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Vodilo o inertizaciji za prepreļ itev eksplozij

Guidance on Inerting for the Prevention of Explosions

Leitlinien für die Inertisierung zum Explosionsschutz

Atmospheres explosibles - Guide de l'inertage pour la prévention des explosions

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Guidance on Inerting for the Prevention of Explosions

Atmosphères explosibles - Guide de l'inertage pour la prévention des explosions

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COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This Technical Report (CEN/TR 15281:2006) has been prepared by Technical Committee CEN/TC 305 “Potentially explosive atmospheres – Explosion prevention and protection”, the secretariat of which is held by DIN.

1 Scope

Inerting is a measure to prevent explosions. By feeding inert gas into a system which is to be protected against an explosion, the oxygen content is reduced below a certain concentration until no explosion can occur. The addition of sufficient inert gas to make any mixture non-flammable when mixed with air (absolute inerting) is only required in rare occasions. The requirements for absolute inerting will be discussed. Inerting may also be used to influence the ignition and explosion characteristics of an explosive atmosphere.

The guidance given on inerting is also applicable to prevent an explosion in case of a fire.

The following cases are not covered by the guideline:

- admixture of an inert dust to a combustible dust;
- inerting of flammable atmospheres by wire mesh flame traps in open spaces of vessels and tanks;
- fire fighting;
- avoiding an explosive atmosphere by exceeding the upper explosion limit of a flammable substance.

Inerting which is sufficient to prevent an explosion is not a protective measure to prevent fires, self-ignition, exothermic reactions or a deflagration of dust layers and deposits.

2 Normative references

The following referenced documents are indispensable for the application 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 1127-1:1997, *Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology.*

EN 14034-4, *Determination of explosion characteristics of dust clouds – Part 4: Determination of the limiting oxygen concentration LOC of dust clouds.*

prEN 14756, *Determination of the limiting oxygen concentration (LOC) for gases and vapours.*

EN 50104, *Electrical apparatus for the detection and measurement of oxygen – Performance requirements and test methods.*

IEC 61508-1, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements (IEC 61508-1:1998 + Corrigendum 1999)*

IEC 61508-2, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety- related systems (IEC 61508-2:2000).*

IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements (IEC 61508-3:1998 + Corrigendum 1999).*

IEC 61511-1, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements (IEC 61511-1:2003 + corrigendum 2004).*

IEC 61511-2, *Functional safety – Safety instrumented systems for the process industry sector – Part 2: Guidelines for the application of IEC 61511-1 (IEC 61511-2:2003).*

IEC 61511-3, *Functional safety – Safety instrumented systems for the process industry sector – Part 3: Guidance for the determination of the required safety integrity levels (IEC 61511-3:2003 + corrigendum 2004).*

3 Terminology and abbreviations

For the purposes of this Technical Report, the terms and definitions given in EN 1127-1:1997 and the following apply.

3.1 Terminology

3.1.1
inerting
replacement of atmospheric oxygen in a system by a non-reactive, non-flammable gas, to make the atmosphere within the system unable to propagate flame

3.1.2
absolute inerting
absolutely inerted mixture is one which does not form a flammable atmosphere when mixed with air in any proportion because the ratio of inert to fuel is sufficiently high

3.1.3
Limiting Oxygen Concentration (LOC)
experimentally determined oxygen concentration which will not allow an explosion in a fuel/air/inert gas mixture

NOTE It is a characteristic which is specific for a given fuel/inert gas combination. The determination should be in accordance with pr EN 14756 for gases and vapours and EN 14034-4 for dusts respectively.

3.1.4
Maximum Allowable Oxygen Concentration (MAOC)
concentration which should not be exceeded in the system which has to be protected, even with anticipated upsets or operating errors

NOTE It is set using a margin below the limiting oxygen concentration. This margin should consider variations in process conditions which might deviate from the experimental conditions.

3.1.5
explosion
abrupt oxidation or decomposition reaction producing an increase in temperature, pressure, or in both simultaneously

[EN 1127-1:1997, 3.6]

3.1.6
Lower Explosion Limit (LEL)
lower limit of the explosion range

3.1.7
Upper Explosion Limit (UEL)
upper limit of the explosion range

3.1.8
explosion range
range of concentration of a flammable substance in air within which an explosion can occur

3.1.9
Trip Point (TP)
oxygen concentration at which the oxygen monitoring instrumentation initiates a shut down procedure to make the equipment safe and prevent the atmosphere inside from becoming flammable

3.1.10
Set Point (SP)
oxygen concentration at which the oxygen monitoring instrumentation controls the flow, pressure or quantity of inert gas

NOTE A suitable allowance for variation of flows, temperatures and pressure fluctuations should be made to ensure that when the oxygen level reaches the set point, the control system can prevent the oxygen level from rising to the trip point under normal operation and foreseeable disturbances.

3.1.11
safety margin
difference between the trip point and the maximum allowable oxygen concentration

3.1.12
inert gas
gas that neither reacts with oxygen nor with the gas, vapour or dust

3.1.13
pressure-swing inerting
reduction of oxidant concentration in a closed system by pressurising with inert gas and venting back to atmospheric pressure

3.1.14
vacuum-swing inerting
reduction of oxidant concentration by the evacuation of a closed system, and the restoration to atmospheric pressure by the admission of inert gas

3.1.15
flow-through inerting
replacement of an oxidant by a continuous flow of inert gas into a system which is vented to atmosphere

3.1.16
displacement inerting
displacement of an oxidant by an inert gas of a significantly different density, where significant mixing does not take place

3.2 Abbreviations

B	bulk density of powder
C_0	initial oxygen concentration (fractional)
C_b	oxygen concentration in air in powder (usually 0,21) (fractional)
C_f	oxygen concentration after flow purging (fractional)
C_i	concentration of oxygen in inert gas
C_m	maximum allowable oxygen concentration
C_n	oxygen concentration after n purges
C_p	specific heat of inert gas at constant pressure
C_{st}	stoichometric composition of the fuel in air
C_r	required maximum fractional oxygen concentration in vessel
C_v	specific heat of inert gas at constant volume
D	vent diameter, inches
F	safety factor for flow purging
f	void fraction
h	distance from end of vent, ft
J	rate of pressure rise in a vacuum system, mbar min^{-1}

K	weight of 1 bag of powder
k	ratio of specific heats of gases, C_p/C_v
LOC	limiting oxygen concentration
M	mean partical size, µm
$MAOC$	maximum allowable concentration
MOC_C	minimum oxygen for combustion with carbon dioxide as diluent
MOC_N	minimum oxygen for combustion with nitrogen as diluent
m	molecular weight of purge gas
N	exponent in Husa’s 1964 equation dependent on vent diameter
n	number of cycles or additions
P_1	lower purge pressure (absolute)
P_2	upper purge pressure (absolute)
Q	purge gas flow-rate
R	upper/lower purge pressure ratio (absolute), i.e. P_2/P_1
S	void fraction of bulk powder
SP	set point
TP	trip point
t	time
$t*$	time interval between start of charging of successive bags
U	vessel ullage volume
V	system volume
V_0	volume of oxygen in vessel at start
$V*$	volume of oxygen in each bag
V_n	volume of oxygen in vessel after nth bag charged
V_s	bulk volume of solids being charged
V_v	volume of double valve arrangement
v	purge gas superficial velocity, ft/sec
v/v	volume/volume
x	required oxygen content % v/v

NOTE Where units have specific units, then these should be used. Where no units are shown, the variables are either dimensionless or any consistent set of units may be applied to the equation.

4 Inert gases

Inerting may be achieved by using a non-flammable gas which will neither react with a given fuel nor with oxygen. This has to be considered carefully. Some material may react with steam, carbon dioxide or even nitrogen under some conditions. For example, molten lithium metal reacts with nitrogen.

The most commonly used inert gases are:

a) Nitrogen
Nitrogen may either be received from a commercial supplier with an appropriate purity or may be generated from ambient air at technical quality by on-site facilities.

b) Carbon dioxide
Carbon dioxide may be received from a commercial supplier at an appropriate purity.

c) Steam
Steam with pressures over 3 bar might be used as an inert gas, as its oxygen content is usually negligible. Condensation has to be taken into account and might lead to a pressure drop which supports air ingress into the plant or create a vacuum. When using steam for fire fighting in dust plants the condensation can be an advantage as the dust becomes wet, preventing a dust dispersion and extinguishing smoulders. However, there can be a risk of increased mass, chemical reaction due to the water, or microbial activity.

d) Flue gases
Flue gases from combustion can be used if the oxygen concentration can be controlled sufficiently. Fluctuations in oxygen concentration have to be taken into account, and appropriate measures to minimise fluctuations have to be taken (e.g. gas buffer storage). Flue gases shall be assumed to be similar to nitrogen when defining the limiting oxygen concentration.

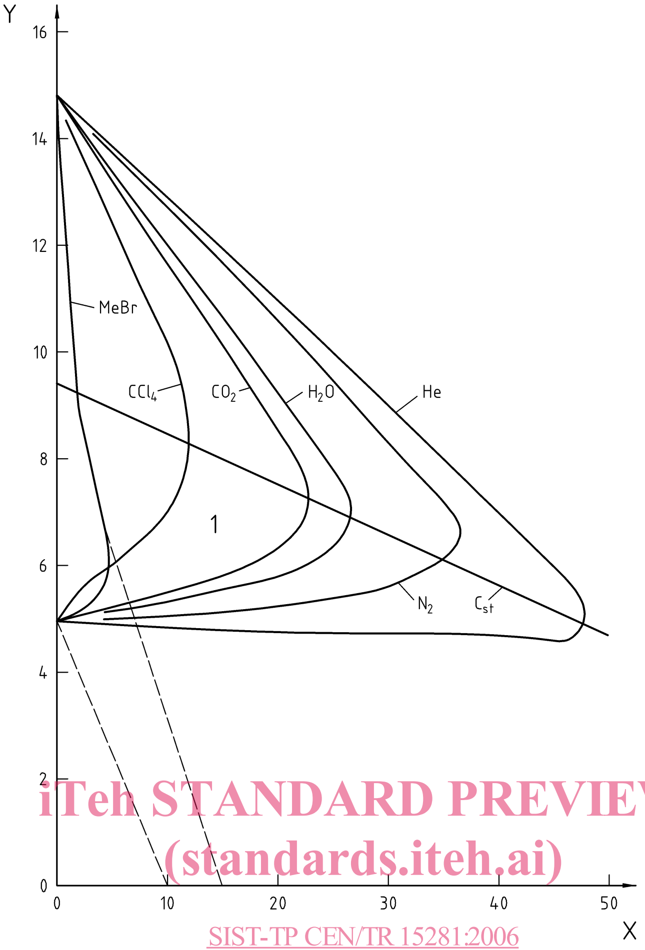
e) Noble gases
Argon or other noble gas may be received from a commercial supplier at an appropriate purity. Their use will be limited due to economic reasons to applications where no other inert gas can be identified. Helium may be advantageous as an inerting medium where hydrogen is used, as the molecular size of helium approaches that of the hydrogen, so leaks may be more readily detected.

5 Influence of the oxygen concentration on explosive atmospheres

5.1 General

Limiting oxygen concentrations are measured in air for a given fuel by reducing the oxygen concentration and varying the fuel concentration until an explosion is no longer observed. The limiting oxygen concentration depends on the type of inert gas used, the temperature, and the pressure of the system. The effect of various inert gases is shown in Figure 1.

The higher the concentration of inert gas required for inerting, the lower is the limiting oxygen concentration. Limiting Oxygen Concentrations for several gases and vapours are given in [9] and [24], and have been determined using the method outlined in prEN 14756. Other available values generally quoted in the open literature may have been obtained using a different method, and due care should be exercised when using such values unless the method used is known to give comparable results to the method of prEN 14756.



Key

% air = 100 % - % methane - % inert

X = Added inert, volume-percent

Y = Methane, volume-percent

1 = Flammable mixtures

C_{st} = stoichometric composition of the fuel in air

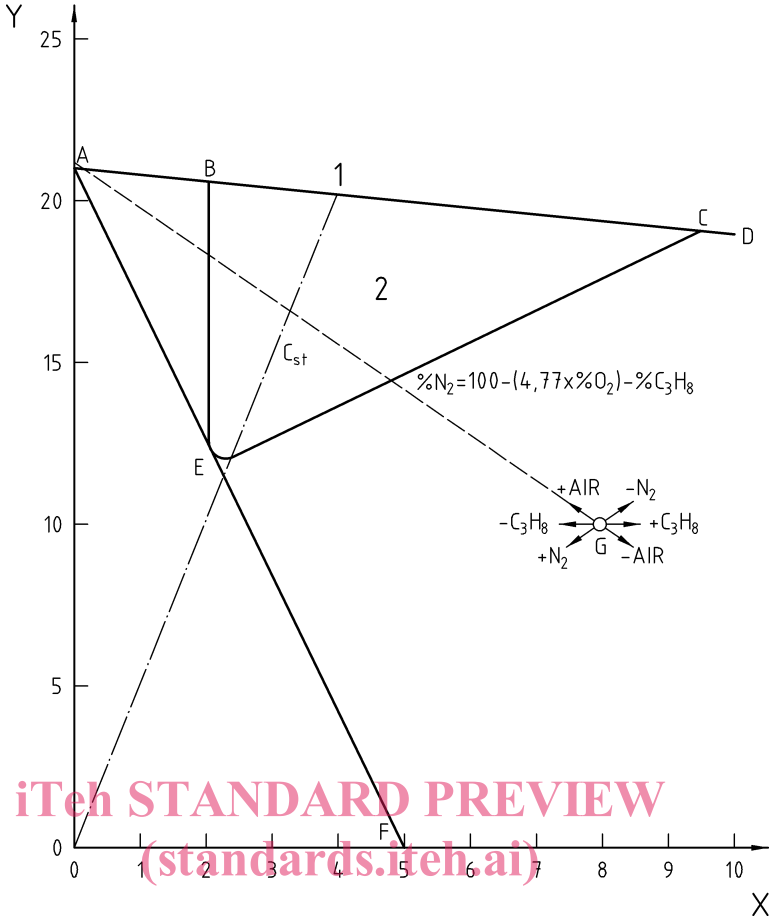
Figure 1 — Influence of inert gas on explosion limits of methane (according to [32], Figure 28)

The experimentally determined limiting oxygen concentration is a fuel and inert gas specific characteristic. Therefore both components have to be defined to give an appropriate value for the limiting oxygen concentration (see prEN 14756 for gases and EN 14034-4 for dusts). The following information is required:

- gases and vapours: composition;
- dusts: composition, particle size, moisture content;
- inert gas: composition and oxygen content.

5.2 Gas and vapour explosions

The explosible range of a flammable gas under the given process conditions can be shown in a suitable flammability diagram. Figure 2 shows such a diagram on rectangular coordinates for a mixture of a fuel, air and an inert gas (Note that ATEX does not cover oxygen enriched atmospheres so the diagram is limited to 21% oxygen). Values for limiting oxygen concentration for various materials and mixtures are given in [9] and [24].



Key

X = Propane (C_3H_8), % v/v

Y = Oxygen, % v/v

1 = Impossible mixtures above ABCD

2 = Only BEC flammable

C_{st} = stoichometric composition of the fuel in air

Figure 2 — Flammability diagram for air-propane-nitrogen (according to [8])

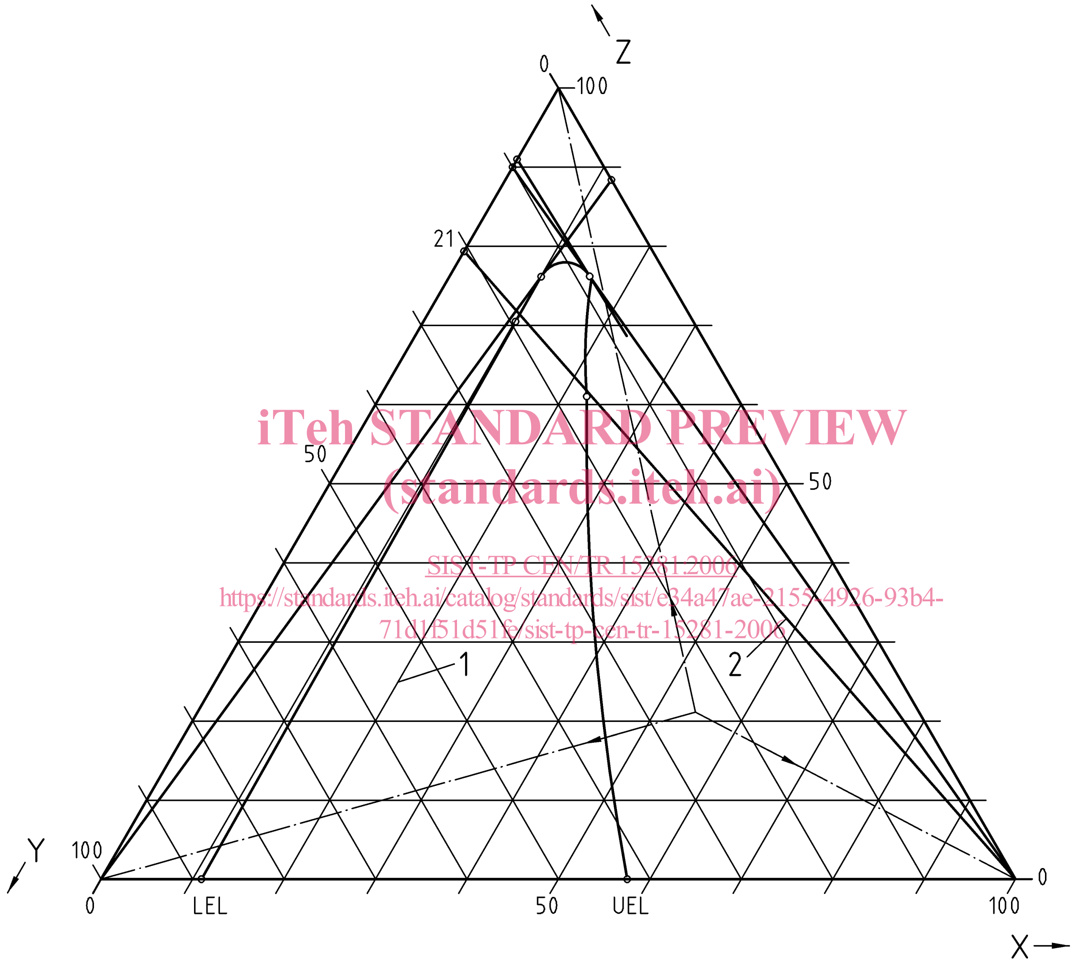
Absolute inerting is established when inert gas is added to the explosible mixture to such an extent, that by addition of any amount of air or fuel the explosible range can no longer be reached. The release of such an inerted atmosphere to the ambient air would thus not result in the formation of an explosive atmosphere.

Absolute inerting is achieved in Figure 2 if the composition of the inerted mixture lies in the area below and to the left of the line drawn from 21 Vol.-% oxygen apex (point A) and a tangent to the explosible range (point E), cutting the ordinate at point F. Any mixture with less than 5 % propane will always be non-explosible when mixed with air, and therefore is absolutely inert.

Sometimes data are only available for fuel-oxygen-inert gas mixtures, so the diagram may be constructed on triangular coordinates with oxygen as one of the axes, and the diagram can then be used for determining the flammable limits in air. This is shown in Figure 3. Each point within the triangular diagram corresponds to a certain composition of the mixture. The apices of the triangle represent the pure components, and points along the sides of the triangle give the two-component mixtures. The concentration of one component can be determined from the distance of the mixture point to the side of the triangle opposite to its apex of the triangle. If one of the three components is added to the mixture, the concentration changes along the straight line between the mixture point and the triangle apex of the added component. The ratio between the two other components of the mixture does not change if the third component is fed into the system.

If nitrogen is the inert gas, the air composition can be fixed along the side for inert gas-oxygen at 21 Vol.-% oxygen. The line connecting this point with the triangle apex of the fuel marks all compositions which can occur for a fuel/air-mixture. This line crosses the limits of the explosible range giving the lower and upper explosions limits of the fuel in air.

When inert gas is added the concentration changes along the straight line towards the triangle apex for inert gas. To determine whether the explosible range can be entered again by adding oxygen or fuel, lines are drawn from the oxygen or fuel apex respectively.



Key

X = Fuel

Y = Oxygen

Z = Nitrogen

1 = Explosible range

2 = Fuel-air-mixtures

Figure 3 — Triangular flammability diagram for fuel-oxygen-nitrogen

Flammability data for gases, vapours or dusts should be determined using the methods specified in prEN 14756 or EN 1839. Data using these methods can be found in the literature such as [9] for pure substances, and in [24] for mixtures. Where values are found from the open literature then, unless it is known that the method used gives comparable results to those determined using EN 1839 and prEN 14756, the reliability of the data should be carefully checked.

5.3 Dust explosions

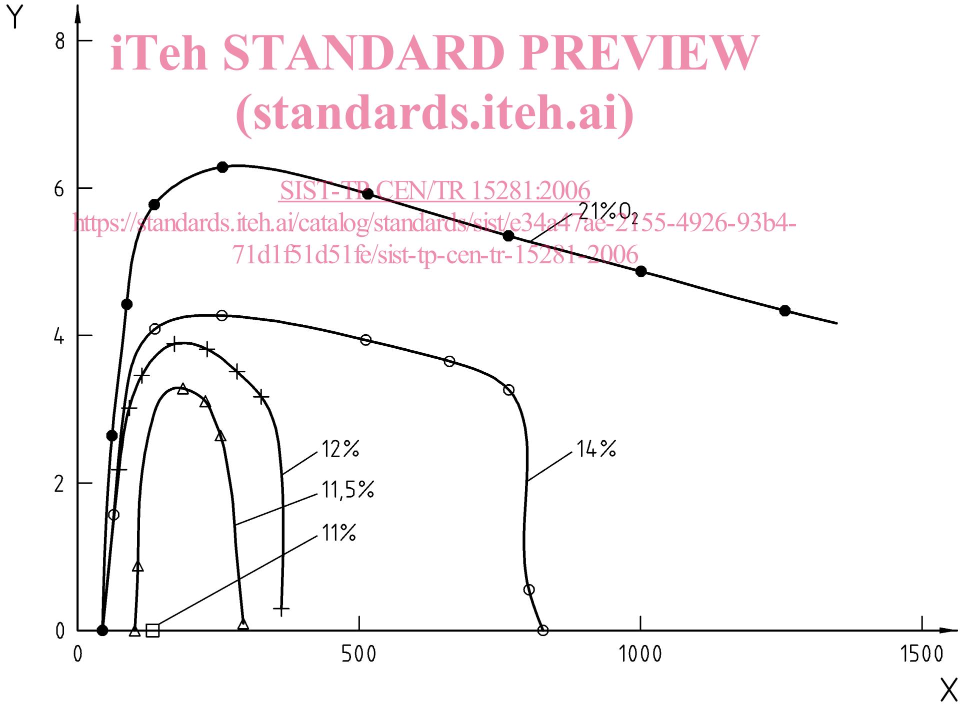
Dust concentrations cannot be controlled as gas or vapour concentrations can. Therefore only the oxygen concentration can be varied in this case, and the variation of the limiting oxygen concentration with the dust concentration cannot be taken into account for practical applications.

It has to be pointed out that in this case the required reliability of the inerting system depends on the likelihood of the ignition source in the process.

The influence of oxygen concentration on explosion pressure and rate of pressure rise for brown coal are shown in Figures 4 and 5, and the effect of various inert gases on the maximum pressure for brown coal is shown in Figure 6.

Note that some dusts such as metals may have limiting oxygen for combustion concentrations as low as 2 % v/v. The limiting oxygen concentration should be determined using the method described in EN 14034-4. Although the limiting oxygen concentration for many dusts is presented in the open literature, care is required as many literature sources do not specify the method used. Hence unless the data is known to be reliable and determined by the method specified in EN 14034-4 or a method which gives comparable results, then the limiting oxygen concentration should be determined experimentally using the method of EN 14034-4.

Similarly, dusts may have differences in purity, and so a literature value may not be valid for a particular dust as the composition may be different. This is particularly valid where naturally occurring materials such as flour, wood dust or coal are handled.



Key

X = Dust concentration [g/m^3]

Y = Explosion pressure [bar]

Figure 4 — Influence of oxygen concentration on the explosion pressure of brown coal (according to [7])