuance of a standard for Early Streamer Emission ("ESE") lightning Protection Systems, and to conduct a *de novo* review, re-weighing and considering all evidence, including evidence not previously available, anew. (For the history of previous proceedings, see especially, the Standards Council decision of July 18,1995, Agenda item 94-5, D#95-25, and the Standards Council decision of January 12, 1994, Agenda item 94-5, D#94-11). Specifically the request seeks to have the Standards Council reopen the proceedings and reconsider the issuance of a standard for ESE lightning Protection systems along the lines set forth in a proposed settlement agreement which would resolve litigation by the requesting parties against NFPA ("Settlement Agreement"). A Copy of the Settlement Agreement has been made a part of the record.
>
> After a hearing and consideration of the entire record before it, the Standards Council has concluded that reopening the proceedings pursuant to the request and in accordance with the Settlement Agreement is appropriate, will allow the Council to give full consideration to any existing and new information that is available, and is fully consistent with the regulations and procedures of the

NFPA and the Standards Council. The Council therefore, has voted to grant the request. Specifically, the Council, by this decision, undertakes to reopen the proceedings for consideration of issuance of a standard for ESE Lightning Protection Systems in full accordance with the terms of the Settlement Agreement.[1]

The instructions to the third-party independent evaluation panel as contained in the Settlement Agreement were specific and are presented as follows:

> f. As proposed by the Plaintiffs, the independent third-party shall consist of a panel headed by Dr. John Bryan, with one or two scientists or similarly-qualified technical persons chosen by Dr. Bryan. No person at the National Institutes of Standards and Technology ("NIST") who prepared or assisted in any way in the report on ESE technology previously issued by NIST, or any person who submitted comments in connection with the NIST report, shall be a member of this panel. If, for any reason, a member of this panel is unable to participate in the third-party evaluation, the evaluation shall be completed by the remaining member(s) of the panel or a substitute panel member may be chosen by Dr. Bryan. This panel, in issuing its report, shall address the following issues, and any other issues it deems relevant: (1) whether the ESE lightning protection technology is scientifically and technically sound; and (2) whether the ESE lightning protection technology is supported by adequate scientific theoretical basis and laboratory testing. The independent third party shall be instructed to specifically address in its report how it has addressed any and all issues.[2]

B. Panel Formation

The selection of the third-party independent panel members was

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[1]NFPA, Decision of The Standards Council, "NFPA 781", West Point, NY, 10-8-98, p. 1.

[2]NFPA, Agreement of Settlement and Release, "ESE Lightning Protection Systems", West Point, NY, 10-8-98, p 4.

completed on October 23, 1998 and the two additional panel members were Richard G. Biermann, Des Moines, IA and Glenn A. Erickson, Hastings, MN. None of the panel members were atmospheric scientists or "lightning experts", and did not claim to have expertise in the lightning protection study area.

The panel members were selected because of their long and varied experience in building, electrical and fire code development and the consensus standards process of the National Fire Protection Association and other code development organizations. The panel members were selected by the Chair for their consensus standards committee experience with their professional and personal reputations for reliable, fair, equitable and valid consideration of the consensus code and standards process.

The National Fire Protection Association agreed to provide administrative support for the third-party independent panel through the Codes and Standards Administration Division with Leona A. Nisbet as it's Director.

C. Information Solicitation

As a portion of the Settlement and Agreement it was stipulated that material and information could be provided for consideration by the third-party independent panel from any interested party. Thus, an announcement was prepared in October, 1998 by the Chair of the third-party independent panel with Leona A. Nesbit, Director of NFPA's Codes and Standards.

This solicitation announcement was published in NFPA publications and other trade journals in November, 1998 in the following format:

> Early Streamer Emission (ESE) Lightning Protection Technology To Be Studied
>
> At its October 1998 meeting, the Standards Council agreed to reopen proceedings on the issuance of a standard on Early Streamer Emission (ESE) Lightning Protection Systems. In connection with this decision, the Council authorized the creation of an independent panel which will be issuing a report concerning ESE lightning protection technology to the Council.
>
> This panel will be chaired by Dr. John L. Bryan, Frederick, MD, who has designated Mr. Richard Biermann, Des Moines, IA and Mr. Glenn Erickson, Hastings, MN to serve with him on the panel.
>
> The panel will address the following issues, and any other issues it deems relevant: 1)whether ESE lightning protection technology is scientifically and technically sound; and 2) whether the ESE lightning protection technology is supported by an adequate scientific theoretical basis and laboratory testing. The panel is inviting anyone with information which may be relevant to its inquiry, to submit it for the panel's consideration.
>
> Anyone wishing to submit information to the Panel, should send it no later than 1 March 1999 to the attention of NFPA Codes and Standards Administration, NFPA, 1 Batterymarch Park, Quincy, MA USA 02269-9101 (fax: 617-770-3500).[3]

D. Number and Types of Materials Reviewed

From the published deadline for the receipt of information of March 1, 1999 the third-party independent panel received and reviewed a total of

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[3]National Fire Protection Association, NFPA News, Vol. 2, Number 1, December 1998, p. 1.

377 items as itemized and listed in the Bibliography in section IV of this report. The tabulation of these materials is presented as follows:

Summary of ESE Third-Party Evaluation Panel Materials Reviewed

Personal Communications-Letters (to)	
Third-Party Ind. Panel .	75
NFPA Personnel . .	48
Others . . .	55
Total =	178
Reports, Papers, Documents (From)	
Public . . .	163
NFPA Standards System .	36
Total =	199
Total All Materials = .	377

II. PANEL EVALUATION

The third-party evaluation panel decisions were developed through a consensus discussion involving all three panel members from the individual panel member's review of the submitted documents and personal communications. All of the items submitted to the panel obviously

influenced the deliberations and decisions of the panel. However, the numbers of the documents from item IV. A Selected Bibliography, are referenced where it appeared the specific document was significantly related to the panel's decision as are the referenced quotations.

A. Scientific and Technical Basis of ESE

Before considering the specific questions posed to the third-party evaluation panel it would appear to be essential to understand the concept and philosophy of the early streamer emission lightning protection technology. Allen *et al.,* (10) have provided the following explanation of the ESE concept:

> A simple passive Franklin rod, on the roof of a large building, may not give full protection against a strike to the fabric, since upward corona may be initiated at parts of the structure more favorably placed in relation to the downward leader. However, if the corona can be activated at an earlier time in the downward progress, development of the upward leader may be advanced sufficiently, by such an activated rod, to overcome the distance disadvantage and effect an attachment before corona at other sites can develop sufficiently to compete with it. Extension of this argument suggests that the corona set up at the active rod, place centrally, for example, could replace the coronas from the separate passive rods place in a conventional system around the roof of the building.
>
> This principle forms the basis of the so-called "early streamer emission" devices which have been developed in recent years.[4]

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[4]Allen, N.L., K.J. Cornick. D.C. Faircloth and C.M. Kouzis, "Tests of The Early Streamer Emission Principle for Protection Against Lightning", IEEE Proceedings Science Measurement Technology, Vol. 145, No. 5, 9-98, p. 200.

The specific question charged to the independent third-party evaluation panel in the Settlement Agreement was: "whether the ESE lightning protection technology is scientifically and technically sound." The panel determined this question could only be answered validly with an examination of the laboratory tests (small-scale) and the Field tests (large-scale) data provided to it in the submitted documents.

1. Consideration of Laboratory Tests

A number of "lightning protection researchers" indicated their conclusions that laboratory tests did not adequately simulate lightning in the natural state due to the difference in scale between the laboratory arcs and the natural stroke lengths with the difference between positive and negative lightning. (249) (353) Pederson (312) has indicated a general caution relative to the application of laboratory tests in the following manner:

> High voltage laboratories have been extensively used to simulate lightning phenomena. However, such simulations should be performed and interpreted with great care.[5]

However, small scale tests have been proven effective in examining specific aspects of the various types of lighting system air terminals, in particular by measuring the number of laboratory arcs attracted with the timing of the attraction of the arcs. In general, the laboratory tests have indicated the ESE terminals have a recorded advantage in the attraction of

[5]Pederson, Aage, A. Bondiv-Clargerie, V. Cooray and L. Dellera, "Lightning Threat and Protection in Perspective", International Conference on Lightning Protection, ICLP, Birmingham, 9-98, p. 1.

the laboratory arc or are equivalent in the attraction of the arc to the Franklin terminal. (NFPA 780 recognized) Allen *et al.,* (10) have indicated the results of their laboratory comparison of a ESE terminal and a traditional Franklin rod in the following terms:

> It is shown that the ESE devices showed a small advantage, in time to breakdown, over the Franklin rod.[6]

Chalmers *et al.,* (62) indicated in their laboratory tests of ESE devices and Franklin rods that one ESE device reached breakdown at a time significantly earlier than the Franklin rod and two ESE devices caused discharges at the same time or later than a Franklin Rod. In addition these researchers indicated that Franklin rods of different shapes resulted in varying times to breakdown.

Berger (20) concludes his laboratory studies comparing the conventional Franklin rod with a pulsating ESE terminal in the following manner:

> The conventional Franklin rod has been tested and then compared to an air-terminal using an Early Streamer Emission (E.S.E.) triggering device designed to enhance the protection area of the Franklin rod. Extensive tests have shown that a high voltage pulse E.S.E. air-terminal is more effective than the conventional Franklin rod used in the standards.[7]

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[6]Allen, N.L., K.J. Cornick. D.C. Faircloth and C.M. Kouzis, "Tests of The Early Streamer Emission Principle for Protection Against Lightning", IEEE Proceedings Science Measurement Technology, Vol. 145, No. 5, 9-98, p. 200.

[7]Berger, Gerard, "Testing to Show a Time Advantage in Production of a Lightning Up Leader", CRNS Laboratoire De Physique Des Discharges, p. 1.

A series of laboratory evaluations were conducted on three various ionizing ESE air terminals by the ETL testing organization in 1995, comparing the initiation time of the device in comparison with a standard Franklin air terminal. (89) (91) (93) The examination was under laboratory conditions with the initiation time of the devices measured in nanoseconds, with 100 strikes to the devices. The three ESE devices all were reported to have lower initiation times than the Franklin rod, varying from a difference of 13.74 nanoseconds to 47.58 nanoseconds with the mean difference being 25.18 nanoseconds. In addition, ETL conducted a similar comparison evaluation between a standard sharp-pointed Franklin rod and a rounded Franklin rod and found a difference in the initiation time of 0.44 nanosecond. (95)

The Department of Electrical Engineering and Electronics at the University of Manchester Institute of Science and Technology (76) conducted Laboratory evaluation studies between three ESE devices and a standard Franklin rod. With one ESE device the Franklin rod was struck 27 times and the ESE device was struck 22 times. With the second ESE device the Franklin rod was struck 72 times and the ESE device was struck 42 times. The evaluation between the third ESE device and the Franklin rod resulted in each of the devices being struck 101 times, with eight discharges striking neither device. During this entire evaluation program in the laboratory a total of 420 electrical discharges were generated, with

200 of these discharges striking the Franklin rod for 47.6 per cent, 165 discharges striking the ESE device for 39.3 per cent, and 55 discharges did not strike either device for 13.1 percent of the discharges. The conclusion of this study were stated as follows:

> The results produced from this test show a complete random nature of discharges to the Franklin and ESE terminals under identical electrical and geometrical conditions. They did not substantiate claims of enhanced properties from the ESE terminals.[8]

The disparity of results from the conducted laboratory evaluations of lightning protection air terminals may arise from a number of intervening variables involving the location of the devices, the interference of each device to the performance of the other device, the intensity of the laboratory discharge and the gap provided in the laboratory for the electrical discharge. Montadon (236) has reminded us of a fact related to any air terminal as follows:

> It is well known that a Franklin rod cannot provide a 100 % protection against lightning discharges to its surroundings. Therefore it is a challenge to study on one hand side the protection efficiency of such a rod and on the other side to try to enhance the efficiency by all kinds of additional devices.[9]

Van Brunt *et al.*, (369) in the NIST report have elaborated on the view by Montandon relative to the effectiveness of lightning protection

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[8]Department of Electrical Engineering and Electronics, "Report on The Results of Tests of ESE & Franklin Terminals", The University of Manchester, Institute of Science and Technology, Test Report No. 43427, p. 6.

[9]236. Montandon, Eric, Consultant-Switzerland, "Personal Communication & Papers", 2-16-99, p. 1.

air terminals in the following manner:

> There is no reason to believe that an air terminal is 100% efficient in attracting lightning, regardless of what kind of ESE device it uses, if any. Considering the wide range of possible atmospheric conditions and types of lightning behavior that have been recorded, it is not surprising that air terminals of all types will sometimes fail. Tall structures are reported to be struck occasionally by lightning at points far below the top, i.e., outside of the "protection zone". Any claims of 100% efficiency in the performance of a lightning attractor should be viewed with skepticism.[10]

Grumley and Berger (140) have indicated that they believe the efficiency of an air terminal is related to both the design of the air terminal and the height penetration of the electrical intensification in the following manner:

> Importantly, the electrical field intensification of an air terminal is related to the height penetration into the electrical field and its radius of curvature. This suggests that there is no universal air terminal.[11]

Heary, *et al.* (154) (162) have reported on laboratory tests under varying atmospheric conditions with the use of exterior and interior test arrangements. Their conclusions indicated that atmospheric lightning thunderstorm conditions are necessary for air terminal testing and a superiority of the ionizing terminal over the standard air terminal.

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[10]Van Brunt, Richard J., Thomas L. Nelson, Samar L. Firebaugh, Early Streamer Emission Air Terminals Lightning Protection Systems: Literature Review and Technical Analysis, Quincy, MA, National Fire protection Research Foundation, 1-31-95, p. 25.

[11]Gumley, J. R., G. Berger, A Review of The Lightning Attachment Process and Requirements to Achieve Improved Modeling, Erico Lightning Technologies, Hobart, Australia, p. 3.

2. Consideration of Field Tests

It would appear from the literature that field tests of the performance of lightning protection system air terminals are as controversial as are the laboratory tests of air terminals. Field tests are subject to the occurrence of natural atmospheric conditions conducive to the initiation of lightning strikes. Thus, rockets trailing wire leaders to induced charges have been utilized in some field experiments.

Moore (249) has discussed the difference in the environmental situation between the generator created electrical arc in the laboratory and the natural lightning, and thus, the necessity for external field tests for the evaluation of air terminals as follows:

> Such a laboratory test does not simulate how a given rod would respond to natural lightning because there is insufficient time in the laboratory tests for the ions created by the strong fields to move above the tip of a rod as they would during a natural strike. Streamers can be provoked from all manner of proposed air terminals in the laboratory with no indication as to how they would serve as lightning protectors; any differences in their behavior appear to be caused by their shapes, not by their protective capabilities.[12]

Eybert Berard *et al.,* (97) have reported on field tests conducted in St. Privar d'Allier France in 1996 and at Camp Blanding Florida in 1993 to 1995 utilizing the rocket triggering system to an altitude of 500 to 800

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[12]Moore, Charles B., New Mexico Tech., "Personal Communication, Papers & Photos", 2-16-99, p. 2.

meters. These experiments appeared to be rather limited due to the atmospheric conditions. However, they did indicate the voltage the ESE device received with out a loss of operational capability, and the reported domination of the ESE device over a simple rod.

Gumley *et al.*, (142) have reported on an experimental test site operational during the 1997-98 storm season in northern Australia. A total of 500 triggering events were recorded with the largest event recording an electrical field at ground of 100 kV/m. From an analysis of the large event they concluded that their air terminal arrangement produced field intensification that may be too high for optimum leader development

Rison, and Moore *et al.*, (244) (245) (337) have conducted studies with air terminals exposed to natural thunderstorms at the Langmuir Laboratory for Atmospheric Research of the New Mexico Institute of Mining and Technology. These evaluations have concentrated on comparing the performance of both blunt and sharp-pointed Franklin rods in addition to comparing the performance of ESE air terminals and Franklin rods (248) (336) in the natural environment of an exposure near the summit of 3,287 m high South Baldy Peak. These studies comparing the sharp-pointed and the blunt Franklin rods indicated the blunt rods were more effective. Over a four-year period nine blunt rods were involved with cloud to ground discharges while none of the adjacent sharp-pointed rods appeared to have been struck.

Rison (336) reported in 1991 on studies conducted at the Langmuir Laboratory from July 15 to august 23, 1991 to evaluate whether a radioactive ESE air terminal provided protection within a 100 meter radius as reported by the Manufacturer. The ESE device was installed on a twenty foot mast 4 meters below South Baldy Peak. Video cameras were used to record the occurrence of lightning strikes. There were two recorded lightning strikes within the 100 meter radius area during the approximate five week study, one 85 meters from the ESE device and one approximately 78 meters from the device. However, the following statement should be noted from the report:

> Near the end of the test period, it was noticed that the radioactive Preventor had been damaged --the weld had broken between the spherical ball on the Preventor and the nut to which it attached. It is not certain when or how this happened. There was no evidence of tampering or vandalism. Examination of the tip of the Preventor under a microscope showed evidence of melting, such as would occur if lightning were to have struck it. Most likely, the Preventor was struck by lightning at a time when the camcorders were not turned on (when the peak was in a cloud, or a storm occurred in the early morning hours), and the lightning broke the weld.[13]

Thus, it might appear that the ESE device was active in a lightning strike not recorded by the video cameras utilized during the study, since there were periods during the study when the cameras were inactive.

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[13]Rison, William, A Study of Lightning Strikes in The Vicinity of a Radioactive Preventor, Langmuir Laboratory, New Mexico Tech., Socorro, NM, 11-8-91, p. 4.

Moore *et al.* (248) reported in 1998 a summary of all the field tests of the radioactive "Preventor" ESE device during the summers of 1990, 1991, 1993, 1994, 1995, 1996, and 1997. Moore's analysis is as follows:

> In the six summers during which the "preventor" was exposed to thunderstorms overhead, lightning struck six different sites within 100 meters of the device yet the "preventor" itself was never struck.
>
> Digitized measurements with quarter-microsecond time resolution, of the currents that flowed from the "Preventor" during two nearby lightning strikes in September 1997 showed no indication that the "Preventor" emitted any effective "early streamers". In fact, during one of these discharges, lightning struck a blunt rod located 20 meters distant yet no streamers were emitted from the "Preventor" to connect with this close strike.[14]

It should be noted these seven-year tests involved a single ESE device of a radioactive type. It should also be noted that Moore's (243) field studies under natural lightning conditions have questioned the validity of the effectiveness of the sharp-pointed Franklin air terminal as follows:

> The failure of radioactive-ionizing and of sharply pointed air terminals to participate in lightning discharges by being pre-eminent connectors of lightning to earth is no surprise to scientists studying thunderstorms and lightning. For the past 40 years, I have been measuring the electric currents flowing into the air from both radioactive electrodes and from sharply pointed ones under the influence of the strong electric fields beneath thunderstorms but not one of my well-exposed electrodes has ever been struck by lightning.[15]

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[14]Moore, C. B., William Rison, and G. D. Aulich, An Assessment of The Radioactive "Preventor" as an Early Streamer Emitting Lightning Protector, New Mexico Tech., Langmuir Laboratory for Atmospheric Research, Socorro,NM, 12-29-98, pp. 24-25.

[15]243. Moore, Charles B., New Mexico Tech., "Personal Communication to Subcommittee of NFPA Board of Directors", 9-4-95, p. 1.

The NIST study by Van Brunt *et al.* (369) has summarized the contributions of both the laboratory and the field tests to the continuing debate as to the effectiveness of the ESE air terminals in the following manner:

> Although much has been learned about the operation of ESE terminals compared to conventional terminals from laboratory-scale tests which suggest that ESE devices do indeed enhance streamer emission, these results have not, and probably cannot, be used to make quantitative determinations of the relative efficiencies of these terminals for atmospheric conditions under a thunderstorm. At the present time, the results from a limited number of field tests with natural lightning are inconclusive with respect to providing estimates of relative efficiencies. It is not clear that enough data can ever be acquired from such tests to draw quantitative conclusions about attraction efficiency. Tests in the natural environment appear to be most useful in identifying and documenting conditions under which air terminals fail.[16]

B. Adequacy of Theoretical Basis and Lab Tests

The third-party independent evaluation panel was charged in the Settlement Agreement with evaluating the following question: "whether the ESE lightning protection technology is supported by adequate scientific theoretical basis and laboratory testing." The evaluation of this question necessitated an examination of the submitted documents. The role of laboratory testing has been examined in answering the previous question relative to the basis of ESE technology.

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[16]Van Brunt, Richard J., Thomas L. Nelson, Samar L. Firebaugh, Early Streamer Emission Air Terminals Lightning Protection Systems: Literature Review and Technical Analysis, Quincy, MA, National Fire protection Research Foundation, 1-31-95, P. 26.

1. Consideration of Scientific Theoretical Basis

The scientific and theoretical basis for the ESE lightning protection technology appears to be based on the laboratory performance of the air terminals shown to be superior or at least equivalent to the Franklin rod.

Berger (31) has indicated that it is possible to predict the threshold field Ei for the activation of the ESE air terminal from the laboratory experiments in the following manner:

> This concept leads to predict the threshold field Ei (initiation field) generated by the negative lightning downward leader for which the positive upward leader starts its continuous propagation from the tip of a lightning rod conductor the height h of which being known.[17]

As was indicated in the previous section of this report there appears to be no correlation between the performance of the ESE or Franklin air terminals in the high voltage laboratory situations and the field test results under natural lightning storm conditions. Almost all of the laboratory comparative tests have been between the radioactive ESE air terminals and the conventional Franklin air terminal. The material submitted to the independent third-party evaluation panel contains little data on tests of the sparking type of ESE devices. As Moore (242) (243) (249) has indicated the seven year field tests did not result in the activation of a radioactive ESE device and in 40 years the activation of a Franklin rod.

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[17]Berger, Gerard, Expert Testimony, U.S. District Court, District of Arizona, 11-16-98, p. 1.

Van Brunt *et al.* (369) in the NIST report has indicated there appears to be some physical basis for the ESE air terminals from the laboratory tests, but the efficiency of this basis has not been determined in the natural lightning situation. This information was presented as folows:

> A reasonable physical basis for the operation of an ESE device appears to exist in the sense that there is good evidence from laboratory investigations that the probability of initiating a streamer discharge from an electrode can be increased significantly by irradiation or electrical triggering. However, the precise amount by which this enhancement in streamer initiation improves the lightning attraction efficiency of an air terminal remains questionable. There is reason to doubt that it significantly extends the maximum range of protection.[18]

In contrast, Moore (249) reports the following experimental experience relative to the ESE lightning protection technology:

> On the other hand, a September 1998, high-speed, digitized measurement of the current flowing from the tip of a standard, UL-approved, sharp-tipped Franklin rod during a strike to Earth 155-meters distance showed that it emitted three early streamers starting at about 260 microseconds before the strike. This sequence is shown in Figures 2 and 3. These streamers carried the largest currents we have yet measured and they were early enough to meet the early streamer criteria. None of these early streamers connected with the approaching lightning, however; after emission and early propagation, they all extinguished without contact with the negative, stepped leader, probably because the electric fields at their tips were not strong enough for continued propagation.
>
> This of course, is why the so-called "early streamer" hypothesis fails. The factor that determines the continued propagation of an upward-going streamer is the strength of the electric field ahead of the leader

[18]Van Brunt, Richard J., Thomas L. Nelson, Samar L. Firebaugh, Early Streamer Emission Air Terminals Lightning Protection Systems: Literature Review and Technical Analysis, Quincy, MA, National Fire protection Research Foundation,1-31-95, p. 25.

> tip, not increased ionization back at the air terminal, the feature claimed for the ESE devices.[19]

Mackerras, *et al.,* (219) have reviewed the performance of ESE air terminals in the laboratory experiments and the field studies, as well as the studies of the performance of the ESE lightning protection systems. They essentially agree with Moore (249) and have concluded the propagation of a leader from the tip of the air terminal is not influenced by the characteristics of the air terminal as follows:

> Once a streamer or leader discharge has propagated into the space remote from the air terminal, its further progress depends upon the supply of energy from the electric field in the space near the tip of the discharge and upon the dielectric properties of the air undergoing breakdown. As neither of these factors can be influenced by the air terminal, it is concluded that it is not possible to gain a significant improvement in lightning interception performance by causing the early emission of a streamer from an air terminal.[20]

Mackerras *et al.,* (219) have also indicated they believe there is no physical basis for the claims of enhanced lightning protection from ESE air terminals based on the earlier time of the emission of an upward leader. They indicate that the ESE air terminal is subject to the identical physical laws as any air terminal concerning streamer to leader transition.

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[19]Moore, Charles B., New Mexico Tech., "Personal Communication, Papers & Photos", 2-16-99, p. 4.

[20]Mackerras, D., M. Darveniza and A.C. Liew, "Review of Claimed Enhanced Lightning Protection of Buildings by Early Stream Emission Air Terminals", IEE Proceedings -Science Measurement Technology, Vol. 144, No.1, 1-97, p. 1.

2. Consideration of System Performance

It would appear the ultimate evaluation of any complete lightning protection system would be the performance of the systems as installed on buildings. The submitted materials included one reference to the failure of a conventional system with Franklin rods (328) and there was one newspaper account of a Franklin rod system failure resulting in personnel injuries. (252) There were several studies of failures of ESE lightning protection systems. (146) (220).

The failure of the Franklin rod system resulting in the eleven personnel injuries occurred at the Robert F. Kennedy stadium in Washington, D.C. on June 13, 1998. (252) Richardson reported on the failure of a Franklin rod air terminal located approximately four feet from an externally mounted camera on the building which was damaged by a lightning strike. (328)

Makerras *et al.*, (220) have reported on four cases of lightning striking buildings in Singapore from the late 1960's until the 1980's. Hartono and Robiah (146) have reported on ten cases of failures on buildings protected with ESE lightning protection systems. This study utilized photographs of the building conditions both before and after the reported lightning strikes on the damaged areas of the buildings. It was found from this photographic study the damage appeared to be dependent on the number of strokes received, the strength of the lightning stroke and

the shape of the structure at the point of the stroke. Although not specified in the study Hartono and Robiah have indicated lightning strike damage was found on buildings protected with Franklin air terminals as indicated in the following statement:

> Studies conducted on the buildings equipped with the standard lightning air terminals (Franklin rod type) also exhibited similar lightning damage locations on or near the rooftop. Based on this comparison, we conclude that no advantage can be obtained by using the ESE device in protecting the building against direct lightning strikes.[21]

It should be noted that all of the incidents of system failure submitted to the panel lacked the necessary detailed documentation to enable a valid analysis as to the effectiveness of the system. Even the most detailed photo study lacked the necessary documentation consisting of the following: The manufacture and model of the air terminal. The date the installation was completed, thus establishing the age of the system when the lightning strike occurred. The maintenance and condition of the system when the strike occurred, including the condition of the down conductors and the grounding system. It would appear that detailed documentation of lightning protection system operations or failures is a needed component for the evaluation of the effectiveness of lightning protection systems of all types on various buildings of differing heights and configurations.

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[21]Hartono, Zainal Abidin and Ibrahim Robiah, A Long Term Study on The Performance of Early Streamer Emission Air Terminals in a highly Isokeraunic Region. 2-19-99, p. 2.

Van Brunt *et al.,* (369) has referenced this problem of adequate data on lightning protection system performance in the following manner:

> There are reports of incidents where ESE devices failed to provide the protection specified by the manufacturer [156,158,165,215]. Statistics on the failure of conventional systems have also been documented [109]. When examining reports of "failures", one can always raise questions about their cause, e.g., whether they are primarily a consequence of exaggerated claims made by the manufacturer or a consequence of misuse (faulty installation) of the device. Reports of isolated failures raise legitimate concerns, but are seldom accompanied by enough supporting data about the event to enable a determination of why the failure occurred. Generally it is difficult to draw significant conclusions from single events that can be used to improve system design or evaluate system performance.[22]

Thus, given the present situation of lightning protection system performance not being a priority of the proponents of the systems, the manufacturers, the insurance companies or public officials it would appear little valid information or data relative to a validation of the theoretical basis of the systems will be obtained.

III. RECOMMENDATIONS TO STANDARDS COUNCIL

Based on a thorough and complete evaluation of the 377 items submitted to the third-party independent panel the members of the panel have agreed in a complete consensus on the following recommendations to the National Fire Protection Association Standards Council. It should be

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[22]Van Brunt, Richard J., Thomas L. Nelson, Samar L. Firebaugh, Early Streamer Emission Air Terminals Lightning Protection Systems: Literature Review and Technical Analysis, Quincy, MA, National Fire protection Research Foundation,1-31-95, p. 25.

recognized the Standards Council is the official designated authority on any action to be taken relative to the NFPA lightning protection documents.

A. Scientific and Technical Basis of ESE

The initial question posed to the third-party independent evaluation panel was stated as: "whether the ESE lightning protection technology is scientifically and technically sound." The panel's review of the submitted materials resulted in the following determinations:

1. The ESE air terminals appear to be technically sound since they are generally equivalent to the conventional Franklin air terminal in laboratory experiments.

2. However, neither the ESE air terminals nor the conventional Franklin rod appear to be scientifically or technically sound when evaluated in field tests under natural lightning conditions.

3. The ESE lightning protection technology as currently developed in the installation of complete systems does not appear to be scientifically and technically sound in relation to the claimed areas of protection or the essentials of the grounding system.

B. Adequacy of Theoretical Basis and Lab Tests

The second specific question posed to the third-party independent review panel was stated as: "whether the ESE lightning protection technology is supported by adequate scientific theoretical basis and

laboratory testing." The panel's review of the submitted materials resulted in the following determinations:

1. There does appear to be an adequate theoretical basis for the early streamer emission lightning protection air terminal concept and design from a physical viewpoint.

2. There does not appear to be an adequate theoretical basis for the claimed enhanced areas of protection with limited down conductors and grounding system.

3. The high voltage laboratory tests of the ESE air terminals appear to be adequate in scope and quantity, but they are limited in that they are not equivalent to an evaluation of the complete ESE lightning protection system under natural thunderstorm conditions.

C. NFPA Lightning Protection Documents

The third-party independent evaluation panel was also directed in the Settlement Agreement as follows: "This panel, in issuing its report, shall address the following issues, and any other issues it deems relevant:" The panel considered the issues of the existing NFPA 780 document titled: Standard for The Installation of Lightning Protection Systems 1997 edition. (294) and the proposed NFPA 781 document titled: Standard for Lightning Protection Systems Using Early Streamer Emission Air Terminals. (277) The panel considered the need for each document and each committee's membership and balance in accordance with NFPA

procedures. The panel's review of the submitted materials resulted in the following determinations:

1. The current NFPA 780 Committee should be discharged and the Committee should be completely restructured. The committee needs new and additional memberships in the membership categories of enforcer, consumer, user, insurance, labor, special expert and research/testing..

2. The Council should solicit memberships from prominent users such as: FAA, DOE, DOD, NASA, IBM, Reedy Creek Improvement District, phone, radio, television organizations and electric power utilities.

3. The NFPA 780 document should be reformulated as a Guide or Recommended Practice. It appears to the panel the NFPA 780 document does not meet the NFPA criteria for a standard since the recommended lightning protection system has never been scientifically or technically validated and the Franklin rod air terminals have not been validated in field tests under thunderstorm conditions. The NFPA criteria for a standard as stated in the NFPA 99 Directory (298) is as follows:

> Standard --A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fineprintnote and are not to be consider as part of the requirements of a standard.[23]

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[23]NFPA, National Fire Protection Association 1999 Directory, Quincy, MA, 11-98, p. 52.

It appeared to the panel the NFPA 780 document is currently not suitable for mandatory reference by another standard or code or for adoption into law. The current NFPA 780 document appears to have been recognized by historical precedent rather than by experimental and scientific validation.

4. The current provision in the NFPA 780 document scope as follows: "except those concepts utilizing early streamer emission air terminals." Should be removed. The restructured 780 Committee should include representatives from the total lightning protection community.

D. NFPA Initiatives

The panel in reviewing the submitted material from the NFPA standards system for the years 1986 to 1998 (263 - 297) have developed the following determinations:

1. The NFPA Fire Investigations group should form a task force with an NFPA electrical engineer to conduct detailed documented investigations of lightning strike incidents to provide the needed field experience relative to the performance of lightning protection systems. These investigations should include such needed data as: Manufacturer and installer of the system. Date of installation of the system. Lightning damage to the system. The maintenance and condition of the system, including down conductors, grounding methods and system performance.

2. The NFPA Fire Analysis and Research group should develop a system for collecting the needed notification and statistical data on lightning strike incidents resulting in personal injuries or significant property damage for the investigation task force. Such a system could include the resources of the NFPA International Fire Marshals Association, the Insurance company members of NFPA and Underwriters Laboratories.

3. The Standards Council should monitor the activities of the restructured NFPA 780 committee for a guide or recommended practice document, with semi-annual written reports from the committee staff liaison.

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