INTERNATIONAL STANDARD

IEC 61779-6

First edition
1999-06

Electrical apparatus for the detection and measurement of flammable gases –

Part 6:
Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of flammable gases

Appareils électriques de détection et de mesure des gaz combustibles –

Partie 6:
Directives pour le choix, l'installation, l'utilisation et l'entretien des appareils électriques de détection et de mesure de gaz inflammables

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL APPARATUS FOR THE DETECTION AND MEASUREMENT OF FLAMMABLE GASES -–

Part 6: Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of flammable gases

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61779-6 has been prepared by subcommittee 31L: Electrical apparatus for the detection of flammable gases, of IEC technical committee 31: Electrical apparatus for explosive atmospheres.

The text of this standard is based on the following documents:

FDIS	Report on voting
31L/60/FDIS	31L/61/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A, B, C and D are for information only.

A bilingual version of this standard may be issued at a later date.

INTRODUCTION

Flammable gas detection apparatus may be used whenever there is the possibility of a hazard to life or property caused by the accumulation of a flammable gas-air mixture. Such apparatus can provide a means of reducing the hazard by detecting the presence of the flammable gas and issuing suitable audible or visual warnings. Gas detectors may also be used to initiate specific precautions (for example plant shutdown, evacuation, operation of fire extinguishing procedures).

Apparatus may be used to monitor a gas atmosphere below the lower flammable limit in circumstances where accumulation of gas may result in a concentration of the gas/air mixture to potentially explosive levels.

ELECTRICAL APPARATUS FOR THE DETECTION AND MEASUREMENT OF FLAMMABLE GASES –

Part 6: Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of flammable gases

1 General

1.1 Scope

1.1.1 This part of IEC 61779 gives guidance on the selection, installation, use and maintenance of electrically operated group II apparatus for the detection and measurement of flammable gases complying with the requirements of IEC 61779-1 to IEC 61779-5. It is a compilation of practical knowledge to assist the user, and applies to apparatus, instruments and systems that indicate the presence of a flammable or potentially explosive mixture of gas or vapour with air by using an electrical signal from a gas sensor to produce a meter reading, to activate a visual or audible pre-set alarm or other device, or any combination of these.

NOTE – When in classified areas, the apparatus should be so installed and used that it is not capable of itself igniting a combustible gas-air mixture. It should therefore comply with the requirements of IEC 60079-10.

For the purpose of this standard, flammable gases shall include flammable vapours.

1.1.2 This standard applies only to group II apparatus intended for use in industrial and commercial safety applications, involving areas classified in accordance with IEC 60079-10.

For the purpose of this standard, apparatus includes

a) fixed apparatus;
b) transportable apparatus; and
c) portable apparatus.

1.1.3 This standard is not intended to cover the following:

a) apparatus intended only for the detection of non-flammable toxic gases;
b) apparatus of laboratory or scientific type intended only for analysis or measurement purposes;
c) apparatus intended for underground mining applications;
d) apparatus intended for applications in explosives processing and manufacture;
e) apparatus intended only for process control applications;
f) apparatus intended for the detection of a potentially flammable atmosphere resulting from dust or mist in air.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61779. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61779 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(426):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 426: Electrical apparatus for explosive atmospheres*

IEC 60079 (al parts), *Electrical apparatus for explosive gas atmospheres*

IEC 60079-0:1998, *Electrical apparatus for explosive gas atmospheres – Part 0: General requirements*

IEC 60079-10:1995, *Electrical apparatus for explosive gas atmospheres – Part 10: Classification of hazardous areas*

IEC 60079-19:1993, *Electrical apparatus for explosive gas atmospheres – Part 19: Repair and overhaul for apparatus used in explosive atmospheres (other than mines or explosives)*

IEC 60079-20:1996, *Electrical apparatus for explosive gas atmospheres – Part 20: Data for flammable gases and vapours, relating to the use of electrical apparatus*

IEC 61779-1:1998, *Electrical apparatus for the detection and measurement of flammable gases – Part 1: General requirements and test methods*

IEC 61779-2:1998, *Electrical apparatus for the detection and measurement of flammable gases – Part 2: Performance requirements for group I apparatus indicating up to 5 % methane in air*

IEC 61779-3:1998, *Electrical apparatus for the detection and measurement of flammable gases – Part 3: Performance requirements for group I apparatus indicating a volume fraction up to 100 % methane in air*

IEC 61779-4:1998, *Electrical apparatus for the detection and measurement of flammable gases – Part 4: Performance requirements for group II apparatus indicating a volume fraction up to 100 % lower explosive limit*

IEC 61779-5:1998, *Electrical apparatus for the detection and measurement of flammable gases – Part 5: Performance requirements for group II apparatus indicating a volume fraction up to 100 % gas*

2 Definitions

For the purpose of this part of IEC 61779, the following definitions apply.

2.1
aspirated apparatus
combustible gas detecting apparatus that obtains the gas by drawing it to the gas sensor – for example by means of a hand-operated or electric pump

2.2
catalytic sensor
sensor, the operation of which depends upon the oxidation of gases on an electrically heated catalytic element

2.3
clean air
air that is free of flammable gases and interfering or contaminating substances

2.4
continuous duty apparatus
combustible gas detecting apparatus that is powered for long periods of time, but may have either continuous or intermittent sensing

2.5
continuous sensing
mode of operation in which power is applied continuously to the sensing element and readings are taken continuously

2.6
diffusion apparatus
apparatus in which the transfer of gas from the atmosphere to the gas sensing element takes place by diffusion, i.e. there is no aspirated flow

2.7
electrochemical sensor
sensor, the operation of which depends upon changes of the electrical parameters of electrodes placed in an electrolyte due to redox reactions of the gas on the surface of the electrodes

2.8
electromagnetic radiation absorption sensor
sensor, the operation of which depends upon the absorption of electromagnetic radiation by the gas being detected

2.9
explosion protected apparatus
apparatus incorporating a type of protection covered by the IEC 60079 series of standards

2.10
explosive gas atmosphere
mixture with air, under normal atmospheric conditions, of flammable material in the form of gas or vapour, in which, after ignition, combustion spreads throughout the unconsumed mixture

NOTE 1 – This definition specifically excludes dusts and fibres in suspension air. Mists are not covered by this standard.

NOTE 2 – Although a mixture that has a concentration above the upper explosive limit (see 2.1.9) is not an explosive atmosphere, in certain cases for area classification purposes, it is advisable to consider it as an explosive gas atmosphere.

NOTE 3 – Normal atmospheric conditions include variations above and below reference levels of 101,3 kPa and 20 °C provided the variations have a negligible effect on the explosive properties of the flammable materials.

2.11
explosive range
range of gas or vapour mixtures with air between the explosive (flammable) limits

2.12
fixed apparatus
apparatus which is intended to have all its parts permanently installed

2.13
flashpoint
lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapours in a quantity such as to be capable of forming an ignitable vapour/air mixture

2.14
group II apparatus
electrical apparatus for places with a potentially explosive atmosphere, other than mines susceptible to firedamp

2.15
infrared absorption sensor
sensor, the operation of which depends upon the absorption of infrared radiation by the gas being detected

2.16
intermittent sensing
mode of operation in which the power or flow to the sensor is applied intermittently according to a predetermined cycle and readings taken at the predetermined cycle

2.17
lower flammable limit (LFL)
volume ratio of flammable gas or vapour in air below which an explosive gas atmosphere does not form, expressed as a percentage (see annex A)

NOTE – This is also known as lower explosive limit (LEL).

2.18
open path infrared sensor
sensor capable of detecting gas at any location along an open path traversed by an infrared beam

2.19
portable apparatus
spot reading or continuous duty apparatus that has been designed to be readily carried from place to place and to be used while it is being carried. Portable apparatus is battery operated and includes, but is not limited to

a) hand-held apparatus, typically less than 1 kg, suitable for single-handed operation;

b) personal monitors, similar in size and mass to the hand-held apparatus, that are continuously operating (but not necessarily continuously sensing) while they are attached to the user; and

c) larger apparatus up to 5 kg that can be operated by the user while it is suspended by hand, by a shoulder strap or by a carrying harness; it may or may not have a hand directed probe

2.20
relative density
density of gas or vapour relative to the density of air at the same pressure and at the same temperature (air is equal to 1,0)

2.21
release rate
quantity of flammable gas or vapour emitted per unit time from the source of release which itself could be a liquid surface

2.22
remote sensor
sensor which is not integral with the main body of the apparatus

2.23
sample line
pipeline by means of which the gas being sampled is conveyed to the sensor

2.24
sampling probe
separate sampling line, that may or may not be supplied with a portable apparatus that is attached to the apparatus as required.

NOTE – The sampling probe is usually short (for example of the order of 1 m) and rigid (for example it may be telescopic) but may be connected by a flexible tube to the apparatus.

2.25
semi-conductor sensor
sensor, the operation of which depends upon changes of the electrical conductance of a semi-conductor due to chemisorption of the gas being detected at its surface

2.26
sensor
assembly in which the sensing element is housed that may contain associated circuit components

2.27
sensing element
that part of a sensor that reacts in the presence of a flammable gas mixture to produce some physical or chemical change that can be used to activate a measuring or alarm function, or both

2.28
single point sensor
sensor capable of detecting gas at a single point location

2.29
source of release
point or location from which a flammable gas, vapour or liquid may be released into the atmosphere such that an explosive gas atmosphere could be formed. [IEV 426-03-06, modified]

2.30
spot reading apparatus
apparatus intended to be used for short periods of time as required (typically 5 min or less)

2.31
thermal conductivity sensor
sensor, the operation of which depends upon the change of heat lost by conduction of an electrically heated element located in the gas to be measured, compared with that of a similar element located in a reference gas cell

2.32
transportable apparatus
apparatus not intended to be portable, but which can be readily moved from one place to another

2.33
upper flammable limit (UFL)
volume ratio of flammable gas or vapour in air above which an explosive gas atmosphere does not form, expressed as a percentage (see annex A)

NOTE – This is also known as upper explosive limit (UEL).

2.34
ventilation
movements of air and replacement with fresh air due to the effects of wind, temperature gradients or artificial means (for example fans or extractors)

3 Measuring principles

The measuring principles of various sensors are given below as well as typical advantages and disadvantages of each.

3.1 Catalytic sensor

The principle of operation of the catalytic sensor depends upon the oxidation of flammable gas at the surface of an electrically heated catalytic element (filament or bead). This oxidation causes, for example the temperature of the sensing element to change as a function of the concentration of gas so detected. The resultant change of electrical resistance is determined. A reasonable concentration of oxygen in the order of 10 % or greater is required for catalytic sensors to operate.

By their very nature, catalytic sensors will directly detect flammable gases; the other types of sensors described in 3.2 to 3.6 indirectly infer the presence of flammable gases by the response of the sensor to other gas properties.

Since oxidation depends upon the presence of oxygen, detection apparatus should use only this type of sensor for gas concentrations up to the lower flammable limit.

The catalytic sensor may be used in either

a) diffusion mode; or

b) aspirating mode.

3.1.1 Advantages

The sensors detect flammable gases by a process of combustion and are suitable for the detection of a wide range of flammable gases but with possible variations in sensitivity.

3.1.2 Disadvantages

The main disadvantages with catalytic sensors are the following:

a) Range limitation

The catalytic sensor depends upon catalytic oxidation for its principle of operation and it functions only when sufficient oxygen is present. This type of sensor should be used for the detection of gas/air mixtures up to the lower flammable limit.

WARNING – ABOVE THE LOWER FLAMMABLE LIMIT, A CATALYTIC SENSOR MAY RESPOND AMBIGUOUSLY AND IN SOME CASES THE INSTRUMENT MAY ERRONEOUSLY INDICATE THAT THE FLAMMABLE GAS AND AIR MIXTURE IS BELOW THE LFL.

b) Interfering gases and vapours

If the atmosphere to be monitored contains gas(es) that dilute(s) or displace(s) air, for example nitrogen or carbon dioxide, the catalytic sensor may give a low or even zero response. Similar problems may occur in steam-laden atmospheres, quite often owing to saturation of the sintered flame arrestor due to condensation. High concentrations of inert gas (for example argon or helium) may also change the thermal balance of the sensor resulting in apparent reading of combustible gas.

c) Inhibition (catalyst poisoning)

Catalytic sensors are susceptible to permanent or temporary inhibition of the catalyst by certain airborne contaminants such that the sensor may eventually produce low, or zero response to the presence of gas.

NOTE – For this reason, it is therefore important that all catalytic gas detection apparatus is regularly tested in accordance with 9.2.

This inhibition may be permanent or temporary according to the nature of the contaminant. Permanent inhibition, usually known as "catalyst poisoning", may result from exposure to such substances as silicones, tetraethyl lead, sulphur compounds and phosphate esters. In some cases substances such as halogenated hydrocarbons may cause temporary inhibition.

While many catalytic sensors are highly resistant to such contaminants and require no additional protection in this regard, those that are not may be protected, in some cases, by the use of activated carbon or other types of filter. However, carbon filters should be used with great care because, while they may offer excellent protection from contaminants, they may also prevent the detection of most hydrocarbons other than methane and may cause considerably increased response times.

Their performance may also be affected by the level of humidity in the atmosphere.

An alternative technique sometimes used to reduce the effects of inhibition is the electrical operation of the sensor in intermittent mode. However, there are circumstances in which such sensors may give a false response, for example when they are suddenly exposed to a high concentration of gas during the "power-off" part of the switching cycle. Particular caution is necessary when using such portable apparatus in leak-detection mode or in similar operations.

The manufacturer’s guidance should be sought where the presence of contaminants is suspected, or where temporary or permanent inhibition is experienced.

3.2 Thermal conductivity sensor

The principle of operation of the thermal conductivity sensor depends upon the heat loss by conduction of an electrically heated resistance element (i.e., filament, bead or thin film resistor) located in a gas sample stream of fixed velocity or in a diffusion chamber. The resulting change of electrical resistance is then determined.

This type of sensor is best suited for detecting individual gases of high or low conductivity relative to air.

Thermal conductivity sensors are suitable for monitoring those gases whose thermal conductivity differs substantially from that of air (where air is the reference environment) but only at relatively high concentrations, usually above the lower flammable limit. Apparatus incorporating thermal conductivity sensors should not be used for measuring gas concentrations below the LFL except in the case of gases such as hydrogen for which such sensors are especially sensitive.

Errors may result if:

a) the apparatus is used to attempt to detect gases for which it is not calibrated;

b) a flow-sensitive type of thermal conductivity sensor is used and the gas sample flow is not stable;

c) the gas sample is not conditioned to remove water vapour or other interfering vapours or gases, some of which may even result in negative response;

d) there are variations in ambient temperature without compensatory ambient temperature control on the complete sensor;

e) additional gases of different thermal conductivities compensate the resulting conductivity so that the signal may even be zero.

3.2.1 Advantages

The sensor is capable of measuring high concentration and is independent of the oxygen level in the gas-flow.

3.2.2 Disadvantages

Disadvantages with the use of thermal conductivity sensors include the following:

a) these sensors are not selective for individual gases;

b) the sensitivity is often limited and the detection limit may exceed the LFL unless the thermal conductivity of the gas is sufficiently different from that of air;

c) the thermal conductivities of flammable gases differ widely. The lighter gases, for example methane and hydrogen, are more conductive than air, whereas the heavier gases are less conductive. The response to a gas mixture is therefore indeterminate unless the proportions of the constituent gases in the mixture are known. In the worst case, a mixture of high and low conductivity gases could produce no instrument response;

d) this type of sensor is essentially dependent on thermal conduction and convection from a heated filament and is therefore likely to give misleading results if the recommended conditions of gas flow are not maintained as per the manufacturer's instructions;

e) some instruments specifically rely on convection and will be sensitive to orientation.

3.3 Electromagnetic radiation absorption sensor – usually infrared

The principle of operation of this type of sensor depends upon the absorption of energy of a beam of electromagnetic radiation by the gas being detected. Most existing instruments operate within the IR spectrum.

Detection apparatus with electromagnetic sensors may take various forms but may be categorized as

a) specifically adapted analysers with sampling systems;

b) single-point, self-contained electromagnetic detection apparatus suitable for installation in potentially explosive atmospheres;

c) light "pipes" – for example a fibre optic cable which directs an electromagnetic light source from a control unit to a sensor cell at a remote location.

In cases a), b) and c) the absorption of electromagnetic radiation by the gas is detected by spectrometric means and produces an electrical signal to provide indications of gas concentrations and alarms.

Electromagnetic sensors may be used for the detection of most flammable gas(es) in any specified range of concentrations up to 100 % (v/v) with the exception of hydrogen.

NOTE – Open-path, electromagnetic radiation detection apparatus differs from the other types mentioned in this standard in that it does not measure the concentration of gas at a particular point location, but rather measures the path integral of gas concentration along an investigative beam. It is therefore capable of detecting the presence of gas over a wider area than other types. However, it is inherently not capable of distinguishing between a high concentration of gas occupying a short section of the open path, and a low concentration of gas occupying a longer section of the path, and therefore does not comply with IEC 61779-1, IEC 61779-4 and IEC 61779-5.

3.3.1 Advantages

The sensor measures the concentration of the specific gas for which it is calibrated independent of oxygen concentration. By appropriate selection of wavelength, specific gases can be detected. Most flammable gases of the hydrocarbon family absorb radiation in the infrared part of the electromagnetic spectrum. By selection of the optical path length, concentrations from 0 % to 100 % v/v can be measured. Response time is limited by the time taken for gas to be introduced into the optical path which can be fast. However, in practice, weather protection housings, gas filters and hydrophobic barriers, where fitted, will limit the response times attainable.

Certain types of sensors using advanced signal processing have self-diagnosing and self-calibrating capabilities, thereby reducing the need for human intervention in the absence of malfunction alarms. Other advantages include

a) high stability capability;

b) no ambiguity at concentrations above the LFL;

c) immunity to poisoning effects;

d) reduced maintenance capability due to modern technologies, for example automatic calibration self-check, etc.;

e) availability of warnings to detect failure of the IR source or excessive contamination of the optical system.

3.3.2 Disadvantages

Infrared sensors are calibrated to detect a particular gas or, in some cases, a limited range of gases. Other gases will not be detected if their infrared absorption band is outside that of the calibration bandwidth. Apparatus incorporating such sensors should therefore be used only for the detection of gas mixtures for which they have been calibrated. When filters are used to keep optical components clean, they may be blocked under excessively dirty conditions.

Serious errors are likely to occur with some detectors due to the presence of water vapour or interfering gases or both.

This sensor is not suitable for measuring hydrogen.

Some types of infrared sensors, particularly open-path designs, are sensitive to misalignment caused by shock and vibration.

3.4 Semi-conductor sensor

The principle of operation of the semi-conductor sensor depends upon changes of electrical conductance that occur by chemisorption when the heated semi-conductor sensing element is exposed to gas. Gas concentrations are deduced from the measured change of conductivity.

Semi-conductor sensors may be used in either diffusion mode or in a sampling system.

This type of sensor is normally used for the detection of a specified gas in a nominated range of concentrations.

3.4.1 Advantages

Semi-conductive sensors are sensitive to a wide range of gases and produce large signal changes at low gas concentrations.

3.4.2 Disadvantages

Semi-conductor sensors for flammable gases are generally non-specific, vulnerable to both humidity changes and interfering gases and may exhibit drift both of zero and span. Some gases, for example NO_2, produce negative signals.

NOTE – Normally, the manufacturer will give guidance on substances that will inhibit operation of the sensor or produce false indications.

3.5 Electrochemical sensors

The principle of operation of the electrochemical sensor depends upon the change of the electrical parameters of electrodes when a specific gas is present. The change in the electrical parameters occurs due to a chemical redox reaction on the surface of electrodes placed in an electrolyte. Electrodes and electrolyte are usually confined in semi-permeable membranes.

3.5.1 Advantages

Electrochemical cells are compact, require little power, and have a high sensitivity to certain gases.

3.5.2 Disadvantages

Disadvantages include the following:

a) electrochemical cells are incapable of detecting the most simple hydrocarbons (for example methane, ethane, propane, etc.);

b) the electrochemical cell can gradually be consumed;

c) electrochemical cells may detect other interfering gases;

d) periodic adjustment is necessary to correct for drifts in zero and span;

e) response and recovery times are comparatively slow (typically >30 s);

f) low temperature operations (<–15 °C) and high temperature operations (>50 °C) may be precluded by electrolyte properties.

3.6 Flame ionization detectors (FID)

The operating principle of the flame ionization detector depends upon the ionization of the organic compounds. The ion cloud so formed migrates under the potential gradient between the electrodes in the ionization chamber, resulting in an electric current. This current is proportional to the concentration of gas/vapour in the gas stream.

This type of sensor is used for the detection of gas/air mixtures up to the lower flammable limit.

3.6.1 Advantages

This type of sensor is used where high sensitivity, wide measuring range, small measuring uncertainty, poison resistance and fast response time are of main interest.

The sensor is suitable for the measuring range from ml/m^3 (10^{-6}) up to the lower flammable limit.

3.6.2 Disadvantages

The principle of operation is not selective because generally all organic compounded carbons will cause a signal. If different gases or vapours are expected at the place of operation, the sensor should be calibrated for that gas or vapour to which the apparatus is least sensitive. These sensors are not suitable for inorganic gases such as H_2.

The pressure of the gas sample, air and flammable gas should be kept constant, but it should be noted that the flame arrestors used in the sampling line can be soiled and difficulty may be experienced in keeping the sample flow constant.

4 Selection of apparatus

In this clause and clauses 5 and 6, there is a need for documentation of plant information, site information and decisions to be made. Annex B shows a typical check-list for many of these decisions.

4.1 General

In selecting flammable gas detection apparatus, account should be taken of any features of the apparatus that may necessitate particular caution in its use and the interpretation of the output. Each of the various types of sensor has inherent limitations, as described in clause 3.

NOTE – This standard is not intended to discourage the use of apparatus using detection principles other than those described in 3.2 to 3.6 or to inhibit the development of new detection principles. However, it is of primary importance that the capabilities of the detection principle should be such that the performance of the apparatus is adequate for the intended application. Assessment of the apparatus against the performance requirements specified in IEC 61779-1, IEC 61779-4 and IEC 61779-5 may provide a basis for judgement in appropriate circumstances (see annex D).

4.2 Selection criteria

4.2.1 General criteria

4.2.1.1 The following criteria are among those which should be considered when selecting appropriate gas detection apparatus:

a) the gas(es) which the apparatus is required to detect, and the range of concentrations of each which may be encountered;

b) the intended application of the apparatus, for example area monitoring, personnel safety, leak detection or other purposes;

c) whether the apparatus is required to be fixed, transportable or portable;

d) the classification of the intended zone(s) of use in accordance with national regulations;

e) the environmental conditions that will be met in the area(s) of use;

f) any features of particular apparatus that require caution to be taken in the use or interpretation of its output;

g) time dependency and interaction with safety devices;

h) calibration requirements including zero checks.

4.2.1.2 A gas detection and measurement system should be so designed that the delay time of the whole system is less than the maximum delay time allowable for the provided application. The following factors should be taken into account:

a) delay time of the sampling system;

b) response time of the sensor;

c) delay time of data transmission lines;

d) delay time of alarm devices and switching circuits;

e) time taken for executive action devices, for example shut-down valves, to operate;

f) potential release rate of flammable gas.

4.2.2 Gases that the apparatus is required to detect

The gas detection apparatus is required to be sensitive to each of the gases that it is required to detect and also to be suitable for the range of gas concentrations that will be encountered. Reference should be made to the manufacturer's information to determine the suitability of particular detectors.

WARNING — THERMAL CONDUCTIVITY, INFRARED, ELECTROCHEMICAL, AND SEMICONDUCTOR SENSORS MAY BE SENSITIVE TO CERTAIN NON-FLAMMABLE GASES, IN ADDITION TO THE RANGE OF FLAMMABLE GASES WHICH THEY ARE INTENDED TO DETECT. FOR EXAMPLE SEMICONDUCTOR SENSORS MAY BE SENSITIVE TO WATER VAPOUR OR TO COMBUSTION PRODUCTS IN ADDITION TO FLAMMABLE GASES. ADVICE SHOULD ALWAYS BE SOUGHT FROM THE MANUFACTURER

CONCERNING THE EFFECT OF INTERFERING GASES ON PARTICULAR SENSORS. THESE CAN ALSO BE SENSITIVE TO NON-FLAMMABLE GASES AND INSENSITIVE TO FLAMMABLE GASES.

It is not normally possible to determine the concentrations of individual flammable gases in a mixture of flammable gases using the type of apparatus covered by this standard. In general, sensors of the type described in 3.1 to 3.6 respond to most or all of the flammable components of a mixture, without distinguishing between them.

Where a range of gases is likely to be present in an area to be monitored, it is recommended that a detector be selected that has been calibrated to the gas in that range to which it is least sensitive. However, care should be taken to ensure that the sensors so calibrated will remain adequately sensitive to the other gases likely to be present. If this is not practicable, then an alternative approach is to select separate sensors, calibrated to the different gases likely to be present.

Those parts of the gas detection apparatus that are located in, or may be taken into, a hazardous area should be certified for the gases that may be encountered. The certification should cover use of the apparatus in the appropriate gas group, IIA, IIB or IIC, and temperature class, according to IEC 60079-0.

WARNING – GAS DETECTION APPARATUS OF THE TYPES COVERED BY THIS STANDARD ARE NOT NORMALLY DESIGNED OR CERTIFIED FOR USE IN OXYGEN ENRICHED OR DEFICIENT ATMOSPHERES AND THEIR USE IN SUCH ATMOSPHERES SHOULD BE AVOIDED. FOR EXAMPLE PARTICULAR CARE SHOULD BE TAKEN WHERE OXY-ACETYLENE WELDING OPERATIONS ARE BEING CARRIED OUT IN AN AREA PROTECTED BY GAS DETECTION APPARATUS; SHOULD AN UNLIT OXYGEN ENRICHED ACETYLENE JET BE ACCIDENTALLY DIRECTED AT ANY OF THE GAS SENSORS, AN UNCONTROLLED IGNITION COULD OCCUR; OXYGEN ENRICHED ACETYLENE IS A PARTICULARLY DANGEROUS GAS MIXTURE.

4.2.3 Intended application of the apparatus

4.2.3.1 Fixed apparatus and fixed systems

Fixed apparatus should be selected where it is required to provide permanent gas monitoring in selected areas of a plant or other installation.

In general, fixed apparatus consists of sensors or sampling points that are located in the hazardous area, and associated equipment that may be located either in the hazardous area or in a non-hazardous area such as a control room. All parts of the apparatus or system are permanently installed.

There are three main types of fixed apparatus that are commonly used.

a) Apparatus having the sensor and control unit situated within the hazardous area. In this situation the sensor and control unit may be combined or supplied as separate items.

b) Apparatus having sensors separate from the control equipment. This type of apparatus usually consists of individual sensors in the hazardous area, connected to the associated control equipment in a safe area.

NOTE – This is the most suitable type for the majority of industrial applications, particularly if a rapid response is required.

c) Sampling apparatus. This type of apparatus usually consists of one or more sampling points in the hazardous area, connected to a sensor by means of aspirated sample lines. It may be more suitable than type a) where comparatively static process conditions apply and where conditions (environmental or accessibility) at the same point are unfavourable to the sensor.

NOTE – Apparatus and systems of the kind described in c) above should not be confused with those for process control, which do not come within the scope of this standard.

Gas detection apparatus may be designed to produce any or all of the following:

1) indication of gas concentration;
2) audible and/or visual alarms;
3) outputs to initiate actions such as process shutdown and automatic safeguard actions, for example process control, ventilation, elimination of ignition sources, etc.

Where item 3) is required, additional hardware may be necessary.

Each installation should be considered in its own right, in consultation with the manufacturer and safety authorities and in compliance with any mandatory local safety regulations.

4.2.3.2 Transportable apparatus

Transportable apparatus should normally be selected for such purposes as monitoring temporary work areas ("hot" work) and areas where flammable liquids, vapours or gases may be transferred.

4.2.3.3 Portable apparatus

Portable apparatus should normally be selected for such purposes as leak detection, verification of gas-free conditions, safety checks and similar applications.

Portable apparatus is normally used in diffusion mode, but where leak detection is involved or where the apparatus is used for the detection of gas in confined spaces beyond the normal reach of the user, either a static sample probe or a hand or mechanically aspirated sample probe will be necessary.

Where a portable apparatus is, from time to time, likely to be exposed to gas concentrations greater than the lower flammable limit (LFL), care should be taken to select apparatus suitable for that purpose.

4.2.3.4 Portability of the apparatus

Factors that are important in selecting portable or transportable apparatus include its size, weight and robustness, its power supply requirements, the type of indication required, and the visibility or audibility of any alarms.

4.3 Miscellaneous factors affecting selection of apparatus

4.3.1 Electromagnetic immunity

Some types of flammable gas detection apparatus are susceptible to external radiofrequency interference which causes malfunctions such as apparent errors in calibration, zero drift and false alarm signals. Where such problems are anticipated, suitable apparatus, immune to such interference, should be selected (see also 6.6.6).

4.3.2 Intended zone(s) of use

Gas detection apparatus is normally used in unclassified, zone 1 and zone 2 areas. However, certified intrinsically safe apparatus according to Ex ia can also be used for zone 0 areas. Gas detectors are typically designed and intended for combustible gas detection in air which contains approximately 21 % oxygen by volume. For a description of system safety and instrument response expected under deficient or enriched oxygen conditions, consult the instruction manual, or contact the manufacturer for a recommendation.

4.3.3 Other use

If it is necessary to detect mixtures in concentrations above the LFL, use an instrument or dilution accessory designed for this purpose.

5 Behaviour of gas releases

5.1 Nature of a release

5.1.1 General

The extent and/or rate of build-up of a flammable atmosphere is mainly affected by the following chemical and physical parameters of the release, some of which are intrinsic properties of the flammable material, others are specific to the process. For simplicity, the effect of each parameter listed below assumes that the other parameters remain unchanged.

5.1.2 Release rate of gas or vapour

The greater the release rate the larger the extent and/or rate of build-up of the flammable atmosphere.

The release rate itself depends on other parameters, namely:

a) geometry of the source of release

This is related to the physical characteristics of the source of release, for example an open surface, leaking flange, etc.;

b) release velocity

For a given source of release, the release rate increases with the release velocity. In the case of a product contained within process equipment, the release velocity is related to the process pressure and the geometry of the source of release.

A significant release rate combined with a high velocity will generate a momentum jet which will affect the behaviour of the released gas at least in the vicinity of the source.

Gas escaping with high velocity (for instance, a leak from a pressurized line or container) will behave initially as a momentum jet directed away from the source of release. As the distance from the source of release increases, the momentum of the jet will decay until eventually the dispersion of the gas will be controlled by the buoyancy effects and subsequently by gas diffusion patterns;

c) concentration

The concentration of flammable vapour or gas in the released mixture influences the release rate;

d) volatility of a flammable liquid

This is related principally to the vapour pressure, and the heat of vaporization. If the vapour pressure is not known, the boiling point and flashpoint can be used as a guide.

An explosive atmosphere cannot exist if the flashpoint is significantly above the relevant maximum temperature of the flammable liquid. The lower the flashpoint, the greater the extent and/or rate of build-up of a flammable atmosphere will be. Some liquids (for example certain halogenated hydrocarbons) do not possess a flashpoint although they are capable of producing an explosive gas atmosphere. In these cases, the equilibrium liquid temperature which corresponds to the saturated concentration at the lower flammable limit should be compared with the relevant maximum liquid temperature. Liquids have to be taken into account when their temperature is above TF-5K, where TF is the flashpoint and 5K the safety margin;

NOTE – Under certain conditions, the mist of a flammable liquid may be released at a temperature below its flashpoint and still produce an explosive atmosphere.

e) liquid temperature

The vapour pressure increases with temperature, thus increasing the release rate due to evaporation.

The temperature of a liquid after it has been released may be increased, for example by a hot surface or by a high ambient temperature.

5.1.3 Flammable limits

The lower the LFL volume ratio of flammable gases or vapour in air, the greater will be the extent and/or rate of build-up of a flammable atmosphere (see annex A). Given identical release rates, lower LFL gases reach their ignition concentration more quickly than high LFL gases.

LFL and UFL both vary with temperature and pressure but normal variations in these parameters do not appreciably affect the limits. A useful reference is IEC 60079-20.

5.1.4 Ventilation

With an increased efficiency of ventilation the extent and/or rate of build-up of a flammable atmosphere will be reduced. Obstacles which impede the ventilation may increase the extent and/or rate of build-up of a flammable atmosphere. On the other hand, some obstacles, for example a bund, walls or ceilings, may limit the extent and/or rate of build-up of a flammable atmosphere.

5.1.5 Relative density of the gas or vapour which is released

The behaviour of gas released with negligible initial velocity (for instance, vapour produced by a liquid spillage) will be governed by buoyancy and will depend on the relative density of the gas with respect to air.

If the gas or vapour is significantly lighter than air, it will tend to move upwards. If significantly heavier, it will tend to accumulate at ground level. The horizontal extent and/or rate of build-up of a flammable atmosphere at ground level will increase with increasing relative density and the vertical extent and/or rate of build-up of a flammable atmosphere above the source will increase with decreasing relative density.

NOTE 1 – For practical applications, a gas or vapour mixture which has a relative density below 0,8 is regarded as being lighter than air. If the relative density is above 1,2, it is regarded as being heavier than air. Between these values, both of these possibilities should be considered.

NOTE 2 – Mixtures of high and low density gases with air will show less variation of density and once mixed, they will not separate again; they can only become more diluted.

5.1.6 Source temperature and/or pressure

A temperature and/or pressure of the gas or vapour prior to the release, significantly different from the ambient pressure and temperature, may affect the absolute density of the release, and hence its behaviour at least in the vicinity of the source.

5.1.7 Other parameters to be considered

Other parameters such as climatic conditions and topography may also have to be taken into consideration.

If there is significant ambient air movement or the release is into enclosed spaces, then the above behaviour will be modified as described in the following subclauses.

5.2 Outdoor sites and open structures

In the case of outdoor sites and open structures, the dispersion of gas following a release may be affected both by the wind speed and by the wind direction. In open areas, the lateral spread of gas upwind of the release will be reduced, whilst downwind of the release it will be increased. This effect will be greater at high wind speeds. More complex air flow patterns will occur around buildings or other structures. In these cases, the wind direction may have a significant influence, and the possibility of gas accumulating in partially enclosed spaces, or in spaces with restricted air movement, should be considered. Where it is intended to install gas detectors in a major plant, the use of mathematical models of gas dispersion, or of scaled wind tunnel tests, may be appropriate at the design stage.

Local thermal effects may be significant in controlling air flow patterns and may, therefore, influence the dispersion of gas. For example large thermal gradients may be generated close to hot surfaces. In addition, the relative density of the gas will be affected by both the temperature of the gas itself and of the surrounding air.

5.3 Buildings and enclosures

5.3.1 General

Within buildings and enclosures the tendency for gases to form a hazardous accumulation following a release is generally greater than in outdoor locations. When a gas is released into an enclosed space, it mixes with the air in the enclosure to form a gas/air mixture. The manner in which this mixture forms will depend upon the gas release velocity, the location of the release, the gas density, ventilation, and any superimposed thermal flows. These factors should be taken into consideration in determining appropriate positions for sensors.

5.3.2 Unventilated buildings and enclosures

In theory, in the absence of any ventilation air flow and/or thermal effects, the release of a lighter than air gas will tend to form a layer of gas/air mixture extending from the level of the source of release to the ceiling. The release of a heavier than air gas will tend to produce a layer of gas/air mixture extending from the level of the source of release to the floor.

If the release takes the form of a momentum jet, this behaviour may be modified. For example if a jet of lighter than air gas is directed downwards from the source of release, then the layer of gas/air mixture may extend from the ceiling to a position below the level of the source of release. Similarly, if a jet of heavier than air gas is directed upwards from the source of release, then the layer may extend from the floor to a position above the level of the source of release.

NOTE – If a source of a gas release is present in buildings or enclosures, then there should be adequate ventilation provided.

5.3.3 Ventilated buildings and enclosures

The ventilation of buildings and enclosures is achieved by "natural means," "mechanical means", or a combination of the two.

NOTE – When a release concentration has decreased to approximately LFL (lower flammable limit), it will tend to move with the normal air flow due to the small difference in density between the gas mixture and the uncontaminated air.

5.3.4 Natural ventilation

Natural ventilation is the flow of air into and out of a building or enclosure through any purposely built or inadvertent openings in its structure. Ventilation air flows are caused by two effects; firstly, any pressure difference across the enclosure created by wind and, secondly, buoyancy due to any difference in temperature (and hence density) of the atmosphere contained within the enclosure and the outside air. For natural ventilation due to the latter effect where the temperature in the building or enclosure is below that of the outside air, a downward flow will tend to be produced.

The release of a gas or vapour into a naturally ventilated building or enclosure will tend to result in the formation of a gas/air mixture in a manner similar to that described in 6.3.2. However, in this case, the gas concentration in the mixture will be lower for a given release rate due to dilution by the ventilation air flow.

If a heavier than air gas or vapour is released into an enclosure in which natural ventilation produces an upward flow, then the gas/air mixture may extend above, as well as below, the level of the source of release. Conversely, if a lighter than air gas or vapour is released into an enclosure in which ventilation produces a downward flow, then the gas/air mixture may extend below, as well as above, the level of the source of release.

NOTE – Further information on natural ventilation is given in IEC 60079-10.

5.3.5 Mechanical ventilation

Mechanical ventilation is the term used to describe air flow through an enclosure induced by mechanical means, i.e. fans. Ventilation air flows set up by mechanical means can be high (for example greater than 12 volume changes per hour).

The gas concentration within an enclosure ventilated by mechanical means will, in general, be much less than that resulting from a similar release into a naturally ventilated enclosure.

In a well-designed ventilation system the whole volume within an enclosure is swept by the ventilation air flow. Where the geometry of the enclosure gives rise to regions of poor air movement or "dead spaces," a gas/air mixture may accumulate. Therefore, detectors should be sited in these spaces.

NOTE – Smoke tracers may assist in identifying the air movement within an enclosure and the presence of any dead spaces where gas/air mixture may accumulate.

If a sensor is installed in the intake or exhaust duct of a mechanical ventilation system (depending on where the release might occur), then the alarm set point should be set as low as reasonably practical.

Some sensors use sintered materials as flame arrestors and the ability of an air/gas mixture to diffuse through the sinter to the sensing element can be adversely affected by very high air velocities that may occur in ducting arrangements.

5.4 Environmental considerations

Environmental operational parameters should be included in the instruction manual.

Where environmental conditions are beyond specified values, the manufacturer should be contacted to ensure that the apparatus is suitable.

6 Installation of fixed gas detection apparatus

Many factors are involved in the selection of detector head quantity and location including industry/national standards which may dictate these requirements.

6.1 Basic considerations for the installation of fixed systems

If the instrument or any auxiliary components are installed in a hazardous (classified) location, they should be suitable for the area in which they are installed and so marked.

Two main types of fixed systems are commonly used.

a) *Systems consisting of remote sensors connected to the control equipment by electrical cables*

These systems are the most suitable for the majority of industrial applications. A system of this type should, in general, be installed so as to be capable of continuously monitoring every part of the plant or other premises where flammable gas(es) may accidentally accumulate. It should be capable of giving the earliest possible warning of an accidental release or accumulation of gas within practical limits of the system, for example as related to the number and location of sensors.

Remote sensors should be connected to their associated control equipment according to the national requirements for installation of electrical equipment. The sensors and any other parts of the system which are located in a hazardous area should incorporate an explosion protection technique covered by the IEC 60079 series of standards for the intended zone of use.

b) *Systems consisting of sampling apparatus*

These systems are used when comparatively static process conditions apply, and rapid response is less important. Where a system involving timed sequential sampling of a number of sample points is installed, the interval in time between two successive samples being taken at any one sample point should be sufficiently short that a potentially hazardous accumulation of flammable gas(es) cannot occur during the interval. The length of any sample tube and the sampling flow rate should also be such that a potentially hazardous accumulation of flammable gas(es) cannot occur during the time taken for a sample to pass from the sampling point to the sensor. For this reason, sample tubes should be as short as is reasonably practicable.

6.2 Location of sensors

6.2.1 General

6.2.1.1 A fixed gas detection system should be so installed that it is capable of monitoring those parts of a plant or other premises where flammable gas(es) accidentally accumulate and may create significant hazard. The system should be capable of giving an early audible or visual (or both) warning of both the presence and the general location of an accidental accumulation of flammable gas(es), in order to initiate one or more of the following actions, either automatically or under manual control:

a) safe evacuation of premises;
b) appropriate fire-fighting procedures;
c) shutdown of process or plant; and
d) ventilation control.

6.2.1.2 Considerations for the locations of sensors

WARNING – SENSORS SHOULD BE LOCATED IN POSITIONS DETERMINED IN CONSULTATION WITH THOSE WHO HAVE A SPECIALIST KNOWLEDGE OF GAS DISPERSION, AND THOSE WHO HAVE A KNOWLEDGE OF THE PROCESS PLANT SYSTEM AND EQUIPMENT INVOLVED, TOGETHER WITH THE SAFETY AND ENGINEERING PERSONNEL.

The rationale for the selection of location of sensors should be formally recorded.

NOTE – Reference may be made to IEC 60079-10 for further information on area classification and gas dispersion.

Factors which should be taken into account in determining suitable sensor locations include, but are not limited to, the following:

a) indoor or outdoor site;

b) potential sources – the location and nature of the potential vapour/gas sources (for example density, pressure, amount, source temperature, and distance) need to be assessed;

c) chemical and physical data of the potential gases/vapours present;

d) liquids with low volatility need sensors near the potential source of release;

e) nature and concentrations of gas releases likely (for example high pressure jet, slow leaks, spillage of liquids);

f) presence of cavities and jets;

g) topography of the site;

h) air movements;

    1) indoors: natural ventilation, mechanical ventilation,

    2) outdoors: wind speed and direction;

i) temperature effects;

j) environmental conditions of the plant;

k) population of plant and locations;

l) location of potential sources of ignition;

m) detectors should be installed so that they are not vulnerable to mechanical or water damage from normal operations;

n) locations should be such that sensors can be readily maintained and calibrated;

o) structural arrangements (such as walls, troughs or partitions) which could allow vapour/gas to accumulate; and

p) prescribed locations.

6.2.2 Other factors

In general, sensors should be sited above the level of ventilation openings and close to the ceiling for the detection of gases lighter than air, and below the ventilation openings and close to the floor for the detection of gases heavier than air.

Where it is required to detect the possible ingress of gas or vapour into a building or enclosure from an external source, sensors should be sited adjacent to the ventilation openings. These sensors should be in addition to any required for the detection of releases within the building or enclosure.

If ceilings or floors are compartmentalized by equipment or other obstructions, sensors should be installed in each compartment.

Any thermally induced flow (for example from hot surfaces on plant or equipment) may affect the distribution of a gas/air mixture.

6.3 Installation of sensors

Sensors should be located in all areas where hazardous accumulations of gas may occur. Such areas may not necessarily be close to potential sources of release but might, for instance, be areas with restricted air movement. Heavier than air gases are particularly likely to accumulate in pits and trenches if these are present. Similarly, lighter than air gases may accumulate in overhead cavities.

Sensors should also be located close to any potential sources of major release of gas, although to avoid nuisance alarms, sensors should generally not be located immediately adjacent to equipment which may produce inconsequential leakage in normal operation. In general, on open sites minor leaks may be dispersed without causing a hazardous accumulation.

Where it is necessary only to detect the escape of gas from within a given area, then sensors may be placed at intervals around the perimeter of the site. However, such an arrangement may not provide an early warning of a release. This arrangement should not be used alone if a release could cause a significant hazard to personnel or property within the perimeter itself.

Sensors shall be connected to their respective control unit, as specified by the manufacturer (observing maximum loop resistance, minimum wire size, isolation, etc.), and use a cable, wire and conduit system, or other system suitable and approved for the purpose and area classification.

Lubricate all threaded connections, but ascertain that the lubricant contains no substance (for example silicone) that might be deleterious to the sensors.

In many cases, the orientation of the sensor may be specified by the manufacturer.

Adequate drainage should be incorporated into the system design to minimize moisture and condensation in the instrument, detector head and interconnecting cable/conduit system.

Any potential flammable gases introduced into sampling systems should be vented in a safe manner.

6.4 Timing of installation during construction operations

Sensors should be installed as late as possible in any programme of construction operations (i.e. the construction of a new plant, refitting or maintenance) but before the presence of gas or vapours in the system, so as to avoid damage to the sensors resulting in particular from such activities as welding and painting.

If already installed, sensors should be protected with an air-tight seal to avoid contamination during construction work, and should be clearly marked as being non-operational.

6.5 Safety in fixed systems

6.5.1 General

If the gas detector system or channels of a system fail or are removed from service, so that areas of the plant cannot be monitored sufficiently, additional measures may be required to preserve safety.

Additional measures may include

a) signalling of gas detection apparatus faults;
b) use of portable or transportable gas detection apparatus;
c) additional ventilation;
d) elimination of ignition sources;
e) interruption of supply of flammable gases or liquids, rinsing and draining of installation parts;
f) switching-off of plants or parts of them.

6.5.2 Redundancy in fixed systems

In general, a fixed system should be so installed that failure of individual elements of the system, or their temporary removal for maintenance, does not compromise the safety of the premises being protected. Duplication or triplication of remote sensors and control apparatus is recommended in all areas where continuous monitoring is required.

6.5.3 Protection against loss of main power supply

Protection against loss of the main power supply should include

a) *main power supply*

The main power supply should be designed so that the unrestricted operation of gas detection apparatus and alarm functions are guaranteed.

Breakdown or fault of main energy supply should be detectable. Safety of the monitored area shall be preserved by appropriate measures.

The main power supply shall have a separate circuit with specially marked fuse used only for the gas detection apparatus;

b) *emergency power supply*

If the emergency power supply is required to maintain the function of the gas detection apparatus, it should do so until the normal state of supply is restarted or the monitored area no longer requires monitoring. Any peripheral external power supply shall be suitable for the area for which it is to be used (for environmental consideration and for the area classification).

Breakdown of emergency power supply should be indicated by an alarm signal.

6.6 Environmental conditions

Fixed apparatus, or more particularly their sensors, may be exposed to a very wide range of environments for very long periods of time. Great care should be exercised in the selection of this apparatus in relation to the likely environmental conditions of use.

6.6.1 Adverse weather conditions

Sensors located in buildings or enclosures are generally not exposed to adverse weather conditions. However, sensors located on outdoor sites and open structures may be subjected to severe environmental conditions, and account should be taken of these conditions at all times, for example high winds may cause drift of the zero reading and even apparent transient loss of sensitivity during calibration due to dilution of the calibration gas being detected. Therefore, great care should be taken in the location of sensors in exposed sites, and adequate weather protection measures should be provided for the sensor. Steam, driving rain, snow, ice and dust, etc. may also adversely affect sensors. Certain materials, although otherwise suitable for sample lines or weatherguards, may deteriorate from sunlight or other environmental conditions.

6.6.2 Excessive ambient temperatures

Where there are excessive ambient temperatures, detection errors and reduced sensor life may occur. In addition, at high temperatures the detector may operate outside the temperature range specified by the manufacturer and may no longer comply with its certification.

Gas detectors operating at temperatures below –10 °C may be beyond the specified temperature range and accuracy may therefore decrease. Portable applications may get around this limitation by keeping the detector in a warm area when not in use.

In general, the positioning of gas detectors directly above sources of heat such as ovens and boilers should be avoided and a suitable position at an equivalent height away from the source of heat should be chosen.

All detector heads and instruments should be mounted in areas which ensure compliance with the manufacturer’s operating temperature specifications.

6.6.3 Vibration

Where vibration is beyond specified values, particularly for equipment mounted on machinery, care should be taken to ensure that it has been designed to withstand vibration or that suitable vibration isolation mountings are provided.

6.6.4 Use of sensors in corrosive atmospheres

Precautions should be taken to protect sensors from damage resulting from exposure to corrosive atmospheres (for example ammonia, acid mist, H_2S etc.).

6.6.5 Mechanical protection

Sensors mounted in positions where they may be exposed to mechanical damage should be adequately protected in accordance with recommendations provided by the manufacturer.

6.6.6 Electromagnetic immunity

Where necessary, adequate precautions, for example by screening, should be made to guard against the effects of external radiofrequency interference.

NOTE – Reference should be made to applicable national regulations regarding electromagnetic compatibility.

6.6.7 Hosing down

The practice of "hosing down" a plant may cause severe degradation of gas sensors and should, therefore, be avoided if possible. If it cannot be avoided, the sensors should be protected.

6.6.8 Airborne contaminants

Sensors should not be exposed to airborne contaminants which may adversely affect their operation. For example materials containing silicones should not be used where catalytic sensors are installed.

6.7 Sample lines

Care should be taken to avoid condensation in the sample line(s). The material of the sample line(s) should be selected so as to avoid adsorption of the gas being detected. Sample lines should be as short as possible. In addition, care should be taken to avoid dilution of the sample by leakage or diffusion of diluent air, or gas, into or out of the sampling line.

6.8 Access for calibration and maintenance

Sensors should be readily accessible to permit regular calibration, maintenance and electrical safety inspection. If it is impossible to achieve regular direct access to the sensor then, as a minimum requirement, some form of remote gas calibration facility should be provided.

However, in principle, gas detection apparatus should be used and installed in such a way that only authorized personnel can influence the operation of the apparatus.

6.9 Commissioning

6.9.1 Inspection

The complete installation should be inspected to ensure that the work has been carried out in a satisfactory manner, and that, where appropriate, the methods, materials and components used are in accordance with IEC 60079-0. The operating instructions, plans and records should also have been supplied. Among the items to be inspected are the following:

a) confirm electrical connections are properly tightened;

b) check for sample-line leaks and proper flow;

c) check for clogged or dirty flame-arresting systems;

d) check the battery voltage and/or battery condition and make any required adjustments or battery replacements (according to the instruction manual);

e) perform a test of the failure (malfunction) circuit(s).

6.9.2 Initial gas calibration

After installation on site each sensor should be calibrated according to the manufacturer's instructions. Calibration should only be carried out by a suitably competent person.

Where a number of gases are likely to be present, reference should be made to the additional precautions described in 4.2.2.

6.9.3 Adjustment of alarm set points

In the case of detection apparatus indicating up to the lower flammable limit only, the alarm set point (or the lowest, where there are two or more set points) should be as low as possible commensurate with the need to avoid nuisance alarm signals.

Adjustments should be carried out in accordance with the manufacturer's instructions.

6.10 Operating instructions, plans and records

Instructions on the use, testing and operation of fixed gas detection systems should be made available.

For maintenance and record purposes, plans of the installation should be provided that show the locations of all parts of the system (control units, sensors, junction boxes, etc.) together with the routes and sizes of all cables and wires. Junction box and distribution cable diagrams should also be included.

The records should be updated when any changes are made to the installation.

It is extremely important that the equipment manufacturer's installation manual be read thoroughly, and the instructions followed completely.

7 Use of portable and transportable flammable gas detection apparatus

7.1 General

The various types of portable and transportable gas detection apparatus may be used in a variety of ways according to their particular design and specification.

Small, hand-held apparatus may be used for leak-detection or spot checks, while larger portables, some with visual and/or audible alarms, may be used in multi-role mode so as to include leak detection, spot checking and local area monitoring functions, according to the particular needs of the user.

Transportable apparatus is intended for use for temporary area monitoring in locations where there is a probability of generating potentially flammable gas or vapour mixtures, for example during the loading or unloading of fuel or chemical tankers or where temporary "hot work" (in connection with maintenance activities) may be in progress in classified hazardous areas under the authority of a gas-free certificate. Transportable apparatus is not intended to be hand carried for long periods of time, but is intended to be in place for hours, days or weeks.

Due to their very nature, portable and transportable apparatus may encounter a wide range of climatic, handling or more generally environmental conditions. Thus, the user should pay particular attention to the actual conditions imposed on an apparatus and assess that it is designed or protected so as to meet these conditions.

7.2 Initial and periodic check procedures for portable and transportable instrumentation

Due to the fact that portable and transportable instruments are generally not used continuously, initial and periodic check procedures are of the utmost importance to ensure that this apparatus is in a proper state of operation. The manufacturer's instructions for these checks should be precisely followed and attention is drawn to the following points which need special attention.

- The zero reading, when the apparatus is operated in clean air, should be verified and, if necessary, adjusted according to the manufacturer’s instructions or using a zeroing procedure specified by the manufacturer.
- Similarly, the response of the apparatus to a known calibration gas mixture using the gas that the apparatus is intended to detect, should be verified and adjusted, if necessary, according to the manufacturer’s instructions.

NOTE – For catalytic sensors the mixture shall contain at least 10 % by volume of oxygen.

7.3 Guidance on the use of portable and transportable apparatus

7.3.1 In areas being surveyed with portable apparatus where gases or vapours may be stratified rather than uniformly mixed, spot checks may be made at different levels (using an extension probe, if necessary).

7.3.2 When sampling vapour above a liquid, care should be taken to avoid the sample line or sensor from coming into contact with the liquid, since this may block the gas entry to the apparatus and could damage the sampling system. Use a hydrophobic filter or equivalent where there is danger of drawing liquid into the detector.

NOTE – Only sample lines recommended by the manufacturer should be used.

7.3.3 When taking a portable apparatus from a cool environment to a warm environment, it is important that time is taken to allow the apparatus temperature to rise sufficiently to avoid vapour condensation which may cause incorrect readings.

7.3.4 When using portable gas detection apparatus, it is necessary to be aware that most flammable gases and vapours (for example ammonia, hydrogen sulfide) are also toxic at low percentages of LFL and may as a minimum cause corrosion and, at worst, cause death.

7.3.5 If the portable instrument is of the multi-gas type containing sensors for the detection of toxic gases at low concentrations then calibration with some toxic gases, typically hydrogen sulphide and chlorine, may cause inhibition of some flammable gas-sensing elements, particularly catalytic devices.

7.3.6 Any portable or transportable gas detection apparatus that is used infrequently should, nevertheless, be regularly inspected, maintained and calibrated, so that it may be available for immediate use when required.

7.3.7 If a portable or transportable gas detection apparatus is dropped or otherwise damaged, it should immediately be taken out of service for inspection, for any necessary repairs and for re-calibration, before re-use.

7.3.8 Portable and transportable apparatus should have a type of protection appropriate for the zone of use. During use, portable and transportable apparatus should not be transferred from a zone of lower risk to a zone of higher risk unless it is suitably protected for the higher risk. Additionally, the apparatus group and the temperature class should be appropriate for all gases and vapours in which the apparatus may be used.

8 Special precautions for fixed and portable apparatus

8.1 Flammable gas detection apparatus is not normally designed to detect the presence of flammable materials that are not in a volatile state under the conditions that measurements are made.

8.2 Flammable gas detection apparatus will not indicate the presence of flammable liquids with high flashpoint well above the ambient temperature, dust or fibres.

8.3 Many types of flammable gas detection apparatus are sensitive to a range of gases. The presence of gases other than that for which the apparatus is calibrated may influence its indications.

Where an apparatus is to be used to detect the presence of more than one gas, it should be calibrated accordingly. The calibration may be with several gases or with the gas to which the apparatus is least sensitive. However, gas detection apparatus of this kind should not be regarded as being suitable for gas analysis. Where unknown substances are likely to be encountered, low alarm or action set points should be chosen to allow for variations in sensitivity.

8.4 Erratic indications may indicate apparatus malfunction or some atmospheric disturbance. Where doubt exists, a check should be made with a second apparatus and/or the apparatus should be checked under controlled conditions before its continued use.

8.5 The presence of low concentrations (for example a small percentage of LFL) of flammable gas can produce indications that may be mistaken for zero drifts. In case of doubt, the apparatus should have clean air supplied and then be rechecked.

Where off-scale indications occur (in either direction), this may indicate the presence of a potentially explosive atmosphere. It may then be necessary to flush the sensor with clean air and to cross-check for the presence of gas by taking the reading again or by using another type of gas detection apparatus. In such cases, the presence of a potentially explosive atmosphere should be assumed until proven otherwise.

8.6 Condensed moisture (for example from steam) may physically block the flame arrestors or other membranes of certain types of gas sensors, so as to make them inoperative, and care should be exercised accordingly.

8.7 Care should be taken to ensure that the materials from which the apparatus has been constructed are compatible with the gas or vapour to be detected. For example copper should not be contained in any apparatus likely to be used for the detection of acetylene or its derivatives because of the possibility of the formation of potentially percussive acetylides.

8.8 A non-conducting sample probe should be used if there is a danger of electrical shock. A probe with a special tip and/or a liquid trap inserted in the sample line may be available to reduce the chance of liquids being ingested by instruments requiring a drawn sample.

9 Maintenance, routine procedures and general administrative control

9.1 General

Routine maintenance of the flammable gas detection system is an extremely important factor affecting the reliability of the units. Only through a conscious programme which yields complete, dedicated maintenance on a high priority level, will optimum system performance and reliable operation be achieved.

Flammable gas detection apparatus or systems vary in application from portable units taken to sites where gas/air atmospheres are expected to be present, to fixed systems which may rarely sense a gas/air mixture in their working lifetime.

Inadequate maintenance, incorrect zero adjustment and, in portables, deteriorated batteries are all causes for errors in gas detection. It is important to remember that errors and failures in gas detection apparatus or systems may not be self-evident, and therefore gas detection should be only part of the overall strategy for plant and personnel protection.

The reliability of the measurement depends on the use of test gas. All types of apparatus should be checked at regular intervals with the test gas recommended by the manufacturer.

When it is necessary to detect the presence of several gases mixed with air, the sensitivities to these gases should be checked periodically with appropriate test gases.

To ensure that certification is not invalidated, any repair or maintenance that involves certified apparatus should not be carried out without full instructions and drawings from the certificate holder. Preferably the equipment should be returned for repair to the certificate holder.

NOTE 1 – In many countries, the legal liability for maintenance of certification on apparatus may rest with the owner/user.

NOTE 2 – The requirements included in IEC 60079-19 should be accepted.

9.2 Operational checks

The following inspections and tests should be made on a regular basis as specified below to maintain the reliable operation of the gas detection system.

NOTE – If the status of an instrument is not known, it should be checked prior to operation.

9.2.1 Fixed systems

a) Regular visual inspection

Regular inspection of the control panel should be made (for example one per shift). Records made of each check, including any problems, should be signed, dated and filed. Problems found should be corrected promptly.

b) Regular functional verification

Regularly, verification of the control and alarm panel should be made using test switches to ensure that lights, alarms and electronics are operating normally. This functional check will vary depending on the unit used. Problems found should be corrected promptly.

c) Regular calibration and system operation test

This test is of vital importance to the ongoing reliability of the system. It includes subjecting each head to the calibration gas, thus allowing a complete loop check of the electronics and the sensor by maintaining accurate records of information about system patterns, particularities, component life, etc. By doing so, potential problems can be averted before they develop.

NOTE 1 – This is the most important test to be made on the system and should be made on all sites at the time of installation and again at regular intervals. Guidance may be obtained from the manufacturer.

An in-depth calibration should be performed regularly by the plant instrument maintenance personnel, or their equivalent, on every sensor (detector head). For start-up of new installations the calibrations may initially need to be performed more frequently. Records should be maintained for each detector head.

The time intervals at which these procedures should be carried out will depend upon many factors including: the nature of the apparatus, i.e. whether portable, transportable or fixed; the detection technique employed; the prevailing environmental conditions at the installation; the previous history of performance; and reliability in the application concerned.

Regarding calibration, gas detection apparatus should be

1) calibrated in accordance with the manufacturer's instructions, using the recommended test kit/equipment;
2) calibrated on commissioning and tested/re-calibrated at defined intervals thereafter;
3) regularly inspected for possible malfunctions, damage or other deterioration;
4) if portable, response tested or re-calibrated immediately before each occasion of use;
5) if several gases are likely to be present, detectors should be calibrated to the gas for which they are least sensitive.

NOTE 2 – It is acceptable to use a calibration gas, different from that monitored, provided that an appropriate correction is made, so that the detectors when calibrated give the correct response to the monitored gas. However, if methane is to be detected, use methane in air calibration gas.

9.2.2 Portable and transportable gas detection apparatus

a) Visual inspection
   1) Check the instrument for abnormal conditions such as malfunctions, alarms, non-zero readings, etc.
   2) Ensure that the detector head assembly is free of obstructions or coatings which could interfere with the gas or vapour reaching the sensing element. Ensure that the sample drawn is correct for sample-draw systems.
   3) For sample-draw systems, inspect flow lines and fittings. Cracked, pitted, bent or otherwise damaged or deteriorated flow lines or fittings should be replaced with those recommended by the manufacturer.

b) Response (sensitivity) check
   1) Ensure that the instrument indicates zero when zero gas is present; temporarily isolate the sensing element if necessary. When the reading is stable, adjust the instrument if necessary (according to the manufacturer’s instructions).
   2) Following the manufacturer's instructions, apply a known calibration gas to the detector head. If the reading is not within specifications, adjust or re-calibrate according to the instruction manual (or return the instrument to the individual responsible for such adjustments/re-calibrations).
   3) Complete the maintenance records; refer to annex C for a typical maintenance record.

9.3 Maintenance

9.3.1 General

Maintenance operations should not compromise safety in the area being protected.

Maintenance procedures should be undertaken only by personnel trained in the operation, maintenance and repair of flammable gas detection instruments.

If the maintenance facility is not adequately equipped and/or qualified personnel are not available to perform the manufacturer's recommended checkout and maintenance procedures, the user should return the instrument to the manufacturer or other qualified outlet for repair.

Complete, explicit instructions for testing and checkout of replaceable instrument components may be obtained from the manufacturer. Suitable parts lists are provided in the instruction manual.

After any defective operations are corrected (repaired or replaced in strict accordance with the manufacturer's instructions), a full workshop calibration test, as described in 9.8, should be conducted.

9.3.2 Fixed apparatus

Repair or maintenance of fixed apparatus (whether incorporating single-point sensors, open-path sensors or a combination of these) should be carried out under a controlled procedure. Defective apparatus should be removed for repair in a workshop outside the area being protected. If a replacement apparatus cannot be provided immediately, then transportable apparatus should be used as a temporary substitute.

9.3.3 Portable and transportable gas detection apparatus

For portable and transportable gas detection apparatus, it is important that the whole unit should be removed to a non-hazardous location for repair and testing.

9.3.4 Off-site maintenance, general

Defective units should be

a) returned to the manufacturer;

b) returned to a repair agent authorized by the manufacturer; or

c) repaired in a special workshop set up by the user for gas detector maintenance.

9.3.5 Maintenance procedures

9.3.5.1 Given the variety of instruments available, it is not practical for this standard to tabulate each maintenance, repair and calibration step in detail. What follows is a listing of the principal items that all maintenance procedures should include.

9.3.5.2 If an instrument is in the shop for scheduled maintenance, the full maintenance procedure should be conducted. If specific instrument failure is the cause of return, the complaint should be noted and only applicable check-out tests need to be conducted. However, all instruments should undergo a full calibration test before being returned to service.

9.3.5.3 The instrument maintenance record for the instrument should be reviewed for previous service history. See annex C for typical instrument maintenance record for flammable gas detectors.

9.3.5.4 When receiving a failed instrument, it should be determined if the instrument's power supply (including any voltage regulation stages and/or battery chargers supplied) is the primary cause for failure before proceeding further.

9.3.5.5 After checking the power supply, repair personnel should proceed with the checkout of sensors, flow systems readout devices and alarm devices – identifying and correcting all deficiencies. The manufacturer's instructions should be followed when deciding whether to replace an assembly or repair it by replacing a component part. If components are replaced, the replacement components should meet the specifications and tolerances of the original components.

9.4 Sensors

9.4.1 Depending on the time interval since the last sensor replacement, anticipated field usage, and response to the gas mixture during calibration, good maintenance practice suggests sensor evaluation/replacement at service intervals recommended by the manufacturer. It is further recommended that sensors be evaluated after exposure to high concentrations of flammable gas or after severe impact or mechanical vibration has occurred.

9.4.2 If a flame arrestor is part of the sensor assembly, it should be checked for proper attachment and fit, and signs of corrosion, dirt or moisture. Any necessary cleaning or replacement should be in accordance with the manufacturer's instructions.

9.5 Flow systems

This subclause is applicable only to instruments utilizing aspirated sampling.

9.5.1 The flow system shall be checked for leakage, restrictions, and proper aspirator bulb or electrical pump operation. Any necessary cleaning, repair or replacement should be in accordance with the manufacturer's instructions.

9.5.2 All filters, traps and flame-arresting assemblies should be emptied, cleaned or replaced in accordance with the manufacturer's instructions.

9.5.3 The flow system and sample chamber should be examined for deposits of foreign material and steps taken to prevent future occurrences.

9.5.4 All flow connections should be tightened in accordance with the manufacturer's instructions.

9.5.5 All valves and moving pump parts should be lubricated *only* according to the manufacturer's instructions.

NOTE – Silicone compounds typically should not be used for this purpose; check with the manufacturer if there is any question regarding the acceptability of silicone compounds or other materials.

9.5.6 Automatic sample-draw systems should be adjusted to correct flowrate values using recommended test instruments.

9.5.7 The loss-of-flow trouble signals should be checked for proper operation.

9.6 Readout devices

9.6.1 If the instrument incorporates a meter, perform the following procedures:

a) inspect the meter for broken or cracked lens;

b) inspect analogue meters for defects – for example bent pointers, loose dials, loose up-scale and down-scale stops, etc.;

c) inspect digital meters for defects – for example missing segments, faded segments, etc.;

d) conduct other electrical and mechanical meter tests which the instrument manufacturer deems necessary to assure proper performance.

9.6.2 Other readouts (for example solid state) and outputs (for example alarm outputs) as may be incorporated should be tested (electrically) at specified test points according to the manufacturer's instructions.

9.7 Alarms

If alarms are incorporated, check for proper alarm operation by offsetting electrical zero (or by other methods as recommended by the manufacturer) until the alarm(s) is(are) initiated. Check failure (malfunction) circuits by disconnecting components (or other actions recommended by the manufacturer) and observing whether or not the failure alarm operates.

9.8 Workshop calibration test

9.8.1 The instrument shall be calibrated in accordance with this recommended practice using the manufacturer's calibration mixtures and specified calibration procedure. A known flammable gas-air mixture equivalent to 25 % to 75 % of full-scale concentration, preferably near mid-scale (hereafter known as "calibration mixture"), in sufficient quantity and accuracy for shop use, can be purchased commercially. All calibration mixtures and associated calibration apparatus should have the following characteristics to ensure reliable results.

a) Calibration mixtures should be certified or analysed to be accurate to at least ±5 % of the actual labelled concentration.

b) A regulator assembly of sufficient sensitivity and stability should be used to reduce compressed cylinder pressure. The regulator should be suitable for this service, and incorporate appropriate connections.

c) A direct-reading flowrate indicator, preset regulator, expandable bladder or other flow-controlling element should be installed in the calibration mixture supply line to permit adjustment of flow rate to the instrument manufacturer's specified value, range and accuracy.

d) The calibration system should be resistant to absorption of, and corrosion by, the calibration mixture.

e) Appropriate adapters to connect the calibration system with the flammable gas detection instrument should be used. The design of calibration fixtures for diffusion-type sensing systems requires adapters, designed to ensure that the calibration mixture uniformly surrounds the sensor.

9.8.2 For the calibration test, the type of gas or vapour recommended by the instrument manufacturer (and for which the instrument is factory calibrated) should be used. In some cases, an instrument calibrated for a flammable vapour cannot readily be provided with stable calibration mixtures in the form of compressed cylinders or low-pressure containers. In these cases, the manufacturer should provide relative response data to permit the use of more commonly available gas mixtures for calibration.

9.8.3 All tests should be conducted in a manner to ensure safe venting of calibration mixtures.

9.8.4 Instruments should be allowed to stabilize at operating temperature, and then operating controls should be adjusted in accordance with the instruction manual.

9.8.5 The calibration system should be connected to the instrument and the final span reading noted. The calibration should be adjusted, if necessary, so the output reading equals the concentration of the calibration mixture. The calibration mixture should be removed, and it should be ascertained that the instrument returns to "zero." This procedure may require repeating if the instrument zero and span adjustment interact.

9.8.6 Ascertain that any/all alarms are actuated when the set point(s) is reached. The manufacturer's recommendations should be followed when selecting the calibration mixture for instruments with alarms, as the concentration required is usually slightly higher than the nominal alarm setting (to guarantee prompt alarm actuation).

9.8.7 The calibration test herein described shall be the last conducted before an instrument is released from the workshop. It is recommended that the calibration data be recorded on the *instrument maintenance record*. The *instrument maintenance record* (or comparable document) should be updated before returning the instrument to service. See annex C for a typical *instrument maintenance record* for flammable gas detectors.

9.9 Routine tests and re-calibration procedures

All detection apparatus, whether portable, transportable or fixed (including both point and open path types) should be subjected to routine tests and re-calibration procedures. These should be carried out in accordance with the instruction manual and using the recommended field calibration kit.

For new installations it may be prudent to carry out such procedures more frequently at first (perhaps weekly), increasing the time intervals (to, perhaps, quarterly) as confidence grows with experience in the installation concerned.

9.10 General administrative control

Gas detection apparatus should be individually identifiable. Portable and transportable apparatus should be marked with an identification of the calibration date and, according to the control system employed, the length of time to the next re-calibration.

Records should be made and filed for all inspections, verifications, tests and work done on the detection system. An excellent means of keeping records for the system which also aids in keeping abreast of the required maintenance tasks, such as calibration, is the use of certain computer programmes.

Apparatus awaiting re-calibration or maintenance should be kept separately from apparatus awaiting return to service after such operations.

Spares may deteriorate in storage owing to mishandling or age and should always be tested before use. In particular, care should be exercised with optical surfaces.

10 Training

Training is needed for both those maintaining and using these devices. A distinction has been made between maintenance and operator training for the sake of clarity and the fact that those who use the system are not normally those who maintain it. It is important to establish these roles early in the development stage.

10.1 Operator training

Operator training should be designed to ensure operator understanding and familiarity with the system. Additionally, it should advise and show operators how to make visual and functional checks, and whom to contact if the unit(s) are believed to be malfunctioning. Of primary importance, operators should have instructions to follow in the event of a gas detector alarm. Periodic refresher training sessions should be given.

Instructions should be drafted prior to the installation of the detection system and should include such items as what to do in the event of an alarm, safety considerations for each unit and whom to contact if a head or system malfunction is discovered. The user should be clearly informed of the calibration gas(es) and of the response he may observe with other gases.

10.2 Maintenance training

Maintenance training should be designed for those charged with system maintenance and system calibration and should include details of how to perform calibration, how the detector functions, etc.

Training may be done in house by competent knowledgeable persons, or by vendor-assisted training sessions. Vendor literature should be obtained and made available to these persons.

Annex A
(informative)

Flammability limits (LFL and UFL) of certain flammable gases and vapours

Table A.1 provides guidance on the flammability limits (i.e. LFL and UFL) of certain flammable gases and vapours.

The data in the following tables are taken direct from IEC 60079-20.

Table A.1 – Flammability data

The following headings are used in table A.1:

Ref – Reference number for each gas or vapour

Rho, *ρ* – Density relative to air (normally at standard temperature and pressure, unless otherwise stated)

FP – Flash point

Ign temp – Ignition temperature

MESG – Maximum experimental safe gap

T class – Temperature class according to IEC 60079-0

Group – See 3.2

Table A.1 – Flammability data

Ref.	Gas or vapour	Formula	Rho	FP	Flammability limits				Ignition	MESG	T class	Group
			ρ	°C	Lower	Upper	Lower	Upper	temp.			
					vol per cent		mg/l		°C	mm		
1	Acetaldehyde	CH_3CHO	1,52	–38	4,00	60,0	74	1108	204	0,92	T3	IIA
2	Acetic acid	CH_3COOH	2,07	40	4,00	17,0	100	428	464	1,76	T1	IIA
3	Acetic anhydride	$(CH_3CO)_2O$	3,52	49	2,00	10,0	85	428	334	1,23	T2	IIA
4	Acetone	$(CH_3)_2CO$	2,00	<–20	2,50	13,0	60	316	535	1,01	T1	IIA
5	Acetonitrile	CH_3CN	1,42	2	3,00	16,0	51	275	523	1,50	T1	IIA
6	Acetyl chloride	CH_3COCl	2,70	–4	5,00	19,0	157	620	390		T2	(IIA)
7	Acetylene (see 4.3)	$CH{\equiv}CH$	0,90		2,30	100,0	24	1092	305	0,37	T2	IIC
8	Acetyl flouride	CH_3COF	2,14	<–17	5,60	19,9	142	505	434	1,54	T2	IIA
9	Acrylaldehyde	$CH_2{=}CHCHO$	1,93	–18	2,85	31,8	65	728	217	0,72	T3	IIB
10	Acrylic acid	$CH_2{=}CHCOOH$	2,48	56	2,90		85		406	0,86	T2	IIB
11	Acrylonitrile	$CH_2{=}CHCN$	1,83	–5	2,80	28,0	64	620	480	0,87	T1	IIB
12	Acryloyl chloride	$CH_2CHCOCl$	3,12	–8	2,68	18,0	220	662	463	1,06	T1	IIA
13	Allyl acetate	$CH_2{=}CHCH_2OOCCH_3$	3,45	13	1,70	9,3	69	3800	348	0,96	T2	IIA
14	Allyl alcohol	$CH_2{=}CHCH_2OH$	2,00	21	2,50	18,0	61	438	378	0,84	T2	IIB
15	Allyl chloride	$CH_2{=}CHCH_2Cl$	2,64	–32	2,90	11,2	92	357	390	1,17	T2	IIA
16	Allyl 2, 3-epoxypropyl ether	$CH_2{=}CH\text{-}CH_2\text{-}O\text{-}\underline{CHCH_2CH_2O}$	3,94	45					249	0,70	T3	IIB
17	2-Aminoethanol	$NH_2CH_2CH_2OH$	2,10	85					410		T2	IIA
18	Ammonia	NH_3	0,59		15,0	33,6	107	240	630	3,18	T1	IIA
19	Amphetamine (INN)	$C_6H_5CH_2CH(NH_2)CH_3$	4,67	<100								IIA

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho ρ	FP °C	Flammability limits Lower	Flammability limits Upper	Flammability limits Lower	Flammability limits Upper	Ignition temp. °C	MESG mm	T class	Group
					vol per cent		mg/l					
20	Aniline	$C_6H_5NH_2$	3,22	75	1,20	11,0	47	425	630		T1	IIA
21	Azepane	$CH_2(CH_2)_5NH$	3,41	23					279	1,00	T3	IIA
22	Benzaldehyde	C_6H_5CHO	3,66	64	1,40		62		192		T4	IIA
23	Benzene	C_6H_6	2,70	–11	1,20	8,6	39	280	560	0,99	T1	IIA
24	1-Bromobutane	$CH_3(CH_2)_2CH_2Br$	4,72	13	2,50	6,6	143	380	265		T3	IIA
25	2-Bromo-1,1-diethoxyethane	$(CH_3CH_2O)_2CHCH_2Br$	7,34	57					175	1,00	T4	IIA
26	Bromoethane	CH_3CH_2Br	3,75	<–20	6,70	11,3	306	517	511		T1	IIA
27	Buta-1,3-diene	$CH_2{=}CHCH{=}CH_2$	1,87	–85 gas	1,40	16,3	31	365	430	0,79	T2	IIB
28	Butane	C_4H_{10}	2,05	–60 gas	1,40	9,3	33	225	372	0,98	T2	IIA
29	isoButane	$(CH_3)_2CHCH_3$	2,00	gas	1,3	9,8	31	236	460	0,95	T1	IIA
30	Butan-1-ol	$CH_3(CH_2)_2CH_2OH$	2,55	29	1,70	12,0	52	372	359	0,94	T2	IIA
31	Butanone	$CH_3CH_2COCH_3$	2,48	–9	1,80	10,0	50	302	404	0,84	T2	IIB
32	But-l-ene	$CH_2{=}CHCH_2CH_3$	1,95	–80 gas	1,60	10,0	38	235	440	0,94	T2	IIA
33	But-2-enes (isomer not stated)	$CH_3CH{=}CHCH_3$	1,94	gas	1,60	10,0	40	228	325	0,89	T2	IIB
34	But-3-en-3-olide	$CH_2{=}CCHO(O)O$	2,90	33					262	0,84	T3	IIB
35	2-(2-Butoxyethoxy)ethanol	$CH_3(CH_2)_3OCH_2CH_2OCH_2CH_2OH$	5,59	78					225	1,11	T3	IIA
36	Butyl acetate	$CH_3COOCH_2(CH_2)_2CH_3$	4,01	22	1,3	7,5	64	390	370	1,04	T2	IIA
37	n-Butyl acrylate	$CH_2{=}CHCOOC_4H_9$	4,41	38	1,2	8,0	63	425	268	0,88	T3	IIB

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho ρ	FP °C	Flammability limits				Ignition temp. °C	MESG mm	T class	Group
					Lower	Upper	Lower	Upper				
					vol per cent		mg/l					
38	Butylamine	$CH_3(CH_2)_3NH_2$	2,52	–12	1,7	9,8	49	286	312	0,92	T2	IIA
39	isoButylamine	$(CH_3)_2CHCH_2NH_2$	2,52	–20	1,47	10,8	44	330	374	1,15	T2	IIA
40	Butyl 2, 3-epoxypropyl ether	$CH_3(CH_2)_3OCH_2CHCH_2O$	4,48	44					262	0,78	T3	IIB
41	Butyl glycolate	$HOCH_2COOC_4H_9$	4,45	61						0,88		IIB
42	isoButylisobutyrate	$(CH_3)_2CHCOOCH_2CH(CH_3)_2$	4,93	34	0,80		47		424	1,00	T2	IIA
43	Butylmethacrylate	$CH_2{=}C(CH_3)COO(CH_2)_3CH_3$	4,90	53	1,00	6,8	58	395	289	0,95	T3	IIA
44	tert-Butyl methyl ether	$CH_3OC(CH_3)_3$	3,03	–27	1,50	8,4	54	310	385	1,00	T2	IIA
45	n-Butylpropionate	$C_2H_5COOC_4H_9$	4,48	40	1,10	7,7	58	409	389	0,93	T2	IIA
46	But-l-yne	$CH_3CH_2C{\equiv}CH$								0,71		IIB
47	Butyraldehyde	$CH_3CH_2CH_2CHO$	2,48	–16	1,80	12,5	54	378	191	0,92	T4	IIA
48	isoButyraldehyde	$(CH_3)_2CHCHO$	2,48	–22	1,6	11,0	47	320	176	0,92	T4	IIA
9	Isobutyric acid	$(CH_3)_2CHCOOH$	3,03	58					460	1,02	T2	IIA
50	Butyryl fluoride	C_3H_7COF	3,10	<–14	2,60		95		440	1,14	T1	IIA
51	Carbon disulphide (see 4.4)	CS_2	2,64	–30	0,60	60,0	19	1900	95	0,20 0,34	T6	IIC
52	Carbon monoxide (saturated at 18° C) (see 4.5)	CO	0,97		10,90	74,0	126	870	605	0,84	T1	IIB
53	Carbonyl sulphide	COS	2,07		6,5	28,5	160	700	209	1,35	T3	IIA
54	Chlorobenzene	C_6H_5Cl	3,88	28	1,40	11,0	66	520	637		T1	IIA
55	1-Chlorobutane	$CH_3(CH_2)_2CH_2Cl$	3,20	–12	1,80	10,0	69	386	250	1,06	T3	IIA

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho	FP	Flammability limits				Ignition	MESG	T class	Group
			ρ	°C	Lower	Upper	Lower	Upper	temp.			
					vol per cent		mg/l		°C	mm		
56	2-Chlorobutane	$CH_3CHClC_2H_5$	3,19	<–18	2,20	8,8	82	339	388	1,16	T2	IIA
57	1-Chloro-2, 3-epoxypropane	OCH_2CHCH_2Cl	3,30	28	2,30	34,4	86	1325	385	0,74	T2	IIB
58	Chloroethane	CH_3CH_2Cl	2,22		3,60	15,4	95	413	510		T1	IIA
59	2-Chloroethanol	CH_2ClCH_2OH	2,78	55	5,00	16,0	160	540	425		T2	IIA
60	Chloroethylene	$CH_2{=}CHCl$	2,15	–78 gas	3,60	33,0	94	610	415	0,96	T2	IIA
61	Chloromethane	CH_3Cl	1,78	–24 gas	7,60	19,0	160	410	625	1,00	T1	IIA
62	Chlormethyl methyl ether	CH_3OCH_2Cl	2,78	–8								IIA
63	1-Chloro-2-methylpropane	$(CH_3)_2CHCH_2Cl$	3,19	<–14	2,00	8,8	75	340	416	1,25	T2	IIA
64	2-Chloro-2-methylpropane	$(CH_3)_3CCl$	3,19	<–18					541	1,40	T1	IIA
65	3-Chloro-2-methylprop-l-ene	$CH_2{=}C(CH_3)CH_2Cl$	3,12	–16	2,10		77		476	1,16	T1	IIA
66	5-Chloropentan-2-one	$CH_3CO(CH_2)_3Cl$	4,16	61	2,00		98		440	1,10	T2	IIA
67	1-Chloropropane	$CH_3CH_2CH_2Cl$	2,70	–32	2,40	11,1	78	365	520		T1	IIA
68	2-Chloropropane	$(CH_3)_2CHCl$	2,70	<–20	2,80	10,7	92	350	590	1,23	T1	IIA
69	Chlorotrifluoroethylene	$CF_2{=}CFCl$	4,01	gas	4,6	64,3	220	3117	607	1,50	T1	IIA
70	1-Chloro-2,2,2-trifluoroethyl methyl ether	$CF_3CHClOCH_3$	5,12	4	8,00		484		430	2,80	T2	IIA
71	α-Chlorotoluene	$C_6H_5CH_2Cl$	4,36	60	1,20		63		585		T1	IIA
72	Coal tar naphtha								272		T3	IIA
73	Coke oven gas (see 4.1)											

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho	FP	Flammability limits				Ignition	MESG	T class	Group
			ρ	°C	**Lower**	**Upper**	**Lower**	**Upper**	**temp.**			
					vol per cent		mg/l		°C	mm		
74	Cresols (Mixed isomers)	$CH_3C_6H_4OH$	3,73	81	1,10		50		555		T1	IIA
75	Crotonaldehyde	$CH_3CH{=}CHCHO$	2,41	13	2,10	16,0	62	470	280	0,81	T3	IIB
76	Cumene	$C_6H_5CH(CH_3)_2$	4,13	31	0,80	6,5	40	328	424	1,05	T2	IIA
77	Cyclobutane	$CH_2\ (CH_2)_2CH_2$	1,93		1,80		42					IIA
78	Cycloheptene	$CH_2(CH_2)_5CH_2$	3,39	<10	1,10	6,7	44	275				IIA
79	Cyclohexene	$CH_2(CH_2)_4CH_2$	2,90	–18	1,20	8,3	40	290	259	0,94	T3	IIA
80	Cyclohexanol	$CH_2(CH_2)_4CHOH$	3,45	61	1,20	11,1	50	460	300		T3	IIA
81	Cyclohexanone	$CH_2(CH_2)_4CO$	3,38	43	1,00	9,4	42	386	419	0,98	T2	IIA
82	Cyclohexene	$CH_2(CH_2)_3CH{=}CH$	2,83	–17	1,20		41		244		T3	IIA
83	Cyclohexylamine	$CH_2(CH_2)_4CHNH_2$	3,42	32	1,60	9,4	63	372	293		T3	IIA
84	1,3-Cyclopentadiene	$CH_2CHCHCHCH$	2,30	–50					465	0,99	T1	IIA
85	Cyclopentane	$CH_2(CH_2)_3CH_2$	2,40	–37	1,4		41		320	1,01	T2	IIA
86	Cyclopentene	$CH{=}CHCH_2CH_2CH$	2,30	<–22	1,48		41		309	0,96	T2	IIA
87	Cyclopropane	$CH_2CH_2CH_2$	1,45		2,40	10,4	42	183	498	0,91	T1	IIA
88	Cyclopropyl methyl ketone	$CH_3COCHCH_2CH_2$	2,90	15	1,70		58		452	0,97	T1	IIA
89	p-Cymene	$CH_3C_6H_4CH(CH_3)_2$	4,62	47	0,70	6,5	39	366	436		T2	IIA
90	2,2,3,3,4,4,5,5,6,6,7,7-Dodeca-fluoroheptyl methacrylate	$CH_2{=}C(CH_3)COOCH_2(CF_2)_6H$	9,93	49	1,60		185		390	1,46	T2	IIA
91	Decahydronaphthalene trans	$CH_2(CH_2)_3CHCH(CH_2)_3CH_2$	4,76	54	0,70	4,9	40	284	288		T3	IIA
92	Decane (Mixed isomers)	$C_{10}H_{22}$	4,90	46	0,70	5,6	41	433	201	1,05	T3	IIA

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho	FP	Flammability limits				Ignition temp.	MESG	T class	Group
			ρ	°C	Lower	Upper	Lower	Upper	°C	mm		
					vol per cent		mg/l					
93	Dibutyl ether	$(CH_3(CH_2)_3)_2O$	4,48	25	0,90	8,5	48	460	198	0,88	T4	IIB
94	Di-tert-butyl peroxide	$(CH_3)_3COOC(CH_3)_3$	5,0	18					170	0,84	T4	IIB
95	Dichlorobenzenes (isomer not stated)	$C_6H_4Cl_2$	5,07	66	2,20	9,2	134	564	648		T1	IIA
96	3,4-Dichlorobut-1-ene	$CH_2{=}CHCHClCH_2Cl$	4,31	31	1,30	7,2	66	368	469	1,38	T1	IIA
97	1,3-Dichlorobut-2-ene	$CH_3CCl{=}CHCH_2Cl$	4,31	27					469	1,31	T1	IIA
98	Dichlorodiethylsilane	$(C_2H_5)_2SiCl_2$		24	3,40		223			0,45		IIC
99	1,1-Dichloroethane	CH_3CHCl_2	3,42	–10	5,60	16,0	230	660	440		T2	IIA
100	1,2-Dichloroethane	CH_2ClCH_2Cl	3,42	13	6,20	16,0	255	654	438	1,82	T2	IIA
101	Dichloroethylene	$ClCH{=}CHCl$	3,55	–10	9,70	12,8	391	516	440	3,91	T2	IIA
102	1,2-Dichloropropane	$CH_3CHClCH_2Cl$	3,90	15	3,40	14,5	160	682	557		T1	IIA
103	Dicyclopentadiene (Technical)	$C_{10}H_{12}$	4,55	36	0,80		43		455	0,91	T1	IIA
104	1,2-Diethoxyethane	$C_2H_5O(CH_2)_2OC_2H_5$	4,07	16					170	0,81	T4	IIB
105	Diethylamine	$(C_2H_5)_2NH$	2,53	–23	1,70	10,0	50	306	312		T2	IIA
106	Diethyl carbonate	$(CH_3CH_2O)_2CO$	4,07	24	1,4	11,7	69	570	450	0,83	T2	IIB
107	Diethyl ether	$(CH_3CH_2)_2O$	2,55	–45	1,70	36,0	50	1118	160	0,87	T4	IIB
108	Diethyl oxalate	$(COOCH_2CH_3)_2$	5,04	76						0,90		IIA
109	Diethyl sulphate	$(CH_3CH_2)_2SO_4$	5,31	104					360	1,11	T2	IIA
110	1,1-Difluoroethylene	$CH_2{=}CF_2$	2,21		3,90	25,1	102	665	380	1,10	T2	IIA
111	Dihexyl ether	$(CH_3(CH_2)_5)_2O$	6,43	75					187		T4	IIA

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho	FP	Flammability limits				Ignition	MESG	T class	Group
			ρ	°C	Lower	Upper	Lower	Upper	temp.			
					vol per cent		mg/l		°C	mm		
112	Diisobutylamine	$((CH_3)_2CHCH_2)_2NH$	4,45	26	0,80	3,6	42	190	256	1,12	T3	IIA
113	Diisobutyl carbinol	$((CH_3)_2CHCH_2)_2CHOH$	4,97	75	0,70	6,1	42	370	290	0,93	T3	IIA
114	Diisopentyl ether	$(CH_3)_2CH(CH_2)_2O(CH_2)_2CH(CH_3)_2$	5,45	44	1,27		104		185	0,92	T4	IIA
115	Diisopropylamine	$((CH_3)_2CH)_2NH$	3,48	–20	1,20	6,3	49	260	285	1,02	T3	IIA
116	Diisopropyl ether	$((CH_3)_2CH)_2O$	3,52	–28	1,00	21,0	45	900	405	0,94	T2	IIA
117	Dimethylamine	$(CH_3)_2NH$	1,55	–18 gas	2,80	14,4	53	272	400	1,15	T2	IIA
118	1,2-Dimethoxyethane	$CH_3O(CH_2)_2OCH_3$	3,10	–6	1,6	10,4	60	390	197	0,72	T4	IIB
119	Dimethoxymethane	$CH_2(OCH_3)_2$	2,60	–21	3,00	16,9	93	535	247	0,86	T3	IIB
120	2-Dimethylaminoethanol	$(CH_3)_2NC_2H_4OH$	3,03	39					220		T3	IIA
121	3-(Dimethylamino) propiononitrile	$(CH_3)_2NHCH_2CH_2CN$	3,38	50	1,57		62		317	1,14	T2	IIA
122	Dimethyl ether	$(CH_3)_2O$	1,59	–42 gas	2,70	32,0	51	610	240	0,84	T3	IIB
123	N,N-Dimethylformamide	$HCON(CH_3)_2$	2,51	58	1,80	16,0	55	500	440	1,08	T2	IIA
124	3,4-Dimethyl hexane	$CH_3CH_2CH(CH_3)CH(CH_3)CH_2CH_3$	3,87	2	0,80	6,5	38	310	305		T2	IIA
125	N,N-Dimethylhydrazine	$(CH_3)_2NNH_2$	2,07	–18	2,4	20	60	490	240	0,85		IIB
126	1,4-Dimethylpiperazine	$NH(CH_3)CH_2CH_2NH(CH_3)CH_2CH_2$	3,93	9					199	1,00	T4	IIA
127	N,N-Dimethylpropane-1,3-diamine	$(CH_3)_2N(CH_2)_3NH_2$	3,52	26	1,20		50		219	0,95	T3	IIA
128	Dimethyl sulphate	$(CH_3O)_2SO_2$	4,34	39					449	1,00	T2	IIA
129	1,4-Dioxane	$OCH_2CH_2OCH_2CH_2$	3,03	11	1,90	22,5	74	813	379	0,70	T2	IIB

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho ρ	FP °C	Flammability limits Lower	Upper	Lower	Upper	Ignition temp. °C	MESG mm	T class	Group
					vol per cent		mg/l					
130	1,3-Dioxolane	$OCH_2CH_2OCH_2$	2,55	–5	2,3	30,5	70	935	245		T3	IIB
131	Dipentene, crude	$C_{10}H_{16}$	4,66	42	0,75	6,1	43	348	255	1,18	T3	IIA
132	Dipentyl ether	$(CH_3(CH_2)_4)_2O$	5,45	57					171		T4	
133	Dipropylamine	$(CH_3CH_2CH_2)_2NH$	3,48	4	1,60	9,1	66	376	280	0,95	T3	IIA
134	Dipropyl ether	$(C_3H_7)_2O$	3,53	<–5					215		T3	IIB
135	1,2-Epoxypropene	CH_3CHCH_2O	2,00	–37	1,90	37,0	49	901	430	0,70	T2	IIB
136	Ethane	CH_3CH_3	1,04		2,50	15,5	31	194	515	0,91	T1	IIA
137	Ethanethiol	CH_3CH_2SH	2,11	<–20	2,80	18,0	73	468	295	0,90	T3	IIB
138	Ethanol	CH_3CH_2OH	1,59	12	3,1	19,0	59	359	363	0,91	T2	IIA
139	2-Ethoxyethanol	$CH_3CH_2OCH_2CH_2OH$	3,10	40	1,80	15,7	68	593	235	0,84	T3	IIB
140	2-Ethoxyethyl acetate	$CH_3COOCH_2CH_2OCH_2CH_3$	4,72	47	1,20	12,7	65	642	380	0,97	T2	IIA
141	2- (2-Ethoxyethoxy) ethanol	$CH_3CH_2OCH_2CH_2OCH_2CH_2OH$	4,62	94					190	0,94	T4	IIA
142	Ethyl acetate	$CH_3COOCH_2CH_3$	3,04	–4	2,20	11,0	81	406	460	0,99	T1	IIA
143	Ethyl acetoacetate	$CH_3COCH_2COOCH_2CH_3$	4,50	65	1,00	9,5	54	519	350	0,96	T2	IIA
144	Ethyl acrylate	$CH_2{=}CHCOOCH_2CH_3$	3,45	9	1,40	14,0	59	588	350	0,86	T2	IIB
145	Ethylamine	$C_2H_5NH_2$	1,50	<–20	2,68	14,0	49	260	425	1,20	T2	IIA
146	Ethylbenzene	$CH_2CH_3C_6H_5$	3,66	23	1,00	7,8	44	340	431		T2	IIA
147	Ethyl butyrate	$CH_3CH_2CH_2COOC_2H_5$	4,00	21	1,40		66		435	0,92	T2	
148	Ethylcyclobutane	$CH_3CH_2CHCH_2CH_2CH_2$	2,90	<–16	1,20	7,7	42	272	212		T3	IIA

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho ρ	FP °C	Flammability limits Lower vol per cent	Flammability limits Upper vol per cent	Flammability limits Lower mg/l	Flammability limits Upper mg/l	Ignition temp. °C	MESG mm	T class	Group
149	Ethylcyclohexane	$CH_3CH_2CH(CH_2)_4CH_2$	3,87	<24	0,90	6,6	42	310	238		T3	IIA
150	Ethylcyclopentane	$CH_3CH_2CH(CH_2)_3CH_2$	3,40	<5	1,05	6,8	42	280	262		T3	IIA
151	Ethylene	$CH_2{=}CH_2$	0,97		2,3	36,0	26	423	425	0,65	T2	IIB
152	Ethylenediamine	$NH_2CH_2CH_2NH_2$	2,07	34	2,7	16,5	64	396	403	1,18	T2	IIA
153	Ethylene oxide	CH_2CH_2O	1,52	<–18	2,60	100,0	47	1848	435	0,59	T2	IIB
154	Ethyl formate	$HCOOCH_2CH_3$	2,55	–20	2,70	16,5	87	497	440	0,91	T2	IIA
155	2-Ethylhexyl acetate	$CH_3COOCH_2CH(C_2H_5)C_4H_9$	5,94	44	0,75	6,2	53	439	335	0,88	T2	IIB
156	Ethyl isobutyrate	$(CH_3)_2CHCOOC_2H_5$	4,00	10	1,60		75		438	0,96	T2	IIA
157	Ethyl methacrylate	$CH_2{=}CCH_3COOCH_2CH_3$	3,90	(20)	1,50		70			1,01		IIA
158	Ethyl methyl ether	$CH_3OCH_2CH_3$	2,10		2,00	10,1	50	255	190		T4	IIB
159	Ethyl nitrite (see 4.2)	CH_3CH_2ONO	2,60	–35	3,00	50,0	94	1555	95	0,96	T6	IIA
160	0-Ethyl phosphorodichloridothioate	$C_2H_5OPSCl_2$	7,27	75					234	1,20	T3	IIA
161	Ethylpropylacrolein (isomer not stated)	$C_8H_{14}O$	4,34	40					184	0,86	T4	IIB
162	Formaldehyde	$HCHO$	1,03		7,00	73,0	88	920	424	0,57	T2	IIB
163	Formic acid	$HCOOH$	1,60	42	10,0	57,0	190	1049	520	1,86	T1	IIA
164	2-Furaldehyde	$OCH{=}CHCH{=}CHCHO$	3,30	60	2,10	19,3	85	768	316	0,88	T2	IIB
165	Furan	$CH{=}CHCH{=}CHO$	2,30	<–20	2,30	14,3	66	408	390	0,68	T2	IIB
166	Furfuryl alcohol	$OC(CH_2OH)CHCHCH$	3,38	61	1,8	16,3	70	670	370	0,8	T2	IIB
167	1,2,3-Trimethylbenzene	$CHCHCHC(CH_3)C(CH_3)C(CH_3)$	4,15	51	0,80	7,0			470		T1	IIA

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho	FP	Flammability limits				Ignition	MESG	T class	Group
			ρ	°C	Lower	Upper	Lower	Upper	temp.			
					vol per cent		mg/l		°C	mm		
168	Heptane (mixed isomers)	C_7H_{16}	3,46	–4	1,10	6,7	46	281	215	0,91	T3	IIA
169	Heptan-1-ol	$CH_3(CH_2)_5CH_2OH$	4,03	60					275	0,94		IIA
170	Heptan-2-one	$CH_3CO(CH_2)_4CH_3$	3,94	39	1,10	7,9	52	378	533		T1	IIA
171	Hept-2-ene	$CH_3(CH_2)_3CH{=}CHCH_3$	3,40	<0					263	0,97	T3	IIA
172	Hexane (mixed isomers)	$CH_3(CH_2)_4CH_3$	2,97	–21	1,00	8,4	35	290	233	0,93	T3	IIA
173	1-Hexanol	$C_6H_{13}OH$	3,50	63	1,20		51		293	0,98	T3	IIA
174	Hexan-2-one	$CH_3CO(CH_2)_3CH_3$	3,46	23	1,20	8,0	50	336	533		T1	IIA
175	Hydrogen	H_2	0,07		4,00	77,0	3,4	63	560	0,28	T1	IIC
176	Hydrogen cyanide	HCN	0,90	<–20	5,40	46,0	60	520	538	0,80	T1	IIB
177	Hydrogen sulfide	H_2S	1,19		4,00	45,5	57	650	270	0,89	T3	IIB
178	4-Hydroxy-4-methylpenta-2-one	$CH_3COCH_2C(CH_3)_2OH$	4,00	58	1,80	6,9	88	336	680		T1	IIA
179	Kerosene			38	0,70	5,0			210		T3	IIA
180	1,3,5-Trimethylbenzene	$CHCCH_3)CHC(CH_3)CHC(CH_3)$	4,15	44	0,8	7,3	40	365	499	0,98	T1	IIA
181	Metaldehyde	$(C_2H_4O)_4$	6,10	36								IIA
182	Methacryloyl chloride	CH_2CCH_3COCl	3,60	17	2,50		106		510	0,94	T1	IIA
183	Methane (firedamp)	CH_4	0,55		4,40	17,0	29	113	537	1,14	T1	I
184	Methane (see 4.6)	CH_4			4,40	17,0	29	113	537		T1	IIA
185	Methanol	CH_3OH	1,11	11	5,50	36,0	73	484	386	0,92	T2	IIA
186	Methanethiol	CH_3SH	1,60		4,1	21,0	80	420	340	1,15	T2	IIA

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho ρ	FP °C	Flammability limits Lower vol per cent	Flammability limits Upper vol per cent	Flammability limits Lower mg/l	Flammability limits Upper mg/l	Ignition temp. °C	MESG mm	T class	Group
187	2-Methoxyethanol	$CH_3OCH_2CH_2OH$	2,63	39	2,40	20,6	76	650	285	0,85	T3	IIB
188	Methyl acetate	CH_3COOCH_3	2,56	–10	3,20	16,0	99	475	502		T1	IIA
189	Methyl acetoacetate	$CH_3COOCH_2COCH_3$	4,00	62	1,30	14,2	62	685	280	0,85	T3	IIB
190	Methyl acrylate	$CH_2{=}CHCOOCH_3$	3,00	–3	2,40	25,0	85	903	415	0,85	T2	IIB
191	Methylamine	CH_3NH_2	1,00	–18 gas	4,20	20,7	55	270	430		T2	IIA
192	2-Methylbutane	$(CH_3)_2CHCH_2CH_3$	2,50	<–51	1,30	8,0	38	242	420	0,98	T2	IIA
193	2-Methylbutan-2-ol	$CH_3CH_2C(OH)(CH_3)_2$	3,03	18	1,40	10,2	50	374	392	1,10	T2	IIA
194	3-Methylbutan-1-ol	$(CH_3)_2CH(CH_2)_2OH$	3,03	42	1,30	10,5	47	385	339	1,06	T2	IIA
195	2-Methylbut-2-ene	$(CH_3)_2C{=}CHCH_3$	2,40	–53	1,30	6,6	37	189	290	0,96	T3	IIA
196	Methyl chloroformate	CH_3OOCC	3,30	10	7,5	26	293	1020	475	1,20	T1	IIA
197	Methylcyclobutane	$CH_3CH_2CH_2CH_2$										IIA
198	Methylcyclohexane	$CH_3CH(CH_2)_4CH_2$	3,38	–4	1,15	6,7	47	275	258		T3	IIA
199	Methylcyclohexanols	$CH_3C_6H_{10}OH$	3,93	68					295		T3	IIA
200	Methylcyclopentadienes (isomer not stated)	C_6H_8	2,76	<–18	1,30	7,6	43	249	432	0,92	T2	IIA
201	Methylcyclopentane	$CH_3CH(CH_2)_3CH_2$	2,90	<–10	1,00	8,4	35	296	258		T3	IIA
202	Methylenecyclobutane	$C({=}CH_2)CH_2CH_2CH_2$	2,35	<0	1,25	8,6	35	239	352	0,76	T2	IIB
203	4-Methylenetetrahydropyran	$OCH_2CH_2C({=}CH_2)CH_2CH_2$	3,78	2	1,50		60		255	0,89	T3	IIB
204	2-Methyl-l-buten-3-yne	$HC \equiv CC(CH_3)CH_2$	2,28	–54	1,40		38		272	0,78	T3	IIB

Table A.1 – Flammability data *(continued)*

Ref.	Gas or vapour	Formula	Rho ρ	FP °C	Flammability limits Lower	Flammability limits Upper	Flammability limits Lower	Flammability limits Upper	Ignition temp. °C	MESG mm	T class	Group
					vol per cent		mg/l					
205	Methyl formate	$HCOOCH_3$	2,07	–20	5,00	23,0	125	580	450		T2	IIA
206	2-Methylfuran	$OC(CH_3)CHCHCH$	2,83	<–16	1,40	9,7	47	325	318	0,95	T2	IIA
207	2-Methylhexa-3, 5-dien-2-ol	$CH_2{=}CHC{=}CC(OH)(CH_3)_2$	3,79	24					347	1,14	T2	IIA
208	Methylisocyanate	CH_3NCO	1,96	–7	5,30	26,0	123	605	517	1,21	T1	IIA
209	Methyl methacrylate	$CH_3{=}CCH_3COOCH_3$	3,45	10	1,70	12,5	71	520	430	0,95	T2	IIA
210	Methyl 2-methoxypropionate	$CH_3CH(CH_3O)COOCH_3$	4,06	48	1,20		58		211	1,07	T3	IIA
211	4-Methylpentan-2-ol	$(CH_3)_2CHCH_2CHOHCH_3$	3,50	37	1,14	5,5	47	235	334	1,01	T2	IIA
212	4-Methylpentan-2-one	$(CH_3)_2CHCH_2COCH_3$	3,45	16	1,20	8,0	50	336	475	1,01	T1	IIA
213	2-Methylpent-2-enal	$CH_3CH_2CHC(CH_3)COH$	3,78	30	1,46		58		206	0,84	T3	IIB
214	4-Methylpent-3-en-2-one	$(CH_3)_2(CCHCOCH)_3$	3,78	24	1,60	7,2	64	289	306	0,93	T2	IIA
215	2-Methylpropan-l-ol	$(CH_3)_2CHCH_2OH$	2,55	28	1,70	9,8	52	305	408	0,96	T2	IIA
216	2-Methylprop-l-ene	$(CH_3)_2C{=}CH_2$	1,93	gas	1,6	10	37	235	483	1,0	T1	IIA
217	2-Methylpyridine	$NCH(CH_3)CHCHCHCH$	3,21	27	1,20		45		533	1,08	T1	IIA
218	3-Methylpyridine	$NCHCH(CH_3)CHCHCH$	3,21	43	1,40	8,1	53	308	537	1,14	T1	IIA
219	4-Methylpyridine	$NCHCHCH(CH_3)CHCH$	3,21	43	1,10	7,8	42	296	534	1,12	T1	IIA
220	α-Methyl styrene	$C_6H_5C(CH_3){=}CH_2$	4,08	40	0,90	6,6	44	330	445	0,88	T2	IIB
221	Methyl tert-pentyl ether	$(CH_3)_2C(OCH_3)CH_2CH_3$	3,50	<–14	1,50		62		345	1,01	T2	IIA
222	2-Methylthiophene	$SC(CH_3)CHCHCH$	3,40	–1	1,30	6,5	52	261	433	1,15	T2	IIA
223	2-Methyl-5-vinylpyridine	$NC(CH_3)CHCHC(CH_2{=}CH)CH$	4,10	61					520	1,30	T1	IIA