

Third-Party Lightning Protection System Certification Program for Explosives Facilities

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Abstract

This paper describes a third-party certification program developed for lightning protection systems (LPS) installed to military specifications, including protection of structures housing explosives. The Extended Master Inspection Program was developed by the Lightning Protection Institute - Inspection Program (LPI-IP) as a supplement to their proven Master Installation Certification Program. The Extended Master Inspection Program provides a respected alternative independent third-party resource for the certification of lightning protection systems for structures housing explosives; addressing NFPA, UFC, Army, Navy, and Air Force explosives safety standards. The paper provides a description of the structure of the program and details the interaction between the installer, authority having jurisdiction (or owner's representative), and certification body (including third-party inspector). It also describes the documentation and distribution of pre-inspection reference material in the form of the lightning protection system inspection plan. The program also addresses the assessment of the grounding and bonding of the LPS and the methods used to do such. The paper describes the interactive process used to quantify what level of electrical testing that would be acceptable to the AHJ.

I. Introduction

The Lightning Protection Institute - Inspection Program (LPI-IP) was established in 2011 as an alternative to Underwriter's Laboratories' third-party certification program for lightning protection system installations. It has become well-established in the field, having provided over 1500 certifications in 2017. The scope of certifications associated with the LPI-IP Master Installation Certification Program are related to NFPA 780 (2017), LPI-175 (2017), and UL 96A (2018). The LPI-IP Inspection Program requires confirmation of parts of the system installation that cannot be visually inspected by requiring photographs and signatures of witnesses to verify the content of the photographs. Such parts of the system include the grounding system and any concealed conductors and components.

Unified Facilities Criteria (UFC) 3-575-01 (2012) requires third party certification for installed lightning protection systems. The US Air Force requires that this third-party certification be provided by organizations other than Underwriters Laboratories. As a response to numerous requests to perform inspections of lightning protection systems for structures housing explosives and fill the need as a certifying body responsive to the needs of these customers, the LPI-IP Extended Master Inspection Program was developed. Details of the program are described in this paper.

Standards for ammunition and explosives (AE) facilities are generally based on DoD 6055.09-M, Volume 2 (2012) and NFPA 780, Chapter 8 (2017). NFPA 780 (2017), 8.10 requires that the

initial installation of lightning protection for explosives facilities be inspected by a party approved by the authority having jurisdiction (AHJ). Each service has an implementing document for AE facilities.

II. General Description

The Master Installation Certification is applicable to a lightning protection system for the complete structure. The Master Installation Certification Program also has certifications available for a *Reconditioned Master Installation Certificate*, applicable for structures that have been previously certified and are upgraded to meet current standards, and a *Limited Scope Inspection Report*, which includes certification of an LPS specific to only part of a structure (e.g., a radar dome, renewable energy system, cooling tower, etc.). The Extended Master Inspection Certification Program does not currently offer reconditioned or limited scope certifications but does provide an option for a certification that does not address the surge protection requirements of the applicable standards.

The Extended Master Inspection Program is based on the concepts of the proven Master Installation Certification Program. Both have the requirement that the General Contractor, Electrical Contractor, or Owner's Representative witness the installation of any parts of the grounding and lightning protection system that will be concealed at the time of the completion inspection. Photographs that capture the details of the installation are required to be included with the application, along with the identification of the witness verifying the authenticity of the information provided. LPS design drawings are also forwarded with the application. Once the application is received, a staff engineer reviews the package for compliance with the identified standard(s) and a field inspection is scheduled to confirm the installation meets the standard(s).

The Extended Master Inspection Program differs from the Master Installation Certification Program in that the Extended Master Inspection Program requires electrical resistance to earth and bonding testing in accordance with the specified standard and that a lightning protection test plan be provided that identifies the test point locations for each type of test. The inspection test plan must be agreed by the installer and owner's representative as documented by signatory to the plan.

The final confirmation of compliance is the on-site inspection that includes a visual inspection of the installation with electrical testing identified in the Lightning Protection Test Plan. The electrical testing will consist of 3-point fall-of-potential earth resistance tests and bonding resistance testing witnessed by the inspection team.

III. Applicable Requirements

A. General

The scope of the Extended Master Inspection Certification Program covers not only standards LPI-175 (2017), NFPA 780 (2017), and UL 96A (2018) but also includes UFC 3-575-01 (2012), AFI 32-1065 (2015), PAM 385-64, and NAVSEA OP 5 (2011). The standard(s) to which the Extended Master certification is required must be selected by the applicant.

When UL 96A (2018) is specified on the Extended Master Inspection Certification Program it must be paired with an additional standard. UL 96A does not require electrical testing such as bonding or resistance to earth testing as a certification criterion. As a result, it does not qualify for the Extended Master Inspection Certification Program unless paired with another standard. Additionally, when LPI-175 (2017) is indicated as the only standard for the certification, the visual inspection recommendations of LPI 177 (2017) are applicable and the inspection should include continuity (bonding) and ground resistance testing.

UFC 3-575-01 (2012) provides policy and guidance for design criteria and standards regarding static electricity protection, lightning protection systems and related grounding for facilities and other structures. The document standardizes the tri-service criteria using NFPA 780 as a baseline document. Compliance with UFC 3-575-01 is mandatory for DoD facilities located on or outside of DoD installations. However, UFC 3-575-01, 1.5 indicates ordnance facilities or locations where ordnance and explosives are handled and stored require special protective measures and should comply with UFC 4-420-01 (2015), NAVSEA OP 5 (2011), Department of the Army Pamphlet 385-64 (2013), and AFMAN 91-201 (2016); as applicable. AFMAN 91-201, 5.22 reiterates that the DoD has selected the LPS criteria of NFPA 780 for ammunition and explosives (AE) facilities.

B. Ammunition and Explosives (AE) Facilities

Enclosure 4 of DoD 6055.09-M, Volume 2 (2012) provides the minimum explosives safety criteria for the design, installation, inspection, testing, training, and maintenance of lightning protection systems. The Department of Defense Ammunition and Explosives Safety Standard identifies NFPA 780 as the baseline criteria (as modified within Enclosure 4), including the inspection and maintenance requirements of Annex D and the grounding system measurement techniques given in Annex E. DoD 6055.09-M, Volume 2 (2012) is implemented by the Air Force in AFI 32-1065 (2015) by the Army in PAM 385-64 (2013) and by the Navy in NAVSEA OP 5.

DoD 6055.09-M requires that lightning protection systems be electrically tested when placing a new facility into service and after any facility modification that may have affected the system. The maximum interval between electrical testing shall be 2 years or an interval determined by a continuously validating statistical model determined by the DoD Component and approved by the DDESB. Electrical testing of the lightning protection system shall be performed in accordance with the requirements of NFPA 780, Annex D. A maximum value of 1 ohm bonding resistance and 25 ohms resistance to earth is specified in DoD 6055.09-M. These values are reflected in specific service requirements with some variation in the procedures to follow if the 25 ohms resistance to earth value is not achieved.

AFI 32-1065 (2015), 14.1 requires that the lightning protection system comply with the most restrictive of the requirements of NFPA 780 and UFC 3-575-01 (2012). It requires that the visual inspection include an inspection of all visible parts of the lightning protection system. AFMAN 91-201 (2016) specifies that the electrical testing conducted include bonding resistance testing

and resistance to earth testing. The maximum allowable values are 1 ohm for bonding resistance and 25 ohms for resistance to earth.

The test method prescribed in AFI 32-1065, Attachment 6, A6.1 allows the use of the procedure recommended by the test instrument manufacturer (see Figure 1 for a characteristic example) or the use of auxiliary probe locations for fall-of-potential ground resistance tests. It recommends that the test be conducted at the corner of the building and, where possible, opposite of the point the electrical service enters the structure. Where real estate is not sufficient to conduct the test at that point or other items such as buried metallic conductors are present between the grounding system and reference electrodes that may influence the accuracy of the measurement, the next best location should be selected. The attachment allows, but does not require, the temporary disconnection of the electrical service from the other grounding electrodes/systems. The requirements indicate that a resistance-to-earth test is required at each electrode for buildings without a ground loop conductor. It is unclear as written whether the requirement applies only to tests using auxiliary probe locations or independent of reference probe configuration. A conservative interpretation would be to assume the latter.

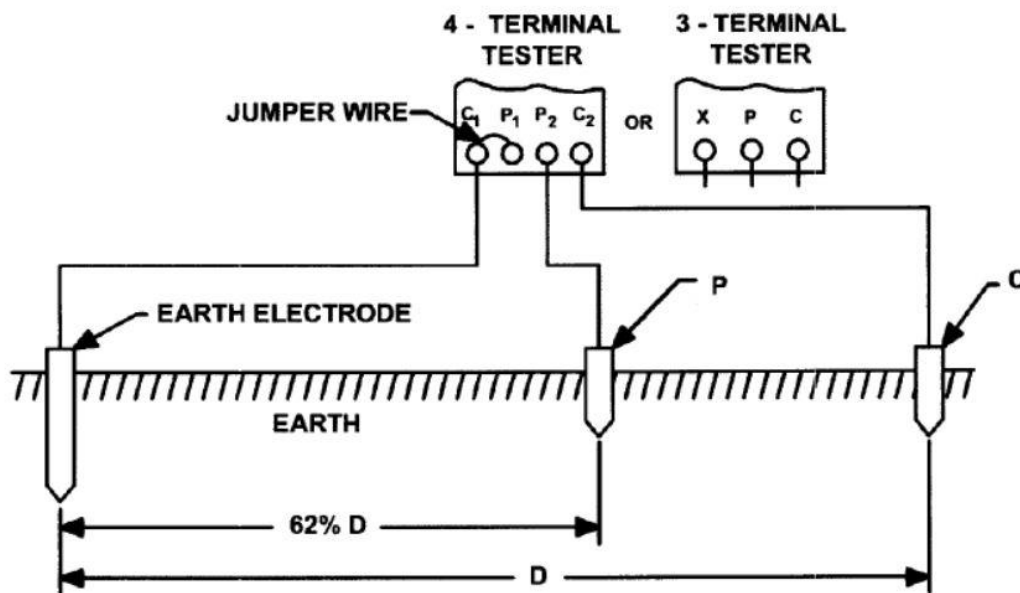


Figure 1. Reference electrode configuration for 3-point fall-of-potential test (source Figure B-4, PAM 385-64 (2013))

AFI 32-1065 (2015) electrical test requirements also include a sketch of the grounding and lightning protection system showing test points and service entry points for the facility. The sketch should show the location of the probes during the ground resistance test. Figure 2 reproduces Figure A6.1 of AFI 32-1065 (2015); which provides the information required in the grounding system sketch and illustrates the configuration of auxiliary probe locations for fall-of-potential ground resistance tests. The spacing between the potential (P) reference electrode and both the current (C) reference electrode and the item under test is required to be the same and at a distance no less than half of the diagonal dimension of the building under test; but not less than

25 feet (7.6 meters). As shown in Figure 2, the potential (P) reference electrode shall be located perpendicular to the structure. The current (C) reference electrode shall be located 90 degrees from the line formed by the item under test and potential reference electrode; in the direction away from the structure and grounding electrode under test for tests conducted at the corner. For a grounding electrode not located at a corner, it will generally not be possible to locate the current reference away from the structure but instead locate it parallel to the structure.

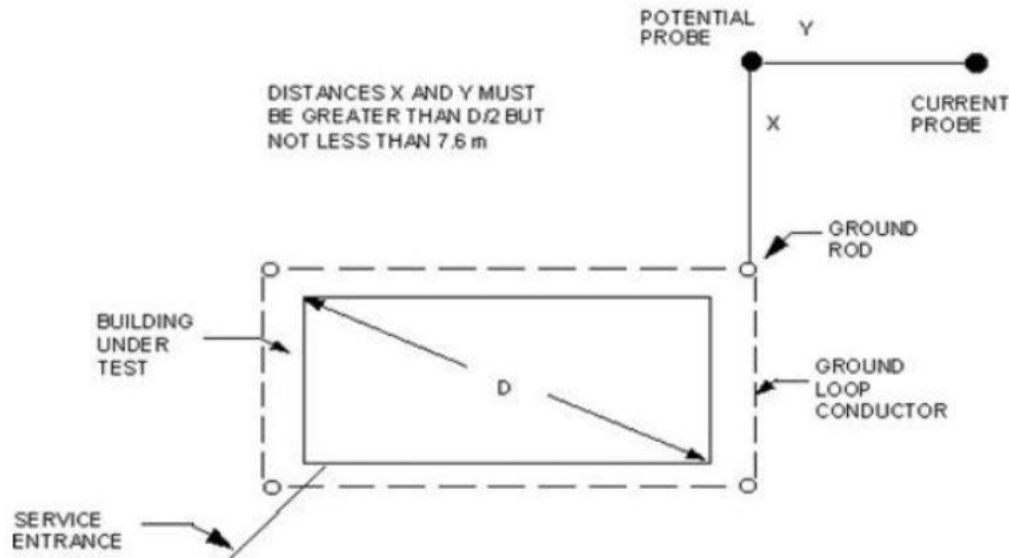


Figure 2. Grounding system sketch for resistance to earth test with reference electrode locations (from AFI 32-1065 Figure A6.1)

NAVSEA OP 5 (2011), 6-1 identifies NFPA 780 as providing minimum acceptable requirements for the protection of structures used for developing, manufacturing, testing, handling, storing, maintaining, demilitarizing or disposing of ammunition and explosives from effects of direct and indirect lightning strikes; except as modified therein. A grounding system test plan is required that addresses visual inspection and electrical testing of a lightning protection system for structures housing ammunition and explosives. The specific grounding system test plan for a structure must identify the bonding and ground system test locations, along with a listing or description of the item to be tested and the type of test to be conducted. It is recommended that, as a minimum, a sketch of the facility be included as part of the specific test plan for each structure. The standard allows only the three-point fall-of-potential test method for use in measuring the resistance to earth of grounding systems in ordnance facilities. Reference electrode configurations shown in Figures 1 and 2 are allowed. For the standard “in-line” configuration shown in Figure 1, NAVSEA OP 5, Table 5-2 provides a guide to approximate spacings of reference electrodes.

The completion inspection for an integral lightning protection system is required to include a comprehensive point-to-point bonding test of each air terminal to their grounding electrode to ensure a resistance of 1 ohm or less.

Visual inspections of integral systems shall include a 100 percent visual inspection of all air terminals and the entire length of conductors to the grounding system connection points. The visual inspection also requires an inspection of surge protection systems.

Department of the Army Pamphlet 385-64 requirements are also based on NFPA 780. The focus of the visual inspection is confirmation that the installation is in accordance to NFPA 780 and confirmation that bonding connections are firmly attached. Electrical testing includes bonding and resistance to earth testing. The reference point for bonding testing will be a down conductor at the point it enters the earth. The earth electrode system is to be disconnected when practical. Items to be confirmed to be bonded are other down conductors, each LPS component, components of all other subsystems on the facility, and all metal bodies with a surface area equal or greater than 400 square inches that are bonded to the lightning protection system.

Resistance to earth testing shall be conducted using the 3-point fall of potential method with either a 3 or 4 terminal earth resistance tester. Section B-4 identifies the distance between the center of the grounding system under test and the potential (P) reference electrode should be 62% of the distance between center of the grounding system under test and the current (C) reference electrode. Table B-1 specifies reference electrode spacings for selected grounding electrodes.

Ground loop electrodes are required to exhibit a resistance to earth less than or equal to 25 ohms. If the measured resistance exceeds this value, additional three-point fall-of-potential testing must be performed to establish the S-curve shown in Figure 3(b) below to determine whether the reference electrode locations yield accurate results. Biddle Manual 25Ta (1981) provides additional information on the development and use of the S-curve in determining the quality of a 3-point fall of potential measurement. If the result is still above 25 ohms, an earth resistivity test should be performed to determine if the high reading is due to soil conditions. If so, additional ground electrodes or introduction of earth enhancing material may be necessary.

I. Application Information

It is the responsibility of the lightning protection installer to document and distribute any pre-inspection reference material required as a part of the certification. It is also the responsibility of the installer company to confirm the scope of the required certification with all parties. This includes confirmation of the standards that will be applicable to the installation and whether the required surge protection is a part of this effort or will be the responsibility of another organization (e.g., electrical contractor).

The Extended Master Installation Certificate Application requires the general tracking information such as the identification of the installation contractor, identification of the structure, location and use of structure, and points of contact of each for logistics. It is also necessary to identify the witnesses that verify any photographs or other documentation used to confirm that parts of the lightning protection system that will be concealed at the time of site inspection, are installed as described.

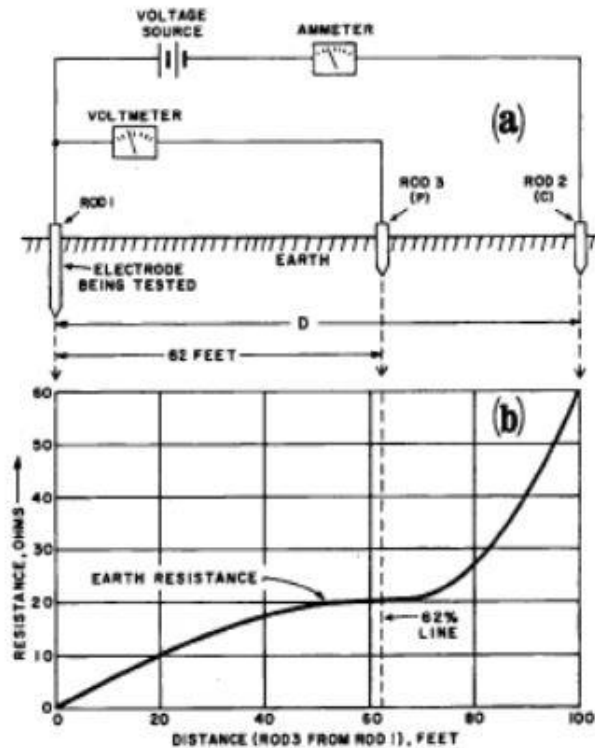


Figure 3. Example of S-curve related to reference electrode spacing (from Biddle Manual 25Ta (1981))

The application form requests specific information related to the contents, construction, physical dimensions, and incoming services of the structure. A detailed description of the lightning protection system is also required. A set of as-built drawings of the lightning protection system provides much of the necessary details but the application form also requires information on the bonding of incoming services, with details on the technique used. The form also identifies the number, type, and material of grounding electrodes used; material used for roof and down conductors; and whether natural components are used.

The program allows the option of have the certification include surge protection or have it excluded from the certification. This is not in any way to infer that surge protection is not an important integral part of the lightning protection system. Instead, the option to provide a certification that does not include surge protection is an acknowledgement that there are projects where the surge protection design and installation is performed by a contractor not related to lightning protection. In those cases, it is suggested that it be certified at some point that the surge protection meets the lightning protection requirements of the applicable standard(s).

The following documents shall be provided by the lightning protection installer to complete the Extended Master Installation Certificate Application:

- LPI-IP Extended Master Installation Certificate application.
- Lightning Protection As-Built Drawings – Reference test Points
- Approved Grounding System Plan – Reference Test Points

- Photos/photo waiver (if applicable)
- Site AHJ sign off on test plan

UFC 4-420-01 (2015), 2-3.1 requires the lightning protection system design for all new above-ground magazine designs be reviewed and approved by the Department of Defense Explosives Safety Board (DDESB). Where the DDESB review is available, it could also be included in the Pre-Inspection package to aid in the review of the lightning protection system.

II. Lightning Protection Inspection Plan

A. *Development and Submission of Plan*

LPI-IP requires that a Lightning Protection Inspection Test Plan be developed to define the details of the on-site certification inspection. This plan is not as extensive as the Maintenance and Inspection (M&I) Plan described in NFPA 780, 8.9 and 8.10 or similar versions detailed in the other standards covered by the Extended Master Inspection Program. It should be a subset of the M&I plan as the purpose of the on-site certification is to ensure the installed system meets the requirements of the applicable standards. For example, if NAVSEA OP 5 (2011) is identified as a Lightning Protection Specified Standard for an integral lightning protection system it would be reasonable to include a continuity test between an air terminal and the associated down conductor ground point as discussed in 6-9.1.2.

The Lightning Protection Inspection Plan is developed by the installing contractor in coordination with the owner's representative. The installer is responsible for the documentation of the plan and obtaining approval of the lightning protection inspection plan from the owner/owner's representative, confirmed by signature to the plan, prior to application submission.

The first step in developing the Lightning Protection Inspection Test Plan is to identify the standards applicable for the lightning protection system and whether these are applicable specifically to the above-ground lightning protection system (strike termination, roof and down conductors, bonding, and surge protection) or also includes the grounding system for the structure. The same standard could be cited for both but there could be one standard cited for the requirements of the above-ground lightning protection system and a different one for evaluation of the grounding subsystems. This is primarily relevant to the development of the electrical test requirements to be applied during the approval inspection.

The Lightning Protection Inspection Test Plan should also identify the lightning protection applicable requirements, along with the maximum bonding resistance value allowed; as well as the applicable requirements for the resistance to earth testing with the maximum resistance required. Finally, the bonding and resistance to earth test locations shall be identified in one or more drawings along with details such as reference point locations for bonding tests and reference electrode locations for resistance to earth tests. Depending on the specific application, this information could be added to lightning protection system as-built drawings or be developed specifically for the Lightning Protection Inspection Test Plan. NAVSEA OP 5 (2011) provides

some acceptable example sketches of a structure identifying electrical test points and associated data sheet in Figures 5-7 through 5-9. The resistance to earth reference electrode locations would have to be added to the sketch for it to be the sole drawing but these could alternatively be added to an additional grounding system drawing.

B. Visual Inspection

The installation completion inspection will consist of a visual inspection of rooftop lightning protection system down conductors, common bonding and grounding electrode system. As discussed in Section III, NFPA 780 provides the baseline requirements for the design and installation of the lightning protection systems described in each of the standards covered by this program; with modifications specific to some standards. This allows that a baseline visual inspection checklist be developed to provide consistency between inspections. The specific visual inspection checklist used will be tailored as necessary to account for any unique items specific to the standard(s) selected for certification.

C. Electrical Testing

The electrical testing should include bonding (electrical continuity) testing and resistance to earth testing. Specific details on each of the tests will be a function of the standards selected. Bonding test requirements will be dependent upon the standard(s) identified for the lightning protection system along with any specific details identified in the project specification. A maximum bonding resistance of 1 ohm and resistance to earth value of 25 ohms is generally specified in each of the standards included in the program, but there is variation as to the items to be tested and the grounding system reference point criteria. For resistance to earth testing, the applicable requirements will be taken from the standard(s) specified for grounding.

It is the responsibility of the lightning protection installer to provide all test equipment, user documentation and calibration records. The installer shall perform the electrical testing in accordance with the test plan, using the method and test points identified on the drawings provided in the Lightning Protection Inspection Plan agreed by the installer and owner's representative.

III. Post Inspection Deliverables

Upon satisfactory completion of the on-site inspection, a certificate indicating the installation meets the requirements of the standards specified on the application form will be issued to the installer. It is the responsibility of the Installation Contractor to provide the findings of the inspection to the owner or owner's representative of the inspected site, including all electrical test results collected during the inspection. The certificate with associated test results and other findings could be included in the final package provided to the owner's representative, along with the Lightning Protection System Maintenance and Inspection Plan and other contract deliverables that are not a part of the certification program.

IV. Summary and Recommendations

The LPI-IP Master Inspection Certification Program is a well-established lightning protection system certification program with over 1500 certifications issued in 2017. The same program concepts have been implemented in the Extended Master Inspection Certification Program that is now being used to provide certification for lightning protection system installations to selected military standards. The certification program is designed to provide positive controls to allow consistency between inspections and yet still allow flexibility to meet the needs of the customer.

While there are some differences in the implementation of the baseline requirements between the services, there is a large core of the requirements that are consistent across all the standards included in the Extended Master Inspection Certification Program. NFPA 780, including Annexes D and E, provides baseline criteria for DoD 6055.09-M, Volume 2; which is implemented by the services in UFC 3-575-01, NAVSEA OP 5, AFI 32-1065, and DA PAM 385-64. Maximum allowable values for bonding resistance and resistance to earth are generally consistent, although there are some differences in the steps to be taken if the resistance to earth value exceeds the allowable 25 ohms. All standards cite the 3-point fall-of-potential test to measure resistance to earth, although there are some differences in the preferred method for configuration of the current and potential electrodes used in the test. The Lightning Protection Test Plan is designed as a tool to address these deviations while providing consistency by taking subjective decisions out of the hands of the inspectors and addressing such decisions prior to the on-site inspection in a manner that is documented and agreed by both the installer and the owner's representative.

The Extended Master Inspection Certification Program relies on positive confirmation through documentation. The installer certifies in a signed application that the materials utilized in this installation comply with the material considerations and minimum requirements detailed in the current edition of the standard specified in the application are met. The installer also certifies that all witness signatures submitted as a part of the application are authentic and all information on this application is accurate at the time of submission. Decisions on electrical test points and methods are agreed by all parties and documented in the Lightning Protection Test Plan.

It is recommended that UFC 3-575-01, 3-1 be revised to reflect that an LPI-IP Extended Master Inspection Certification or UL Lightning Protection Inspection Certificate would be acceptable to ensure compliance with NFPA 780, unless the design and inspection are otherwise identified to comply with a different standard for a specific facility. This change would allow other users of UFC 3-575-01 to utilize the nationally-recognized lightning protection certification program as an option to Underwriters Laboratories.

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