

DETERMINATIONS OF GAS CONCENTRATION IN TESTS CARRIED OUT ON PRESSURIZED CARCASSES

GABRIELA PUPĂZAN¹, SORIN BURIAN², MARIUS DARIE³, TIBERIU
CSASZAR⁴, COSMIN COLDA⁵, DĂNUȚ GRECEA⁶, ADRIANA
ANDRIȘ⁷, ALEXANDRU BELDIMAN⁸

Abstract: The paper estimates the resolution value of the test gas concentration found by indirect measurement, using a high-precision oxygen analyser (two decimal places). The first part of the paper briefly presents the pressurized housing protection "p" type of equipment protection to explosion and their specific test requirements. The last part of the paper presents a model for calculating the resolution of the test gas concentration.

Keywords: value resolution, test gas concentration, pressurized housings, purging.

1. INTRODUCTION

The operation of installations and equipment using combustible gases involves the build-up of flammable clouds (mixtures) in the form of fine gas dispersion [11], [12].

Explosive atmospheres are mixtures of air with flammable substances, in the form of fine gas dispersion, under normal atmospheric conditions, for which, after ignition, the combustion violently (explosively) propagates from the initiating source to the entire volume of mixture [1].

Explosive clouds generate explosions, following direct contact with efficient ignition sources. These explosions occur with the release of a large amount of heat and,

¹ *Asist. Res., PhD. Stud, INCD INSEMEX Petrosani, Gabriela.Pupazan@insemex.ro*

² *Sc. Res. Ist, PhD. Eng., INCD INSEMEX Petrosani, Sorin.Burian@insemex.ro*

³ *Sc. Res. Ist, PhD. Eng., INCD INSEMEX Petrosani, Marius.Darie@insemex.ro*

⁴ *Sc. Res. Ist, PhD. Eng., INCD INSEMEX Petrosani, Tiberiu.Csaszar@insemex.ro*

⁵ *Sc. Res. IInd, PhD. Eng., INCD INSEMEX Petrosani, Cosmin.Colda@insemex.ro*

⁶ *Sc. Res. IIIrd, PhD. Eng., INCD INSEMEX Petrosani, Danut.Grecea@insemex.ro*

⁷ *Sc. Res., Eng., INCD INSEMEX Petrosani, Adriana.Andris@insemex.ro*

⁸ *Tehn., INCD INSEMEX Petrosani, Alexandru.Beldiman@insemex.ro*

at the same time, flames arise, generating fires, high temperatures, vertiginous increases in pressure, etc.

The emission of flammable substances, followed by their ignition, can produce a wide variety of thermal and dynamic effects [2].

Any explosion (whether or not followed by a fire) is the consequence of random cumulative effects of a technical cause (s), on one hand, and of circumstances created by negligence, lack of foresight or caution and different levels of non-compliance with technical operating requirements, on the other hand [10], [13].

2. FEATURES FOR TESTING EQUIPMENT PROTECTED TO EXPLOSION BY PRESSURIZED HOUSING "p" PROTECTION TYPE

The purge test for pressurized casings without any internal release source and the fill test for static pressurization shielded equipment involves filling with test gas, at a concentration of at least 70%, in any measured point [14]. After the pressurized housing is filled, test gas supply is switched off and air supply is switched on, at the minimum purge flow rate specified by the manufacturer. Purging time must be measured and recorded. If a second test is required, the pressurized housing must be filled with a second test gas, the density of which is opposite to the first gas (relative to air density), at a concentration of at least 70% in any measured point and purging time for the second test must be also measured [5].

Equipment explosion-proofed [15] by air or inert gas pressurized housings, having a density equal to the density of air $\pm 10\%$, must be initially filled with air at normal atmospheric pressure. Their housing must then be purged with the inert gas specified by the manufacturer.

Equipment explosion-proofed by housing pressurized by static pressure must be initially filled with air at normal atmospheric pressure [3]. Equipment must then be filled with inert gas according to manufacturer's specifications. After filling, there must be no points inside the housing in which oxygen concentration exceeds 1% (v/v), compared to atmospheric conditions [6].

The shielding gas supply must then be switched on at the minimum purge rate specified by the manufacturer.

The dilution test shall be performed after the purge test and the shielding gas source shall be set to the minimum flow rate specified by the manufacturer.

The purge test for equipment with a pressurized housing, where the flammable substance is not a liquid, the pressurization is carried out by continuous circulation and the shielding gas is air, must be carried out using the test procedure specific to pressurized equipment [7].

In addition, during the test, the test gas must be injected into the pressurized housing through the receiving system at a maximum release rate so as to represent the most unfavorable release conditions, taking into account the position, number and

DETERMINATIONS OF GAS CONCENTRATION IN TESTS CARRIED OUT ON PRESSURIZED CARCASSES

nature of releases and their proximity related to the flammable equipment outside the dilution area.

If a second test is required, the test must be repeated using a second test gas and purging time must be recorded as the measured purge time.

Interior atmosphere of the pressurized housing must be tested in various points where it is assumed that the test gas is most likely to persist and in the vicinity of the flammable equipment outside the normal dilution area.

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

If the test consists of sampling, quantities taken 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 purge and dilution tests [8].

For specific applications, tests may be performed for specific flammable gases and vapors. In this case, flammable gases must be specified and the test gas (es) must be chosen to have densities within $\pm 10\%$ of the heaviest gas and the lightest gas specified. In the case of a single specified gas, a single test shall be performed with a test gas having a density within $\pm 10\%$ of the specified gas.

If it is necessary to cover all flammable gases, two tests must be carried out. A test must be performed to cover gases lighter than air, using helium as test gas. The second test must be performed to cover gases heavier than air, using argon or carbon dioxide as test gas.

Test gas concentration in sampling points, after purging and where the dilution is applied, when air is the shielding gas, must not exceed the following values:

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

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

If the shielding gas is an inert gas, the oxygen concentration after purging and dilution must not exceed 2% (V/V).

3. TEST GAS CONCENTRATION RESOLUTION CALCULATION MODEL

Internationally, for purge testing of explosion-proof equipment by pressurized casings, the assessment of test gas concentration values is performed indirectly by

measuring oxygen concentration using high-precision oxygen analyzers that have a value resolution of hundredth of percent [9].

The theoretical model resulting from the balance of concentrations of gaseous substances present inside the equipment casing during the purge test shall be used to determine the test gas concentration [4].

Indicated equation of the analyzer:

$$C_{\text{indicat}} = C_{O_2} + k_{Ar} \cdot C_{Ar} + k_{g1} \cdot C_{g1} \cdot C_x + k_{g2} \cdot C_{g2} \cdot C_x \quad (1)$$

$$C_{O_2} + C_x + C_{N_2} + C_{Ar} = 1 \quad (2)$$

$$\frac{C_{O_{2mi}}}{C_{N_2} + C_{Ar}} = \frac{C_{O_{2mi}}}{1 - C_{O_{2mi}}} = ct. \quad (3)$$

$$\frac{C_{O_2}}{C_{Ar}} = \frac{20,95\%}{0,98\%} = c \quad (3.1)$$

By dividing the relation (2) to C_{O_2} results:

$$1 + \frac{C_x}{C_{O_2}} + \frac{C_{N_2}}{C_{O_2}} + \frac{C_{Ar}}{C_{O_2}} = \frac{1}{C_{O_2}} \quad (4)$$

Replacing the report $\frac{C_{N_2} + C_{Ar}}{C_{O_2}}$ from expression (4) with the one from expression (3) the resulted value of C_{O_2} becomes:

$$C_{O_2} = C_{O_{2mi}} (1 - C_x) \quad (5)$$

Replacing the value of C_{O_2} in expression (1), it becomes:

$$C_{\text{indicat}} = (1 - C_x) \cdot C_{O_{2mi}} \cdot \left(1 + \frac{k_{Ar}}{c}\right) + C_x (C_{g1} \cdot k_{g1} + C_{g2} \cdot k_{g2}) \quad (6)$$

$$C_x = \frac{C_{\text{indicat}} - C_{O_{2mi}} \cdot \left(1 + \frac{k_{Ar}}{c}\right)}{k - C_{O_{2mi}}} = \frac{C_{O_{2mi}} \cdot \left(1 + \frac{k_{Ar}}{c}\right) - C_{\text{indicat}}}{C_{O_{2mi}} \cdot \left(1 + \frac{k_{Ar}}{c}\right) - k} \quad (7)$$

DETERMINATIONS OF GAS CONCENTRATION IN TESTS CARRIED OUT ON
PRESSURIZED CARCASSES

To identify the relationship between value resolutions of the gas concentration to be measured, the following relation is used:

$$\Delta C_x = \frac{-\Delta C_{indicat}}{C_{O_{2ini}} \cdot \left(1 + \frac{k_{Ar}}{c}\right) - k} \quad (8)$$

where:

$C_{O_{2ini}}$ - oxygen content of atmospheric air;

$C_{indicat}$ - oxygen concentration indicated by the analyser;

C_{g1} - gas 1 concentration in the mixture;

C_{g2} - gas 2 concentration in the mixture;

k_{g1} - gas 1 correction coefficient in the mixture;

k_{g2} - gas 2, correction coefficient in the mixture;

C_{O_2} - oxygen concentration in the mixture;

C_{Ar} - argon concentration in air.

The parameter that influences the indication of the oxygen analyser is the offset value. Values of this parameter for test gases used are given in Table 1.

Table 1. Values of this parameter for test gases used

No.	Substance	Offset (at 20°C) echiv. [%] oxygen	Value resolution [%]
1	Helium	0,29	-0,0484
2	Carbon Dioxide	-0,26	-0,0472
3	Argon	-0,22	-0,0472

4. CONCLUSIONS

The use of oxygen analysers for the purpose of indirectly measuring the concentration of test gases to perform tests for pressurized equipment has the advantage of generating a general solution applicable to all test gases.

On the other hand, the value of about 21% v/v of oxygen in the atmospheric air makes the value resolution of test gases measurement by using the method of indirect measurement with the help of oxygen analysers to be five times lower than the value resolution of the oxygen analyser.

REFERENCES

- [1]. Burian S., Ionescu J., Darie M., Csaszar T., Andriș A., (2007), *Requirements for Installations in Areas with Explosive Atmosphere, Other than Mines, (in Romanian)*, INSEMEX – Petroșani Publishing House, Romania.
- [2]. Dobra R., Buica G., Pasculescu D., Leba M., *Safety management diagnostic method regarding work cost accidents from electrical power installations*, InProc. 1st Int. Conf. on Industrial and Manufacturing Technologies (INMAT), Vouliagmeni, Athens, Greece 2013.
- [3]. Ionescu J., Burian S., Darie M., Csaszar T., Andriș A., *Explosion protection of equipment associated with large pressurized encapsulations*, INSEMEX – Petrosani, 2008.
- [4]. Ionescu J., *Method for evaluating pressurized equipment using tracer gas*, INSEMEX – Petrosani, 2007.
- [5]. Marcu M.D., Popescu F.G., Pana L., *Modeling and simulation of power active filter for reducing harmonic pollution using the instantaneous reactive power theory*. Environmental Engineering and Management Journal, June 2014, Vol.13, No. 6, Pages: 1377-1382, DOI:10.30638/eemj.2014.148.
- [6]. Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.
- [7]. Niculescu, V. Arad, M. Marcu, S. Arad, F.G. Popescu, *Safety barrier of electrical equipment for environments with a potential explosion in underground coal mines*. MINING OF MINERAL DEPOSITS. Volume: 14 Issue: 3 Pages: 78-86, DOI: 10.33271/mining14.03.078, 2020.
- [8]. Popescu F.G., Pasculescu D., Marcu M.D., Pasculescu V.M., *Analysis of current and voltage harmonics introduced by the drive systems of a bucket wheel excavator*, Mining of Mineral Deposits, Volume 14, Issue 4, 2020, Pages 40-46. ISSN: 24153435, DOI: 10.33271/mining14.04.040, 2020.
- [9]. Pupăzan Gabriela, *Possibilities to improve the explosion safety regime for large equipment, License paper*.
- [10]. ATEX Directive, Directive 2014/34/EU of the European Parliament and the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres, Official Journal of the European Union, L96/309, 29.03.2014.
- [11]. NEx 01-06: 2007 on explosion prevention for the design, installation, commissioning, use, repair and maintenance of technical installations operating in potentially explosive atmospheres, indicative NEx 01-06.
- [12]. Romanian Government Decision no. 245/2016 on establishing the conditions for making available on the market the equipment and protection systems intended for use in potentially explosive atmospheres.
- [13]. SR EN 1127-1:2019 - Explosive atmospheres - Explosion prevention and protection. Part 1: Fundamental concepts and methodology, ASRO, 2019.
- [14]. SR EN 60079-2:2015 - Explosive atmospheres. Part 2. Equipment protection by pressurized enclosure "p", ASRO, 2015.
- [15]. SR EN (IEC) 60079-0:2018 - Explosive atmospheres - Part 0: Equipment – General requirements, ASRO, 2018.