Lightning as a source of ignition.

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It has become evident that in those industries that would be most affected by lightning events that sometimes the least attention to the consequence to those events has been considered.

This paper will introduce the concept of isolated lightning protection systems and separation distances.

This paper will look at the steps that the designer would need to take to protect a site and work with suppliers and contractors to deliver a compliant system of protection.

The paper shall look at the current regulations from COMAH, DSEAR and standards BSEN 62305, BSEN 1127 and the BSEN 60079 series.

Common installation errors shall be investigated, and industry practices challenged by comparing actual installs to the requirements of regulations.

With the publication of the new wiring regulations 18th edition BS7671, the paper will show how new installations will be impacted by the revised sections 443 and 534 on risk assessment and installation of surge protection devices or SPDs.

Finally, we shall see what work flow is required to produce a risk assessment to a compliant design and installation.

Keywords. Risk reduction, Lightning, surge protection, COMAH, DSEAR, BS EN 62305, isolated lightning protection. Risk assessment, transient overvoltage, surge suppression BS7671.

Starting with the risk assessment.

The standards that apply and that shall be referred to.

The standards and regulations that guide the designer to apply risk assessments to COMHA sites are as follows,

BS EN 62305 including the national supplements (Annexe D) on the use of lightning protection systems for structures with a risk of explosion,

BS EN 60079 for the installation and use of equipment in hazardous areas,

BS EN 1127 Explosion Prevention & Protection. Basic concepts and methodology.

HSE ACOP L138 dangerous substances and explosive atmospheres

HSE INDG370 Controlling fires and explosive risk in the workplace

Petroleum (Consolidation) Regulations 2014

The primary legislation applying to the control of substances that can cause fires and explosions in the workplace is the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) (SI 2002 No.2776). Updated in 2015

So, there is no shortage of guidance on the subjects of dealing with lightning as a source of ignition. It is the case that these documents identify lightning as a specific source or hazard and that they also describe the methodology to mitigate from the risk of explosion.

Lightning is a form of ignition as defined by HSE and British Standards.

Lightning is a natural form of electrostatic discharge.

Lightning by definition poses a risk in ATEX installations.

DSEAR places duties on employers (and the self-employed, who are considered employers for the purposes of the Regulations) to substitute, control, mitigate risk from dangerous substances.

Complying with DSEAR involves:

Preventing or controlling risks

Employers must put control measures in place to eliminate risks from dangerous substances, or reduce them as far as is reasonably practicable. Where it is not possible to eliminate the risk completely employers must take measures to control risks and reduce the severity (mitigate) the effects of any harmful event.

Control measures

Where the risk cannot be eliminated, DSEAR requires control measures to be applied in the following priority order:

reduce the quantity of dangerous substances to a minimum

avoid or minimise releases of dangerous substances

control releases of dangerous substances at source

prevent the formation of a dangerous atmosphere

collect, contain and remove any releases to a safe place (for example, through ventilation)

avoid & control ignition sources.

DSEAR goes on to mention in the risk assessment that there shall be consideration of the likelihood that ignition sources including electrostatic discharges will be present and become active and effective.

Lightning is the most powerful form of electrical discharge so, we refer to the standard that deals with risk from lightning strikes, BS EN 62305, this risk process like any other will firstly analyse risk, then quantify the risk, then it is possible to calculate the total risk for the site.

The methods to control risk will be prevent, reduce (using protective measures) and insure to an acceptable level of risk.

Under the standard BS EN 62305 there are four sources of risk, numbered S1 to S4. S1 being a direct strike to the structure and S2 a strike near to the structure, S3 is a direct hit to overhead lines and S4 is a strike near the cables. The fitted lightning protection is the only way to deal with a direct hit, whilst the effects on the internal electrical systems from the other three sources of risk are mitigated by surge protection devices as a primary protection solution.

Then we have types of damage D1 to D3 where D1 is injury to living beings, D2 is physical damage to the structure and damage to the environment due to release of chemicals or similar, D3 is failure of electrical or electronic systems.

Finally, in the risk assessment we have types of Loss from L1 to L4, the highest loss is human life for L1, then L2 is loss of service to the public, L3 is cultural loss and L4 is economic loss.

In the cases we are looking at L1 and L2 are the most that a BS EN 62305 risk assessment normally cover. L3 clearly applies to certain structures only, whilst the economic loss would only be possible to calculate if there was access to the accounts of the site being assessed.

From the onset of the risk assessment process then it is accepted albeit uncomfortably so, that not all the losses are accounted for by most persons carrying out such risk assessments. This would be due to lack of knowledge or an approach to risk assessments that involves completing them as quickly as possible.

After all the data has been collected for the risk assessment there will be one of 5 possible outcomes. Firstly, that there was no lightning protection system (LPS) required and then the alternative is that the fitted LPS is required and would be lightning protection levels (LPL) 1 to 4. LPL1 and 2 being the highest level for the most dangerous or sensitive structures. Then LPL 3 and 4 is for the less onerous structures like retail or low-level blocks of flats.

It is vital to remember that by simply carrying out a risk assessment you have not controlled lightning. The risk assessment draws a line in the sand based on the likelihood of death or serious injury resulting from a lightning event. It does not mean that a lightning event will not occur if, a risk assessment (when correctly carried out) suggests that protection is not required, it is vital to ensure that even minor injuries, disruption to local services and the environment are also accounted for.

We turn our attention now to BS EN 1127, from the following section.

6.4 Requirements for the design and construction of equipment, protective systems and components by avoidance of effective ignition sources

6.4.8 Lightning

The conductive paths for the lightning shall be achieved in such a way, that warming up, ignitable sparks alternatively spray sparks cannot become the ignition source of the explosive atmosphere. That applies also to lightning strikes in greater distances.

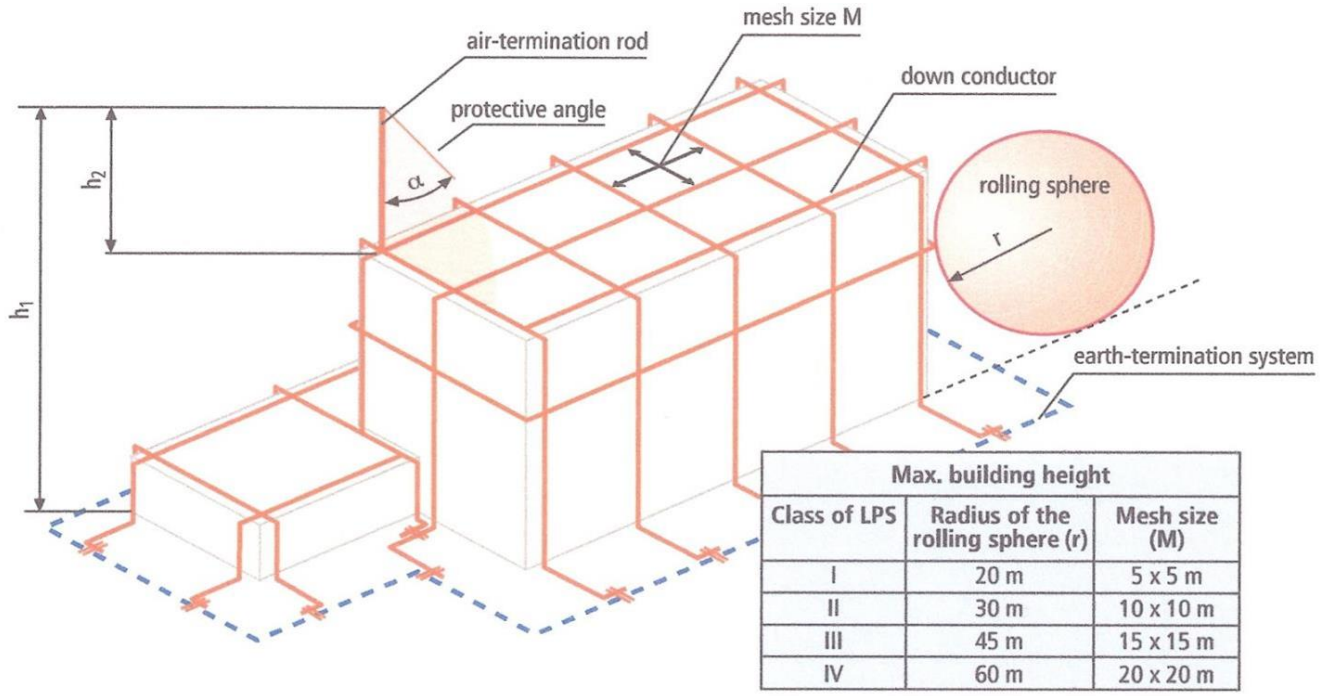
The measures have at least to be implemented in such a way, that a bolt of lightning of a radius of 30 m can be controlled. (LPL 2 minimum) the 30m referring to the size of the rolling sphere used in the risk assessment.

Lightning protection measures by their effect or configuration need not impair other protective measures, e.g. cathodic corrosion protection.

In addition to electric lines, metallic plant parts which are reliable conductively connected are presumed to be conductors between metal parts and earth connection.

It is very clear that in hazardous areas the minimum LPL required is 2. The image 1 below shows the reality of LPL2 that the rolling sphere, that is used to determine the location of air terminations. The down conductor spacing is 10m and the roof line mesh shall be 10 x 10m. That works well on flat roofed structures but that is not always the style of construction we are dealing with.

Image 1, the relationship of rolling sphere to lightning protection installation mesh size.



Max. building height		
Class of LPS	Radius of the rolling sphere (r)	Mesh size (M)
I	20 m	5 x 5 m
II	30 m	10 x 10 m
III	45 m	15 x 15 m
IV	60 m	20 x 20 m

The text from BS EN 1127 highlighted another important point in the first paragraph.” The conductive paths for the lightning shall be achieved in such a way, that warming up, ignitable sparks alternatively spray sparks cannot become the ignition source of the explosive atmosphere. That applies also to lightning strikes in greater distances.”

Now the most common method of installing LPS is to cross bond all metal parts so there is a common equipotential network and no chance of flash over.

However, it is the case that exposed metal clamps that are part of the LPS especially those within or near atmospheres that have the possibility of chemical attack on those metal parts, that those parts become loose or corroded. This brings the chance of flash over due to those loose parts or corroded parts to the forefront of a risk assessment and the designers mind. Tests carried out at the DEHN laboratory have shown that under strike conditions it takes just normal levels of corrosion or weathering due to exposed metals in certain atmospheres to produce sparks, this is not normally an issue on a church spire but a major issue in ATEX zones.

BSEN62305:2012 Part 3 paragraph 3.34 states that under the following circumstances we should consider a structure at risk of explosion:

“Structures containing solid explosive materials or hazardous zones as determined in accordance with BSEN60079-10-1 and BSEN60079-10-2”

BSEN62305:2012 Part 2 paragraph 5.4 (the procedure to evaluate the need for protection) Note 2 states:

“Where protection against lightning is required by the authority having jurisdiction for structures with a risk of explosion, at least a class II LPS should be adopted.”

Note 3 states:

“When the damage to a structure due to lighting may also involve surrounding structure or environment, additional protection measures may be required”

The standard does not go into more detail regarding note 3 but it is safe to assume that it is suggesting more protection, a higher level of design & specification rather than the lowest common factor.

Image 2 below shows typical corrosion of flat copper tapes coastal town location.

Image 2 showing effects of salt water atmosphere corrosion on flat copper tapes of fitted LPS.

The components within a British Standard range of lightning protection parts are not EX tested. These parts are typically flat tape of various metals and clamping devices to structural parts and/or the tapes.

The path from the air termination to the earth pit must be continuous and any clamps designed such they are EX approved.

Looking at another section is BS EN 1127.

5 Possible ignition sources

5.7 Lightning

If lightning strikes in an explosive atmosphere, ignition will always occur. Moreover, there is also a possibility of ignition due to the high temperature reached by lightning conductors.

Large currents flow from where the lightning strikes and these currents can produce sparks in the vicinity of the point of impact.

Even in the absence of lightning strikes, thunderstorms can cause high induced voltages in equipment, protective systems and components and can lead to ignition hazards.

For protective measures against ignition hazards due to lightning see 6.4.8.

6.4.8 Lightning

Equipotential bonding as well as circuit points and connection with pipes are to be designed in such a way, that during the electric flow of a lightning strike no sparks or improper high warming up occurs.

Appropriate connections at pipes are welded flags or bolts or tapped holes in the flanges for the input of screws.

For equipment Category 1, these connections shall be so dimensioned, that they can bear the electric current of the lightning.

Additionally, for equipment Category 1, overvoltage protection systems (SPDs) are to be installed outside of hazardous places.

Protective measures for Category 3: Lightning arrestors are not necessary, as the probability of the coincidence of a lightning and the occurrence of explosive atmosphere can be regarded to be extremely low. If necessary, organisational precautions can be applied (e.g. during maintenance).

So, we can already see that the performance of the traditional flat copper tape LPS as favoured by most lightning protection installers is not suitable for more demanding installations. Many locations with salt laden or other gaseous emissions badly degrade the materials and connection points so introducing the risk of sparking and therefore explosion.

Even without the environmental issues the effects of lightning flowing down the tapes can still produce sparks as the traditional parts or components are not approved for use within ATEX zones.

From BS EN 1127 “Lightning will always lead to ignition, either from thermal rise, flash over, sparking, physical damage to structures or from induced energy leading to faults within localised LV distributions systems and equipment”

The tape can suffer from an electrodynamic effect during strike events, this means the huge amount of current flowing with its very dramatic short rise time causes the tape to “thrash about” breaking the fixings and in so doing create sparks.

BSEN 60079-14 Electrical Installations in Hazardous Areas states:

Bonding connections should only be made through specifically designed connection points and not rely on fortuitous contact. All connections should be secured against self-loosening. This requires the use of materials that are designed for the particular application and are fit for purpose.

Electrical energy carrying systems within zone 0/20 or 1/21 must have very low power levels, produce no hot surfaces, limit current and voltage under normal and fault conditions, reduce inductance and capacitance and will not create electrical sparks or will have insufficient energy to ignite the most easily ignitable concentration of a flammable mixture.

Clearly from the requirements of BSEN 60079-14 any conventional cross bonded lightning protection system still presents a risk of ignition as the potential energy levels, sparking across joints and bonds, huge inductive voltages in conventional conductors mean that gasses, vapours and dust are still at risk from sparks and hot surfaces.

It takes just 280 micro Joules of energy to ignite Methane gas and only 20 micro Joules to ignite Hydrogen gas. A level IV cross-bonded lightning protection system is designed to deal with 100kV and will certainly experience in excess of 1,000,000 Joules or 1MJ, in a fault condition.

The image 3 below shows a typical installation of a metal AD tank “protected“, by the copper tape down conductor. The tape we can see has been routed between the two skins that makes the tanks side wall construction, in doing so it is impossible to inspect and the problem due to the electrodynamic effect poses a real risk to the tank, its contents and the surrounding area. For a non ATEX application copper tape on a metal tank appears pointless and in this application, it is very dangerous.

Image 3 Copper tape conductors on metallic AD tank farm.

On the same tank there is an expansion pressure release valve on the top and there will be an ATEX zone. From the image 4 below the extent of the ATEX zone has not been allowed for with the air termination that has been installed. The termination is an aluminium spike clamped to the hand rail, all within the ATEX zone. This is an example of how not to install the LPS But it is very common and inexpensive to do. This is a non- compliant system to DSEAR.

Image 4, air terminations on AD tank farm within ATEX zones.

The Isolated Lightning Protection System.

In BS EN 60079-14

Explosive Atmospheres – Part 14: Electrical installations design, selection and erection

6.6 Lightning protection

In the design of electrical installations, steps shall be taken to reduce to a safe level the effects of lightning (see BS EN 62305-3:2010, Annex D).

Subclause 16.3 gives details of lightning protection requirements for Ex ‚ia" apparatus installed in locations requiring EPL ‚Ga".

Then in the Annex D of BS EN 62305 the installation of the isolated lightning protection system is to be encouraged.

The definition of an isolated LPS within ATEX applications is simple, that the elements of the system are ATEX approved and that the strike interception point is well beyond the ATEX zone.

That the separation distance is maintained and that there are no joints in the conductor, within the ATEX zone and that there is no electrical connection to the structure, the LPS is then isolated from the zone and the structure.

Below is a comparison of two installations highlighting the importance of isolated systems.

Image 5 is a methane gas bag with lightning protection fitted. This bag has a ATEX zone over the whole surface of the tank, yet the installer has draped the braided conductor over the tank in the hot cross bun fashion. There is then no separation from the bag or the zone, any strike will destroy the bag and likely kill anyone around at the time. There are signs present that inform me that no flames or naked lights are to be present and that no mobile phones are permitted but it is OK to permit a direct lightning strike onto the gas bag.

Image 5 Methane bag with braided LPS fitted.

Image 6 below shows the ATEX zones around another installation as part of the design process.

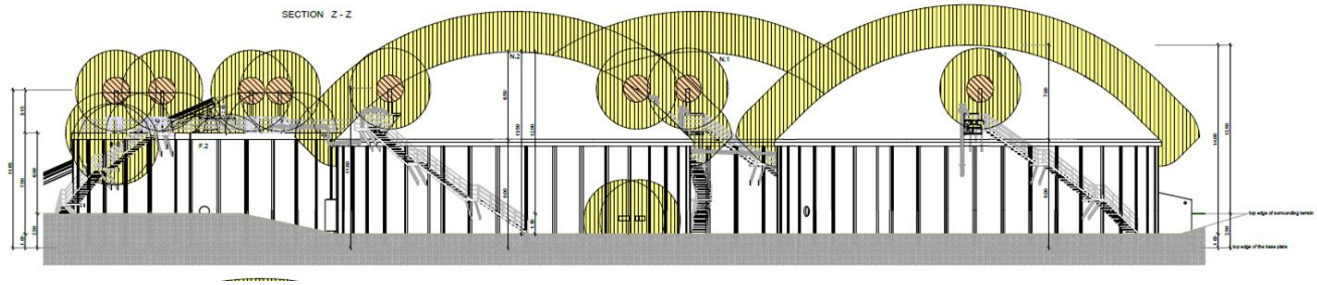


Image 6 ATEX zones site profile.

And Image 7 below shows the ATEX zone plan

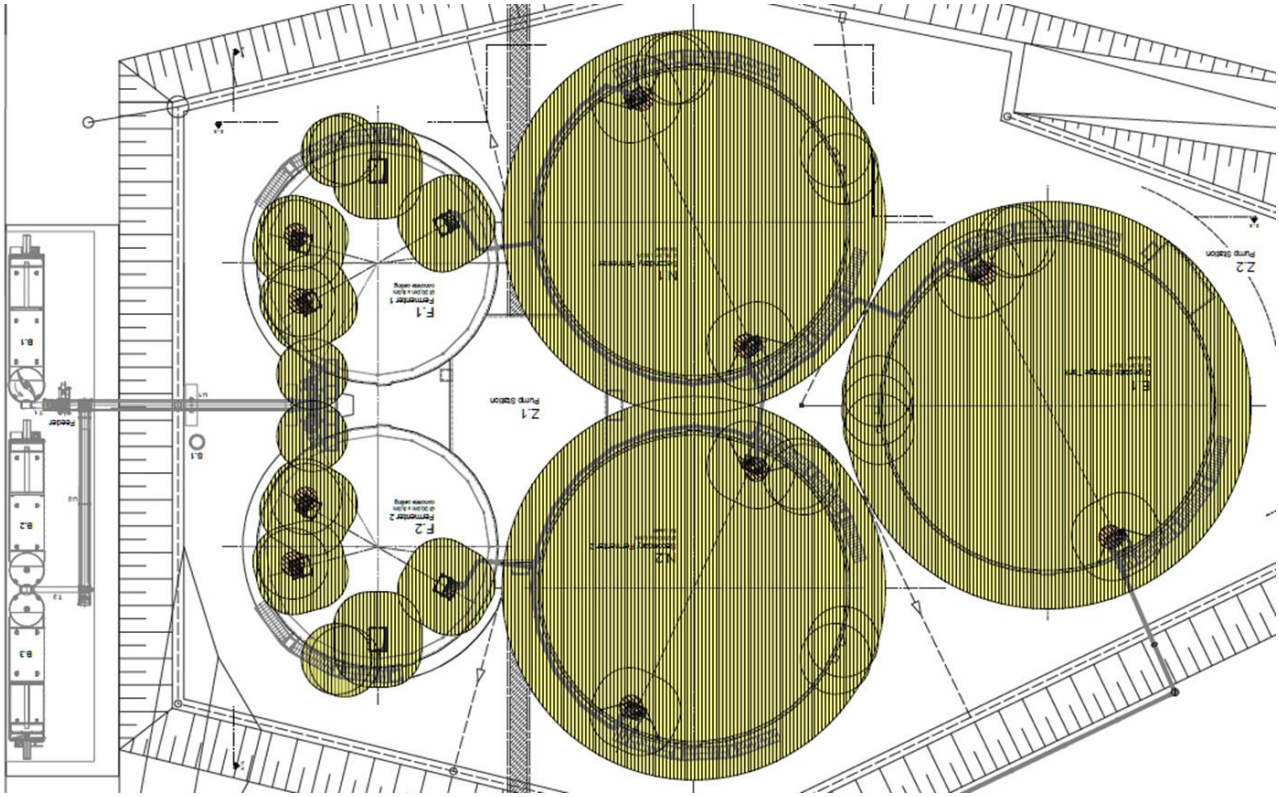


Image 7 plan of site ATEX zones on tank farm.

From such drawings it is possible to design a full isolated LPS so that the separation distances are always maintained and the extent of the ATEX zones is included in the design and they will be determined by the rolling sphere method. Shown in image 8 below.

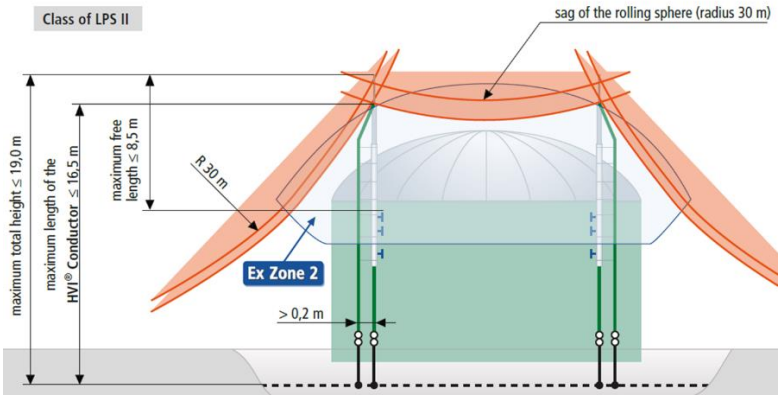


Image 8 principle of the rolling sphere on digester tank.

The concept of the isolated system is now being illustrated. The protection in this case would be served by masts fixed to the tank side walls and of such spacing and height that the tank and the ATEX zone are well under the strike points of the air terminations. In this arrangement the air termination is connected to twin down conductors one is contained within the masts supporting tube and the other conductor is adjacent to the first conductor on outside of the tube. This gives better separation by using current division down more conductor paths.

The conductors are not connected electrically to the tank walls and the final connection is to the earth ring electrode.

Image 9 below shows the LPS arrangement on the tank side wall. The parallel paths of the twin conductor are shown and the earth termination to the ring electrode. The tank side fixings of the LPS are not metallic and neither is the conductor coating.

Image 9, LPS down conductor arrangement.

Another arrangement would be the free-standing masts fixed such that again the height and position of the masts clear the tanks and the ATEX zones. Image 10 below shows a typical arrangement, also note that there is no catenary wire linking each mast tip as in fact the catenary method is not approved, and neither are catenary wire parts. Also, not approved is using lamp posts instead of tested and approved mast arrangements. It suggests that the lamp post just happened to be the correct height whilst the masts are telescopic to achieve the correct clearance distances.

BSEN62305:2012 Part 3 paragraph 5.1.2 (choice of LPS) states that:

“An isolated LPS should be considered when the thermal and explosive effects at the point of strike, or on the conductors carrying the lightning current, may cause damage to the structure or to the contents. Examples include; structures with combustible covering and areas at risk of explosion or fire”

It goes on to say:

“An isolated LPS should be considered when the susceptibility of the contents warrants a reduction in the radiated electromagnetic field associated with lightning”

5.2.4 (construction) says: “Easily combustible parts of the structure shall not remain in direct contact with the components of an external LPS and shall not remain directly under any metallic roofing that might be punctured by a lightning flash”

Annexe D4 states: “An isolated LPS is encouraged, earthing requirements of 5.4 are applicable (a type B or buried ring conductor), SPD’s shall be provided as part of the LPS for all locations where explosive material is present.”

So, an overwhelming level of recommendations and regulations for the selection of an isolated lightning protection system.

Image 10 mast isolated LPS on gas bubble.

Finally, an explanation of the down conductor component used in the isolated systems. The conductor is called HVI or high voltage insulated. It is a round cable looking like a large hose pipe or coax cable this has the added benefit of defeating copper tape theft.

The HVI® Conductor incorporates two basic features:

High-voltage-resistant insulation of the copper inner conductor

Lightning voltage is safely led in at the infeed point (strike point), thus preventing creeping flashover (voltage flashover) across the surface between the infeed point and the first earthing point. The whole arrangement of the strike or infeed point to the first earthing point is all located well outside the ATEX zone, this distance is typically 1.5m long and mounted 1m from the extent of the ATEX zone.

The HVI conductors can be installed in and through ATEX zones 1 or 2 for gas/vapour or 21 or 22 for dust. Any risk of flash over from the high energy lightning discharge is limited to the first 1.5 metre of conductor, this is also called the sealing end and should be free from conductive or earthed elements, this places that energy and any risk of flashover outside the zone. See image 11 below on the construction of the strike point and sealing end.

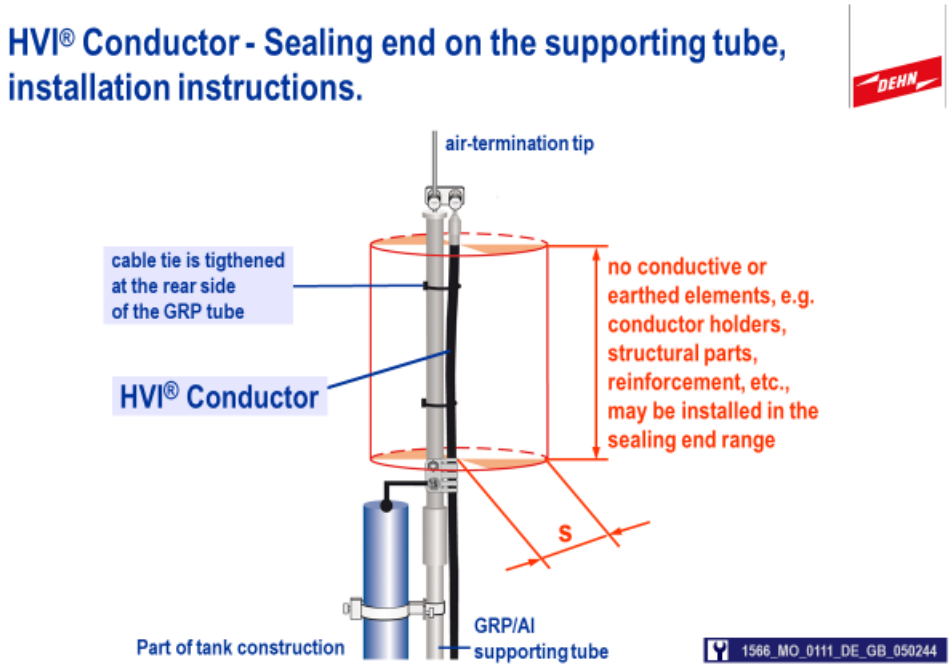


Image 11 The strike point and sealing end of a HVI isolated LPS.

The Lightning current carrying conductor of the HVI Conductor is wrapped with insulating material in such a way that the required separation distance from other conductive parts of the building, electric cables and pipes is maintained. The coaxial conductor consists of an inner copper conductor with a high voltage resistant thick-walled insulation and a weather resistant

semi-conductive outer sheath. Thus, creeping flashover along the surface of the conductor is prevented. See image 12 below for a cross section of the cable showing the dissipation of energy.

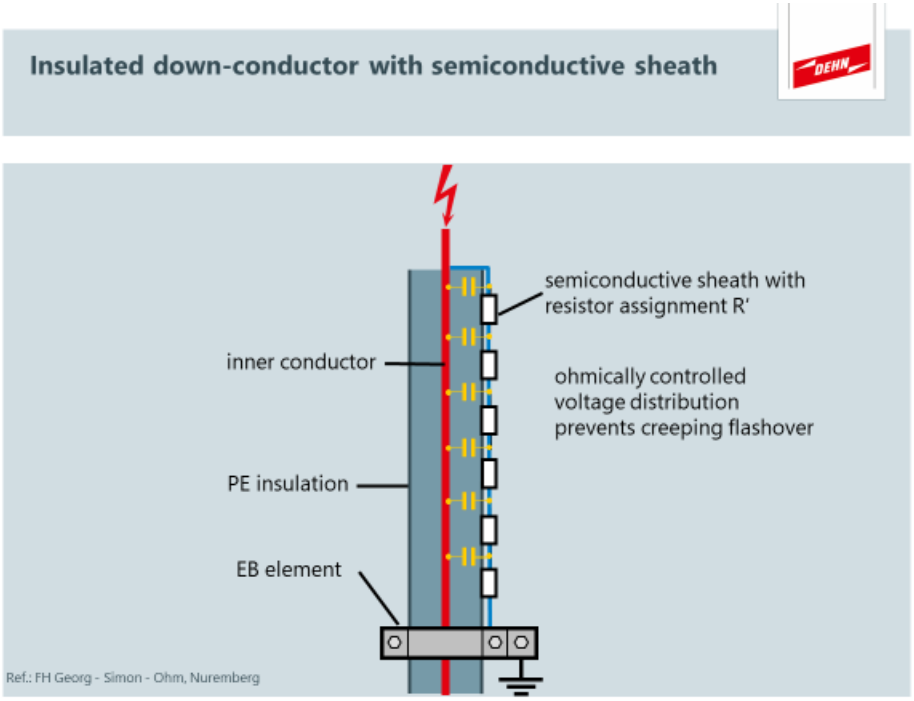


Image 12 showing the dissipation of lightning energy in the sealing end of HVI cable.

Image 13 below shows the whole installed HVI assembly in a ATEX zone 22 dust ventilation on a silo roof. The air termination and strike point are well outside the zone and the mechanical clamping of the assembly to the structure is by ATEX approved parts. Once the HVI cable has left the zone, the rest of the LPS in this case could be the conventional tape type as there is no risk posed of explosion.

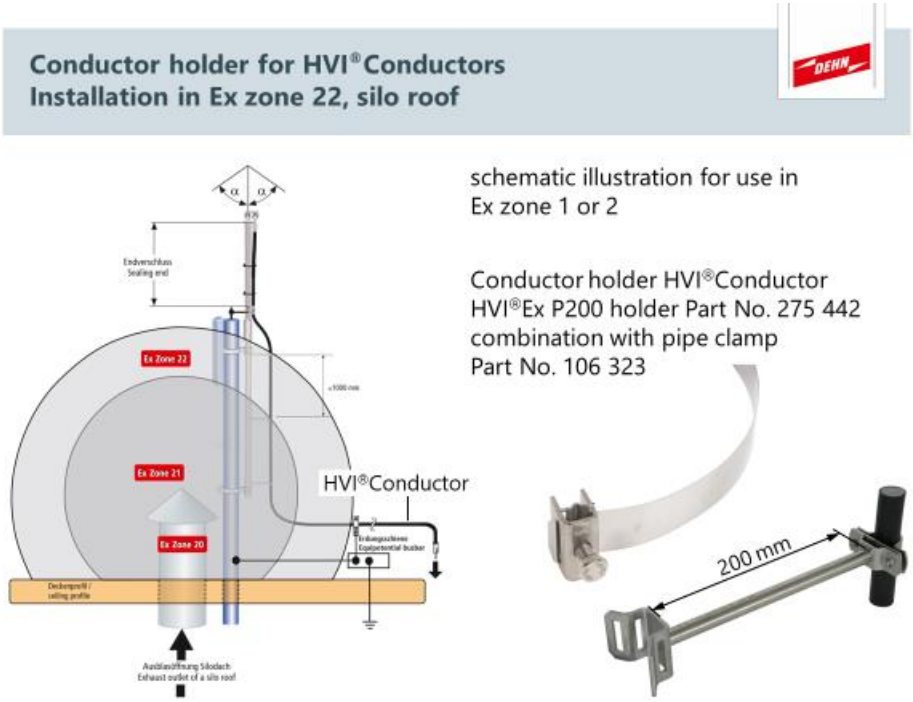


Image 13 showing a silo mounted HVI LPS in a zone 22 application.

In summary,

We have seen how the site operator has many regulatory and legal obligations to mitigate from the effects of lightning strike on the site.

Any site with risk of explosion will have a minimum LPL 2 system fitted and that due to the performance of traditional methods and materials the preferred LPS shall be the isolated system removing the strike risk and flash over from the ATEX zones.

In accordance with the risk assessment in BS7671 18th edition in section 443. Surge protection devices shall be installed. In addition, those SPDs shall be installed in accordance with the LPZ concept to preserve zonal integrity section 534.1 refers.

SPDs are a primary method of protecting installations from the effects of induced currents due to lightning strikes and lower level energy events due to manmade switching events etc.