ASPECTS OF EARTHING OF INSTALLATIONS IN ENVIRONMENTS WITH POTENTIALLY EXPLOSIVE ATMOSPHERES

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Abstract: In environments with potentially explosive atmospheres, earthing protection covers three aspects: protection against electric shock, prevention of electrostatic discharges from equipment/facilities, processed materials or people, and protection against atmospheric discharges. The paper presents some aspects regarding the specific requirements for earthing protection in atmospheres with the risk of explosive atmospheres that must be taken into account when evaluating the risk of explosions. Norms and reference standards are also highlighted, which are constantly changing in step with the latest scientific achievements, emphasizing the importance of updating them with the latest information.

Key words: potentially explosive atmospheres, earthing protection, grounding.

1. INTRODUCTION

In general, the protective earthing system is designed for protection against electric shocks – standards SR HD 60364-4-41:2017/A12:2020/IEC 60364-4-41 and protection against lightning – standards series SR EN 62305-x/ IEC 62305. In addition, in installations in environments with potentially explosive atmospheres, earthing systems (earthing protection) must provide protection against static electricity.

In this work, some particular aspects are highlighted for the protection against electrostatic discharges by grounding installations in Ex environments.

2. PREVENTING DANGEROUS STATIC ELECTRICITY BY GROUNDING

In industrial environments where potentially explosive atmospheres exist, there are many conductors that, if not properly grounded, can become charged to a

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dangerous level. Some of these are component parts of the plant or equipment used and include: plant structure, reaction vessels, pipes, valves, storage tanks and drums. Other parts are there only by accident or carelessness, for example: pieces of wire that are no longer needed, metal containers floating in medium or weakly conductive liquids, or tools accumulating conductive liquids on the surface of insulating materials.

Charges built up on one conductor can then be discharged to earth or to another conductor with the release of all stored energy as a single spark which may be sufficient to ignite the explosive mixture as in Fig 1.

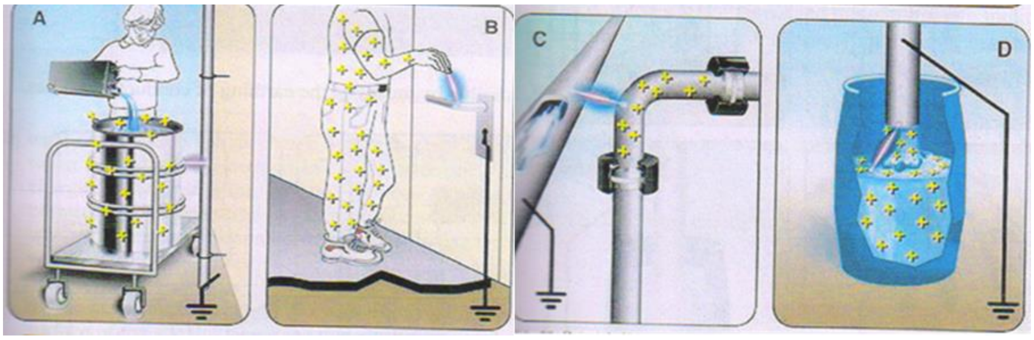

Fig. 1. Electrostatic spark discharges

The most effective way to avoid the dangers of static electricity is to bond all conductors together and then to ground. Bonding the components together is used to minimize the potential difference between conductive objects to an insignificant level, even when the resulting system is not grounded. Grounding, on the other hand, equalizes the potential differences between objects and the ground.

Examples of connecting the components to each other and grounding are shown in Fig 2.

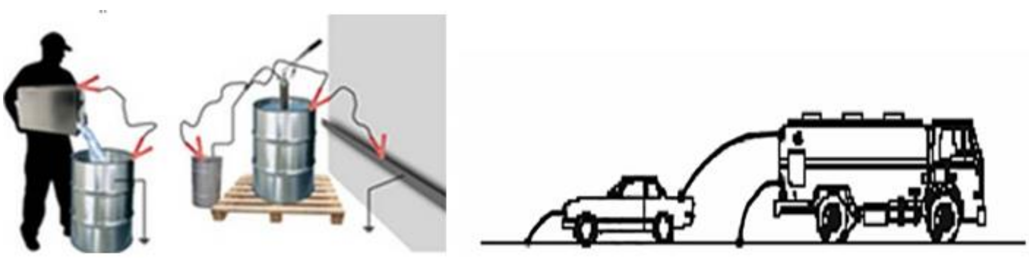

Fig. 2. Earthing and Bonding

A conductive object can be grounded by a direct conductive path to earth or by bonding it to another conductive object that is already grounded. Certain objects are inherently bound to others or inherently grounded due to their contact with the ground. The total resistance between an object and ground is the sum of the individual resistances of the grounding conductor, its connectors, other conductive materials along the desired grounding path, and the resistance of the grounding electrode (i.e. the grounding rod).

3. DISSIPATION CRITERIA OF STATIC ELECTRICITY FROM A CONDUCTOR

The resistances of the electrical paths must be low enough to allow the relaxation of the load and to prevent potential build-up on the conductor to a dangerous level.If this potential is V, the maximum allowed value of the resistance R depends on the rate at which the conductor receives charges, i.e. the charging current I. Because of this principle, the total resistance to earth must not exceed the acceptable level given by the equation:

$$V = I \cdot R \tag{1}$$

To prevent all incendiary discharges it is necessary to ensure that the conductor does not reach the potential necessary to initiate an incendiary discharge.For normal industrial operations this potential is at least 300 V. Using the value of 100 V as the limit value for safe dissipation of static electricity, the value of the total earth resistance R, can be calculated as follows:

$$R = \frac{100}{I} \tag{2}$$

where : R is in ohms
I is in amps

When specifying grounding requirements, each concrete situation must be taken into account, i.e. each individual value of the load current I. Since it is known that the charging currents are in the range between 10 pA and 100 µA, the corresponding values of R are between 10 TΩ and 10 MΩ. For a maximum value of I, a ground resistance of 1 MΩ will ensure safe dissipation of static electricity under all conditions.

However, in most industrial operations I does not exceed 1 µA and the conductor capacitance C does not exceed 100 pF. In this case the ground resistance of 100 MΩ is appropriate.

Conductors that have good contact with the ground have a ground resistance of less than 10Ω. Although a value of up to 1 MΩ is acceptable for static dissipation, values greater than 10 Ω may give an early indication of developing problems (eg corrosion or a poor connection) and should be investigated. It is important that all connections are reliable, permanent and not damaged.

A clear distinction must be made between a value chosen for convenience when monitoring metal-to-metal connections and the 1 MW value which represents the upper limit of the ground resistance of a conductor in all situations.What is most important, however, is that all connections are reliable, permanent and not subject to damage.

Mobile metal elements require special grounding connections, which must have a resistance of less than 1 MW.

In IEC 60079-32-1 TS [1] maximum grounding resistances are given for static electricity control for specific applications.

In some casesvalues up to $10^8\Omega$ are acceptable, especially when the conductor capacitance does not exceed 100 pF.

If the common bonding/earthing system is all metal, typically the resistance of the paths to earth is less than 10Ω. Such systems include those with multiple components. Higher resistance usually indicates that the metal path is not continuous, usually due to corrosion and loose connections. A grounding system that is acceptable for power circuits or for lightning protection will be more than adequate for static electricity grounding.

An important element of protective earthing installations is the earthing socket. The requirements for the resistance of the earth plug are given in the norms I7 and NP 099 [2], [3] [12], [13], [16].

According to point 5.5.7.11. from the standard I7:2011, the resistance of the earth socket can be:

- not more than 4 ohms when used only for protection against electric shock
- not more than 1 ohm when it is shared with the earthing socket for the lightning protection installation of the building.

According to point 12.3.6. from the norm NP 099, the earth socket of the lightning arrester installation is designed according to the provisions of I 20. The dispersion resistance value of the artificial earth plug that is used exclusively for the lightning arrester installation must be a maximum of 5 ohms for installations mounted on the construction and a maximum of 10 ohms for independent lightning arrester installations.

Normative I7 from 2011 with updates from 2023 applies to the design, execution and operation of electrical installations related to buildings, regardless of the form of ownership, including electrical equipment located in environments with a risk of explosion, to which the provisions of NP 099- 04. The regulation NP 099-04 (revision of ID 17-1986) for the design, execution, verification and operation of electrical installations in areas with explosion hazard was developed in 2005 and was not updated with the requirements of the new regulations and standards. With regard to protection by grounding for protection against dangerous static electricity and against atmospheric discharges, reference is made to standard I 20, which, however, is canceled and included in standard I7.

Since the rules and standards in force (latest editions) must be respected when designing and implementing earthing protection systems, they must be updated whenever changes occur in order not to create confusion or contradictions.

4. ASPECTS OF GROUNDING OF MOBILE EQUIPMENT

The grounding requirements of mobile equipment in potentially explosive atmospheres to prevent electrostatic spark discharges are revealed in many studies, in norms and standards, but in practical activity it is found that there are many aspects that are not well managed and that could be a source of danger of ignition of explosive atmosphere by electrostatic discharges. The grounding of fixed equipment is somewhat easier to achieve and control with technical means. A more sensible approach is to make temporary connections to mobile equipment which can be made using pressure type earth clamps or other special clamps. Temporary grounding connections of movable elements can be made with screws, pressure-type earthing clamps or other special clamps. Pressure clamps must have sufficient pressure to penetrate any coating of paint, rust or spilled material to ensure contact with the metal base.

When flammable or combustible products are handled and processed in hazardous areas, it is essential to use certified equipment to protect personnel from electrostatic ignition sources. Certification of equipment for explosive atmospheres requires compliance with the requirements of the ATEX Directive [4], [14], [15], [17].

The question is asked: Earthing clamp shall it be Ex or not? Does the earthing clamp fall within the scope of the directive or not?

Electrostatic discharge, as a source of ignition, is often within the control of the design of the installation, rather than the equipment, and comes within the scope of the ATEX "workplace" Directive 1999/92/EC [5], backed up by standards providing appropriate detailed information.

However, the design of equipment can help to mitigate such risks and appropriate requirements are detailed in European harmonized standards.

Where equipment is otherwise outside the scope of Directive 2014/34/EU, the potential for a static discharge in use does not bring it into scope.

The answer to the question is given in Borderline list – ATEX products from **ATEX 2014/34/EU Guidelines-5th** Edition

Table 1. ***Timers configuration and executed sequences***

Products	**Scope of 2014/34/EU**	**Examples of products**	**Comments**
Simple earthing clamps with and without cord	No		"Simple earth clamps" are clamps with a single earth connection. The clamp shall provide evidence that it is actually making contact. No own source of ignition, and for additional considerations, see note 2.
Complex earthing clamps with and without cord	Yes (Electrical)		The clamp shall provide evidence that it is actually making contact. Potential ignition sources cannot be excluded according to the ignition hazard assessment.

Note 2: Equipment, protective systems, Ex components, safety, controlling, regulating devices and/or other products indicated as not falling within the scope of the ATEX Directive 2014/34/EU, ignition sources and explosion hazards related to the use shall be considered. Friction impacts and abrasion processes involving rust and light metals (e.g. aluminum and magnesium) and their alloys may initiate an aluminothermic (thermite) reaction, which can give rise to particularly incendive sparking.

Although European directives, transposed into national legislation, require employers to assess the risk of explosions and take all measures to prevent ignition sources by using equipment that complies with ATEX requirements, there is a weak application of them in the case of pliers grounding, in many applications using classic clamps for which there are no documents attesting the technical and security performances.

Both IEC 60079-32-1 [1], 13.4.1 and NFPA 77 [6], 7.4.1.6 & 7.4.1.4 state:temporary connections can be made using bolts, pressure-type earth (ground) clamps, or other special clamps. Pressure-type clamps should have sufficient pressure to penetrate any protective coating, rust, or spilled material to ensure contact with the base metal with an interface resistance of less than 10 Ω.

Where wire conductors are used, the minimum size of the bonding or earthing wire is dictated by mechanical strength, not by its current-carrying capacity. Stranded or braided wires should be used for bonding wires that will be connected and disconnected frequently.

However, suppliers have appeared on the market that guarantee these performances, sometimes even through certification of compliance with the ATEx Directive and the applicable standards [IEC 60079-32-1, NFPA 77, SR EN 80079-36, SR EN 80079-37] [1], [6], [7], [8].

Some static earth clamps on the market combine ATEX certification with Factory Mutual approvals, being rigorously tested and certified to ensure they are capable of dissipating static charges from potentially loaded equipment. This is especially important when the equipment may be covered with product deposits or rust that are capable of preventing the clamp from making low-resistance electrical contact with the equipment to be grounded. Establishing a solid electrical connection can only be achieved by penetrating any connection inhibitors such as coatings, product deposits and rust. Factors such as these will prevent the dissipation of static charges from the object to ground if the clamp is not able to penetrate them and make a connection to the base metal of the container or vessel. Once a strong connection is established, it is vital that this connection remains constant throughout the operation of the process. Factory Mutual approved clamps undergo a series of mechanical and electrical tests to ensure they can perform as reliable static grounding clamps in EX/HAZLOC areas. ATEX certification ensures that there are no sources of mechanical sparks such as thermosetting materials or aluminum, or sources of stored mechanical energy, present in the construction of the clamp.

There are four good reasons to use FM approved clamps:

- Clamp Pressure Testing ensures the grounding clamp is capable of establishing and maintaining low resistance electrical contact with equipment
- Electrical Continuity Testing ensures the electrical continuity from the teeth throughout the grounding clamp is less than 1 ohm
- High Frequency Vibration Testing ensures the grounding clamp is capable of maintaining positive contact when attached to vibrating equipment
- Mechanical Pull Testing ensures the grounding clamp cannot be pulled off the equipment without an intentional application of force.

Also using certified ATEX certified clamps ensures that no sources of mechanical sparks are present in the clamp.

Fig. 3. Static Grounding Clamp capable of breaking through coatings, product deposits and rust to ensure a good electrical connection to process equipment

A wide range of ATEX certified clamps are available on the market - simple clamps (Fig 3) as well as self-testing clamps with LED indication or Grounding Clamp With Visible & Audible Alarms (Fig 4), as well as ground monitoring systems with interlocking control.

Fig. 4. Grounding Clamp With Visible & Audible Alarms [9,10]

A good example of ground monitoring systems with interlock control are grounding installations that not only provide a grounding solution but also monitors earth resistance, like battery operated clamps for hazardous environments and specialized earthing systems for road tankers, which designed to break the flow of flammable liquid using relays (figure 5)

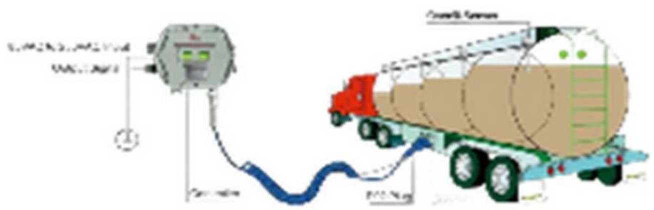

Fig. 5. Grounding Clamp With monitoring system with interlocking control

5. ENSURING SAFETY AND RELIABILITY IN MODERN INFRASTRUCTURES WHIT GROUND RESISTANCES DETECTOR

5.1. Detecting corrosion and other issues

Grounding systems are susceptible to various forms of degradation over time. Ground Resistances Detector are designed to detect issues such as chemical corrosion, metal oxidation, galvanic corrosion, lightning-induced damage, and natural dissolution. By identifying these problems early, the detector helps prevent serious safety hazards and costly repairs.

Corrosion and other forms of degradation can significantly impact the performance of grounding systems. Chemical corrosion occurs when grounding electrodes react with soil chemicals, leading to material loss and increased resistance. Metal oxidation, a common issue in moist environments, results in the formation of non-conductive oxide layers on the electrodes. Galvanic corrosion happens when different metals in the grounding system come into contact, causing one metal to corrode faster than the other. Lightning-induced damage can alter the physical properties of grounding conductors, compromising their effectiveness.

Using the Ground Resistances Detector ensures that these problems are detected early, allowing for timely maintenance and repairs. The most modern Ground Resistances Detector are ground resistance online detector (Fig 6). Through remote monitoring and management of the grounding system, problems can be discovered and handled in time to ensure the safety of production facilities and personnel.

Fig. 6. Ground resistance online detector [11]

A ground resistance online detector is a device designed to continuously monitor the resistance of grounding systems. Unlike traditional methods that require periodic manual testing, these detectors offer real-time data, enabling prompt detection of any issues. This technology is particularly valuable for buried grounding networks, which are often out of sight and difficult to inspect manually.

Ground resistance online detectors utilize advanced sensing techniques to measure the resistance between grounding electrodes and the earth. These devices typically can detect minute changes in resistance, indicative of potential issues within the grounding system. By providing continuous data, ground resistance online detectors allow for early detection of problems such as corrosion or disconnection of grounding conductors. This proactive approach enables maintenance teams to address issues before they escalate, ensuring the integrity and safety of electrical installations.

6. VERIFICATION/MONITORING OF GROUNDING SYSTEMS

Checking earthing as protection against static electricity should be recognized as different from checks made for other purposes such as: maintenance of earthing systems associated with electrical power supply systems and lightning protection installations. Checks must be made both before the plant is put into operation and periodically, and the check documents must be available.

It is desirable to implement automatic monitoring systems that can not only monitor the resistances but also warn about their changes.

It is recommended that employers who, according to Directive 1999/92/Ce, are obliged to take all measures to prevent and protect against explosions, including protection by grounding, treat the grounding installation in the chapter on the assessment of the risk of explosions generated by electricity static from the Explosion Protection Document, in accordance with the requirements of applicable norms and standards. In addition, it must ensure the compliance of the equipment used with the requirements of the ATEx Directive (certificates of conformity) as well as the verification of the installation by competent persons (documents, records). Is recommended **Ensuring Safety and Reliability in Modern Infrastructures whit special devices such as** Grounding Clamp With monitoring system with interlocking control and **Ground Resistances Detector**.

7. CONCLUSIONS

Grounding protection installations in environments with potentially explosive atmospheres must ensure, in addition to electrical protection, protection against atmospheric discharges and protection against dangerous static electricity.

The most effective way to avoid the dangers of static electricity is to bond all conductors together and then to earth, thus preventing electrostatic spark discharges that could ignite the explosive atmosphere.

The methods and means of grounding, protection against dangerous static electricity, must correspond to the norms and standards in force in the electrical field and ATEX.

The paper highlights the importance of certifying the compliance of Static Grounding Clamp with the requirements of the ATEx directive but also with the mechanical requirements, to ensure the necessary pressure so that they are capable of breaking through coatings, product deposits and rust to ensure a good electrical connection to process equipment.

Employers responsible for the explosion protection of installations in environments with potentially explosive atmospheres must apply the best solutions for protection. Therefore, it is recommended that employers responsible for ensuring the security and reliability of grounding protection systems use modern devices that can not only monitor the resistances, but also warn of changes in the resistance.

It is recommended that employers who, according to Directive 1999/92/Ce, are obliged to take all measures to prevent and protect against explosion, treat the earthing installation in the chapter on the assessment of the risk of explosions generated by static electricity in the Explosion Protection Document in compliance with the requirements of applicable norms and standards. In addition, it must ensure the compliance of the equipment used with the requirements of the ATEx Directive (certificates of conformity) as well as the verification of the installation by competent persons (documents, records).

The paper also presents some inconsistencies in the rules in force that are not updated with the new standards and that must be revised in order to be used correctly in the design, installation, maintenance and verification of earthing protection installations.

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