Dilution in pressurized enclosures – critical points

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Abstract. The risk of explosion can occur in all activities involving flammable substances which, when mixed with air, can form an explosive atmosphere. Explosion protection is intended to prevent the ignition of explosive atmospheres. Pressurization, as a type of protection, 'p' is based on the introduction of a protective gas (air or inert gas) in an enclosure to prevent the formation of an explosive atmosphere within the enclosure by maintaining an overpressure relative to the surrounding atmosphere and, where necessary, by the use of dilution. The important tests for explosion protection by pressurization type of protection are based on the filling and purging test. Each of these involves monitoring certain points within the pressurized enclosure to confirm that concentrations are within acceptable limits. The location of these monitoring points can be identified by using computer simulations. This results, in so-called critical points, where the concentration lastly reaches the pre-set values. These critical points bring the advantage of the need to monitor concentrations at a much smaller number of points and thus it is increasing the accuracy of the tests. Following the approach of the work and the experiments carried out, it was found that computer simulation is effective for establishing critical points.

1 Introduction

Within the European Community [1] it is provided that equipment and installations usable in explosive atmospheres should have characteristics compatible with those of explosive atmospheres in which they are to operate.

Technical equipment intended for use in spaces where combustible substances in form of gases, vapors, and mists are present but not continuously, can be effectively protected against explosion by the pressurized housing type of protection.

Explosion risk may occur in all activities involving flammable substances in form of gases, vapors, flammable mists, or combustible dust which, when mixed with air, may form an explosive atmosphere [2].

As explosions can cause loss of life and property, assessing the risk of explosion and establishing appropriate measures to reduce it to acceptable levels, by regulations and standards in force, is particularly important for the health and safety of people and property [1, 3]. The emergence of different types of protection was determined, individually, by

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critical situations, regarding the safe operation of technical equipment in places with explosive atmospheres.

An essential element in assessing explosion risk in workplaces where explosive atmospheres may occur [4] is personal protective equipment (PPE), which should be designed, manufactured, installed, and maintained in such a way that it cannot generate sources of ignition.

Assessment and testing of equipment that is part of an explosion protection system, for certification, shall take into account explosion risk, which should be minimized to ensure people's safety and to prevent material damage and not lastly, environmental damage.

All equipment that is part of an explosion protection system used in potentially explosive atmospheres should meet the following requirements: be adequately protected against explosions; maintain the level of protection for environmental conditions for which they were built; be able to withstand all (foreseeable) demands caused by storage, transport, installation, and operation.

The explosion risk approach by the ATEX Directive 99/92 / EC transposed into national legislation by [3] involves the technical and organizational implementation of the following steps: preventing the emergence of explosive atmospheres by using ventilation and monitoring systems; preventing the ignition of explosive atmospheres by using explosion protection systems; preventing the aggravation of explosions' consequences, by using protection systems.

Pressurization, as a "p" type of protection, is based on inserting a protective gas (air or inert gas) into an enclosure, to prevent the development of an explosive atmosphere inside the enclosure by maintaining an overpressure relative to the surrounding atmosphere and, if necessary, by using dilution. Important tests for explosion protection by pressurization protection type are based on the fill and purge test. Each of these involves monitoring certain points in the pressurized enclosure to confirm that concentrations are within acceptable limits. Setting these monitoring points can be performed by computer simulations [5, 6].

Pressurization "p" is generally applied to large electrical equipment (electric motors, control panels, etc.) that can produce sparks, and electric arcs or generate hot interior surfaces under normal operation. This type of protection is based on applying a protective gas (air or inert gas) to housing, to prevent the development of an explosive atmosphere inside the housing by maintaining an overpressure relative to the surrounding atmosphere and, where necessary, by using dilution.

Pressurization protection [7] is divided into three levels of protection (pxb, pyb, and pzc) which are chosen according to the equipment's (EPL) protection level, required for an explosive external gaseous atmosphere (Mb, Gb, or Gc), according to the possibility of internal release and dependent on the possibility that equipment inside the pressurized encapsulation may cause ignition.

This type of protection ensures a level of safety for use in zone 1 or 2 or 21 or 22, meeting the requirements for equipment of categories 2 or 3.

This is the only type of protection that consumes energy to ensure explosion protection. Energy consumption is required to accomplish purging, circulate the protective gas, keep the overpressure inside the housing, and monitor pressure.

According to [7] the temperature class for equipment protected by "p" pressurized housing is established as follows:

- for protection level "pxb" or protection level "pyb" the temperature class should be based on the hottest external surface of the housing, or the hottest internal surface of a part;
- for the protection level "pzc" the temperature class should be based on the hottest external surface of the housing.

Pressurization represents the technique of protection against the outside atmosphere penetrating inside a casing by maintaining an interior protective gas at a pressure higher than that of the outer atmosphere, which can be achieved either by continuous circulation of the protective gas or by compensating for losses.

Before the application of power to protected equipment, the pressurized housing should be purged with an amount of protective gas at least five times the internal volume of the housing and pipes, thus achieving an overpressure that is maintained during operation and prevents the inflowing of inflammable gases and vapors from the environment (pressurization with compensation of losses).

Continuous flue gas circulation (dilution pressurization) is the technique of maintaining an overpressure inside a pressurized casing by continuously flowing the protective gas into the casing, after purging.

2 Materials & methods

Construction of the pressurized equipment's interior space has an important role in the process of filling or purging, so, for some inner areas, the time to reach the desired concentration value is longer than for other areas.

The interior atmosphere of pressurized housings should be monitored at various points, where it is assumed that the test gas is most likely to persist and in the vicinity of apparatus capable of ignition, found outside the usual dilution zone.

For simple pressurized housings, positions of critical points can be found intuitively, given the relative density of the test gas relative to the air, but for other cases, these points should be explored, an activity that consumes time and gas, but especially does not provide certainty that critical points are accurately identified. But for these particular cases, simulation using fluid dynamics and calculation programs is particularly important and useful. At critical points, the test gas concentration reaches the value prescribed by the test procedure, lastly (figure 1).

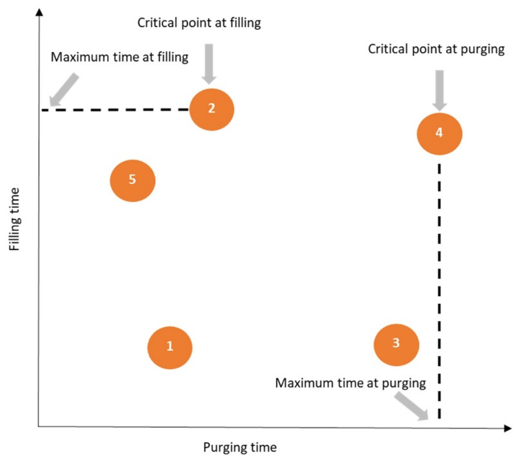

Fig.1. Critical points.

Tests to be considered by the standard [8] aim to highlight the characteristics of mechanical protection, normal degree of protection, and structural stability of plastics and elastomers.

Tests to be considered according to [7, 9] aim at highlighting functional characteristics of explosion protection by pressurized housing/chamber such as guaranteed minimum overpressure, purge time, resistance to maximum overpressure, etc. Tests represent an adjacent step to the evaluation in the certification process of equipment protected by pressurized housing / pressurized chamber.

Gas concentration at test points should be measured over the entire test(s) period. For example, the pressurized housing may be provided with several small diameter tubes, the open ends of which should be placed inside the pressurized housing at the sampling points.

If the test consists of sampling, quantities sampled should not have a significant effect on the test.

If necessary, the openings in the pressurized housing may be closed to allow the pressurized housing to be filled with the specified test gas, provided that they are reopened for the filling test and the purge test.

The pressurized housing should be filled with test gas, at a concentration of at least 70%, at any point [10]. After the pressurized housing is filled, the test gas supply is switched off and the air supply is switched on to the minimum purge flow rate specified by the manufacturer. Test gas concentration at sampling points after purging and where dilution is applied shall not exceed the following values:

- a value equivalent to 25% of the most unfavorable LFL value, when testing for specific flammable gases;
- a value equivalent to 25% of LFL, when a single specific flammable gas is contained;
- 1% for the helium test and 0.25% for the argon or carbon dioxide test when all flammable gases are contained.

These values correspond to approximately 25% of the LFL for light and respectively heavy flammable gases.

If a second test is required, the pressurized housing should be filled with second test gas, representing an opposite value of the density range, at a concentration of at least 70% at any point, and purge time for the second test should be measured. The minimum purge time specified by the manufacturer shall not be less than the measured purge time, or longer than the two measured purge times when two tests are performed.

3 Results and discussions

Simple structures of pressurized housings can be evaluated intuitively based on technical experience gained during several tests and based on physical properties of diffusion and gravitational displacement due to differences in density. Thus, the determination of sampling points of the mixture to be measured to determine test gas concentration shall be established taking into account the relative density of gas to be identified in the mixture by measuring the concentration.

For complex pressurized chamber structures, determination of sampling points of the mixture to be measured to determine test gas concentration to determine the required purge period shall be established taking into account both the relative density of gas to be identified in the mixture and the measured concentration, as well as design characteristics of pressurized enclosure's free internal volume.

In the case of equipment with a simple interior structure, the position of these critical points can be found intuitively, given the relative density of the test gas to air, but in other cases (figure 2), these points should be explored and monitored. This activity consumes time and test gas and does not provide the certainty of checking all critical points.

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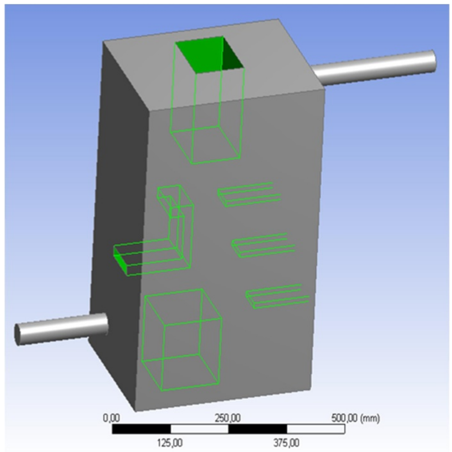

Fig. 2. Dimensions of the pressurized housing and location of the analyzed points.

To underline the efficiency of the simulation process in finding critical points two stages of simulations (filling and purging) were done.

To simulate the filling and purging process, it is initially considered that the entire enclosure has 100% v/v air at all interior points. Carbon dioxide is then introduced at an inlet gauge pressure of 1 kPa. Filling with carbon dioxide is continued until the concentration is at least 70% v/v for all interior points. Three intermediate states in the filling process are shown in figure 3, in which the blue color represents the initial concentration of 0% v/v carbon dioxide, and yellow represents concentrations of almost 70% v/v.

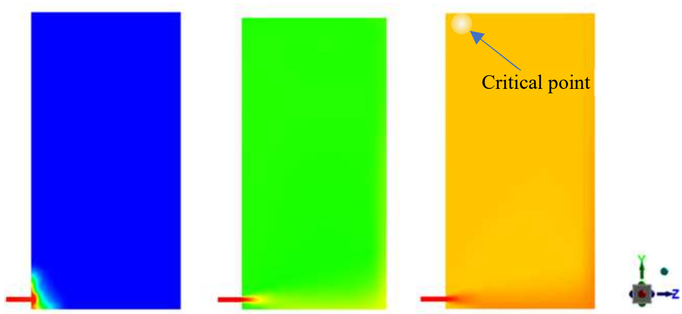

Fig. 3. Variation in CO_2 concentration during filling procedures.

After filling simulation, purging with air is simulated using the same overpressure of 1 kPa. The process is continued until the CO_2 concentration is at most 0.25% v/v for all interior points. Three intermediate states in the purge process are shown in figure 4, in which yellow represents the initial concentration of 70% v/v carbon dioxide and blue represents concentrations of almost 0% v/ v.

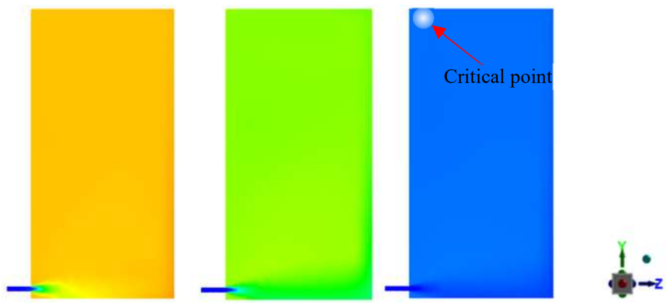

Fig. 4. Variation in CO2 concentration during purging procedures.

By simulation of the filling and purging processes, it was possible to highlight critical points. For the described test, the critical points were identified as being the upper point on the same vertical with the inlet of the closure for both simulation stages: filing and purging.

Consequently, highlighting these critical points has the advantage of minimizing the number of needed measurement points. This is the premise of accurately determining the filling time and also the possibility of accurately determining purging time.

Due to the approximate conditions used for the simulation process the resulted purging time value was not taken into account. In this direction, further research will be needed.

4 Conclusions

Determining the position of critical points, in the case of simple interior structure equipment can be done intuitively, given the relative density of the test gas to air, but in many other cases, these points should be explored and monitored.

The process of intuitive exploration and monitoring consumes time, and test gas and does not provide the certainty of checking all critical points.

The use of the CFD technique for simulation of the filling and purging processes has proven to be effective in highlighting critical points (where the test gas concentration reaches the value prescribed by the test procedure, and lastly).

Subsequent use of critical points in tests allows, by monitorization the determination of purging time with low effort and high accuracy.

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