Lightning Protection Requirements for Aluminum Geodesic Dome Storage Tanks

There has been discussion recently concerning the need for a dedicated lightning protection system on aluminum geodesic domes covering storage tanks. This is partly due to recent lightning-caused fires in such structures.

There are two general concerns: direct lightning attachment and conducting lightning energy to ground. The lightning attachment discussion centers on the suitability of dome components to sustain a direct lightning strike without damage, particularly burn through. The current conducting discussion centers on the ability of the dome structure, roof attachment to the tank shell rim, and the tank shell to safely conduct the lightning energy to ground.

There are some apologists for not protecting these structures basing their arguments on studies regarding other types of aluminum structures, including aircraft. However, the incidence of even one storage tank fire argues persuasively against the relevance of such studies to storage tanks.

REFERENCED DOCUMENTS

Throughout this discussion are references to both API and NFPA documents. The American Petroleum Institute recommended practices (RP) are API 2003, “Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents” and API 545, “Recommended Practice for Lightning Protection of Aboveground Storage Tanks for Flammable or Combustible Liquids”. The National Fire Protection Association (NFPA) standard is NFPA 780, “Standard for the Installation of Lightning Protection Systems”. It should be noted that the API 545 committee has been disbanded and the RP rolled into API 650.

Since this discussion centers on petroleum storage tanks and the API documents specifically address petroleum storage tanks, the API documents should be considered primary. However, the API documents offer little guidance regarding location and spacing of lightning protection system components. The NFPA document does provide such guidance. However,

the designs contained in the NFPA document were originally intended to provide protection for wood barns and houses, not industrial facilities. As such, the 780 document is somewhat lacking when applied to tanks.

LIGHTNING ATTACHMENT

The attachment issue concerns the acceptability of substituting the dome structure in place of air terminals (lightning rods) or other strike termination devices. Reviewing applicable standards and recommended practices, National Fire Protection Association NFPA 780 is the lightning protection standard for the US. NFPA 780, 4.6.1.4 states that metal parts of a structure that are exposed to direct lightning flashes and that have a metal thickness of 3/16" (4.8 mm) or greater shall only require connection to the lightning protection (conductor) system. That thickness requirement is intended to assure that the structure is adequate to accept lightning attachment without burn through or other damage from the heat or impact of a direct lightning attachment.

The structural parts of the dome, including the nodes and beams, can usually meet the thickness requirements to serve as strike termination devices. However, the panels and node covers usually do not. One of the principles of conventional lightning protection is that any portion of a structure not meeting the requirements of a strike termination device must fall within the zone of protection of a portion of the structure that does meet those requirements. Think of an air terminal (lightning rod). The zone of protection is defined as the space adjacent to a lightning protection system that is substantially immune to direct lightning flashes. It is a volume of space around a lightning rod wherein lightning will attach to that lightning rod in preference to anything else around it. As long as the entire protected structure is located within a lightning rod zone of protection, the protection model claims that lightning will always attach to a lightning rod and be harmlessly conveyed around the protected structure to ground, thereby sparing attachment to the parts of the structure that are subject to burn through or other damage.

There are basically three options to determine the zone of protection of a lightning rod: layout, angle and rolling sphere. None of them are met by the structure of a geodesic dome. Therefore, there is nothing on the dome that will protect the panels, leaving them subject to direct attachment and burn

through. However, the options may be met by installing lightning rods on the dome in such a manner that all areas of the dome are within the zone of protection of one or more lightning rods. The easiest way to accomplish this is to install air terminals (lightning rods) on the nodes with spacing that protects the panels.

CONDUCTION OF CURRENT

Section 4.9 describes the conductor system intended to convey the lightning strike energy from the air terminal to ground. Section 4.9.3 allows certain metallic structural members to be substituted for a wire or cable conductor system. If structural steel is electrically continuous and greater than 3/16" thick, it may be used as the conductor system. This thickness requirement is overkill and does not make much sense, as conductors are not subject to the burn through caused by a direct lightning attachment. They only conduct lightning current, so the thickness requirement is probably a holdover from the thickness requirement for a strike termination device. A thickness requirement of 0.064" (0.0016256 m) is specified in NFPA 780, 4.9.3.2 for metal handrails and ladders and 4.6.5.3 for metal masts, so it follows that the minimum thickness of any substituted metal needs be only 0.064".

NFPA 780, 4.19 addresses structural metallic systems. This section allows the metal framework of a structure to be utilized as the main conductors in a lightning protection system. The framework of a geodesic dome is analogous to the structural steel in an ordinary structure. This section also contains the 3/16" thickness requirement, but again, the argument can be supported for allowing the substitution of 0.064" thickness.

Once the current is conducted to the perimeter of the domed roof, it must be transferred to the tank shell. There are several sections contained in NFPA 780 offering guidance. If the attachments between the roof and tank shell are considered to be equivalent to down conductors in a conventional lightning protection system, the requirement is for bonding the roof to the rim of the tank shell at intervals not to exceed 100' per 4.9.10.1. This spacing requirement is supported by the 100' maximum spacing of bypass conductors contained in 7.4.3.2.2.4 (2). These bonding conductors should be as short and straight as practical and allow for full motion of the tank roof on the tank shell rim.

GROUNDING

Once the lightning energy reaches the base of the tank shell, it must be safely dissipated into ground. For lightning protection purposes, flat-bottom metal tanks and other structures are considered inherently self-grounding, per API 545, A.2.1 and API 2003, 5.4.1. This applies whether or not a containment liner or barrier is installed either in or under the tank or structure, per API 545, A.2.2.

If an operator wishes to supplement the inherent self-grounding properties of a tank, there are several different types of grounding electrodes (connection to ground) allowed by standard. These include ground rods, ground plates, ground loop conductors, plant grounding grids and buried metal piping. One way to look at the inherent self-grounding properties of a flat-bottom steel tank is to compare it to a flat plate grounding electrode, as allowed in NFPA 780, 4.13.6. The tank bottom has a much larger area than a flat plate electrode, and is pressed against ground by the weight of the tank and stored product. Therefore, it is actually a pretty good connection to ground.

If a ground grid is installed at a site, each tank should also be grounded to that grid at a minimum of two locations, and preferably at additional intervals not to exceed 100’ around the tank perimeter. Metal piping attached to a tank and buried for a minimum length of 10’ may also be considered to be ground.

This does not address grounding for purposes other than lightning protection. Grounding for other purposes, such as AC power grounding, should be considered by the owner/operator.

REALITY CHECK

A common sense reality check supports this design. The main concern is to lift the heat of a direct attachment off of the geodesic dome panels. Direct attachment could cause a burn through and result in molten roof material falling onto the internal floating roof where, if the seals are not adequately maintained, an explosive atmosphere may be present.

Another concern is to prevent arcing, particularly at the juncture of the geodesic dome and the tank shell rim where an explosive atmosphere may also be present. The use of the system described above reduces these possibilities.

Although not required by any standard, some operators have, as best practice, installed bypass conductors between the internal floating roof and the tank shell as described in API 545 and 2003 and NFPA 780. Some may consider this to be overkill, but it also may contribute to eliminating arcing between the floating roof and tank shell.

CERTIFICATIONS

Often an owner/operator will desire a third-party certification of a completed lightning protection installation. Underwriters Laboratories (UL) is the Nationally Recognized Testing Laboratory (NRTL – pronounced to rhyme with "turtle") in the lightning protection industry. UL converts NFPA 780 into two documents. UL 96 covers Lightning Protection Components and UL 96A covers Installation Requirements. Based upon compliance with these documents, UL can issue certifications of completed installations, best known of which is a "UL Master Label". However, the UL documents specifically exclude from their scope any "structures used for the production, handling, or storage of ammunition, explosives, flammable liquids or gasses, and other explosive ingredients including dust". Because of this exclusion, in place of a Master Label, UL will issue a Letter of Findings or Engineering Inspection Report that have the same import as a Master Label but reference this exclusion.

CONCLUSION

If your geodesic dome tanks exceed your risk threshold, you may want to consider adding air terminals and bonding to your geodesic dome tank. As things stand, the best way to do so and to meet standards is to apply a structural lightning protection system as described above.