White paper

Measurement of flammable gases and explosive gas mixtures with cold extractive analyzers

Author
Michael Ostendorf, Strategic Product management - Endress+Hauser SICK GmbH+Co. KG

Endress+Hauser
People for Process Automation

1. Introduction

In gas analysis, the composition of gas mixtures is examined qualitatively and quantitatively using different measurement principles.
The choice of measurement principles depends on which gas components, in which gas mixtures with which concentrations are to be measured and which properties the respective gases have. In practice, there are a variety of applications that involve different measuring tasks. In addition to the gases and gas mixtures to be measured, the places of use and the respective ambient conditions also vary.

Three tasks can be distinguished for why a gas analysis is typically performed:
- Process control to ensure the quality and efficiency of the manufacturing process and product
- Process monitoring for the safety of the process
- Emission monitoring for compliance with legal requirements regarding the composition of exhaust gases.

This document focuses on measurement for process control and monitoring of processes. The properties of flammable gases and the explosive gas mixtures mean a special technical requirement due to the explosion risk. In order to ensure the safety of an industrial plant as well as of the operating personnel such as service technicians at all times, technical options and operating conditions are described with which the S700 product family with its different housings may be used to measure these gases.

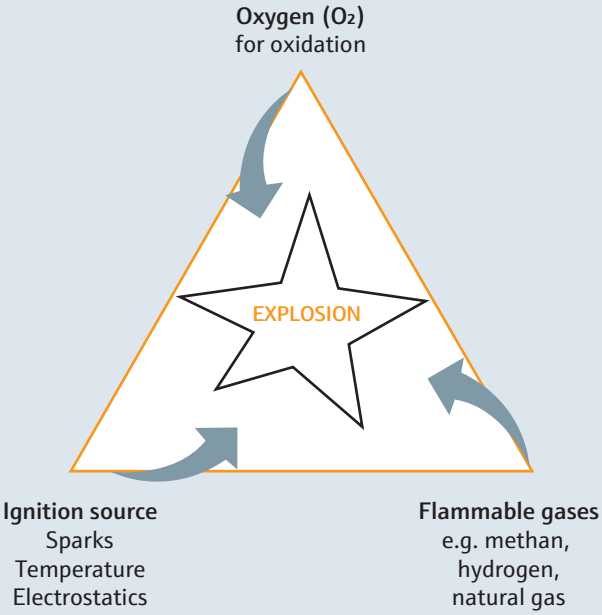
As a preferred solution, the S700 product family can be used flexibly with a wide range of applications. For technical sales and interested users, this document provides both an overview of the available measuring tasks and a foundation and common understanding through the terms and definitions used.

2. Flammable gases and explosive gas mixtures

The measurement of gas concentrations in flammable gases and explosive gas mixtures is of great economic importance in industries such as metal and steel, chemicals, etc., and in some cases has a direct impact on the quality and safety of the plant. There is an increased risk of explosion when measuring gases with these properties.

Explosion

"Explosion" refers to an oxidation or decomposition reaction occurring suddenly, i.e., at a high rate of reaction, which produces an increase in temperature or pressure, or both simultaneously. The best known are reactions of flammable gases, vapors or dusts with oxygen in the air [1]. "



The Physikalische-Technische Bundesanstalt (National Metrology Institute of Germany) describes the formation of an explosion as follows: "For an explosion to occur, the three components "combustible substance in finely divided form," oxygen and an ignition source must come together. These components can be represented as a so-called "explosion triangle" [2]."
If an oxidizing agent is already present in the desired gas matrix in addition to the flammable gas component, explosive gas mixture may be present. Whether the gas mixture can actually burn or explode depends on the concentrations of the gases it contains. In the case of an explosive gas mixture, only an ignition source is still needed to cause an explosion. In practice and in the literature, different terms and definitions are used for gases and gas mixtures.

In order to ensure a common understanding, the definitions listed below will be used.

Ignition source
Ignition sources include hot surfaces, electrical discharges, mechanically generated sparks, shock waves, etc.

1 https://www.bartec.de/de/safety-academy/grundlagen-explosionsschutz
2 https://www.ptb.de/cms/ptb/fachabteilungen/abt3/exschutz/ex-grundlagen/grundprinzipien-des-explosionsschutzes

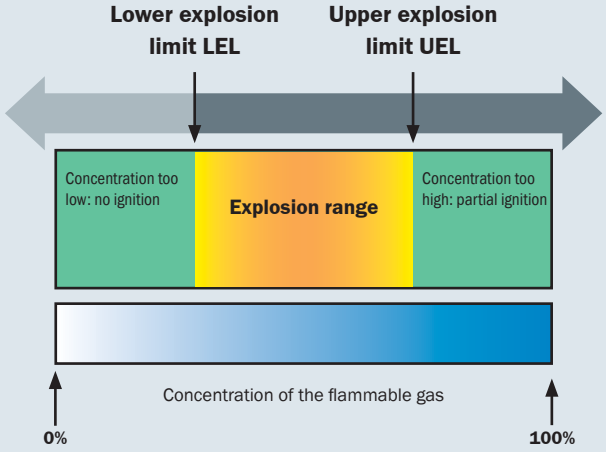
Inertization
Displacement of oxygen in a gas/gas mixture or addition of inert substances as gas, e.g. nitrogen.

Flammable gas
A flammable gas within the explosion limits (LEL: lower explosion limit, UEL: upper explosion limit).

Explosive gas mixture
An explosive gas mixture contains of a flammable gas within its explosion limits (between LEL and UEL) and sufficient amount of oxygen.

Explosion limits

The explosion range is limited by a lower (LEL) and an upper (UEL) explosion limit.



Lower explosion limit (LEL)
The lower explosion limit of a flammable gas is the lowest concentration at which the flammable gas can ignite in a mixture with an oxidizing agent.

Upper explosion limit (UEL)
The upper explosion limit of a flammable gas is the highest concentration at which the flammable gas can ignite in a mixture with an oxidizing agent.

Oxidizing agent
An oxidizing agent (also oxidant or oxidizer) is a substance that can oxidize other substances and is itself reduced in the process.

3. Definitions

3.1. Non-flammable gases and gas mixtures

A non-flammable gas mixture that may contain flammable substances less than 100% of the lower explosive limit (LEL).

A non-ignitable gas mixture will not burn or explode if it comes into contact with an ignition source. If there are components in this gas mixture that burn in high concentrations, e.g. CH4,the concentration of flammable substances is below the lower explosion limit. Example for CH4: 200 ppm. Thus, in the event of a possible fault of mixing with ambient air or another oxidizing agent, no explosive gas mixture can be produced.

Gases and gas mixtures with these properties are referred to as “non-flammable”.

3.2. Flammable gases and gas mixtures

A non-flammable gas mixture that may contain flammable substances ≥ the lower explosion limit (LEL) or > the upper explosion limit (UEL).

A non-ignitable gas mixture will not burn or explode if it comes into contact with an ignition source. In this gas mixture there are flammable components, e.g. CH4 at 15% by volume, whose concentration is above the lower explosion limit (LEL). Mixing with air or other oxidizing agents can produce an explosive gas mixture.

Gases and gas mixtures with these properties are referred to as “flammable”.

As soon as a flammable gas is introduced into the analyzer, a prerequisite for an explosion is fulfilled. Oxygen is present in ambient air in sufficient quantities so that a defective sample gas path or a leak in the analyzer can produce an explosive gas mixture, for example:

- If the pressure in the sample gas path is > ambient pressure, this gas mixture can occur in the housing interior.
- If the pressure in the sample gas path is < ambient pressure, such a gas mixture can occur in the sample gas path.

Important
For the measurement of combustible gases or gas mixtures, specific measures are specified in the design and operation of the analyzer to ensure safe operation, see “Measures for the design and operation of the analyzer”.

3.3. Explosive gas mixtures

An explosive gas mixture containing flammable substances ≥ of the lower explosive limit (LEL), which contains flammable substances + oxidizing agents in sufficient proportions for an ignition source to be sufficient.
An explosive gas mixture burns at a discharge point, e.g. leakage in the event of a fault in the immediate presence of an ignition source. It generates an explosive atmosphere at such a discharge point over time without an immediate ignition source, which poses an explosion risk if the volume is sufficient. Furthermore, an internal ignition source in

the sample gas path can cause an explosion in the sample gas path. The gas mixture itself contains the flammable gas and the oxidizing agent.

Gases and gas mixtures with these properties are referred to as “explosive.”

For explosive gas mixtures, a further differentiation is made depending on the frequency of occurrence according to the IEC EX zone definition.

3.4. Zone definition according to IEC Ex

Classification according to IEC60079-10-1	
Zone 0	Area in which the explosive gas mixtures as a mixture of oxidizing agent and flammable gases are present continuously, for long periods of time or frequently.
Zone 1	Area in which the explosive gas mixtures can occasionally form as a mixture of oxidizing agent and flammable gases during normal operation.
Zone 2	Area in which the explosive gas mixtures as a mixture of air and flammable gases do not normally occur, and if they do, then only rarely and for a short period of time

Important
For the measurement of explosive gas mixtures, specific measures are specified in the design and operation of the analyzer to enable safe operation, see “Measures for the design and operation of the analyzer”.

4. Cold extractive gas analyzers of the modular S700 product family

Flexible analyzer solution for measuring process gases.

The S700 modular gas analyzers can be flexibly configured to create customized designs. For compact and customized system solutions, the S700 offers three housing versions that can be equipped with the following analyzer modules:

- UNOR and MULTOR for NDIR spectroscopy
- THERMOR for thermal conductivity measurement
- OXOR-P for O_2 analysis with the paramagnetic measurement principles
- OXOR-E for O_2 measurement with electrochemical cells

The analyzer modules can be combined with each other and apply to most housing designs. Restrictions are possible depending on the assembly and application.

4.1. Housing versions of the S700 product family

Depending on the measuring task, location and ambient conditions, the following housing versions can be applied: Other options are available to tailor an analyzer to a specific customer requirement.

4.2. Options of the S700 product family

S710 / S711

19” rack housing (3 HE) for analyzer systems and standard applications

S715 / S715 Ex

Wall-mounted housing for use in harsh industrial environments and Ex-Zone 2 (ATEX)

S720 Ex / S721 Ex

Flameproof housing for Ex-Zone 1 (ATEX)

A range of hardware and software options are available, such as interfaces for communication with the customer and other special variants. To ensure the safety of the equipment, the analyzer itself and/or the operator, the following options can be selected:

- A perforated lid with ensured air exchange
- Flushing of the housing
- Flame arresters
- Piped sample gas paths

5. Measures for the design and operation of the analyzer

There are generally different technical approaches to protect the gas analyzer, the customer equipment and the analyzer operator:

- Avoidance or containment of the ignition source to prevent an explosion and/or hazard from an explosion in the event of a fault.
- Avoidance of flammable substances in explosive form to prevent an explosion.
- Inertization (displacement of oxygen) to prevent an explosion

These general technical approaches mean concrete technical measures for the configured analyzers. These technical measures and their effect are briefly described below.

Avoidance or inclusion of the ignition source

- Use piped gas paths and flame arresters to contain a flame generated in the event of a fault
- Do not use components that are not suitable for explosive atmospheres and/or are a possible source of ignition Example: internal pump; not suitable for explosive atmospheres
- Do not measure gases with a low ignition temperature (T6 gases) in combustible concentrations so that in the event of a fault, no explosion can occur due to overheating of electrical components. e.g. heater. Example: CS_2.
- Use of an analyzer with a flameproof housing to contain a flame generated in the event of a fault

Avoidance of flammable substances in explosive form

- Prevent leakage/penetration of flammable gases or oxidizing agent from/in the sample gas path by regularly checking the gas paths for leakage.
- Dilute escaping gases by flushing the enclosure with ambient air and/or ensure regular air exchange inside the housing or
- Flush the analyzer housing with inert gas

6. Specifications

The specifications for the design of the analyzers and the determinations for the operation of the analyzer were developed within the framework of risk assessments. The results differ depending on the housing design and categories of the gas (flammable gas and explosive gas mixture - Zone 2).

The results are summarized in the following table and are considered a general guideline. Application- and execution-specific risk assessments can be used to implement supplementary or restricted measures.

(See table “Measurement of flammable gases and gas mixtures “ next page)

Measurement of flammable gases and gas mixtures

Analyzer/ Enclousure type	Example	General measures	S710 / S711
			
Measurement of combustible gases in concentrations <25% of the lower explosion limit	▪ 5 ppm CH_4 in Air	▪ No safety measure	▪ No safety measure
Measurement of combustible gases in concentrations >25% of the lower explosion limit. The gas mixture must not be explosive, oxidants must not be present in critical concentration (e.g. limiting oxygen concentration)	▪ 100 Vol. % CH_4 or ▪ 50 Vol. % CH_4 in N_2	▪ OXOR E is not available ▪ Internal pump is not available ▪ No measurement of T6 gases (CS_2) ▪ Regular leak test mandatory ▪ Correct gas conditions have to be ensured (pressure, temperature)	▪ Ensure an unhindered air exchange between analyzer and environment ▪ Recommended: Stainless steel tubing ▪ Upon request: Viton hosing with more frequent maintenance / leak test + exchange of tubing ▪ In case of underpressure in the sample gas line: flame arrestors are recommended
Measurement of explosive gas mixtures Zone 2 (combustible gas + oxidant)	▪ 10 Vol. % CH_4 in Air	▪ Stainless steel tubing is mandatory ▪ Flame arrestors are mandatory ▪ OXOR E is not available ▪ Internal pump is not available ▪ No measurement of T6 gases (CS_2) ▪ Regular leak test mandatory ▪ Correct gas conditions have to be ensured (pressure, temperature)	▪ Ensure an unhindered air exchange between enclosure and environment
Measurement of explosive gas mixtures Zone 1 (combustible gas + oxidant)	▪ 10 Vol. % CH_4 in Air	▪ Stainless steel tubing is mandatory ▪ Flame arrestors are mandatory ▪ OXOR E is not available ▪ Internal pump is not available ▪ No measurement of T6 gases (CS_2) ▪ Regular leak test mandatory ▪ Correct gas conditions have to be ensured (pressure, temperature)	▪ Application specific risk assessment required

S715	S715 Ex Protection type: Ex nR (ATEX)	S720 Ex / S721 Ex Protection type: Ex d (ATEX)
		
▪ No safety measure	▪ No safety measure	▪ No safety measure
▪ Permanent enclosure purging with inert gas or ambient/instrument air required ▪ Recommended: Stainless steel tubing ▪ Upon request: Viton hosing with more frequent maintenance / leak test + exchange of tubing + purging with inert gas required ▪ In case of underpressure in the sample gas line: flame arrestors are recommended and/or permanent purging with inert gas	▪ Not possible	▪ Stainless steel tubing mandatory ▪ Flame arrestors mandatory
▪ Permanent enclosure purging with inert gas or instrument air required	▪ Not possible	▪ No additional safety measures
▪ Application specific risk assessment required	▪ Not possible	▪ No additional safety measures

Headquarters

Endress+Hauser
Instruments International AG
Kaegenstraße 2
4153 Reinach
Switzerland

Tel +41 61 715 8100
Fax +41 61 715 2500
info@ii.endress.com
www.ii.endress.com

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