Lightning Protection Requirements for DOD Ammunition and Explosive Facilities

Jeffrey R. Denton, PE, U.S. Army Corps of Engineers,
Engineering and Support Center, Huntsville
email: jeffrey.r.denton@usace.army.mil

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Abstract

A properly maintained lightning protection system (LPS) is mandatory for ammunition and explosives (AE) facilities within the Department of Defense (DOD). The DOD, through the Department of Defense Explosive Safety Board (DDESB), has established explosive safety standards designed to manage risks associated with DoD-titled AE by developing criteria to prevent hazardous conditions to property and life. LPSs are part of those criteria to which the DDESB has developed minimum explosives safety criteria for the design, installation, inspection, testing, training, and maintenance of LPSs.

Lightning protection systems are part of the Explosive Safety Site Planning (ESSP) considerations when an AE mission is under evaluation for DDESB approval. The requirements are more stringent for a LPS protecting AE facilities than for an ordinary facility. Knowledge of these requirements and the criteria source from which they originate will aid the AE mission in preparing for the evaluation process to obtain DDESB approval. The intent of this paper is to inform the reader of the LPS criterion that applies to AE facilities by looking further into the added requirements. Furthermore, this paper will identify and discuss some of the more common LPS deficiencies typically observed during an inspection process.

Introduction

The importance of lightning protection for AE facilities was catastrophically demonstrated on July 10, 1926 near Rockaway Township, NJ when a single lightning bolt struck a storage depot at the Lake Denmark Naval Ammunition Storage Depot, which was part of the larger Picatinny Arsenal. The resulting explosion detonated more than 600,000 tons of explosives, killed 21 people, destroyed roughly 200 buildings in a half-mile radius including the surrounding communities, and resulted in excess of $600 million dollars based on today's currency. In response to this tragic event, the Seventieth Congress established the DDESB in 1928 and directed the Board with oversight of the development, manufacture, testing, maintenance, demilitarization, handling, transportation and storage of explosives. This congressional directive has led to explosive safety standards for which compliance is mandatory for DOD AE missions.

A properly maintained LPS is part of those safety standards. A successful ESSP submission requires documentation that demonstrates an LPS is in place, meets the required installation

standards for the proper level of protection, and is maintained in accordance with applicable industry and DOD standards.

It is not the intent of this paper to discuss every applicable LPS requirement enforceable within the DOD referenced standards. That would be too encumbering for this agenda. Instead, the principle LPS criteria sources for AE facilities will be discussed along with some of the more noteworthy design and installation requirements. Additionally, this paper leans more towards those DOD components supported by the U.S. Army Corps of Engineers (USACE) Facilities Explosive Safety (FES) Mandatory Center of Expertise (MCX), which resides at the U.S. Army Engineering and Support Center, Huntsville (CEHNC). Headquarters USACE (HQUSACE) designated CEHNC as the FES MCX for all HQUSACE elements in November 2017. All being well this information, as presented, will aid all DoD and non-DoD federal agencies owning AE missions with the resource knowledge for the ESSP approval process.

LPS Standards and Criteria for DOD AE Facilities

As mentioned above in the Abstract, LPS codes applicable to AE facilities are more stringent than the LPS codes that apply to ordinary facilities. The principal criterion within the DOD for explosive safety standards is the Manual **DoD 6055.09-M**, ***DOD Ammunition and Explosives Safety Standards***. The Manual is divided into eight volumes. It is applicable to the "OSD, the Military Department, the Office of the Chairman of the Joint Chiefs of Staff and the Joint Staff, the Combatant Commands, the Office of the Inspector General of the Department of Defense, the Defense Agencies, the DoD Field Activities, and all other organizational entities within the Department of Defense…." Because DOD 6055.09-M is a Department of Defense standard, it is applicable to all DOD components including Army, Navy, and Air Force commands. The Manual's purpose is to establish explosive safety standards for the DOD. The Manual's eight volumes address aspects of explosive safety. Volume 2 contains, in part, the electrical and lightning protection safety standards.

DOD 6055.09-M, Volume 2, Enclosure 4 is titled *Lightning Protection*. The first paragraph, V2.E4.1 states that the DOD has designated the National Fire Protection Agency (NFPA) 780 as the criteria for LPSs, except as modified within the Manual. NFPA 780, *Standard for the Installation of Lightning Protection Systems* is the industry standard for LPS design and installation, and is selected by the DOD to be the criterion for LPS design and installation. Enclosure 4 "provides the minimum explosives safety criteria for the design, installation, inspection, testing, training, and maintenance of lightning protection systems." Within Enclosure 4, the DOD requires that LPSs protecting AE facilities must be designed and installed based on the rolling sphere method of using a 100 ft. or less radius zone of protection. Other noteworthy requirements discussed in Enclosure 4 include sideflash protection, surge protection, inspections, testing and even exceptions for the omission of an LPS. NFPA 780 and other criteria (presented below) discuss these same and additional requirements in more detail. The Manual, being a DOD level standard, establishes the principal requirements that are mandatory for AE missions and identifies more comprehensive criteria sources.

It is worth mentioning at this point that Enclosure 3 of Volume 2 addresses the electrical standards, and it establishes the safety standards for electrical equipment and wiring within AE environments. Even though Enclosure 3 does not discuss lightning protection, AE missions need to be aware of some of the unique requirements of electrical systems. Paragraph V2.E3.5 mentions one such requirement that is widely applicable. It concerns the proximity of overhead electrical power lines to the AE facility. This requirement will be discussed in more detail later, but is only found in the DOD 6055.09-M.

Another DOD criterion that is applicable to all DOD components is the **United Facilities Criteria (UFC) 3-575-01**, ***Lightning and Static Electricity Protection Systems***. Even though this UFC is not specific to AE facilities, it contains LPS requirements still applicable to AE facilities. Paragraph 1-1 states that the purpose of the UFC is to provide "policy and design requirements for static electricity protection, and lightning protection systems and related grounding for facilities and other structures." Its applicability is mandatory for DOD facilities per paragraph 1-2. Chapter 3 of the UFC directs that a risk assessment be provided to determine the required level of protection. If an LPS is determined necessary, it must meet the requirements of NFPA 780. The issuance of this UFC supersedes other DOD standards for lightning protection, which include the Naval Facilities Engineering Command (NAVFAC) MIL-HDBK 1004/6, the Army's Technical Manual (TM) 5-811-1, and the Air Force's Air Force Manual (AFM) 88-9 Chapter 3.

Probably considered the national standard for lightning protection, being the most referenced, is the **National Fire Protection Association (NFPA) 780**, ***Standard for the Installation of Lightning Protection Systems***. Latest edition is dated 2017 and is re-issued every three years. DOD selects NFPA 780 as the criteria for LPSs for AE facilities, as mentioned above. Specifically, Chapter 8 of NFPA 780, titled *Protection of Structures Housing Explosive Materials* is written to the LPS requirements for AE facilities and contains the more stringent requirements than that for ordinary facilities, which is included in Chapter 4, *General Requirements*.

Specific to U.S. Army components is **Department of the Army Pamphlet (DA PAM) 385-64**, ***Ammunition and Explosives Safety Standards***. Chief of Staff, Army, is the proponent of the pamphlet, and it prescribes Army policy on ammunition and explosives safety standards. The safety requirements of DOD 6055.09-M are effected within the pamphlet. Chapter 17 begins the discussion of electrical hazards, and Section IV of Chapter 17 addresses the specific lightning protection requirements for AE facilities.

Air Force Manual (AFM) 91-201, ***Explosive Safety Standards*** implements in full DOD 6055.09-M. It is a principal reference for explosive safety criteria within the Air Force, and it identifies hazards and safety precautions when working with explosives. It is applicable to any Air Force component.

Air Force Instruction (AFI) 32-1065, ***Grounding Systems***. This AFI contains requirements for equipment grounding, lightning protection, and static protection. Attachment 5 of the AFI deals specifically with explosive facilities while other parts of the AFI are applicable to all AF facilities. The AFI also implements the maintenance requirements of DOD 6055.09-M.

Naval Sea Systems Command Ordnance Pamphlet 5 (NAVSEA OP 5), ***Ammunition and Explosives Safety Ashore***, provides the Department of the Navy (DON) with explosive safety information and regulations for conventional AE operations. The safety rules and regulations are mandatory for all DON AE activities. Distribution is authorized to U.S. Government agencies and their contractors.

UFC 4-420-01, ***Ammunition and Explosives Storage Magazines***, is a "reference tool" in the planning, siting, and design of AE storage magazines within the DOD. Specifically, Section 3-8.6 discusses the requirements for LPSs on storage magazines. Included in this UFC are the electrical design requirements, part of which includes the LPS.

Though not a public criterion document, **DDESB Technical Paper (TP) 22**, ***Lightning Protection for Explosives Facilities***, provides DDESB guidance for the installation and maintenance of lightning protection systems, and helps clarify the LPS requirements as stated in DOD 6055.09-M and NFPA 780. Authored by DDESB, TP 22 authorized distribution is to U.S. Government agencies and their contractors.

There is no single, authoritative source on lightning safety providing comprehensive aid to designers and installers, even though NFPA 780 is the most recognized and cited source. [1] The above-mentioned criteria encompass what is thought to be the principal criteria for the design, installation, testing and maintenance of lightning protection systems protecting DOD AE facilities.

Some other government agencies outside of DOD have LPS standards for explosive facilities that would be useful to mention here. These are excellent LPS and grounding resources and include, but are not limited to, **Department of Energy (DOE) Manual 440.1-1A**, ***DOE Explosive Safety Manual***, and **National Aeronautics and Space Administration (NASA) Standard 8719.12**, ***Safety Standard for Explosives, Propellants, and Pyrotechnics***. While each of these safety documents discusses applicable LPS requirements in detail, compliance with NFPA 780 is a principal requisite. The International Electrotechnical Commission (IEC) 62305 standard for lightning protection is an international authoritative reference, adopted by many countries, and is a valuable tool for the engineer as a science-based standard for many LPS applications. [1]

Theory of Lightning Behavior and Protection

Many sources provide great in-depth explanation to the science of lightning. This paper will only touch the surface of this science just enough to help illustrate the reasoning behind some of the more stringent requirements applicable to AE facilities.

Lightning is a naturally occurring phenomenon of a transient electrical discharge. As storm conditions develop, lighter, positively charged particles elevate to the top of the clouds while heavier, negatively charged particles drift toward the bottom of the clouds. The electrical field within the cloud strengthens as the opposite charges build up until the electrical field is large enough to breakdown the medium. A neutralizing lightning strike then occurs. The greater majority of lightning strikes occur within the clouds. However, the strikes that are most concerning to people and affect lightning protection systems are those between the clouds and ground. When

the electrical field builds up enough between the negatively charged particles in the cloud and the positively charged particles on the ground, the neutralizing strike occurs, closing the "switch" between the cloud and ground.

The presently understood behavior of a lightning strike is a two-staged process. A downward leader extends from the cloud through a step-by-step descent, called a stepped leader at intervals of about 150 ft. As the negatively charged leader approaches the ground, the air becomes ionized and a positively charged upward streamer rises in response. When the two opposite charged strokes meet, the ionized path completes the circuit resulting in an immediate discharge of electrons to earth. This discharge of electrons has a magnitude ranging around 10 to 400 kilo-amperes (kA). The bright luminous light discharge that is visible occurs during the return stroke. Figure 1 from the Global Hydrology Resource Center (GHRC) website [2] illustrates the separation of charges and some of the various types of lightning resulting from the electric field discharge.

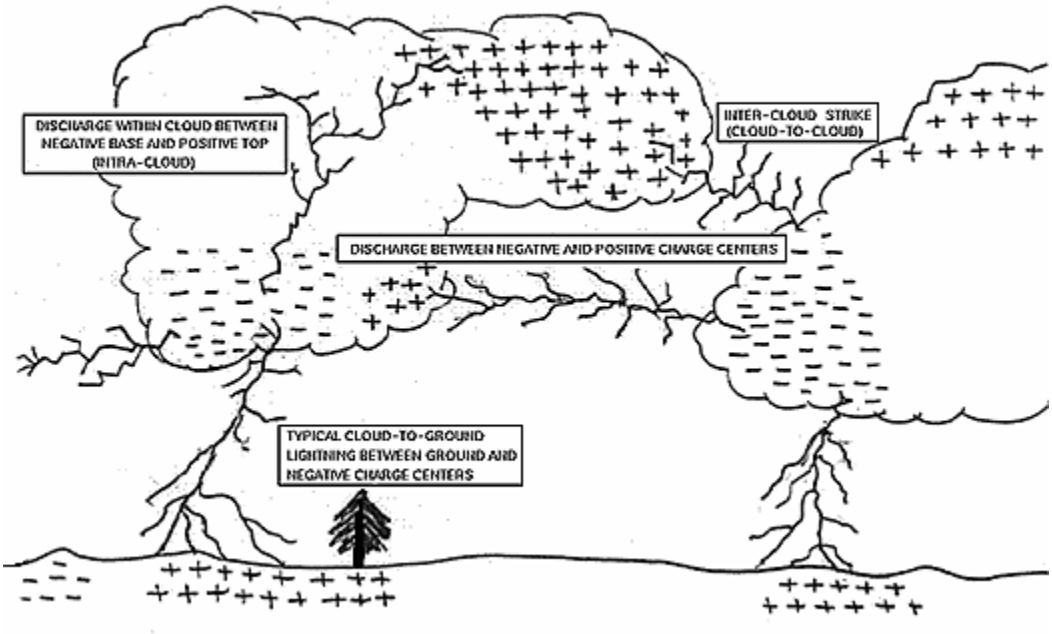

Figure 1. The lower part of a thundercloud is usually negatively charged. The upward area is usually positively charged. Lightning from the negatively charged area of the cloud generally carries a negative charge to Earth and is called a negative flash. A discharge from a positively-charged area to Earth produces a positive flash. [2]

To protect against lightning strikes there are levels of protection to consider when designing an LPS. The International Electrotechnical Commission (IEC) 62305-3 defines four protection levels of an LPS. Based on the four protection levels, DDESB TP 22 describes the protection efficiency of these four levels in terms of "interception efficiency." Interception efficiency is the "probability of the LPS intercepting the minimum value of the lightning current at a given protection level." [3] Lightning events can be measured in terms of peak currents, as alluded above regarding the range of magnitude. Table 1 relates maximum peak current to protection level, interception efficiency, and the zone of protection.

Table 1. Lightning Protection Efficiency [3]

Maximum Current Exceeding the Peak Value	Protection Level	Interception Efficiency (%)	RSM Zone of Protection
2.9 kA	I	99	62.6 ft.
5.4 kA	II	97	100 ft.
10.1 kA	III	91	150 ft.
15.7 kA	IV	84	196.8 ft.

Typically, the protection level selected for a facility is based on statistical probabilities and the risk that the authority having jurisdiction (AHJ) is willing to accept. As DDESB TP 22, Chapter 4 explains, at 99% interception efficiency, the LPS is expected to intercept all lightning strikes with a peak current of 2.9 kA and higher. Conversely, any lightning strike less than 2.9 kA peak current may bypass the system and hit the facility thought to be protected. There is only a 1% chance that a lightning strike will have a peak current less than 2.9 kA and the LPS not intercept the strike. Protection levels greater than 99% (Protection Level I) would be cost prohibitive due to the excessive amount of material required, especially compared to the rarity of an unprotected lightning strike. Protection Level I is not covered in the criteria referenced above.

DOD 6055.09-M requires a 100 ft. radius zone of protection for AE facilities. From Table 1, this is equivalent to a Protection Level II LPS, which is expected to intercept 97% of all lightning strikes. On the other hand, lightning strikes less than 5.9 kA peak current may bypass the LPS and directly hit the facility.

The rolling sphere method (RSM) is an analysis tool used to determine the zone of protection provided by an LPS. It is based on the striking distance (*ds*) of a given lightning current, *Imax* (kA), where $ds = 10\ Imax^{0.65}$. From Table 1, a lightning strike with a peak current of 5.4 kA will have a *ds* approximately equal to 100 ft. Figure 2 illustrates the striking distance model. The imaginary sphere, shown in the blue shaded region, protects any object from a direct strike if it resides below the curved shape of the sphere and remains outside of the attractive radius region. The strike termination device, represented as a 70 ft. high mast pole, provides a zone of protection extending out approximately 95 ft. from the mast pole along the curvature of the sphere. The attractive radius region is representative of the distance at which a downward leader is likely to connect with an upward streamer. Figure 3 demonstrates the RSM over multiple buildings. In theory, the sphere rolls over the buildings fully supported by the strike termination devices (air terminals) of the LPS and provides a zone of protection to all objects remaining underneath and not touching the imaginary sphere.

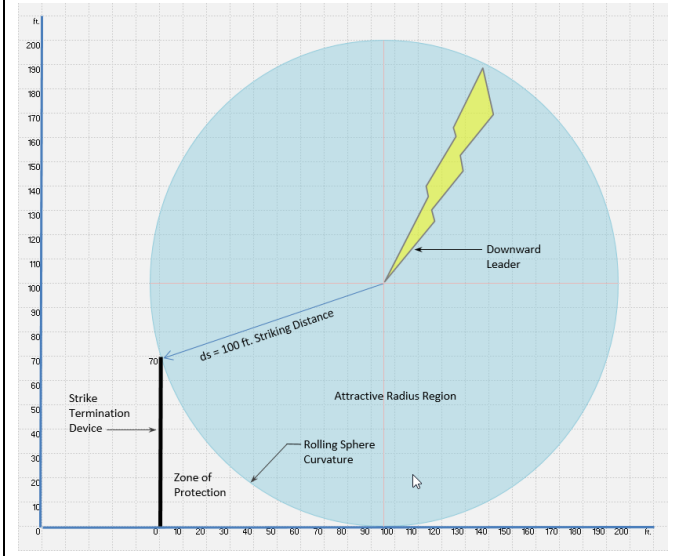

Figure 2. Striking Distance Illustration [3]

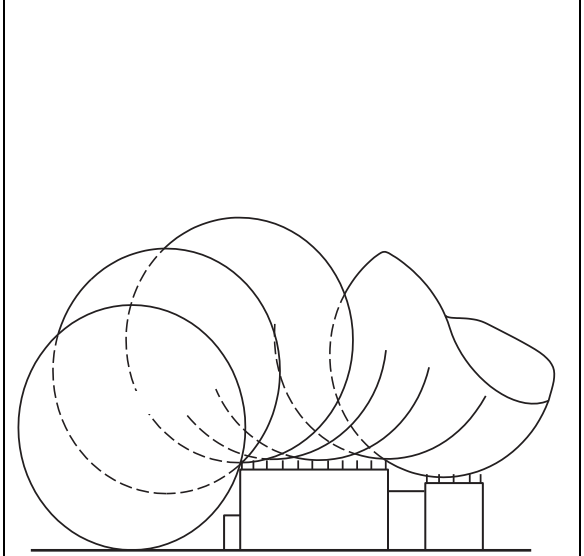

Figure 3. RSM for Multiple Facilities (From NFPA 780)

The protective distance provided by a strike termination device(s) can be calculated with the following equation:

$$d = \sqrt{h_1(2R - h_1)} \; - \; \sqrt{h_2(2R - h_2)}$$ (From NFPA 780, 4.8.3.3)

Where,

d = horizontal protected distance
h_1 = height of higher protecting object or strike termination device
h_2 = height of lower protecting object or strike termination device
R = rolling sphere radius
(Units must be consistent, ft. or m)

LPS Criteria for AE Facilities

Lightning protection criteria for AE facilities require a more rigorous installation than for ordinary facilities. Furthermore, there are some extra requirements that apply to AE facilities that may be overlooked during design and installation. This section will attempt to highlight some of those requirements as well as discuss the more substantial requirements needed for an LPS.

As mentioned earlier, DOD 6055.09-M mandates that all AE facilities have a lightning protection system capable of providing a 100 ft. radius zone of protection based on the RSM. Exceptions to an LPS are permitted by DOD 6055.09-M, AFMAN 91-201, NAVSEA OP 5 and NFPA 780. The reader is encouraged to seek these exceptions out if preferred, but they will not be discussed within this paper. The 100 ft. zone of protection is listed as a requirement in NFPA 780, Chapter 8, which DOD 6055.09-M selected as the LPS criterion. This mandates that the LPS is designed to

Protection Level II, expected to intercept 97% of all lightning strikes. Per NFPA 780, the LPS for ordinary facilities is based on a 150 ft. radius zone of protection. Designed to protect against 91% of all lightning strikes.

AE facilities must have all power and conductive communication circuits, including intrusion detection systems (IDS), installed underground for at least 50 ft. before entering the facility. The cables must be run in metallic conduit. All electrical-type lines must be equipped with a surge protective device (SPD) at the entrance to the facility to prevent electrical surges from entering the facility through these "back door" avenues. This is a requirement for AE facilities and non-AE type facility with an LPS, per NFPA 780. For similar reasons, aboveground metallic utility lines must be bonded to the structural steel of the facility or the LPS before entering an AE facility.

One very distinctive requirement for AE facilities is the proximity of overhead power lines. DOD 6055.09-M places limiting distances that overhead electrical lines can be to a combustible AE facility. There are factors determining this distance, such as voltages and the public traffic route distance (PTRD). Exceptions are permitted and the reader is encouraged to investigate these requirements further if necessary.

AE facilities are required to have a ground ring electrode system rather than individuals ground rods or other type of grounding electrodes permitted for ordinary facilities. Additionally, the ground ring electrode must meet the Class II material requirements even if the facility is less than 75 ft. high.

Specific to Air Force facilities requiring an LPS, if the facility has a perimeter over 300 ft. and does not use the structural steel as strike termination devices, then either a mast or catenary type system must be used. Approval for an integral type LPS with air terminals installed on the facility must come from the major command (MAJCOM) as a waiver. Mast and catenary type systems provide better protection and require less maintenance than integral type systems. Regardless of the size of the facility, consideration for implementing these "indirect" type systems is recommended for AE facilities at any DOD installation.

Naval AE facilities implement a primary and secondary grounding system. This consists of two separate ground rings, or girdles, encircling the facility and bonded together at a minimum of two locations, at opposite sides of the facility. If the facility's perimeter is large enough, additional bonding locations may be added. This grounding system is explained and illustrated in detail in NAVSEA OP 5, Chapters 5 and 6. The reader is once again encouraged to go to this criterion to learn more about implementing this grounding system for DON.

UFC 3-575-01, Chapter 3 instructs that if a facility is required to have an LPS, then it must receive an Underwriters Laboratory (UL) Inspection Certificate as being certified to NFPA 780. The UFC is applicable to all DOD facilities. An exception to the UL certification is written in Chapter 3 for Air Force facilities. Air Force facilities require inspection, certification by an LPS third-party inspector certifying the facility is compliant with AFI 32-1065, and NFPA 780, in that priority order. A UL certification on its own is not acceptable for any Air Force project.

These and other distinctive requirements listed in Table 2 provide a summary reference for the LPS requirements and their criteria references distinctive to AE facilities.

Table 2. LPS Requirements Distinctive to AE Facilities

AE Facility LPS Requirements	**Primary Criteria Reference**
100 ft. radius zone of protection	DOD 6055.09-M, V2.E4.2 NFPA 780, 8.2.1 DA PAM 385-64, 17-19.*b*. AFMAN 91-201, 5.23. NAVSEA OP 5, 6-3.a.
Power and communication installed in metallic conduit and run underground 50 ft. before entering the facility (*Surge protection normally referenced within the same section is very critical and a requirement for all types of facilities with an LPS*)	DOD 6055.09-M, V2.E3.6.2 DA PAM 385-64, 17-26.*b*. AFMAN 91-201, 5.23.5. AFI 32-1065, 15.1. NAVSEA OP 5, 6-7.2.
Above ground metallic utility lines must be bonding to the structural steel or LPS before entering the AE facility	DOD 6055.09-M, V2.E3.6 DA PAM 385-64, 17-26.*d*. AFMAN 91-201, 5.23.5. AFI 32-1065, 15.2. NAVSEA OP 5, 6-6.3.3.
OH power line distances from AE facilities	DOD 6055.09-M, V2.E3.5 DA PAM 385-64, 8.13
Ground ring electrode required for AE facilities	NFPA 780, 8.4.1 DA PAM 385-64, 17-25. AFI 32-1065, A4.1.15. NAVSEA OP 5, 6-5.1.
Ground ring electrode must be sized to Class II material requirements	NFPA 780, 8.4.3 DA PAM 382-64, 17-25. AFI 32-1065, A4.1.15. NAVSEA OP 5, 6-5.1.
Railroad tracks must be bonded to the LPS	NFPA 780, 8.5.7 DA PAM 385-64, 17-22.*f*. NAVSEA OP 5, 6-6.3.1.
Metallic access doors and doorframes shall be bonded to the ground ring electrode	NFPA 780, 8.5.5.1 NAVSEA OP 5, 6-6.3.4.
Metallic fences must be grounded or bonded to the grounding electrode system if located	NFPA 780, 8.8.1 DA PAM 385-64, 17-22.*e*. NAVSEA OP 5, 6-6.3.2.
Bonding techniques	NFPA 780, 8.5.4 NAVSEA OP 5, 6-6.1.
LPS on earth covered magazines	NFPA 780, 8.7.1 UFC 4-420-01, 3-8.6 DA PAM 385-64, 17-19.*g*. NAVSEA OP 5, 6-8.2.
LPS for wharves and Piers	NFPA 780, 8.7.2 NAVSEA OP 5, 6-8.2.3.1.
LPS inspection certificate by UL or another third-party	UFC 3-575-01, 3-1
AF facilities with perimeters larger than 300 ft. and structural steel not used for air terminals must use a mast or catenary type LPS	AFI 32-1065, 14.5.
Naval facilities implement a primary and secondary ground system that must be bonded together at two locations	NAVSEA OP 5, 5-5; 6-5

Inspection and Testing for AE Facilities

A properly maintained LPS is required per DOD 6055.09-M, V2.E4.1. This necessitates that regular maintenance, inspections and testing be performed by the AE mission, as well as having an established training requirement for the LPS personnel (V2.E4.3.4). NFPA 780, 1.6.1 requires conducting periodic inspections or testing for ordinary at intervals determined by the AHJ. This is slightly different from the DOD requirements for AE facilities, where DOD criteria dictates intervals for inspection and testing of LPSs as noted in Table 3. Please refer to the criteria documents for specific inspection and testing requirements and instructions.

Table 3. LPS Inspection and Testing Intervals for AE Facilities

Criteria	LPS Inspection or Test	Intervals
DOD 6055.09-M, V2.E4.3.1	Visual inspection	One year or per the DOD Component and approved by the DDESB
DOD 6055.09-M, V2.E4.3.2	Electrical tests	Maximum every two years or per the DOD Component and approved by the DDESB
NFPA 780, 8.10	Visual inspection	Seven months
NFPA 780, 8.10.6.3	Visual inspection of the SPD	Seven months or after any suspected lightning strike
NFPA 780, 8.10.7	Electrical tests	14 months
DA PAM 385-64, 17-28	Visual inspection	12 months
DA PAM 385-64, 17-28	Electrical tests	Two years
AFMAN 91-201 (per AFI 32-1065, Table 1)	Visual inspection	1-2 years as determined by MAJCOM EE
AFMAN 91-201 (per AFI 32-1065, Table 1)	Visual inspection of SPD	six months and after a lightning strike
AFMAN 91-201 (per AFI 32-1065, Table 1)	Electrical tests	24 months
NAVSEA OP 5, 6-9.	Visual inspection	6 months (100% of air terminals if integral system)
NAVSEA OP 5, 6-9.	Electrical tests	24 months (20% of air terminals if integral system)

In addition to the required inspection and testing listed in Table 3, DOD instructs that a maintenance and inspection plan be in place for AE facilities. Records and data of the inspections and tests are required to be kept on file for a specified duration. Table 4 contains the requirements for record keeping and durations.

Table 4. LPS Records and Training Documentation

Criteria	Records and Trainings	Duration
DOD 6055.09-M, V2.E4.3.3	Records and test measurements	Kept on file for at least six inspection cycles
DOD 6055.09-M, V2.E4.3.4	Establish training requirements for LPS personnel	
NFPA 780, 8.9	Maintenance and inspection plan shall be developed	
NFPA 780, 8.10.7.7	Records and test measurements documented and available for inspection	Time period acceptable to the AHJ
DA PAM 385-64, 17-29	Inspection and test reports will be maintained	For the last six inspection cycles
AFMAN 91-201, 5.24.3	Records and test measurement data shall be kept	For the last six inspection cycles
NAVSEA OP 5, 6-9	Test plan for inspection and testing must be developed; personnel must be trained in DOD LPSs	

Common LPS Deficiencies Observed

To ensure the LPS of an AE facility maintains its integrity and conformance with NFPA 780, DOD 6055.09-M, V2.E4.3.5 requires maintenance be performed and documented as shown above in Tables 3 and 4. Inspections of LPSs are part of the effort to maintain the integrity of the LPS and to continue operating under an approved ESSP. Common deficiencies observed during similar inspections are listed in Table 5, and are provided as a resource and aid in maintaining a properly installed LPS. This list is not exhaustive, but represents those deficiencies likely to be observed during visual inspections.

Table 5. Common Deficiencies Observed During Visual Inspections

Common Deficiencies	**Primary Criteria Reference**
Surge Protective Devices (SPD) must be installed at the entrance and exit of power and communication conductors (including IDS) for AE facilities.	DOD 6055.09-M, V2.E3.6.1, E4.2.3 UFC 3-575-01, 3-4 NFPA 780, 8.6 DA PAM 385-64, 17-26.*a*, *b*. AFMAN 91-201, 5.23.5. AFI 32-1065, 15. NAVSEA OP 5, 6-7.
Aboveground metallic utility lines and pipes must be electrically bonded to the structural steel of the building before entering the building, or they must be run underground the last 50 ft. to the building.	DOD 6055.09-M, V2.E3.6.1 DA PAM 385-64, 17-26.*d*. AFMAN 91-201, 5.23.5. AFI 32-1065, 15.2. NAVSEA OP 5, 6-6.3.3.
Power, data and communication lines must run underground the last 50 ft. before entering the facility.	DOD 6055.09-M, V2.E3.5.1., 6.2 DA PAM 385.64, 17-26.*b*. AFMAN 91-201, 5.23.5 AFI 32-1065, 15. NAVSEA OP 5, 6-7.2.
Down conductors must be secured every 3 ft., or be provided with a positive means of support.	NFPA 780, 4.10 DA PAM 385-64, 17-19.*e*.
Down conductors must be protected from physical damage for a distance of 6 ft. above grade.	NFPA 780, 4.9.11 AFI 32-1065, A4.1.8.
Main conductor bends shall not form an angle of less than 90 degrees, not have a radius of bend less than 8 in.	NFPA 780, 4.9.5 DA PAM 385-64, Table 17-4 AFI 32-1065, A4.1.5.
Metallic access doors and doorframes shall be bonded to the ground ring electrode.	NFPA 780, 8.5.5 DA PAM 385-64, 17-22.*b*.(2) NAVSEA OP 5, 6-6.3.4.
Metallic masses within the sideflash distance shall be bonded to the LPS.	NFPA 780, 8.5.2 DA PAM 385-64, 17-22.*b*.(1) NAVSEA OP 5, 6-6.
Fences shall be grounded where located within 6 ft. of an AE structure to the grounding system of the structure.	NFPA 780, 8.8.1 DA PAM 385-64, 17-22.*e*. NAVSEA OP 5, 6-6.3.2.
Air terminals exceeding 24 in. in height shall require additional support.	NFPA 780, 4.6.2.2.2
Electrical testing and visual inspections must be performed at designated intervals.	DOD 6055.0-M, V2.E4.3 NFPA 780, 8.10 DA PAM 385-64, 17-28. NAVSEA OP 5, 6-9.

Common Deficiency (cont.)	Primary Criteria Reference (cont.)
LPS must be provided with a UL Certificate or a third party certificate.	UFC 30575-01, 3-1
AE facility must maintain separation distances between overhead electrical power lines based on DOD 6055.09-M.	DOD 6055.09-M, V2.E3.5.2 DA PAM 385-64, 8-13 (Table 8-5)

Conclusion

DOD AE facilities are required to have a properly designed, installed, and maintained LPS (approved exceptions noted). The designer, installer and owner must be cognitive of these requirements in order to ensure the AE facility complies with DDESB standards for explosive operations. The LPS of an AE facility must be able to intercept 97% of all probable lightning strikes based on the 100 ft. RSM analysis. Understanding this concept and knowing the criteria resources that define the varied LPS standards for AE facilities will aid in the successful approval of the ESSP.

References

[1] Richard Kithil, "21st Century Lightning Safety for Defense Environments Containing Energetic Substances" (paper presented at the Lightning Protection System Conference, Robins AFB, April 15, 2018).

[2] "Lightning Primer," Types of Lightning Discharges, accessed July 9, 2018, https://ghrc.nsstc.nasa.gov/lightning/lightning_primer.html#, page 4.

[3] Dr. Josephine Covino, "Lightning Protection for Explosive Facilities," Technical Paper 22, March 1, 2010. Department of Defense Explosive Safety Board, Alexandria, Virginia.