THE IMPORTANCE OF INSPECTIONS ON ELECTRICAL INSTALLATIONS IN HAZARDOUS LOCATIONS

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Abstract – Electrical installations in hazardous locations (classified areas) need careful attention because non-conformities can bring considerable risks not only to the site, but also for other industries and residential areas nearby. To assure safe operation of an industrial facility it is necessary not only that all electrical and electronic equipment to be used in hazardous locations is correctly specified and purchased (known as "Ex equipment"), but also properly installed and maintained. The discussion in this paper is largely based upon International Electrotechnical Commission (IEC) standards; however, conceptually the same philosophy applies to American based standards and installations as well.

Index Terms — installations, hazardous areas, inspection, assemblies, non-conformities, IEC, NFPA.

I. INTRODUCTION

Technical standards provide information for developing an adequate Ex maintenance plan, such as IEC 60079-17 [1]. However, despite all information, during technical audits on electrical installations in hazardous locations, errors are found in design, installation and maintenance on installations and on equipment in potentially explosive atmospheres, which can compromise the facility's safety.

Taking into account the offshore data from only 1992 to 2007 in the UK Oil & gas sector, about 3,400 hydrocarbon releases were registered, from which approximately 5.5 % ignited [2].

One alternative to prevent non-conformities is to perform an initial inspection before the operation of the facility, i.e., before the presence of combustible gases and vapors, as recommended in IEC 60079-17 [1]. The main purpose of this inspection is to implement an action plan to fix any non-conformity identified in order to ensure the integrity of the installation. NFPA 70B [3] also highlights the importance of inspections in hazardous locations.

Nevertheless, during the operation stage, some modifications may affect the integrity of Ex equipment, impairing the safety of the plant. Identifying these modifications is essential to establish proper inspection cycles during plant operation.

II. DOCUMENTATION

The design and installation of large industrial facilities or offshore oil platforms, are usually performed through a turn-key contract. The contractor assumes responsibility for carrying out the commissioning and starting up the plant or platform. These activities are strongly based on documentation, so, it is important to monitor that all required documentation is available since the beginning of the project, in order to comply with technical standards and legal requirements, when applicable.

IEC 60079-14 [4] requires that some information of new installations are to be recorded, in order to help further inspections. Among them we highlight the following:

A. Area classification documents

In the concept design phase it is necessary to develop the area classification study, in order to draft the area classification plan. Very often the process information at this stage is still incomplete, and as a consequence, the drawings are issued in a preliminary version.

A survey about the safety of systems in classified areas was carried out in the American Oil, Gas and Petrochemical industries [5] and revealed that related to area classification documents:

1. 20% of designers used just a text description;
2. 20% failed to mention the gas group;
3. 25% included the recommended temperature class for electrical and electronic equipment to be installed in the area;
4. The reliability of these documents was assigned a rating of 6, 10 being the highest rating.

The IEC 60079-10-1 [6] establishes that the area classification documents, which may be issued in paper or electronic means, need to include plans and elevations, showing the type and extent of zones, the gas group, the auto-ignition temperature and the recommended temperature class of the electrical equipment. This standard also recommends referring to the data taken as basis for the study, as:

a) Recommendations from codes and standards;

b) The gas dispersion data;

c) The ventilation parameters in relation to the releases of flammable material, so that the availability and effectiveness of ventilation can be assessed.

It is recommended that the area classification plan shows the zones boundaries, the gas groups and equipment temperature classes, because it will help inspectors when verifying the

suitability of the Ex equipment. These documentation requirements are also emphasized in NFPA 70B [3].

B. Documentation of Ex i systems

Knowing the parameters' calculation of intrinsically safe (is) circuits is critical for determining the compatibility between the intrinsically safe apparatus, the associated apparatus and the installation. It is also helpful for inspections, as the integrity of the intrinsically safe circuits can be checked. The data of associated apparatus (I.S. barriers), as well as the interconnecting cables' capacitance and inductance need to be used to verify the safe interconnections, as specified in IEC 60079-25 [7].

C. Conformity certificates

In many countries when receiving Ex equipment at site, it is necessary to manage the Ex conformity certificates, in order to store them in a safe place. For example, in Brasil they need to be preserved and to be easily accessible for those who perform maintenance on Ex equipment. In North America there is more emphasis placed on equipment labeling and testing / certifying body markings.

In Brasil, the Inmetro Edict 89/2012 [8] establishes requirements for imported Ex equipment also, specially that safety messages regarding the safe use of Ex equipment need to be indicated in Portuguese, the National language.

III. NON-CONFORMITIES AT ERECTION

The installation of Ex equipment requires trained professionals in order to avoid affecting the Ex equipment integrity [3, 4]. However, it is not uncommon to find mistakes. The following examples are some discrepancies found during field inspections.

1) Inadequate fittings. Ex d equipment require flameproof cable entries and plugs. So, the use of non-flameproof accessories with Ex d enclosures is a critical non-conformity [1].

The Fig. 1 shows a flameproof instrument with an unsuitable blanking element.

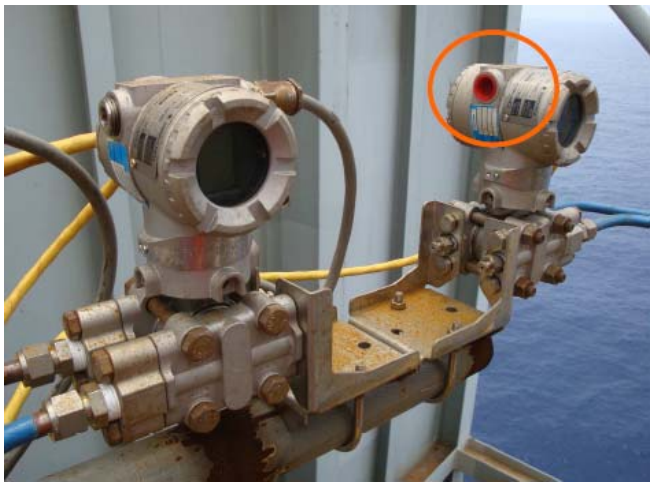

Fig. 1 Unsuitable plastic blanking element in an Ex d enclosure.

2) Lack of blanking elements in unused openings: On Ex d enclosures, unused openings need to be closed with certified blanking elements to keep the integrity of the enclosure if an internal explosion occurs.

Figs. 2 and 3 illustrate these non-conformities.

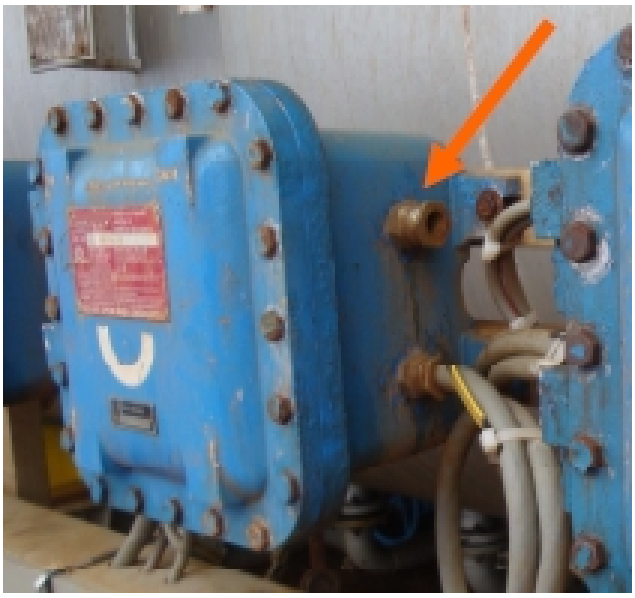

Fig. 2 A cable gland cannot replace a listed metal close-up plug to close an unused opening of an Ex d enclosure.

Fig. 3 An unused cable entry of an Ex d instrument was closed with a room temperature vulcanized (RTV) silicone sealant instead of a certified metal close-up plug.

3) Inadequate screws' tightening – On Ex d enclosures, this non-conformity compromises the Ex-d integrity [3].

The Figs. 4 and 5 illustrate this non-conformity.

Fig. 4 Loose screws of an Ex d enclosure.

Fig. 5 A screw was missed.

4) Improper assembly of cable glands – Certified cable glands must be selected considering the external cable's diameter, and on Ex e enclosures they are very important to avoid the ingress of water and dust into the enclosure.

The Figs. 6 and 7 illustrate non-conformities related with improper installation of cable glands [1].

Fig. 6 Cable-glands incorrectly "filled" with silicone sealant on an Ex e enclosure.

Fig. 7 Cable gland incorrectly "filled" with electrical insulating tape.

5) Piping penetration without sealing: when the conduits cross different floors with different area classifications, they must be sealed, in order to avoid the gas passage between adjacent hazardous locations.

Fig. 8 shows a hole in the floor which interconnects a hazardous area to a non-hazardous one, where the proper sealing compound was missed.

Fig. 8 Floor penetration without a sealing compound.

In Fig. 9, the missing of a sealing compound is a non-conformity [3], because flammable gases can freely flow from a hazardous location to a non-hazardous one.

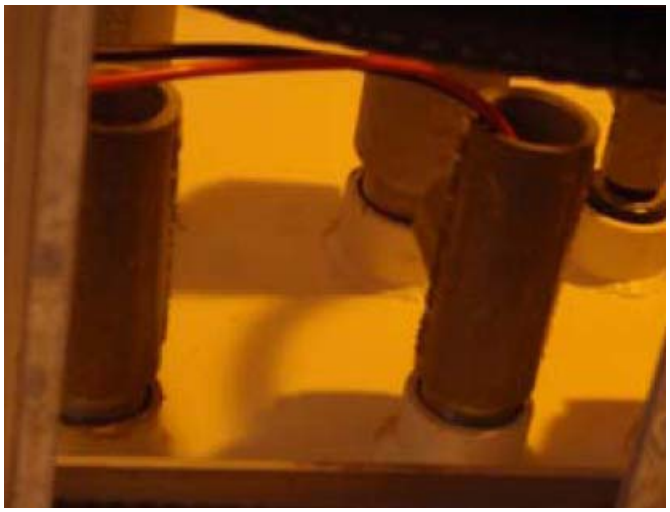

Fig. 9 A conduit sealing fitting improperly installed.

6) Pressurization failure on Ex-p equipment: the integrity of pressurized equipment is effective only when the internal pressure is adjusted within the range recommended by the manufacturer, in order to prevent the ingress of flammable gas. So, leaks can reduce internal pressure and compromise the Ex p equipment integrity.

Excessive pressure can also bring negative consequences to the Ex p enclosure as tensile on hinges and doors bulging.

Fig. 10 illustrates an internal pressure indicator, showing no pressurization inside the Ex p enclosure in a Zone 1 location.

Fig. 10 Underpressure indication in an Ex-p enclosure

7) No conduit sealing fittings: Close to flameproof enclosures it is necessary to install a certified conduit sealing device with the proper sealing compound in order to avoid the “pressure pilling” through the conduit, if an internal explosion occurs [3, 4]. Fig. 11 illustrates a non-conformity of the missing conduit sealing device.

Fig. 11 A plastic flexible conduit connected to an Ex-d enclosure without a conduit sealing device.

IV. PRECAUTIONS

Although it seems to be a simple task, the inspection on hazardous location equipment requires not only skilled professionals, but also the relevant documentation.

For new Ex installations it is recommended that an initial inspection including all electrical and electronic Ex equipment is done before starting the plant [1]. Further, periodic inspections are necessary to verify if modifications implemented in Ex equipment, could compromise the plant safety [9].

A thorough understanding of the safety concepts is required to the Ex inspector. Among some situations, we can highlight:

A. Design based on different standards

In North America the newer design approach for Ex installations is to adapt or combine elements from different standards, as Canadian Electrical Code (CEC), National Electrical Code, (NEC) and IEC [10], aiming to take advantage of the best in global technologies. The counterpart is that the Ex inspector needs to know all relevant technical information, as the standards used on each particular project.

B. Unusual practices supported by standards

According to IEC 60079-14 [4], "a non-hardening grease-bearing textile tape" may be employed outside of an Ex d straight flanged joint, as shown in Fig. 12.

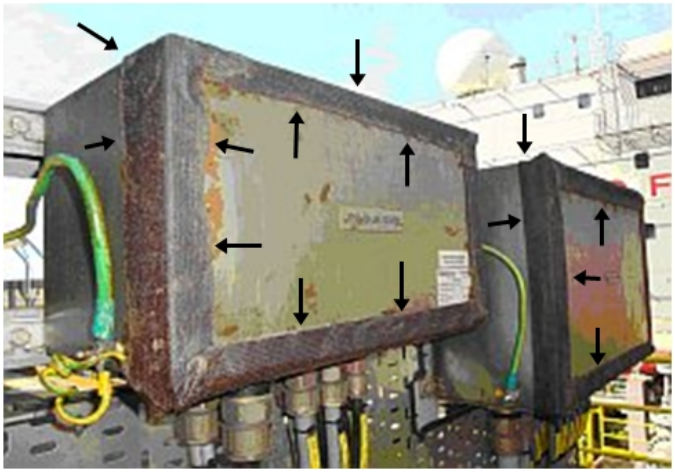

Fig. 12 Application of greased tape over flameproof joints of Ex d enclosures.

It is important to say that the composition of such "grease" is not specified, so users around the world can be encouraged to use tapes which "grease" has combustible components that can be ignited by the hot gases after an internal explosion. Moreover, the tape application hinders the inspection activity, as it will be needed to remove it. As this application is not allowed in many countries (NFPA 70B [3] alerts that special attention should be given to joints), and in fact it seems to be used with restrictions only in UK [11], its inclusion in an International standard should be avoided. Although there are some documents recommending a particular brand of a greased tape "approved by the British gas utility" [12], it was found that such "approval" is related as an alternative of corrosion protection on gas pipes, and not as a tape designed to provide an "ingress protection improvement for Ex d enclosures" [13].

More serious, tests conducted by an accredited Brasilian Ex laboratory [14] in an Ex d IIB enclosure with such tape applied, revealed an explosion propagation (the grease is combustible: flash point = 290 ^{o}C) and also an overpressure event, as shown in Fig. 13. So, as this tape application is a field modification not covered by the equipment conformity certificate, it is considered a non-conformity [3].

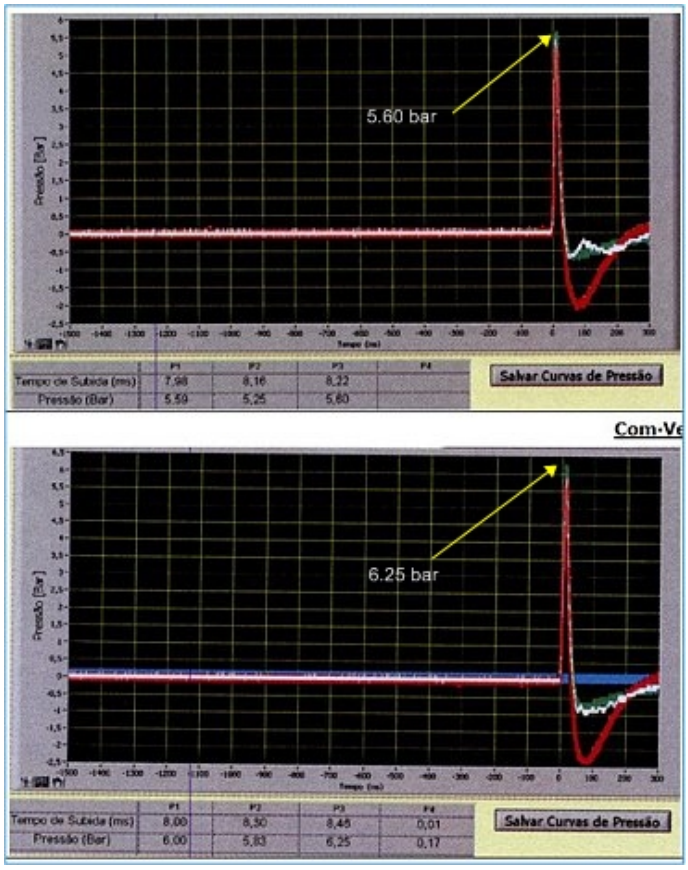

Fig. 13 a) Pressure inside the Ex d enclosure without the greased tape;
13 b) Overpressure of 11.6% after the application of the greased tape.

It is also noted that IEC 60079-14 [4] and NEC [15] establish minimum distances from the flanged Ex d joints to solid obstacles as shown in Table I, which conflicts with the application of such tapes – as they are solid obstacles - over the flamepath extremities.

TABLE I
MINIMUM DISTANCES FOR OBSTRUCTIONS

Gas group	Minimum distance [mm]
IIA	10
IIB	30
IIC	40

C. Underrating the safety

Another point that deserves special attention to inspectors is the 60079-10-1 [6] sub clause 4.2, which mentions that "*a risk assessment may be carried out to assess whether the consequences of ignition of an explosive atmosphere requires the use of equipment of a higher equipment protection level (EPL) or may justify the use of equipment with a lower equipment protection level than normally required*".

This text receives endorsement from the Annex C of IEC 60079-17 [1] where is found a that "*is reasonable to install an EPL lower than required by the classified location, if the resulting explosion is small, and the risk to life can be disregarded.*" As it is well known that small explosions can lead to tragedies by domino effect, and that there is no proven way to predict the consequences of an explosion, it is not "reasonable" to use the EPL underrating. So, this "alternative" cannot be considered safe. NEC [14] does not foresee the use of this criteria.

Moreover, if a device is installed intentionally to cause an explosion, the owner can be prosecuted based on criminal laws and legal Directives of many countries [16].

D. Painting on Ex d enclosures

IEC 60079-14 [4] on clause 10.3 allows enclosure painting by the user (a maintenance task) after the "complete assembly" of the Ex d enclosure. But on the same paragraph it warns that in this case, the ink penetration into the gap is possible to occur, which can compromise the hot gases' cooling when they pass through the flamepath. The NFPA 70B [3] also stresses that grease, paint, and dirt shall be cleaned from machined joints.

As safety cannot be compromised, the inspector can consider that only clean flameproof joints are acceptable, discarding that standard's suggested [4] "painting method".

The previous examples show that standards, especially those developed abroad, must be carefully read and reviewed before being adopted, because some items may be inconsistent [17].

V. CONCLUSIONS

The conformity certification of electrical and electronic equipment intended for use in potentially explosive atmospheres confirms that the equipment follow the standards' requirements, but the plant safety does not rely only on the purchasing of Ex certified equipment.

Periodic inspections on installations in hazardous locations are very important for the plant and persons' safety [18], and require qualified personnel who are trained in safe maintenance practices and the special considerations necessary to maintain electrical equipment for use in hazardous (classified) locations [1, 3].

An item that contributes for a safer plant and also helps the inspection activity is the safety signalization. In Fig. 14 a suggestion for a distinctive sign for hazardous locations [19] is shown.

Fig. 14 An alert sign for hazardous locations

This sign is very convenient as it has no unnecessary text: the main objective is to alert the user. Its design also follows the orientations of ISO 3864-1 [20]. It is composed by the "Ex" (stands for "explosive atmosphere") inside a yellow triangle in a red background, and alerts for a classified location. It facilitates the inspection and the permit to work system as it has information about the zone, gas group and temperature class. This allows inspectors and users to quickly check if the installed equipment is adequate, and also alerts that special precautions should be taken on maintenance services. If more details about the area classification extents are needed, the area classification reference drawing number is also indicated, helping users to find it in a faster way.

The training of Ex inspectors is a weak link, as the majority of courses are only theoretical. Hands-on Ex training using facilities provided with real installations, where non-conformities can be simulated is the best way to prepare Ex installations inspectors [21]. The best results are achieved when the inspectors' team is composed by professionals not involved with the maintenance team of the plant.

In the UK, a survey [22] on more than 71,000 items of installed Ex equipment inspected under a "close inspection" [1], over four years from sectors including gas production, fine chemicals and adhesives, pointed out that:

a) Only 35 % of them were found as "fit for purpose", with no defects;

b) Ignition capable defects were found on 14 %;

c) Other defects compromising safety were found on 27 %, and

d) Minor defects, not directly compromising safety, were found on 24 %.

This data highlights the importance of inspections on electrical and electronic equipment in hazardous locations.

The awareness for maintaining the integrity of Ex installations is essential for safety, since the risk involved in hazardous areas is explosion, which can cause heavy losses not only for the company assets, but also for the city, or even for the

country. The NFPA 70B [3] and IEC 60079-17 [1] highlight that maintenance (and inspections) should be performed only by qualified personnel, trained on the special considerations necessary to properly maintain the electrical equipment for use in hazardous locations.

Considering that industrial plants are usually expanding their processes' units, it is also recommended to review the inspection plan regularly in order to guarantee the plant safety, because it can be necessary to reduce the estimated time interval between inspections due to environmental harsh conditions. For fixed and floating offshore petroleum facilities, API RP 14F [23] has recommendations for the routine and detailed inspections on electrical equipment.

It is highlighted that the investment in refresh training on hazardous locations installations requirements needs to be considered also for operational teams [24], in order to prepare them to quickly identify non-conformities at site and to ask the maintenance team for a prompt repairing action.

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VII. VITAE

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