SLOVENSKI STANDARD
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Ugotavljanje največjega tlaka eksplozije in največje hitrosti naraščanja tlaka plinov in hlapov

Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours

Verfahren zur Bestimmung des maximalen Explosionsdruckes und des maximalen zeitlichen Druckanstieges für Gase und Dämpfe

Détermination de la pression maximale d'explosion et de la vitesse maximale de montée en pression des gaz et des vapeurs

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Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours

Détermination de la pression maximale d'explosion et de la vitesse maximale de montée en pression des gaz et des vapeurs

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This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 305.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (prEN 15967:2020) has been prepared by Technical Committee CEN/TC 305 “Potentially explosive atmospheres — explosion prevention and protection”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 15967:2011.

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directives.

For relationship with EU Directive(s), see informative Annex ZA, and Annex ZB, which are an integral part of this document.

Introduction

This document describes test methods for the determination of:

— the explosion pressure and the maximum explosion pressure; and

— the rate of explosion pressure rise and the maximum rate of explosion pressure rise; of a quiescent flammable gas/air/inert mixture at ambient temperature and pressure.

Maximum explosion pressure and maximum rate of explosion pressure rise are used for designing explosion protection measures, such as explosion pressure resistant or explosion pressure shock resistant apparatus, explosion venting and explosion suppression. These characteristics are particularly influenced by:

— the size and shape of the vessel;

— the type and energy of the ignition source;

— the temperature and pressure;

— the turbulence.

It is therefore necessary to standardize the conditions at which the maximum explosion pressure and the maximum rate of explosion pressure rise are determined.

1 Scope

This document specifies a test method that is designed to produce measurements of explosion pressure and the maximum explosion pressure, the rate of explosion pressure rise and the maximum rate of explosion pressure rise of a quiescent flammable gas/air/inert mixture in closed volume at ambient temperature and pressure. In this document, the term “gas” includes vapours but not mists. Detonation and decomposition phenomena are not considered in this European Standard.

The pressures and rates of pressure rise measured by the procedures specified in this document are not applicable to flameproof enclosures, that is enclosures intended to withstand an internal explosion and not to transmit it to an external explosive atmosphere, or any other closed volume where the internal geometry can result in pressure piling. Even in an enclosure of relatively simple geometry the disposition of the internal components can lead to rates of pressure rise significantly higher than those measured using this document. This document does not apply to the design and testing of flameproof enclosures in conformity with EN 13463-6 (for non-electrical equipment) and EN 60079-1 (for electrical equipment).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13237:2012, *Potentially explosive atmospheres - Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13237:2012 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
explosion pressure

p_{ex}

highest pressure occurring in a closed vessel during the explosion of a specific mixture of flammable substances with air or air and inert gases determined under specified test conditions

Note 1 to entry: p_{ex} is expressed as absolute pressure with gases and vapour and as overpressure with dusts.

3.2
maximum explosion pressure

p_{max}

maximum value of explosion pressure measured in the tests for explosion pressure when the content of the flammable substances in the mixture is varied

Note 1 to entry: p_{max} is expressed as absolute pressure with gases and vapour and as overpressure with dusts.

3.3
rate of explosion pressure rise
$(dp / dt)_{ex}$
highest value of the slope (first derivative) of the pressure-time curve (smoothed if necessary), measured in a closed vessel during the explosion of a specific mixture of flammable substances with air or air and inert substances determined under specified test conditions

3.4
maximum rate of explosion pressure rise
$(dp / dt)_{max}$
maximum value of the explosion pressure rise per unit time measured in the tests when the content of the flammable substances in the mixture is varied

Note 1 to entry: For the purpose of this document, all pressures are expressed in bar absolute and rate of explosion pressure rises are expressed in bar/s.

4 Test Method

4.1 Principle

An explosive test mixture is ignited by a defined ignition source which is positioned in the centre of a test vessel. By means of a pressure measuring system the pressure-time curve that develops following the ignition of the test mixture is recorded.

From the pressure- time curve the highest rate of explosion pressure rise $(dp / dt)_{ex}$ is calculated, and the highest pressure p_{ex} is determined.

Repeat measurements are made with stepwise variations in the content of flammable gas in the mixture.

a) The maximum explosion pressure p_{max} is determined as the maximum observed value of p_{ex}.

b) The maximum rate of explosion pressure rise $(dp / dt)_{max}$ is determined as the maximum observed value of $(dp / dt)_{ex}$.

4.2 Apparatus

4.2.1 General

The test apparatus consists of:

— a test vessel;

— equipment for preparing the test mixture;

— an ignition system;

— a pressure measuring system;

— a temperature measuring device;

— safety equipment.

4.2.2 Test Vessel

The test vessel shall be spherical or cylindrical. The internal volume of the test vessel shall be equal to or greater than 0,005 m^3. If a cylindrical vessel is used, the length to diameter ratio shall be equal to 1.

The test vessel and any equipment (valves, igniter, transducer, etc.) fitted on the vessel shall be designed to withstand a maximum pressure of at least 20 bar.

NOTE Guidance on the design of the test vessel can be found in EN 14460, EN 13445-3 and EN 13480-3.

The vessel shall be made of stainless steel or any material free of any catalytic effects and resistant to corrosion from the initial gas mixture and the products of combustion.

The test vessel shall be fitted with sufficient ports to allow filling, evacuating and purging.

4.2.3 Equipment for preparing the test mixture

The test mixture can be prepared by a partial pressure method or mixing together flows of the component substances. This can be done in the test vessel or outside.

If the test mixture is prepared by a partial pressure method, the vessel used for the preparation of the mixture shall be fitted with:

a) a vacuum pump and a vacuum gauge;

b) pressure gauges or manometers;

c) a means of achieving a uniform test mixture (e.g. a stirrer).

If the test mixture is prepared by mixing flows, the necessary components are:

a) flow meters (mass or volume flow meters);

b) a means of achieving a uniform test mixture (e.g. mixing chamber);

c) an evaporator if liquid samples are used (see Annex E for an example).

The equipment for preparing the test mixture shall be designed in such a way that the flammable gas content in the test mixture is measured with a maximum uncertainty of measurement of ± 10 % relative for a flammable gas content up to 2 % mol or ± 0,2 % absolute for a flammable gas content above 2 % mol.

4.2.4 Ignition System

4.2.4.1 General

The igniter shall be positioned in the centre of the test vessel. Recommended ignition systems are induction spark and fusing wire. The test report shall state which ignition source was used.

For some special mixtures it may be necessary to use a different ignition system in order to achieve ignition of the mixture. If an alternative ignition source is used it shall be fully described in the test report. It is also recommended that specialist advice is sought on the interpretation of the results.

4.2.4.2 Induction Spark

A series of induction sparks between two electrodes is used as the ignition source.

Stainless steel is a suitable material for the electrodes. The electrodes shall be positioned at the centre of the vessel. They shall be pointed rods with a maximum diameter of 4 mm. The angle of the tips shall be 60°. The distance between the tips shall be (5 ± 0,1) mm. The electrodes shall be mounted in the vessel so they are gas tight at the highest pressures generated during the test. The mounting shall be resistant to heat and the test mixture, and provide adequate electrical insulation from the test vessel body.

A high voltage transformer, with a root mean square voltage of 13 kV to 16 kV (AC) and a short circuit current of 20 mA to 30 mA, shall be used for producing the ignition spark. The primary winding of the high voltage transformer shall be connected to the mains via a timer set to the required discharge time.

The spark discharge time shall be adjusted to 0,2 s. If a spark discharge time of 0,2 s does not result in ignition of the test mixture, the test may be repeated with a spark discharge time of up to 0,5 s.

NOTE The power of the spark depends on the gas mixture and its pressure. In air at atmospheric conditions according to calorimetric and electric measurements such a source gives a spark with a power of approximately 10 W.

4.2.4.3 Fusing Wire

This ignition device generates an electric arc by passing an electrical current along a length of straight fusing wire connected between two metal rods.

The electrical power for melting the wire and generating the arc is supplied from an isolating transformer. The ignition energy delivered by the arc depends on the duration of the arc and the power rating of the isolating transformer. The energy delivered shall be in the range 10 J to 20 J, as over this range of energies there is no significant effect on the explosion pressure. This is achieved by limiting the power rating of the isolating transformer to between 0,7 kVA and 3,5 kVA and by the use of a phase control technique. The latter is a chopping technique that allows only part of the AC waveform from the transformer secondary windings to energize the wire.

Brass or stainless steel are suitable materials for the rods. The rods shall be parallel to each other with a separation distance of (5 ± 1) mm. For the fusing wire a straight length of NiCr wire (diameter 0,05 mm to 0,2 mm) shall be soldered to the tips of the metal rods. The rods shall be positioned in the test vessel so the fusing wire is at the centre of the vessel. The electrodes shall be mounted in the vessel so they are gas tight at the highest pressures generated during the test. The mounting shall be resistant to heat and the test mixture, and provide adequate electrical insulation from the test vessel body.

To reduce the time required for replacing the fusing wire after a test, the rods may be mounted in a plug that can be screwed into the test vessel wall.

The cross-section of the wires connecting the transformer to the rods shall be between 2,5 mm² and 7 mm². The length of the wires shall be less than 5 m. The diameter of the rods shall be between 1,5 mm and 5 mm.

If, for practical reasons, the diameter of the rods shall be less than 3 mm additional mechanical support may be necessary.

4.2.5 Pressure Measuring System

The pressure measuring system consists of:

a) a pressure transducer;

   1) The pressure transducer(s) shall be fitted in the test vessel, with the head flush with the internal wall.

   2) The pressure transducer(s) shall be able to measure pressures up to 20 bar. Pressure transducers of lower range may be used if lower explosion pressures are expected.

b) an amplifier;

c) a data recording system.

1) The data recording system shall have a resolution of at least 12 bit and either a sampling rate of 20 kHz, or a sampling rate of $500 / t_{ex}$ samples per second.

2) t_{ex} is the time from ignition to the maximum explosion pressure. (see Figure C.1 and Figure C.2).

d) The pressure measuring system shall have a bandwidth of at least 10 kHz.

To ensure reliability, two pressure measuring systems may be used.

The pressure measuring system shall have an accuracy such that the initial and explosion pressures are measured to ± 0,05 bar or better.

The pressure measuring system shall have a time resolution of at least 1 ms.

4.2.6 Temperature Measuring Device

Any suitable thermocouple with appropriate recording equipment may be used to record this value. Recording the temperature is necessary, because especially p_{ex} and p_{max} are temperature dependent.

4.2.7 Safety Aspects

Ensure that all work is conducted within local and national regulations. Precautions shall be taken to safeguard the health of personnel conducting the tests against the different hazards that may occur during the test e.g.:

a) to prevent a leak of the mixture or waste gases outside the vessel, the gas tightness of the vessel shall be checked;

b) to prevent rupture of the test vessel, it shall be designed to withstand a maximum pressure of at least 20 bar (see 4.2.2), as this can be assumed to be higher than the maximum explosion pressure likely to be generated during a test;

c) if the test mixture is prepared in a separate vessel, this vessel and the connecting line shall be designed to withstand the maximum explosion pressure;

d) to prevent injuries to the operator from flying fragments, all parts of the apparatus that may contain an explosive mixture shall be adequately shielded;

e) adequate ventilation shall be provided to prevent the build-up of an explosive atmosphere in the laboratory as a result

1) of purging of the apparatus;

2) of exhaust from the vacuum pump; or

3) of leaks from the apparatus.

f) all electrical connections shall be adequately insulated to prevent electrocution or shock to personnel;

g) measures shall be taken prior to preparing the mixture to ensure that the substances can be mixed without risk;

h) measures shall be taken to prevent hazards arising from the handling of toxic flammables gases or combustion products;

i) the handling of flammable liquids shall be carried out in such a manner that the risk of a fire is minimized;

j) the handling of gas cylinders shall be carried out in such a manner that the risk of an explosion is minimized;

k) in the event of ignition system failure, the explosive mixture will still be present at the end of the test, purge and dilute to render non-flammable.

4.3 Preparation and preservation of test samples

The components of the test mixture shall fulfil the following requirements:

a) Air: the air shall be free of water and oil. If synthetic air is used, it shall be stated in the report.

b) Inert: the purity of the inert, or the mixture of inerts, shall be 99,8 % mol or better. If a mixture of inerts is used, the composition of the mixture shall be stated in the test report.

c) Flammable gas: the flammable gas may be derived from:

   1) a single substance or a mixture of substances;

   2) a process sample (of known or unknown composition).

When a single substance or a mixture of substances is used, the purity of each substance shall be 99,8 % mol or better. In the case of a mixture of substances or a process sample of known composition, the precision of the composition shall be stated in the test report. In the case of a process sample of unknown composition, the sample shall be defined as well as possible (e.g. process conditions, lower explosion limit).

If the flammable gas is derived from a liquid containing more than one component, the gas phase composition can differ from the composition of the liquid phase and when large quantities of the gas are drawn off, the composition of both the liquid and gas phases can change with time. For these reasons, the test sample shall be taken from the liquid phase.

4.4 Procedure

4.4.1 Preparation of the test mixture

4.4.1.1 General

If liquefied gases or liquids are used, it is necessary to ensure that there is no condensation.

NOTE Condensation can be prevented by checking the vapour pressure of the substances and by local heating to prevent cooling at certain parts of the apparatus (e.g. valves).

The test mixture may be prepared by the method of partial pressures or by the method of mixing flows, either inside or outside the test vessel.

4.4.1.2 Preparation of the test mixture by partial pressures

If the preparation of the test mixture includes evacuating the vessel, the amount of air remaining shall be taken into account when calculating the pressures of combustible substances and air required. In preparing the test mixture, precautions may be necessary to prevent condensation.

The mixture components are sequentially introduced into the vessel to give the required partial pressure. The partial pressure measuring system shall have an accuracy of ± 0,005 bar or better. It is necessary to ensure that the mixture in the vessel is thoroughly mixed during the introduction of each component. If the volume of the feed lines is not negligible compared to the volume of the vessel, they also shall be evacuated or purged.

NOTE For practical reasons, air is often introduced as the last component, especially if atmospheric air is used.

4.4.1.3 Preparation of the test mixture by mixing flows

The test mixture is prepared by thoroughly mixing metered flows of the gaseous components.

If liquid components are used, they shall be vaporized totally before mixing.

It is recommended that if possible the composition of the test mixture is also measured, to check the metering devices are operating correctly and that there are no leaks in the mixing system.

4.4.2 Determination of the explosion pressure p_{ex}, the maximum explosion pressure p_{max}, the rate of explosion pressure rise $(dp/dt)_{ex}$ and the maximum rate of explosion pressure rise $(dp/dt)_{max}$

4.4.2.1 Test procedure

The same sets of data are used for the determination of the explosion pressure and rate of explosion pressure rise, gathered simultaneously by the same procedure.

If the test mixture is not prepared in the test vessel, fill the vessel with the test mixture either by preliminary evacuation or by purging.

The test vessel and the feed lines shall be evacuated to a pressure of 5 mbar or less before filling. Purging shall be done in such a way that the test vessel atmosphere is totally replaced. This is achieved by purging with a volume that is at least ten times the vessel volume.

Once the test mixture has been introduced into the test vessel, the inlet and outlet valves shall be closed. The test mixture shall be left for a period of at least two minutes to ensure it is quiescent. The test mixture is then ignited and the pressure-time curve of the explosion recorded.

During a set of tests the temperature increase of the vessel (caused by the combustion after ignition) shall not be allowed to exceed 15 K (see 4.5.2)

After the test residual overpressure shall be released from the test vessel. Following this, the vessel shall be purged with air to remove the combustion products. The combustion products and purge gas shall be discharged safely.

The humidity of the gas mixture can influence the rate of pressure rise, so it is important to ensure that the test vessel and feed lines have been purged of all moisture before starting the next test.

If soot is formed during the test, the test vessel and the igniter shall be cleaned.

The whole test procedure shall be carried out five times for each composition of the test mixture.

— For the determination of p_{ex} the number of determinations may be reduced to three, provided the relative scatter in the first three tests is not greater than 7 %.

— For the determination of $(dp/dt)_{ex}$ the number of determinations may be reduced to three, provided the relative scatter in the first three tests is not greater than 20 %.

NOTE scatter is defined as modulus of the difference between the individual measured value and the mean of the three measured values; relative scatter is obtained by dividing the scatter by the mean of the three measured values.