

The opportunity of using an integrated system for testing equipment with type of protection 'p' – pressurized enclosure

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Abstract. In the field of equipment intended for use in potentially explosive atmospheres, rigorous testing is essential to ensure operational safety. For large-scale equipment, explosion protection by pressurization represents a feasible solution. Testing of explosion-protected equipment using pressurization involves applying a sequence of tests designed to ensure the integrity of the enclosure and to analyze the dynamics of dilution processes. Although standard testing sessions do not present significant technical challenges, the large number of monitored parameters and the complexity of required actions necessitate the use of an integrated monitoring and control system for the testing parameters. The first part of the paper presents the testing procedure sequence, including the relevant performance requirements. The second part identifies the parameters that must be monitored and the actions that need to be triggered during the testing processes. The third part proposes a block structure for the integrated monitoring system of pressurization parameters during testing. The paper concludes that using an integrated system for pressurization testing offers multiple technical and operational advantages.

1 Introduction

The emergence of these types of protection has been driven by critical situations in the safety regime for operating machinery in potentially explosive atmospheres, as well as by the anticipation of imminent technical advancements.

Each type of protection is based on a technical solution for implementing explosion protection. The technical solution for implementing explosion protection with the highest incidence is based on separating the hazardous atmosphere from those parts of the equipment that may become a source of ignition.

Explosion protection aims to prevent the ignition of explosive atmospheres, i.e., to prevent potential ignition sources and to limit the generation of explosive atmospheres [1-3] by protective measures (isolation, suppression, and constructive limitation).

Protective measures aim to reduce to an acceptable level the likelihood of machinery (electrical and non-electrical) becoming a source of ignition.

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Equipment intended for use in potentially explosive atmospheres must comply with strict safety requirements [4], and testing plays an important role in ensuring compliance.

Protection by pressurized enclosures is an effective and flexible solution for explosion prevention in hazardous industrial environments.

The first evidence of pressurized enclosure protection dates back to 1930 as a method of isolating equipment from the explosive atmosphere. In 1943, the German standard VDE 0170/0171 describes the method of forced air venting, introducing the basic principles of pressurization still used today for the pressurized enclosure type of protection.

Explosion protection by pressurization (Ex p), applicable in particular to large equipment, involves evaluation and test procedures designed to ensure both the validation of the integrity of the pressurized enclosure and the evaluation of the efficiency of the dilution processes as defined by the specific standard [5].

In a constantly evolving technological context, in which the volume of data and the complexity of test operations are constantly increasing, it becomes necessary to use an integrated monitoring and control system capable of accurately managing the critical parameters of the test process.

This paper addresses this issue, proposing a structured and modern solution for the optimization of the testing of Ex equipment protected by pressurized enclosures.

2 Test requirements for pressurized apparatus Ex p - relevant parameters

The constructive solution of this type of protection consists in separating the ignition sources from the potentially explosive atmosphere by maintaining an overpressure inside the enclosure by means of a protective gas, which can be inert gas or even air.

Protection by pressurization is divided into three levels of protection, which are chosen according to the level of protection of the equipment required (Mb, Gb, Db, Gc or Dc), whether there is the possibility of internal leakage and whether the equipment inside the pressurized enclosure is capable of producing ignition, depending on the following two scenarios:

- whether or not there is a release inside the enclosure, and/or
- whether or not the equipment inside can initiate ignition of the Ex classified atmosphere.

According to the specific standard [5], pressurized protected equipment shall be subjected to a series of tests designed to validate the ability of the system to prevent the explosive atmosphere from entering the protected enclosure and to maintain adequate dilution of any internal flammable gases [6].

The tests shall be carried out in a logical sequence to demonstrate the explosion protection performance, namely:

- Determination of the maximum overpressure value;
- Maximum overpressure test;
- Loss test:
 - Loss testing other than static pressurization;
 - Loss testing static pressurization;
- Purge test for pressurized enclosures with no internal vent source and fill test for static pressurization:
 - Pressurized enclosure in which the protective gas is air;
 - Pressurized enclosure in which the protective gas is an inert gas;
 - Pressurized enclosure in which the protective gas may be air or inert gas with a density equal to the density of air ± 10 per cent;
 - Filling test for a pressurized enclosure protected by static pressurization;

- Purge and dilution tests for a pressurized enclosure with an internal venting source:
 - Pressurized enclosure in which the flammable substance has less than 2% (v/v) oxygen and the protective gas is inert gas;
 - Pressurized enclosure with pressurization by continuous circulation, a container system with less than 21% (v/v) oxygen, and the protective gas is inert gas;
 - Pressurized enclosure in which the flammable substance is not a liquid, pressurized by continuous recirculation, and the protective gas is air;
- Minimum overpressure check;
- Tests for a non-defective container system:
 - Overpressure test;
 - Failure test;
- Overpressure test for a limited relief container system.

Description of tests for pressurized enclosures according to the parameters checked

The tests applied to the pressurized enclosure type of protection apparatus, according to the specific standard [5], are intended to verify the performance and safety of this equipment in potentially explosive areas [7]. These tests are grouped according to the technical parameters to be covered, so that each category of tests contributes to ensuring the safety, integrity, and performance of the system in potentially explosive environments, namely:

a) Pressure tests (overpressure, minimum pressure, pressure loss)

Their purpose is to check the behaviour of the pressurized casing under controlled operating conditions. Initially, the maximum allowable overpressure is determined, followed by testing the overpressure resistance of the housing. The leak tightness of the housing is assessed by two types of tests: dynamic pressurization with continuous gas supply and static no gas supply to observe pressure losses. The ability of the enclosure to maintain a minimum overpressure during normal operation, which is essential to prevent the ingress of explosive atmosphere, is also checked. In some cases, a repeat overpressure test shall be carried out, and, for applications with limited releases of hazardous substances, it shall be tested whether the system remains safe even under these particular conditions.

These tests are intended to verify the overpressure behavior and to maintain the minimum required pressure.

b) Leak tightness and leakage (flow, leakage, non-defectability)

The objective of these tests is to verify the integrity of the enclosure against gas or air leakage, which is critical in maintaining explosion protection. The dynamic and static leakage tests are intended to verify leak tightness in service and to ensure that the minimum safe pressure is maintained, and the non-defectability tests are intended to characterize the systems as non-defectable - i.e., incapable of allowing a significant pressure drop to occur without detection or control.

These tests are intended to ensure enclosure integrity and leakage containment.

c) Gas flow rate, flow, and purge time

Included in this category of tests are tests related to the process of purging or filling with inert air/gas, essential for the elimination of the explosive atmosphere before energizing the equipment. The purge test concerns purging without an internal source, while the fill test concerns filling for static mode. Purge and dilution tests with internal source cover purging in the presence of internal emission sources, while the continuous flow pressurization - air/inert gas tests the continuous flow of the protective gas, with applicability to dynamic regimes.

These tests are intended to determine the efficiency of the purging or filling process.

d) Atmospheric composition (oxygen, flammable gases)

These tests check the oxygen concentration and the presence of flammable substances inside the enclosure to prevent an explosive atmosphere. An oxygen content below 2% v/v in an inert gas enclosure is validated, followed by continuous pressurization with max. 21% v/v oxygen. The other tests in this category focus on various shielding configurations - with air, inert gas, or specific protective gas density conditions.

These tests aim to control the concentration of oxygen and flammable gases.

e) Construction parameters and mechanical strength assessment

This group of tests comprises those tests that evaluate the physical ability of the housing to withstand the mechanical stresses generated by pressure. Thus, the maximum overpressure test and the minimum overpressure test contribute to the determination of the mechanical limit, while the minimum overpressure test and tests for a non-defective system confirm that the container is considered non-defective under the specified conditions. The overpressure test reiterates the pressure evaluation for specific applications.

The purpose of these tests is to validate the mechanical strength of the enclosure and its ability to ensure functional integrity and safety under overpressure conditions.

f) Special conditions for the internal environment

Some applications involve special operating conditions inside the enclosure. The effects of using a gas with a density different from air by $\pm 10\%$ v/v are tested, then the protection in almost completely inert environments ($> 98\%$ v/v inert gas) is validated, and the overpressure test - limited release system is dedicated to cases where there are limited releases of flammable substances in pressurized enclosures.

These tests are intended to validate the integrity and reliability of the pressurized enclosure under various internal environmental conditions.

3 Parameters monitored in test processes

3.1 General description

Parameters to be monitored in the test processes of pressurized enclosures include: protective gas concentration (if a specific gas is used), internal overpressure, purge gas flow rate, purge time, measurement frequency, protective gas supply pressure, and enclosure filling time.

Continuous monitoring of these values makes it possible to prevent the build-up of explosive atmosphere inside the pressurized enclosure and to ensure correct functioning of the protection system. If deviations or malfunctions are detected (e.g., pressure below minimum level, insufficient flow, or sensor failure), the system shall react automatically by shutting off the supply, activating alarms, or blocking the start-up of the equipment, according to the safety requirements defined in the specific standard [5].

3.2 Parameters monitored

In pressurization protection systems, monitoring of specific parameters is necessary to ensure safe operation:

- The concentration of the protective gas - this parameter is important when using an inert gas. Monitoring the concentration ensures that the internal atmosphere of the enclosure is non-flammable and therefore suitable to prevent an explosion. Specialized sensors are used to detect and confirm the gas composition during the test.

- Internal overpressure - one of the most important parameters is the internal overpressure, which must be maintained above a minimum threshold to prevent an explosive atmosphere from entering the enclosure.

- Purge gas flow rate - must be sufficient to ensure complete evacuation of the potentially hazardous atmosphere inside the enclosure through dilution processes.

- Purge time - shall be sufficiently long to ensure complete dilution of the internal atmosphere below the lower explosive limit. Purge time is calculated as a function of enclosure volume and gas flow rate.

- Measurement frequency - is the rate at which the system takes data from the sensors. A high measurement frequency allows for quick detection of variations and timely triggering of protective measures. This parameter is important for test accuracy and safety.

- Protective gas supply pressure - the pressure at which protective gas is introduced into the pressurized enclosure. It must be maintained in a safe range to ensure pressurization stability and purging efficiency. It must be high enough to maintain an internal overpressure to prevent the ingress of explosive atmosphere from the outside.

- 10-liter enclosure filling time is a reference parameter used to evaluate the filling rate of a standard enclosure (10-liter volume) with protective gas. It is used to calibrate the system and to verify compliance with the time requirements in the standards. The time must be consistent with the specified flow rate and pressure.

These parameters are interrelated and need to be managed by an integrated system allowing real-time monitoring, automatic recording, and prompt reaction to any deviation as required by the specific standard.

Last but not least, the system must ensure traceability of all monitored parameters.

This involves continuous recording of data, generation of test graphs and reports, and archiving them in digital format in a manner compatible with the requirements of the certification authorities (ATEX).

Effective and safe testing of pressurization protection equipment depends on synchronized monitoring and automatic control of a significant number of parameters. By integrating these functions into a fully automated system, not only are technical benefits such as accuracy and repeatability achieved, but also operational advantages such as reduced testing time, increased safety, and documented compliance with international regulations.

3.3 Parameters monitored and accepted ranges

For the appropriate selection and sizing of the stand equipment, the components must meet the following functional requirements:

1. Gas composition (volume concentrations):

- Carbon dioxide (CO₂): 0,1 % v/v ÷ 100 % v/v

- Helium (He): 0,1 % v/v ÷ 100 % v/v

- Oxygen (O₂): 0,1 % v/v ÷ 30 % v/v

2. Pressure and flow parameters:

- Measured differential pressure: 0 mbar ÷ 2000 mbar

- Protective gas supply pressure: 0 mbar ÷ 1000 mbar

- Protective gas supply flow rate: 0,2 l/min (normal) ÷ 300 l/min (normal)

- Measured system flow rate: 0,2 l/min (normal) ÷ 300 l/min (normal)

3. Time and frequency parameters:

- Measurement duration: 1 second ÷ 60 minutes

- Minimum measurement frequency: at least 1 reading/second

4. Filling performance:

- Time to fill a 10-liter container: maximum 5 seconds (no lower limit imposed)

A monitoring system [8] for performing pressurization tests for p-type enclosures is designed to verify that electrical equipment used in potentially explosive atmospheres complies with the safety requirements for maintaining a controlled internal overpressure.

The main purpose of the system is to monitor, control, and record essential parameters (pressure, time, temperature, flow, etc.) during pressurization tests in order to verify the conformity of the enclosure and the correct functioning of the equipment with pressurized enclosure protection type.

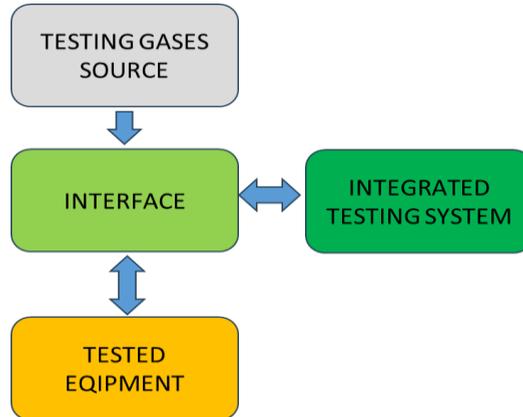


Fig. 1. Block diagram for an integrated test system

Description of the components of the monitoring system for the test of equipment with pressurization type of protection:

- The test gas source provides the necessary gas (compressed air, inert gas, nitrogen) used to create and maintain an overpressure inside the pressurized enclosure. It is provided with pressure and flow regulators for precise adjustment of test conditions.
- Interface: allows the user to configure the test parameters, manage the operation, and follow the progress of the system during the test.
- Integrated test system: is the central control unit that acquires, analyzes, and stores the results.
- Equipment under test (pressurized enclosure): is the device under test into which the test gas is injected. The response of the housing is monitored for pressure variations and possible leakage. The test determines whether the equipment meets the pressurization requirements of the standard.

4 Conclusions

In the current context, where safety requirements in explosive environments are becoming increasingly stringent, implementing an integrated system for testing equipment with a pressurized enclosure protection type is not only necessary for large equipment, but also for smaller equipment. Such a system ensures efficiency, compliance, and reliability, contributing to the obtaining of international certifications and the consolidation of the position on the global market.

This work confirms that using an integrated system for monitoring pressure tests offers multiple technical and operational advantages, such as:

- full automation of the testing process;
- increased accuracy and repeatability of results;
- traceability and digital documentation;
- compatibility with other testing equipment;
- enhanced operational safety for personnel and the environment.

Efficient and safe testing of equipment with pressurized enclosure protection requires real-time monitoring and automatic control of a significant number of parameters. By integrating these functions into a fully automated system, not only are technical benefits such as accuracy and repeatability achieved, but also operational advantages such as reduced testing time, increased safety, and ensured compliance with applicable international standards and regulations.

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