COMITÉ EUROPÉEN DES ASSURANCES

SECRETARIAT GENERAL
3bis, rue de la Chaussée d'Antin F 75009 Paris
Tél. : +33 1 44 83 11 73 Fax : +33 1 44 83 11 85
Web : cea.assur.org

DELEGATION A BRUXELLES
Square de Meeûs, 29 B 1000 Bruxelles
Tél. : +32 2 547 58 11 Fax : +32 2 547 58 19
Web : cea.assur.org

PROPERTY INSURANCE COMMITTEE
Prevention Specifications

CO_2 systems
Planning and Installation

CEA 4007: September 2003 (en)

(EFSAC endorsed)

CEA brings together the views of the European insurance industry and helps to present one influential voice on behalf of this market, especially in areas of change, such as regulation. It regroups 30 national member associations and represents over 5000 European insurance companies.

CEA’s aims are:

to **represent European insurers**: promoting, defending and expressing their views within international bodies and giving expert opinions to public or private European and international organisations with an insurance or reinsurance involvement;

to **exchange information and experience between markets**: drafting studies in the interest of European insurance companies, with a view to improving the service to insureds and to developing insurance in Europe in response to company needs;

and, in a general way, to put forward the **views of European insurers** in economic and social debates.

The **EUROPEAN FIRE AND SECURITY ADVISORY COUNCIL (EFSAC)** is composed of European organizations which have a vital interest in effective fire and security protection and which represent the interests of users, manufacturers, installers, suppliers, authorities and insurers.

EFSAC members are:

- ARGE: European Federation of Associations of Lock and Builders Hardware Manufacturers,
- CEA: Comité Européen des Assurances, Fire/Theft Committee
- CFPA Europe: Confederation of Fire Protection Associations Europe
- EURALARM: Association of European Manufacturers of Fire and Intruder Systems
- EUROFEU: European Committee of the Manufacturers of Fire Protection and Safety Equipment and Fire Fighting Vehicles
- EUROSAFE: European Committee of Safe Manufacturers.
- EFSG: European certification bodies

Contents

Appendices

Tables

Figures

1 General

1.1 Scope

1.1.1 These specifications specify requirements for design, installation and maintenance of installations in buildings and industrial manufacturing plants, and also for the extension or modification of existing installations.

They include not only requirements for the components and installation of CO_2 systems, but also for their application. These specifications are in accordance with current technical knowledge.

The system shall be planned and installed according to these specifications by an approved installer using approved, compatible components. Approval is given by the Insurers.

These specifications do not cover explosion -suppression- and inerting systems.

1.1.2 These specifications describe the minimum requirements.

In this document:

- « shall » indicates a mandatory requirement,
- « should » indicates a recommendation.

1.1.3 A competent authority shall be consulted with regard to factors not covered by these specifications.

1.1.4 CO_2 installations shall comply with these specifications and any national regulations.

1.1.5 The release of the installation may be automatic and manual or manual only. Automatic release should be used unless precluded by local conditions.

1.2 Aims

1.2.1 The function of the installation is to extinguish a fire while it is still in its early stage and, if necessary, to maintain the CO_2 concentration for a period of time to prevent re-ignition.

1.2.2 The design, installation and approval shall be based on a detailed knowledge of the protected zone, its use and the associated alarm system.

It is important to consider the fire precautions of the premises as a whole. An installation may be a « stand alone » fire protection installation or part of a combination of other fire protection measures.

1.3 Definitions

Alarm device: Device which emits audible or visual alarm signals.

Alarms**:** These may comprise one or all of the following:

- local alarm: Audible and, if necessary, visual alarm within the room,

- internal alarm: Audible and visual signals at the fire control panel and, if necessary, at other appropriate places,
- remote alarm: Alarm signalled to appropriate authorities, e.g. the fire brigade.

Aspirating detection devices: Aspirating detection devices comprise detectors in measuring chambers fitted with suction devices. They sample air from the protected space to detect the products of combustion.

Authority**:** Body having jurisdiction over aspects of the installation (e.g. insurer, fire brigade, government agency).

Calculation zone: A zone for which the design quantity of CO_2 required is calculated independently.

CO_2 storage area: The room or area housing the CO_2 supply container.

Control device: A device for initiating the discharge process, actuating the alarm device and actuating any ancillary control equipment.

Deep-seated fire: Fire involving solids subject to smouldering.

Delay time: A pre-set time period between the triggering of the system and the discharge.

Design quantity: The quantity of CO_2 to be discharged into the calculation zone including the quantity for the holding time, if necessary. See also appendix A4.

Discharge time: The time period, during which the design quantity of CO_2 is discharged.

Emergency triggering device: A manually operated device which can be used to trigger the installation in the event of failure of the normal triggering device.

Emergency stop device: A manually operated device, which prevents the release of the CO_2.

Equipment: Component parts of a technical system.

Equipment extinguishing system: Fire extinguishing system for selective application of the extinguishant into the equipment.

Equipment protection (object protection): Protection of individual items of equipment with fire detection and extinguishing systems.

Equipment detection system: Fire detection system for dedicated early detection of incipient fires in the equipment.

Fire detection device: Device reacting to the fire characteristics smoke, heat or flames.

Fire detector: Fire detection device complying with EN 54.

Flooding zone: A zone comprising all calculation zones to be flooded simultaneously with CO_2.

Group of units: Several pieces of equipment which are considered to be a unit for detection and extinguishing purposes. The units may be separated by partitions.

High-pressure installation: An installation, in which the CO_2 is stored at ambient temperature. For example, the pressure of CO_2 in storage at 21 C is 58.6 bar.

Holding time: Time from reaching the design concentration to the time of falling below the design concentration.

Installation: An installed CO_2 fire extinguishing system.

Liquid-phase: Time in which CO_2 is discharged in liquid and gaseous form (two-phase flow).

Local application system: System designed to protect a defined area within a large space.

Low-pressure installation: An installation in which the CO_2 is stored at low temperature, normally -19 C to -21 C.

Non-electrical lock-off device: A mechanical device which prevents the release of CO_2 while maintenance, inspection or service work is carried out in the protected zone.

Pre-liquid-gaseous-phase: Time from the opening of the container or selector valve to the start of a two-phase flow at the most unfavourable nozzle.

Pre-warning time: The time period between the start of the warning indication and the discharge.

Release mechanism: A mechanism which, upon actuation by the control device, automatically opens the container valve and, if fitted, a selector valve to release the CO_2.

Selector valve: A valve in the main feed pipe, which directs the CO_2 from the supply container to the appropriate flooding zone.

Surface fire: Fire involving flammable liquids, gases and solids not subject to smouldering.

Supply quantity: The total quantity of CO_2 available for use within a flooding zone, comprising the design quantity and any supplementary quantity required to compensate for filling variations and pipe losses.

System: System of approved components, which are approved for their correct function and compatibility.

Time-delay device: An automatic device, which delays the release of the CO_2 for a predetermined period of time (pre-warning time), to permit evacuation of personnel.

Total flooding system: An installation to protect the entire volume of an enclosure.

Unit: A piece of equipment inside a housing; may be equipped with its own power supply and ventilation.

1.4 Description of the installation

1.4.1 The block diagram shown in appendix A2 illustrates the functional interaction between the components which shall (solid lines) or may (dotted lines) be present in an installation.

CO_2 installations in general consist of CO_2 containers, valves, fixed pipework with appropriate located nozzles in the protected zone and devices for detecting the fire, alarms, triggering and release.

The CO_2 is stored in containers at room temperature in the case of high pressure systems or in insulated containers at a temperature of approximately - 20 C in the case of low-pressure systems.

1.4.2 Automatic detection and/or manual-triggering devices are used to operate the system. This may be achieved using any approved method or device, which can recognise and indicate the presence of heat, flames or smoke in the protected zone.

1.4.3 The control equipment starts alarm devices, if necessary the time delay device, and opens the valves.

1.4.4 The installation may be equipped with automatic devices used to switch off machinery and close fire doors and other equipment, the purpose being to build-up and to hold the CO_2 concentration.

1.5 Personnel safety

1.5.1 In any installation where personnel could be endangered, suitable safeguards shall be provided to ensure prompt evacuation of the zone, to prevent entry into the zone after discharge, and to provide means for prompt rescue of any trapped personnel. Such safety aspects as personnel training, warning signs, alarm and delay devices shall be considered.

The CO_2 concentration required for extinguishment is dangerous to life. Personal safety measures shall be provided for room and local application systems, if the quantity discharged in the room, or space protected by the local application system, gives a CO_2 concentration of more than 5% by volume. This also applies to areas surrounding the discharge area of local application systems and areas adjoining protected rooms where there is a possibility of such concentrations occurring.

In all cases a lock-off device is needed.

The following requirements shall be met:

- provision of exit routes, which shall be kept clear at all times and the provision of adequate direction signs,
- a flooding zone shall not serve as the only evacuation route for other zones,
- provision of only outward-opening self-closing doors which shall be openable from the
- inside even when locked from the outside,
- provision of alarms, that are distinctive from all other alarm signals and that will operate immediately upon detection of the fire,
- provision of illuminated signs at entrances, until the atmosphere has been made safe,
- provision for adding a non-flammable and non-toxic odour to the CO_2, so that hazardous atmospheres may be recognised,
- provision of warning and instruction signs at entrances,
- if necessary, provision of self-contained breathing equipment and personnel trained in its use,
- provision of means of ventilating the zones after releasing CO_2,
- provision of any other safeguards that a careful study of each particular situation indicates are necessary.

Consideration shall be given to the risk of leakage of CO_2 into adjacent zones, where hazardous concentrations could occur.

1.5.2 In all cases national regulations relating to personnel safety shall be observed.

1.6 Alarm organisation

An effective method of alarm organisation shall be provided to:

- alert appropriate persons,
- alert the fire brigade,
- initiate other required measures.

See also clause 5.6.

1.7 Application

1.7.1 In order to determine the extent of the protection a risk analysis shall be carried out.

1.7.2 The extinguishing efficiency of CO_2 is primarily due to the reduction of the oxygen content in the air to a value at which the fire is no longer self-sustaining. The cooling effect of CO_2 is minimal when compared to this smothering effect. Once a fire has been extinguished it may be necessary, in order to prevent reignition, to maintain the CO_2 concentration until hot objects have had time to cool down.

1.7.3 CO_2 is suitable for extinguishing fires involving certain types of materials and equipment such as:

- flammable liquids and materials which, in case of a fire, exhibit characteristics similar to flammable liquids,
- flammable gases, where provisions are made to ensure that a combustible gas/air mixture cannot recur following successful extinguishment,
- electrical and electronic equipment,
- flammable materials such as wood, paper, textiles etc. These, however, require a higher concentration of CO_2 and a certain holding time. Extinguishment may not be possible if the fire is deep-seated.

1.7.4 CO_2 cannot extinguish fires involving certain types of materials such as:

- chemicals containing oxygen,
- metals and chemicals which react with CO_2, e.g. alkaline metals and metallic hydrides.

1.7.5 Examples of where CO_2 installations are used include:

- paint manufacturing,
- spray painting operations,
- oil baths,
- printing presses,
- electrical switch gear rooms,
- computers,
- restaurant kitchen equipment (fryers, hoods and connected ducts, see chapter 11),
- generators, including cooling systems,
- oil-filled transformers,
- rolling mills, in which light metal alloys are processed,
- diesel generators.

2 Design of the installation

2.1 Type of installation and structural requirements

2.1.1 The choice between a high and low pressure system depends on the quantity of CO_2 to be stored and on the type of distribution required.

2.1.2 The choice between a total flooding and a local application system depends on the integrity of the enclosure and safety of persons.

2.1.3 Buildings, rooms and enclosed objects (flooding zones) protected with CO_2 total flooding systems shall be of such a nature, that the effective CO_2 concentration will be reached and maintained for a sufficiently long period of time.

2.1.4 The integrity of the enclosure (walls, ceilings, floors, doors, windows, etc.) shall withstand the increase in pressure during discharge. Therefore pressure relief devices shall be provided to prevent an excessive pressure increase in the flooding zone unless calculations show that they are unnecessary because of leakages around doors, windows etc.

Note: The ability of the structure to withstand the pressure increase should be evaluated by the architect or the building engineer.

Pressure relief devices shall be open only in case of an over pressure in the enclosure. They shall close automatically when the excess pressure has decreased. An example of the calculation method for pressure relief openings is given in appendix A 9.

2.1.5 The separation should meet the criteria relevant to the protection objectives described in appendix A5. The separation shall be non-combustible or have a fire resistance of at least 30 min according to the national specifications, so that the enclosure is maintained until the end of the holding time.

Openings shall be closeable with closures meeting the criteria above. The closures shall be triggered by the extinguishing installation or the system that triggers the extinguishing installation.

2.1.6 Structural components of the enclosure shall be classified as type A_O openings, if they do not meet the above requirements.

2.1.7 Air currents shall not affect the performance of the CO_2 installation. To meet this requirement the following conditions shall be fulfilled.

Openings from the object or room into the open air, assumed to be open in the event of a fire, shall not exceed:

$0.1\ V_V^{\ 2/3}$ or $50\ m^2$.

If these limits are exceeded the protected object shall be situated in a structure.

If the protected object or room with openings assumed to be open in the event of fire is located closer than 5 m to walls, the construction of the walls shall have a fire resistance of at least 30 min according to the national specifications or be constructed of non-combustible materials in order to ensure that the enclosure is maintained until the end of the holding time.

For objects in large rooms with openings assumed to be open in the event of fire the authorities shall consider, the effect air currents on the performance of the CO_2 installation.

2.1.8 The installation may be as a total flooding system if the surface area A_O of all uncloseable openings, does not exceed 3% of the total surface area A_V of the enclosure (all sides, floor and ceiling). When the uncloseable openings exceed this ratio, the system shall be designed as a local application system.

2.1.9 Objects can be protected by local application systems only when provisions have been made to ensure that an effective CO_2 concentration can be built up and maintained for the required holding time. Adverse conditions (e.g. wind, ventilation) shall be taken into consideration.

2.1.10 If openings must be kept open for operational reasons, suitable measures shall be taken to ensure that they are closed at the beginning of the delay period, if possible, and at the latest when the extinguishant discharge begins.

2.1.11 Smoke and heat venting systems installed in rooms protected by a CO_2 system shall not operate automatically, only manual operation is allowed. The manual operating device shall be operated in the case of fire only by responsible personnel and shall be protected from access by unauthorised persons.

In cases where fast fire development and high temperature rises are to be expected, e.g. in lacquer manufacturing, plastic foam manufacturing and processing, storage of flammable liquids, the smoke vents shall be resistant to thermal stress to preclude damage before the end of the extinguishing period. See table in Annex A 5.

2.2 Design quantity

2.2.1 The required CO_2 design quantity is to be determined in accordance with the following formula for local application and total flooding installations:

$Q = K_B\ (0.75V + 0.2A)$

However the relation

$Q = K_B\ (1.1V + 0.2\ (30\ A_O))$

can be taken as the upper limit, if

$0.75\ V + 0.2\ A_V \geq 1.1\ V$

Note: A_V and not $A = A_V + 30\ A_O$ shall be used in this comparison.

$V = V_V + 4\ V_Z - V_G$

$A = A_V + 30\ A_O$

A_V - Total surface area of all walls, floor and ceiling (including the openings A_O) of the enclosure (real or imaginary, see section 2.2.5), in m^2.

A_O - Total surface area of all openings, which can be assumed to be open in the event of a fire, in m^2.

Q - CO_2 design quantity in kg.

V_V - Volume of the enclosure or the volume of the object (real or imaginary), in m^3.

V_Z - The volume of air, which will be blown into or extracted from the enclosure during the discharge time by ventilation systems which cannot be shut down, in m^3. If the CO_2 concentration is to be maintained for a longer period, the ventilation shall be shut down in any event.

V_G - Volume of the building structure in the calculation zone, which the CO_2 cannot penetrate, in m^3.

K_B - Factor for the material to be protected, which shall be equal to or greater than one.

The coefficient 0.2 in kg/m^2 comprises the portion of CO_2 that can escape.

The coefficient 0.75 in kg/m^3 comprises the minimum quantity of CO_2 taken as a basis for the formula.

Note: Other calculation methods may be used to determine the CO_2 quantity, provided that a full flooding test is performed to show that the CO_2 concentration required in tables 1,2 and 3 is achieved and maintained for the specified holding time. Full details of the calculation and the gas quantity shall be submitted to the authorities before installation.

2.2.2 If calculation zones are not separated by a distance of at least 5 m or as described in section 2.1.5 they shall form one flooding zone.

2.2.3 A maximum of two separate flooding zones may be combined for simultaneous flooding.

2.2.4 The boundary surface between the calculation zones of one flooding zone may be omitted, when determining A in the formula in section 2.2.1.

2.2.5 The sum of all calculation zone boundary surfaces (A_V) shall be used in the formula of section 2.2.1 in accordance with the following.

The boundary surface for total flooding installations is the sum of any area of walls, ceilings and floors including openings.

For the determination of the boundary surface for local application installations, the non-closeable openings of the calculation zone are to be formed by imaginary surfaces. The imaginary surfaces shall have simple geometries, such as cubes, cylinders, spheres. The number of the imaginary surfaces shall be as small as possible.

The boundary surface, consisting of real and imaginary surfaces, shall be at least as large as the protected object and shall enclose all areas of possible leakage and spillage.

For local application systems, where it is not possible to locate nozzles inside the normal calculation zone for reasons, mentioned in 3.4.2, or where important operational reasons make this necessary, the calculation zone shall be extended, so that all nozzles are covered.

A floor shall be present at all times. If this is not the case the authorities shall be consulted.

For the calculation of the design quantity for objects with reservoirs such as the quenching tanks of hardening plant the empty reservoir is to be taken into account for the calculation zone.

2.3 Concentration Factor K_B

2.3.1 The numerical values for K_B given for the combustibles and special risks listed in table 1 to 3 are to be inserted in the formula listed at Section 2.2.1, used to determine the CO_2 design quantity.

2.3.2 K_B factors for hazards not listed in this section shall be determined by using the cup burner apparatus described in appendix A4 or other test methods giving equivalent results.

2.3.3 The K_B factor for combustibles, which could form deep-seated fires do not need to be applied for the following listed solid combustibles:

- single paper width in printing and foaming machines (expanded plastic),
- paper intermediate layers in storage of solids of class B (EN - 2),
- individual wooden pallets in class B storage of combustible products with non-combustible packaging. This does not include stacks or piles of pallets.

2.4 Supply quantity

2.4.1 The CO_2 supply quantity shall be at least as large as the design quantity calculated as per section 2.2.1 for the flooding zone with the greatest extinguishant demand, plus the following supplements:

- an extra quantity, e.g. for leakage and filling tolerances, of at least 10% of the CO_2 design quantity for low pressure systems and high pressure systems with up to 19 cylinders. For high pressure systems with 20 or more cylinders the extra quantity shall be at least 5% ,
- for low pressure systems, the amount in the pipework in liquid form after discharge. This amount shall be calculated or it shall be assumed, that the pipework is filled with 75% liquid CO_2,
- for local application systems:
  - calculated amount, discharged during pre-liquid gaseous phase,
  - for high pressure systems, 30% of the design quantity for residual gas,
  - if flammable liquids are heated throughout and not just at the surface for operational reasons (e.g. oil quench tank in metal hardening plants, bitumen impregnating tank), the supply quantity shall be increased to allow for a second discharge.
  - compensation for extreme temperature:

where the ambient temperature of the enclosure is above 100 C, 2% of the calculated CO_2 design quantity shall be added for each increase of 5 C above 100 C.

where the ambient temperature of the enclosure is below -20 C, 2% of the calculated CO_2 design quantity shall be added for each 1 C below -20 C.

2.4.2 For the protection of special types of buildings, equipment and occupancies see clause 11.

2.4.3 Maximum 30 flooding zones shall be connected to the installation.

Material	Concentration factor K_B	Design concentration in %
Cellulosic material	2.25[1)]	61
Cotton	2.00[1)]	57
Ppaer, corrugated paper	2.25[1)]	61
Plastic material (granular)	2.00[1)]	57
Polystyrene	1.00	34
Polyurethane, cured only	1.00	34

Table 1: K_B-factors for solid combustibles

[1)] *These are materials which could cause deep-seated fires and a concentration of 34 % shall be kept for at least 20 min.*

Material	Concentration factor K_B	Design concentration in %
Acetone	1.00	34
Acetylene	2.57	66
Aviation fuel grades 115/145	1.06	36
Benzol/Benzene	1.10	37
Butadiene	1.26	41
Butane	1.00	34
Butene-1	1.10	37
Carbon disulphide	3.03	72
Carbon monoxide	2.43	64
Coal gas	1.10	37
Cyclopropane	1.10	37
Diesel fuel	1.00	34
Diethyl ether	1.2	40
Dimethyl ether	1.22	40
Dowtherm	1.47	46
Ethane	1.22	40
Ethyl alcohol	1.2	40
Ethyl ether	1.47	46
Ethylene	1.60	49
Ethylene dichloride	1.00	34
Ethylene oxide	1.80	53
Gasoline	1.00	34
n-Hexane	1.1	37

Table 2: K_B factors for gases and liquids

Material	Concentration factor K_B	Design concentration in %
n-Heptane	1.1	37
Hydrogen	3.30	75
Hydrogen sulphide	1.06	36
Isobutane	1.06	36
Isobutylene	1.00	34
Isobutyl formate	1.00	34
JP-4	1.06	36
Kerosene	1.00	34
Methane	1.00	34
Methyl acetate	1.03	35
Methyl alcohol	1.6	49
Methyl butane-1	1.06	36
Methyl ethyl ketone	1.22	40
Methyl formate	1.18	39
n-octane	1.03	35
Natural gas	1.10	37
n-Pentane	1.1	37
Propane	1.06	36
Propylene	1.06	36
Toluene	1.0	34
Quench/lube oils	1.00	34
Table 2: K_B-factors for gases and liquids		

Special equipment	Concentration factor K_B	Design concentration in %
Cable rooms, cable ducts	1.50[1)]	47
Computer and other electronic equipment	1.20[1), 2)]	40
Computer installations	1.50[1)]	47
Electrical switch and distribution rooms	1.20[1)]	40
Generators, including cooling system	2.00[1), 3)]	57
Oil filled transformers	2.00[1)]	57
Output printing areas	2.25[1), 4)]	61
Paint spraying and drying installations	1.20	40
Spinning machines	2.00[1)]	57
Table 3: K_B-factors for special equipment		
[1)] A concentration of 34% shall be maintained for at least 10 min. [2)] Rooms that are only used for electronic data processing. No storage or handling of materials is allowed. [3)] The holding time shall be extended until the generators have stopped. [4)] Paper shall be only processed, not stored.		

2.5 Reserve quantity

A reserve quantity equal to the supply quantity shall be permanently connected in the following cases:

- more than five flooding zones are connected to the installation,
- if the CO_2 supply quantity cannot be replaced within 36 h.

2.6 CO_2 storage

2.6.1 The CO_2 supply quantity and reserve quantity shall be stored in such a way that it is available at all times and cannot be used for other purposes.

2.6.2 The filling ratio of high pressure containers shall be 0.667 or 0.750 kg per litre of the container volume. The container volumes shall be 10.40 or 67.5 l.

Only one container size and one fill ratio shall be used in an installation.

Only CO_2 complying with ISO 5923 - Fire extinguishing media shall be used in these fire extinguishing systems.

2.6.3 The high pressure containers shall be installed vertically so that each individual container can be easily accessed, and shall be fitted with a check valve to the manifold.

2.6.4 The quantity of available extinguishant shall be monitored. Any loss of more than 10% of the extinguishant in any container shall be automatically indicated.

The containers shall be replaced or topped up, if a loss of contents of more than 10% occurs.

2.6.5 In low-pressure systems an automatic refrigeration unit shall be used to keep the CO_2 at an absolute pressure of between 19 bar and 21 bar. A rise in pressure above 22 bar shall be signalled automatically as a fault.

Note: The temperature of the CO_2 during the filling of the containers may be lower than the installation design requires.

2.6.6 The low-pressure container shall be insulated to limit the loss of CO_2 in 24 h to not more than 1.5 % in the event of a failure of the refrigerating system at 35 C or the highest expected ambient temperature.

Insulation shall be protected with metal sheeting to avoid mechanical damage.

2.6.7 Low pressure containers shall be equipped with a manual stop valve upstream of, and as close as possible to, the container valve.

2.6.8 The outlet of the over-pressure release valve on the low-pressure container shall be routed to a place, where it does not endanger personnel.

2.7 CO_2 storage area

2.7.1 The CO_2 storage area should be located in a separate room, which is not exposed to excessive risk of fire, but should be located as close as possible to the flooding zone. However, if this is not practicable, suitable physical security against tampering shall be provided.

2.7.2 The CO_2 storage area shall be:

- easily accessible, even in the event of fire,

- protected against access by unauthorised persons,
- used for this purpose only,
- normally kept at temperatures between 0 C and 35 C,
- equipped with ventilation,
- planned in such a way, that maintenance and inspection can be easily carried out,
- electrically illuminated,
- planned to permit easy evacuation.

The components installed in the CO_2 storage room shall be protected against heating caused by sunlight or other sources.

2.7.3 Operating instructions shall be permanently affixed inside the CO_2 storage area in a highly visible position.

The name of the company responsible for maintenance of the system, the year of installation, instructions for use and maintenance and relevant data for the installation shall be available in the CO_2 storage area.

2.8 Hydraulic calculation

2.8.1 The nozzles and piping shall be sized in such a way that the required CO_2 design quantity shall be discharged into the flooding zone within the discharge time, specified in Section 2.9.

As a basis for the calculation, the method described in appendix A7 or the method described in ISO 6183:1990 can be chosen.

The method described in appendix A7 can be used for all types of CO_2 installations.

The method described in ISO 6183:1990 is only suitable for CO_2 installations with:

- nearly symmetrical pipework (the flow through two branch lines shall not exceed the ratio 40/60),
- one calculation zone only.

Note (informative): The restriction to one calculation zone only is caused by the fact that this method uses only the working pressures of 51.7 or 20.7 bar absolute. If the method should be used for all systems, the working pressure used in the calculation must be decreased to the pressure in the container when half of the design quantity is released. For this pressure the Y- and Z-values must be calculated.

2.8.2 The calculated pressure for any part of the pipework shall be at least:

- P_{abs}= 14 bar for high-pressure installations,
- P_{abs}= 10 bar for low-pressure installations.

2.8.3 In storage areas where the temperature can fall below 0 C the calculation and sizing of high-pressure installations shall be the same as low-pressure installations.

2.8.4 The calculation method used shall be approved by the insurers.

2.9 Discharge times

2.9.1 For total flooding systems the normal maximum discharge time shall not exceed 60s.

However, in installations with supply quantities of more than 3 t of CO_2 protecting zones where slowly developing fires are to be expected, the discharge time may be a maximum of 120 s.

Exceptions to this are given in clause 2.9.2 and 2.9.3.

2.9.2 For total flooding systems protecting

- computer installations,
- electrical switch and distribution rooms, computer and other electronic equipment,
- output printing areas,

the design concentration shall be achieved within 240 s. However a concentration equivalent to the K_B factor 1 shall be reached within the time given in 2.9.1.

2.9.3 For total flooding systems protecting hazards where deep-seated fires are likely to occur the design concentration given by the K_B factor as stated in table 2 shall be achieved within the time given in 2.9.1. However, the design concentration according to the K_B factor for the material which could result in a deep-seated fire shall be achieved within 240 s.

2.9.4 For local application systems, the design quantity shall be discharged in the liquid-phase time of 25-30 s. The design discharge time (pre-liquid-gaseous-phase time and liquid-phase time) shall be maximum 40 s.

2.10 Holding time

In cases where a fire may not be extinguished during the discharge time (e.g. for deep seated fires), the extinguishant shall be contained within the enclosure for a specified holding time. Holding times for particular conditions are specified in tables 1 and 3.

3 Distribution pipework

3.1 Pipes

3.1.1 Pipes and pipe connections shall be made of metal and be able to withstand the possible pressures as shown in table 4 and low temperatures (-50 C) to be encountered. An example for low temperatures is shown in appendix A10.

The piping shall comply with the EN standards or the national regulations.

Sections of pipe, which could be subjected to static pressure (closed piping), shall be protected by a safety valve.

3.1.2 Flexible pipes and hoses etc. shall only be used where fixed pipes are unsuitable.

3.1.3 Installing chokes or plates in piping is prohibited.

3.1.4 In high pressure systems, the cross-section of the manifold attached to the supply containers shall be at least as large as the sum of the cross-sections of all the container valves.

3.1.5 The cross-section of the pipes, valves and hoses except the manifold, may be reduced only along the direction in which the CO_2 flows.

3.1.6 Pipes shall have a nominal diameter not less than 10 mm. For local application installations for in cabinet protection the diameter may be reduced to not less than 6 mm if the pipes are made of stainless steel or alloy copper.

3.1.7 The inside and the outside of the pipes shall be effectively protected against corrosion, if necessitated by environmental conditions. Temperature shocks during discharge shall be taken into account when selecting coatings. Special-alloy steels and/or suitable surface protection coatings shall be used if the use of pipes and connections made of steel does not provide sufficient corrosion protection.

3.1.8 Pipes smaller than 50 mm nominal diameter shall not be connected by welding on site. However, approved factory welding methods may be used.

The welding procedure shall be in accordance with the national regulations.

3.1.9 If condensation could form in the pipes, suitable means shall be provided for drainage. These drainage points shall not be accessible to unauthorised persons.

3.1.10 The piping shall be arranged so that it cannot be damaged due to its own weight, temperature fluctuations, vibrations, release of the extinguishant or other installation-inherent influences. All piping shall be accessible.

3.1.11 The CO_2 installation shall be earthed. If necessary electrical connections between all pipes shall be provided or the system shall be earthed at different points.

Section	**Service pressure in bar**
High-pressure systems between container-and sector valve*	120
High-pressure systems downstream selector valve	60
Low-pressure systems between container-and selector valve* and down-stream selector valve	25
Table 4: Pipe quality requirements	
* *Safety valves shall ensure that the service pressure cannot be exceeded by leakage from the container valves.*	

3.2 Pipe Supports

3.2.1 Particularly when designing low-pressure systems, the low temperatures generated when the CO_2 is discharged shall be taken into account when designing the supports; the anchors shall also be able to withstand static and dynamic loads.

The change in the length of the pipe due to thermal effects shall be borne in mind.

3.2.2 Pipe supports shall be designed so that under extreme loads there is no danger of the installation being damaged.

This condition is deemed fulfilled when the supports have been calculated and constructed using main and additional loads as a basis.

If there is a rise in temperature from + 20 C to + 200 C, the strength of materials used shall not be reduced by more than 25%. Combustible materials shall not be used.

Supports, which do not conform to the requirements in section 3.2.2 to 3.2.7, shall be specially approved.

3.2.3 For minimum cross-sectional areas of supports see table 5.

In the case of pipe supports which are designed such that loads are distributed among more than one individual cross-sectional area, the sum of the individual cross-sectional areas acting parallel to one another shall be at least 1.5 times the respective minimum cross-sectional area.

Each individual cross-sectional area shall not be less than 30 mm^2. In determining whether pipe supports have more than one individual cross-sectional area acting parallel to one another, drillholes for bolts and rivets do not have to be taken into account. Pipe clips and other devices for holding the pipe shall completely surround the pipe and be closed.

Nominal diameter	Rated load in N	Minimum cross-sectional area of supports in mm^2 (thread size)	Minimum depth for fastening plugs in concrete in mm
≤ DN 50	2000	30 (M 8)	30
> DN 50 ≤ DN 100	3500	50 (M 10)	40
> DN 100 ≤ DN 150	5000	70 (M 12)	40
> DN 150 ≤ DN 200	8500	125 (M 16)	50
> DN 200 ≤ DN 250	10000	150 (M 20)	60

Table 5: Supports

3.2.4 Pipe supports with material cross-sections which do not meet the specifications of 3.2.3 require testing and approval.

3.2.5 Support materials shall be at least 3 mm thick. If they are galvanised, a thickness of 2.5 mm will suffice. This does not apply to hangers made of hot-dip galvanised material, which may have a minimum size of 25 mm x 1.5 mm for pipework up to a nominal diameter of 50 mm (12 mm x 1.5 mm, if type approved).

3.2.6 Where in the case of support systems threaded rods are screwed into blind holes such as dowels, provision shall be made on the other end of the threaded rod for possibility of adjustment, allowing the threaded rod to project a minimum 20 mm through the thread.

3.2.7 Support brackets for pipes up to DN 50 may be attached to sloping bearing surfaces. These surfaces shall not deviate from the horizontal plane by more than 10. The brackets may only be subjected to vertically acting loads. The clamping screws shall engage on the sloping support surface.

3.2.8 Supports shall not be used for other purposes. Supports should be attached near joints in the pipe.

3.2.9 The required length of fastening plug depends on the type of plug used and on the type of material into which the plug is driven. Plugs shall be made of non-combustible material. The fixing point must be able to absorb twice the loads stated in table 5 at any time.

Pipe supports shall connect the pipework directly to the building structure and shall not be used for other purposes.

Building members, to which primary supports are attached, shall be strong enough to take the load; if not, additional links to load-bearing members shall be created.

Only pipes with a nominal diameter up to 50 mm may be attached to steel trapezoidal sheets or slabs made lightweight concrete. The design shall be approved by authorities. Care shall be taken to ensure that pipes are supported by the load-bearing structure at a maximum of 12 m spacing and that the last nozzle is no more than 2 m away from such a support.

Fastening plugs in lightweight concrete slabs shall be at least 150 mm away from the edge of the slab.

3.2.10 In the case of local application installations the pipe supports could be fastened direct to objects to be protected. The rated load shall be looked for in any case.

3.2.11 If, in exceptional cases, it is necessary to fasten pipework to equipment or structural members, it shall be remembered that in calculating the fixture for the equipment or structural member at least double the main load and the rated load for the pipe given in table 5 shall be used.

3.2.12 All pipes longer than 1 m shall be fixed with supports. The maximum distance between two supports along the pipe shall not exceed the values given in table 6.

Pipe dimater in mm	**≤ 25**	**> 25**	**≥ 50**
Maximum distance between supports in m	2	3	4

Table 6: Distance of supports

3.2.13 If in the case of pipes > 50 mm the 4 m spacing cannot be adhered to for building design reasons, the distance may be raised to 6 m, if the pipe is provided with double supports.

Additional supports are required in cases where greater loads (such as valves) require supporting.

3.2.14 The distance between a support and the last nozzle shall be as short as possible and shall not exceed:

- 0.1 m for pipe with a diameter ≤ 25 mm,
- 0.25 m for pipe with a diameter > 25 mm.

3.3 Selector valves

3.3.1 The selector valves shall «whenever possible» be located outside the danger zone resulting from a fire in the flooding zone. No flammables shall be stored in the immediate vicinity of the selector valve.

3.3.2 Selector valves shall be arranged so that they will not open when subjected to vibrations either in the operating environment or when the valve at the supply container or other selector valves are opened.

3.3.3 If it is still possible to release the extinguishant even though the mechanism used to automatically open the selector valve has failed, this emergency release mechanism shall not circumvent the national codes for personnel safety and the equipment required to prevent damage due to excessive pressure being exerted by the CO_2 in the flooding zone.

3.3.4 In the case of high-pressure installations the selector valves shall open automatically and, at the latest, simultaneous to the opening of the container valve.

3.3.5 In low-pressure installations selector valves shall open and close automatically. The opening time shall correspond to the discharge time given in clause 2.9.

3.3.6 In the case of an automatically actuated container valve installed in low pressure installations in addition to the selector valve, the selector valve shall be opened after the container valve. The selector valve shall be closed automatically after the end of the discharge time. The container valve shall be closed after the residual liquid CO_2 in the pipe between the container and selector valve has re-entered the container. In this case a safety valve shall be installed on the pipe between the container and selector valves.

Where an automatically actuated container valve is installed, it shall be in addition to the manual isolating valve.

3.3.7 The nominal diameter of the selector valve shall be at least the diameter of the supply pipe.

3.3.8 The safety valve shall discharge the CO_2 to atmosphere, away from windows (including basement windows) and ventilation openings. In no case shall the discharge create a hazard to personnel. The safety valve shall be installed upright.

3.4 Nozzles

3.4.1 For total flooding systems the nozzles shall be arranged so that a uniform build-up of the required CO_2 concentration will be achieved. The maximum protected area per nozzle shall not exceed 30 m^2.

3.4.2 Nozzles shall be sited so as not to disperse combustible materials when the CO_2 is discharged, as this may contribute to the fire hazard.

3.4.3 The nozzles shall be arranged so that the effects of discharge do not damage the components being protected.

3.4.4 In total flooding systems the nozzles shall be located in the upper zone of the flooding zone. If the flooding zone is between 5 m and 10 m in height, additional nozzles shall be installed at one-third of the room height. The lower nozzles shall flood 1/3 of the design quantity. In the case of rooms higher than 10 m, the authorities shall be consulted.

3.4.5 Suitable protective arrangements shall be made in environments where the nozzles could be blocked (such as in spray painting operations, for instance). This protective concept shall be approved by the responsible authorities and executed in such a way, that there will be no adverse effect on the discharge of the CO_2.

3.4.6 To achieve the necessary CO_2 concentration in local application systems for the upper part of open objects higher than 5 m, the type and location of nozzles shall be selected appropriately. It may be necessary to increase the design quantity.

4 Detection

4.1 Type of detectors

Fire detection devices shall be either in accordance with the appropriate part of EN 54 or in accordance with the CEA Specifications for fire detection devices.

4.2 Criteria for selection of detectors

In order to determine the most appropriate form of detection for a particular risk (e.g. detection devices in accordance with EN 54 or those in accordance with the CEA Specifications for fire detection devices), the following points should be considered.

The initial development of the fire, the room height, the environmental conditions and the possibility of false alarms in the protected rooms shall be considered when selecting the fire detection devices.

Fire development

Smoke detectors shall be preferred particularly where, smouldering fires are likely to occur (large amounts of smoke, less heat and no, or minimal, radiation) for example cable fires.

Smoke-, heat- or flame- detectors or combinations of different types of detectors could be used where rapid fire development in the initial phase of the fire is likely (great heat, strong radiation).

Other devices like fusible links shall be preferred for fires involving flammable liquids or plastics materials with large amounts of oxygen.

If the stored goods are prone to smoke damage, smoke detectors shall be used.

Room height

The effectiveness of fire detection devices is hindered by the increased response time caused by the room height. See table 7.

The height of any parts of the ceiling, less than 10% of the total ceiling area and less than the protection zone of one detection device, shall not be taken in account. Otherwise this zone shall be considered as its own room.

The fire detection devices shall be sited appropriate to the object in the case of local application systems.

Ambient temperature

Smoke- and flame-detectors could be used up to ambient temperatures of 50 C, if not excluded by the approval.

A temperature difference of approximately 30 C between ambient and response temperature shall be ensured before heat detectors are used.

Heat detectors including a rate-of-rise element should not be used when the ambient temperature fluctuaties rapidly for operational reasons.

If there is no danger by ice forming, fire detection devices could be used up to temperatures of - 20 C.

Air movement

Smoke detectors can be used up to air speeds of 5 m/s, if the approval does not allow higher speeds.

Vibration

Vibration of fire detection devices mounted on machinery shall be taken into account.

Explosive atmospheres

Where explosive atmospheres may exist electrical systems may be unsuitable due to the potential ignition risk.

Humidity

Condensation shall not affect the response characteristics and false alarms shall not occur.

False alarm

False alarms caused by environmental influences like sunlight, heating etc. or mechanical damage shall be avoided by the appropriate location of the fire detection devices.

Smoke, dust and other aerosols

False alarms may be caused by smoke, dust and other aerosols. Smoke detectors shall only be used if it is ensured that no false alarms can occur. In the case of dust approved special filters or other measures can be used.

Optical radiation

Modulated radiation from the sun or lighting devices can cause false alarms of UV-detectors. This fact shall be taken into account in the location of UV-detectors.

4.3 Electrical fire detection systems

If smoke detectors are to be used to initiate CO_2 discharge, then they should be configured in « coincidence connection » mode. This configuration requires that at least two independent detector alarm outputs are signalled to the detection control and indicating equipment before discharge is initiated.

Where coincidence connection is used, the density of detectors should be at least one detector per 25 m^2 floor area. The remainder of the installation should be in accordance with the CEA Fire Detection Specifications.

4.4 Mechanical or pneumatic fire detection devices

4.4.1 The number and location of fire detection devices depends on their type, the room geometry (size, height, ceiling- and roof surface, etc.) and the environmental conditions in the protected area. Fire detection devices shall be located in such a way as to prevent false alarms.

4.4.2 At least one fire detection device shall be located in each calculation zone.

The maximum area monitored by one fire detection device is 25 m^2.

4.4.3 The distance between the detection devices shall not exceed 6 m and to walls not exceed 3 m. The distance to ceilings shall not exceed 0.3 m. The location of fire detection devices for local application systems shall meet the prevailing conditions.

The horizontal and vertical distance to stored goods or objects shall be at least 0.3 m, except in racks or local application installations.

In the case of roofs with a slope of more than 20° a row of detection devices shall be located near the highest level of the room.

<table>
<tr><th>Room height in m</th><th>Devices refered to in section 4.4</th><th>Device refered to in section 4.3</th></tr>
<tr><td>≤ 8</td><td>allowed</td><td rowspan="2">see CEA Specifications for automatic fire detection and fire alarm systems</td></tr>
<tr><td>> 8</td><td>not allowed</td></tr>
<tr><td colspan="3">Table 7: Detection devices</td></tr>
</table>

5 Control and triggering

5.1 Delay device

5.1.1 To allow people to leave the flooding zone, the discharge shall be delayed for a certain period of time (at least 10 s) after triggering. The pre-warning time shall not be longer than necessary to ensure safe evacuation. If this pre-warning time exceeds 30 s the complete fire protection measures need to be reconsidered by the authority.

5.1.2 It shall be ensured that in any case CO_2 can only be discharged into the protected zone if the pre-warning time has elapsed (e.g. in case of a fault or break down of one or more electrical or electronic components caused, for example, by overload).

5.2 Manual triggering device

5.2.1 The CO_2 installation shall be equipped with a manual triggering device.

Manual triggering devices should be located near the exit, outside the protected rooms or in the case of local application installations near the protected object.

5.2.2 Manual triggering devices shall be installed at normal operating height, at highly visible locations. They shall be protected against being operated accidentally. Each device shall be marked to indicate the protected zone it serves.

5.3 Emergency triggering device

Where a manual emergency triggering device is used it shall be located near the CO_2 supply container. It shall be protected against being operated accidentally. Each device shall be marked to indicate the protected zone it serves.

In no case shall such devices conflict with the requirements for life safety (pre-warning and time delay device).

5.4 Non-electrical lock-off device

5.4.1 Mechanical measures shall be provided to lock-off the CO_2 release.

In multiple-zone systems a non-electrical lock-off device shall be provided for each individual flooding zone.

The non-electrical lock-off device shall not disable the fire detection and alarm functions.

5.4.2 A visual fault indication shall be provided at a continuously manned location or at another highly visible position whenever the CO_2 supply is locked off.

5.4.3 A warning sign, indicating that the CO_2 supply is to be locked-off, before working on the CO_2 installation, is to be affixed at both the CO_2 storage and the access points to the zone protected by the CO_2 installation.

5.5 Emergency stop device

If an emergency stop device is used, then the following conditions shall be fulfilled:

- the emergency stop device shall be effective only for the period during which it is continuously actuated,
- the device shall be active only during the delay time,
- after operation of the emergency stop device, the release of the CO_2 must not start before the delay time specified for the installation has been run,
- the alarm shall continue to sound, while the emergency stop device is actuated ,
- there shall be an indication that the emergency stop device has been actuated at a place where help could be provided. This indication shall remain visible until reset manually.

5.6 Alarm devices

5.6.1 The CO_2 installation shall be equipped with at least one alarm device.

In the event of danger to personnel there shall be two completely independent alarm devices e.g. a pneumatic alarm device powered or triggered by the same source as the time delay device and a monitored electrical alarm device (e.g. 24 V).

5.6.2 An alarm shall be sounded upon triggering.

5.6.3 Audible alarms should be augmented with visual alarm indications.

5.6.4 An alarm shall be sounded at the access points to zones in which life-threatening concentrations of CO_2 have been discharged. It shall continue until such time as normal conditions have been restored, but not less than 30 min.

5.6.5 When the first alarm is started, whenever possible, an alarm signal shall be transmitted to a location, which is continuously manned. Wherever possible, the signals shall also be transmitted to the fire brigade or an alarm receiving centre.

5.7 Wiring

5.7.1 The installation shall comply with national codes, the CEA Specifications for automatic fire detection and fire alarm systems and the following regulations.

5.7.2 The wiring for the CO_2 installation shall be identifiable from all other wiring and cables.

5.7.3 The cable must be so constructed as to avoid an abnormal drop in voltage. To ensure mechanical stability the diameter of the cable strands shall be a minimum of 0.6 mm.

5.7.4 The cable shall « as far as possible » be looped through from one unit to the next in order to keep the number of connections to a minimum.

5.7.5 The cables shall « wherever possible » pass only through protected zones. The cables shall be protected and routed so as to keep damage to the absolute minimum in case of fire; using fire-proof cable as per IEC Standard 331 (resistance period of 3 hours at 750° C) may be advisable.

5.8 Pilot lines and ropes

5.8.1 Pneumatic pilot lines shall be made of galvanised steel, copper or equivalent corrosion-resistant metal. Flexible pipes or hoses etc. shall only be used where fixed pipes are unsuitable.

The strength shall be sufficient for the type of triggering devices used.

5.8.2 The piping shall be arranged so that it cannot be damaged due to its own weight, temperature fluctuations, vibrations, release of the installation or other installation inherent influences. The maximum distance between two supports shall not exceed 2 m for steel pipes and 1 m for copper pipes. All piping shall be accessible.

5.8.3 Ropes with fusible links shall be installed in such a way that damage in the protected area can not occur, for example, through ropes touching parts under voltage.

6 Installation and testing

6.1 Installation

6.1.1 The components shall be installed in such a way that it is possible to inspect them at any time and without undue difficulty.

The components shall be installed so that the hazard of fire, mechanical and chemical damage etc. is minimised.

Fire detection devices shall be installed in such a way that pollution can not occur or they shall be suitable protected.

6.1.2 It is advisable not to route piping and cables through unprotected zones; if this is not possible, the pipe shall in all cases be protected and installed in such a way that damage in case of fire is kept to a minimum.

6.1.3 The inside of the pipe shall be cleaned prior to mounting. The pipes shall be carefully blown out after installation, but before fitting the nozzles.

6.2 Testing

6.2.1 Pipework which may be closed shall be pressure tested with pressures indicated in table 8.

6.2.2 The pipework should be subjected to the prescribed pressure for a period of (30 +10/- 0) min. Not more than 5% loss in pressure shall take place within this period of time. The equipment and pipes shall be carefully emptied and dried after testing.

A visual inspection will be sufficient for pipes downstream from the selector valves. Special attention shall be paid to the correct assembly of threaded connections, bolts and flange bolts.

6.2.3 If pipes cannot be subjected to water pressure testing, then the welded connections can be inspected with the assistance of other methods such as penetrate dye inspection, magnetic techniques, x-rays, etc.

Part of the installation	High-pressure system gauge pressure in bar	Low-pressure system gauge pressure in bar
Between the supply containers and the selector valves	160 ± 5	35 ± 2
All other pipes	80 ± 3	35 ± 2
Table 8: Water pressure testing		

7 Use of the installation

7.1 Instruction and training of personnel

7.1.1 A minimum of two responsible supervisors shall be trained by the installer in the use of the installation.

Personnel who work inside the flooding zone or in adjacent zones shall be thoroughly instructed and trained by the supervisor as to the actions to be taken before, during and after the CO_2 is released.

7.1.2 Personnel assigned to carry out repair or other work, but who are not generally assigned a work site inside the flooding zone, shall commence such work only after having received written permission (date, time and duration) to do so by a responsible supervisor. Such personnel shall also be given training as described above.

7.2 Inspections

7.2.1 Regular inspections shall be carried out to ensure that the installation will function properly.

The frequency and type of inspections will depend on the nature of the installation, national regulations and environmental conditions etc.

7.2.2 The inspections shall be made by qualified personnel specially designated for this work, thoroughly instructed in their duties, with a comprehensive knowledge of the installation.

Daily, weekly and monthly inspections shall be carried out according to the manufacturer's specifications.

7.2.3 Daily inspections

Check all installation indications visually.

7.2.4 Weekly inspections

- fire detection installation,
- quantity of CO_2. If a loss of more than 10% has occurred, the container shall be replaced or topped-up,
- operational position of the valves,
- power supplies.

7.2.5 Monthly inspections

- equipment used to actuate fire doors and hatches, power supplies, etc.,
- audible and visual alarm devices,
- delay device,
- nozzles,
- enclosure,
- additional equipment.

7.3 Log book

A log book shall be maintained. The following entries are to be made:
- the results of inspections,
- maintenance and repair work (reason, nature),
- all other events which affect the installation (e.g. fires, unintentional release, deactivation, faults).

7.4 Other obligations

7.4.1 If any changes are made which could have an adverse influence on the effectiveness of the installation (characteristics of fire risk, enclosure, ventilation), the insurer shall be notified and the installation modified as appropriate.

7.4.2 If the installation is not functional for more than 24 hours, this shall be reported to the insurer, and other bodies, if appropriate.

Other fire prevention measures should be carried out immediately.

8 Maintenance

To ensure the continued availability of the installation in accordance with its approval, regular maintenance including periodical inspections shall be carried out.

Maintenance work shall be conducted in such a way as to keep shut-down periods to a minimum, both in time and extent. In multi-zone installations the zones can be shut down sequentially, so as to disable only a small part of the installation at any one time.

Repair works shall start as soon as possible within 24 hours after the faults have been detected.

Maintenance shall be carried out by an approved installer, preferably by the company which originally installed the system, and shall be carried out at least once a year.

9 Documentation

The installer shall submit technical documentation which shall give sufficient information to enable the evaluation of the risk and the effectiveness of the CO_2 installation:

- Name and location of the risk,
- drawings on a scale not smaller than 1:100,
- protected hazard,
- total flooding or local application installation,
- type, arrangement, direction, surface coverage and performance characteristics of the nozzles,
- type and location of the fire detection devices, manual and emergency triggering devices,
- internal diameters and lengths of the pipes,
- pressure drop data for valves and fittings,
- calculation of the required CO_2 supply quantity,
- hydraulic calculations including appropriate isometric drawings etc.,
- location and size of the CO_2 storage,
- other information, which is necessary for the evaluation of the risk and the CO_2 installation, e.g. pressure test certificate,
- inspection and maintenance instructions.

10 Approvals

10.1.1 An approval inspection shall be carried out by an expert of the insurers, to check that the installation is in accordance with these specifications.

10.1.2 The CO_2 installation shall be designed, installed and maintained in accordance with these specifications by an approved installer.

The approval of the installer shall be given by the insurers according to the CEA specifications for installing firms of security systems against fire and/or theft.

10.1.3 In the installation, only components approved by the insurers shall be used. The appropriate compatibility of the components shall be certified by a system approval. See the list of components in appendix A3.

10.1.4 A flooding test shall be carried out, unless it is possible to use another procedure, to check that the installation complies with these specifications. The development of the CO_2 concentration shall be continuously recorded. The period of time during which the measured concentration values are recorded and logged shall be not less than ten minutes or the required holding time, commencing from the time at which the installation was released.

At least a function test of the CO_2 installation shall be carried out. The minimum amount of CO_2 for this test is the amount which is necessary for reaching the liquid phase at the most unfavourable nozzle.

10.1.5 In rooms with a risk of explosion, prior to the function tests the correct earth connection of the system shall be checked. A check of any explosible mixture in the flooding zone shall be carried out using suitable gas sensors. The user shall give authorisation for the function tests.

If flooding in rooms with a risk of explosion is not possible, the reasons shall be declared in the installation certificate of the installer.

10.1.6 The CO_2 installation and the protected risk shall be inspected at least once a year by an expert of the insurers.

11 Protection for special types of buildings, equipment and occupancies

11.1 Protection of deep-fat fryers and associated vent hoods and ducts

In addition to these specifications for CO_2 installations, the following is to be observed when installing CO_2 fire protection for deep fat-fryers and the associated vent hoods and ducts.

11.1.1 The heating elements for deep fat-fryers and the adjacent cooking ranges may be put into operation only if the associated extraction equipment is running.

11.1.2 Heating elements for deep fat-fryers vats shall be fitted with a thermostat to prevent overheating. National codes shall be observed when designing the overheating protection equipment.

11.1.3 The equipment heating element(s) and the extractor system shall be switched off automatically when the CO_2 system is released.

If, where a central extraction blower is used, it is not possible to shut off the vent hood, a shut-off valve shall be installed in the appropriate branch duct at a point before it joins with the central extraction duct. This flap shall be actuated automatically and simultaneously with the release of the CO_2.

11.1.4 When calculating the amount of extinguishant required, the calculation zone used for the extraction equipment comprises the volume of the extractor hood itself plus the volume of the ductwork up to the blower or the shut-off flap. The concentration factor for the extraction system is $K_B = 1$; the flooding period is 30 s.

11.1.5 For deep fat-fryers vats, 64 kg of CO_2 shall be provided for each m^2 of fat surface area, to handle the extinguishing cycle and in particular to cool down the fat. The CO_2 shall be applied to the surface of the fat over a flooding period of four minutes using « snow-type » nozzles.

11.1.6 Adjacent cooking ranges shall be incorporated into the CO_2 protection concept. The concentration factor for ranges is $K_B = 1$; the flooding period is 30 s.

11.1.7 If nozzles with cross sections of less than 7 mm^2 must be used, then they shall be equipped with a filter installed at the nozzle inlet point. The nozzle and filter shall have been approved from the responsible authorities.

11.1.8 Nozzles within the extraction system shall be protected against the entry of grease.

11.1.9 Deep fat-fryers vats, the cooking ranges and the vent extraction system shall always be flooded simultaneously, when the CO_2 system is released.

11.1.10 Maximum temperature sensors shall be used for fire detection.

They shall be installed:

- in front of the filters,
- inside the vent hood, behind the filters,
- in the vent extraction ductwork; the number here will depend on the length of the duct, but must be at least two.

The fire detection elements shall comply with safety category IP54 specifications. The electrical connection components for the fire detection devices shall be situated outside the venthood and the ductwork.

11.1.11 Only those components and materials shall be employed in CO_2 systems, which are suitable for use under the operating conditions encountered here «heat, oils, grease and cleaning agents».

11.1.12 The suitability of the nozzles selected and the nozzle arrangement shall be demonstrated in pilot applications through fire testing; in all other cases a test flooding cycle shall be executed.

Nozzles of this design shall then be used in the same arrangement for all other installations.

Explanatory note: The methods used to calculate the extinguishant quantity and flooding time for the deep-fat fryer vat differ from the usual determinations used for CO_2 systems. The design extinguishant quantity at 64 kg of CO_2 per m^2 and the flooding period of four minutes were established through extinguishing tests. They ensure that an overheated vat will be cooled enough to prevent the possibility of re-ignition.

For examples for the calculation of the design quantity see appendix A8.

11.2 Protection of enclosed hardening plants

11.2.1 Enclosed hardening plants are systems which are substantially sealed from the outside environment; they are used to heat-treat metals. Working with an automatic charge and feed concept, the metals are heated up to hardening temperature, quenched and drawn.

The hardening plants may be equipped with a quenching vat, which is enclosed by means of an interlocking chamber, or they may incorporate an integrated, open quenching vat.

11.2.2 The function of the CO_2 system described below is to fight a fire, which started at the oil fill in the quenching vat. Also to be considered in this situation are the fire hazards which could arise at associated plant components, such as the interlock door and fume extraction system, or the oil-covered metals.

Particularly when dealing with enclosed quenching vats, the danger of foaming, resulting from water in the oil, shall be taken into account. The oil foam can exit to the outside through openings in the housing and ignite there.

11.2.3 Dependability and effectiveness of the CO_2 system require that additional system design measures be incorporated into the hardening plant. If no sprinkler system is present, then an automatic CO_2 local application system shall be provided to fight fires which could occur at the other external components of the hardening system, e.g. at the controls.

11.2.4 Every furnace shall be provided with a switch used to interrupt automatic control and the supply of heating energy. This switch shall be located at a suitable and easily accessible point.

11.2.5 It shall be possible to drain within a period of three minutes the oil fill from the quenching vat into an enclosed receptacle outside the fire area. Draining may only be initiated manually.

11.2.6 There shall be equipment present to prevent a partial vacuum or an explosive mixture of gas from forming when the system is switched off or the oil is drained. This may be accomplished, for instance, by automatically injecting inert gas.

11.2.7 The quenching vat shall be equipped with the instruments necessary to monitor the fill level and temperature.

11.2.8 The pilot lights for the flare-off unit used with enclosed quenching vats, and at the flame curtain on the interlocking door, shall be provided with automatic, electrical ignition devices.

11.2.9 Any failure of the pilot lights shall be signalled. If the pilot light for the flame curtain at the interlocking door fails, then the door shall be blocked automatically.

11.2.10 The oil fumes and flare gases shall be routed through separate lines. This does not apply to systems in which the oil flames are passed to the flare units together with the heating gas.

11.2.11 The concentration factor K_B is 2.

11.2.12 With enclosed quenching vats the flooding area is formed by the interlocking chambers with the quenching vats, the fume extraction unit and the outer section of the interlocking door with feed table.

11.2.13 In the case of integrated, open quenching vats the flooding area is formed by the ejection shaft and the quenching vat.

11.2.14 The entire volume of the quenching vat is to be used as the basis for calculating extinguishing quantities.

11.2.15 The maximum flooding period is two minutes.

11.2.16 A drain shall be provided at a suitable and easily accessible location along the piping between the hardening plant and the CO_2 supply container. It shall be in the form of a vertical down pipe at least 0.5 m long and with a nominal diameter of at least 15 mm.

11.2.17 It shall be possible to release the CO_2 by hand; it should be possible for the system to be released automatically in response to suitable fire detection devices. The automatic system controls and the supply of heating energy shall be switched off when the system is released.

11.3 Protection of rotary printing presses

11.3.1 For the calculation of the design quantity in addition to clause 2.2.5 the protected volume of the calculation zone shall cover the upper paper width.

Folding machines connected to the presses shall be included in the CO_2 protection.

11.3.2 Additional nozzles shall be installed near colour trays and where upper paper widths are located.

11.4 Protection of painting tunnels

11.4.1 In painting tunnel installations with the air stream directed down from a filter ceiling into the working area with velocities > 0.5 m/s, fire detection devices shall not only be installed below the filter ceiling but also near the grid floor at the longitudinal walls of the compartment.

The distance between fire detection devices shall not exceed 2m, the distance to the grid floor shall be between 0.5 m and 0.8 m.

No detection devices near the grid floor are necessary if the passage colour installation is monitored by flame detectors configured in coincidence connection and the ventilation is shut down automatically by the detection system.

11.4.2 The ventilation system shall be shut down after the delay time has been finished.

If CO_2 is sucked out of the flooding zone by the ventilation system after shut down, this amount of CO_2 shall be added additionally in the calculation of the total design quantity.

11.5 Equipment protection for electric and electronic systems

11.5.1 General

The widespread use of electric and electronic equipment in all types of operations makes it necessary to augment and improve fire protection (e.g. existing room fire protection systems) by installing equipment protection systems incorporating fire detection and extinguishing systems for such equipment.

Equipment protection systems can minimise the damage and downtime caused by fires through early detection and more specific extinguishing. Hazards to the environment and to personnel are reduced by minimising the amount of extinguishant used.
An incipient fire inside or outside electric and electronic equipment, for example at the connectors and other accessories located within the normal airflow pattern, can lead to the fire spreading through the equipment (stack draught effect).
Thus equipment protection systems provide a safety barrier by means of detection, shut-down and extinguishing at critical points.

Equipment protection systems, however, cannot serve as a substitute for room protection.

In addition to these guidelines, the guidelines for the planning and installing of automatic fire detection shall be applied.

11.5.2 Planning

Planning, installation and maintenance shall be co-ordinated between the equipment manufacturer, the user, the insurer and the installer for the fire detection and extinguishing systems. The overall fire protection concept, incorporating the equipment protection system, is dependent on influencing factors which shall be identified by risk analysis. The major influencing factors are:

- internal and external fire hazards,
- personnel safety,
- significance of the equipment in operations,
- interruptions in operation,
- time required for replacement,
- size and location of the building, partitioning and technical equipment,
- size and arrangement of the equipment,
- manned or unmanned operation,
- existing protective measures.

The results of the risk analysis and the individual safety and protection needs will determine the degree of protection. In order to ensure complete fire protection, all the equipment which is force-ventilated by climate control systems shall be protected.

11.5.3 Scope of protection

The following listed equipment may be protected as determined by the risk analysis.

11.5.3.1 Application areas for equipment protection systems include EDP systems and similar electronic configurations such as:

- instrumentation and control systems,
- telecommunication exchanges and PBX equipment,
- CNC machines and/or industrial robots,
- CAD/CAM systems,
- printer systems.

11.5.3.2 The primary devices in EDP systems include those listed below:

- central processing unit,
- disk controllers and disk storage units,
- processors for data teleprocessing/network-submaster station (nodal) computers,
- modem cabinets,
- magnetic cassette systems, robot systems,
- laser printing systems.

Depending on the degree of fire safety required, additional units may be protected; examples include:

- magnetic tape controllers and drives,
- high-speed printers.

11.5.3.3 In order to ensure complete fire protection, all the equipment which is force-ventilated by climate control systems shall be protected. Devices which are a part of the infrastructure, are to be included in the scope of protection such as:

- line power distribution points, energy supply packs (including non-interruptable power supply),
- air conditioning systems and climate-control cubicles.

11.5.4 Planning of the fire detection system

11.5.4.1 The design of the system shall take into account and be adapted to suit the conditions under which the equipment is operating. The following criteria shall be observed when doing so:

- operational and environmental influences (e.g. temperature, humidity, dust, aerosols, vapours, radiation),
- operating mode (e.g. manned and unmanned areas, clarity and accessibility of the devices, intermittent or continuous operation),
- type of cooling (natural draught, forced ventilation, liquid-cooled equipment),
- electromagnetic interferences.

11.5.4.2 Normally smoke detectors shall be used.

11.5.4.3 Units with forced ventilation shall be monitored by aspirating detection systems installed outside the unit itself.

Naturally ventilated units (convection) can also be monitored with point detectors. When liquid media are used for cooling, special adaptations of the above mentioned detection systems may be required, depending on the exact design of the unit.

11.5.5 Detector arrangement

11.5.5.1 The detectors shall be arranged so that the fire parameters are sure to be sensed.

11.5.5.2 Aspirating detection devices shall sense the air in the main cooling air stream. This requirement will usually be satisfied when the inlet openings are positioned as close as possible to the air outlet vent of the unit being monitored. The aspirating detection device shall not adversely affect the flow of cooling air to the unit. Any reduction of the operating safety of the protected units shall be avoided; it shall be possible to carry out maintenance work with minimum hindrance.

The arrangement of the aspirating detection devices shall be co-ordinated with the manufacturer of the equipment.

The nominal electric operating data for the fan in the extraction system shall be monitored. Changes in the air stream in the suction system (e.g. clogging or breaks) which impact on the function shall be indicated.

11.5.5.3 If point detectors, primarily smoke detectors, are installed in units, the volume being monitored shall not exceed 2.5 m^3 per detector. At least one detector shall be installed per unit. If structures inside the units being monitored will hinder the response of the detector, then additional detectors shall be provided.

It is also permissible to install ceiling-mounted point detectors to monitor individual units, taking into account the air flow situation in the room and provided that:

- the distance between the detector and the unit's air discharge opening is small (reference value < 1 m),
- the air exchange rates and/or velocities in the room are negligible,
- the detector can be positioned in the air stream.

11.5.6 Detection zone

The room and equipment detectors shall be connected to separate detection zones. Multiple detectors at a unit or a group of units with functional dependence can be in one detection zone. A maximum of five adjacent units of functional dependence may be monitored with a single aspirating detection system to achieve dependable and selective fire detection in the fire's incipient stage. Further reduction may be necessary:

- as a consequence of the number and type of air discharge openings at the units,
- where units are not positioned immediately adjacent to each other.

Where the distance between units is greater than 5 m or where the units are not dependent in function, then separate aspirating detection systems shall be installed.

11.5.7 Alarms and Control

11.5.7.1 If the report of a fire does not only trigger an alarm but also initiates control functions, then the following specifications shall be observed:

- control procedures which are simple in nature, such as sounding a local alarm or closing doors may be initiated by a single detector or a single group,
- control procedures which are more serious in nature, such as sounding an external alarm or shutting down machinery, shall be activated only when two detectors or two groups have responded,
- control procedures which have grave consequences such as activating the extinguishing system, shut-down with loss of data, or a suspension of operations, shall be initiated only after two groups have responded.

11.5.7.2 In the case of pre-warning, i.e. if a single group or detector in the equipment monitoring system has responded, then:

- an internal alarm (audible and, if necessary, visual) shall be initiated,
- response by a further group or detector in the room monitoring system and/or in the cable gallery can trigger the main alarm for the room or cable gallery.

11.5.7.3 In case of a main alarm, i.e. if a second group or a further detector in the equipment monitoring system has responded , then:

- an alarm (audible and, if necessary, visual) shall be initiated inside the hazard area and the alarm shall be transmitted to a continuously manned location,
- response by a further group or detector in the room fire detection system and/or in the cable gallery should initiate the main alarm for the room or the cable gallery,
- all power to the unit or group of units in the flooding zone shall be switched off,
- the climate control system and climate control cubicles shall be switched off,
- fire isolation barriers and other operating equipment may be operated,
- interlock circuits may be necessary when a second detection zone responds,
- the equipment-centred extinguishing system, if present, shall be activated.

An alarm plan tailored to the particulars of the project shall be prepared, incorporating the measures listed above and any supplementary measures.

11.5.8 Power supply

In the case of equipment protection systems an uninterrupted supply of power for the fire detection equipment and control components including the fan shall be assured for a period of at least four hours.

It shall be possible, following a four-hour period, to operate the alarm devices for the area of the equipment protection system with the maximum energy demand, for a period of at least 30 minutes.

If emergency power sources (substituting for the mains supply) are provided, then the mains feed to the fire detection and control devices for the equipment protection system shall be connected to these sources.

11. 5.9 Selection of the extinguishant

The extinguishant shall be free of residues to the greatest possible extent, shall be minimally corrosive and shall not be electrically conductive. Gaseous extinguishants, and CO_2 in particular, are suitable. The following explanations refer to CO_2.

11.5.10 Calculating the quantity of extinguishant

11.5.10.1 The quantity of extinguishant shall be selected so that a concentration sufficient to extinguish the fire will be built up throughout the unit, to include any areas within the unit which are separated by partitions, internal components, etc. Exceptions are units, such as disk drives, which are sealed in dust-proof enclosures.

11.5.10.2 A concentration factor (K_B) of 1.5 shall be used in calculations. A concentration equivalent to at least K_B=1 shall be created after 20 seconds at the latest and shall be maintained simultaneously at all points within the flooding zone for at least 15 seconds.

11.5.10.3 Several units may be combined to form a flooding zone. Flooding zones shall correspond to one or several detection zones.

11.5.10.4 The amount of CO_2 for a flooding zone is determined by the sum of the design quantities of CO_2 to be used for the individual units plus a surplus of 10%.

11.5.11 Extinguishant supply

11.5.11.1 For high-pressure systems the CO_2 shall be stored in containers charged with 4 kg, 7.5 kg, 20 kg or 30 kg. A weighing device shall be provided to monitor the charge in the CO_2 storage containers for loss.

11.5.11.2 Storage containers of the same or the next larger size may be used to optimise the amount of CO_2 applied in a flooding zone. All the CO_2 storage containers shall be equipped with identical container valves.

11.5.11.3 In multi-zone systems with more than five flooding zones there shall be a CO_2 reserve quantity equivalent to at least the largest CO_2 supply quantity; it shall be permanently attached to the piping network.

11.5.11.4 All CO_2 reserve quantities are to be continuously monitored for loss.

11.5.11.5 The CO_2 supply containers shall be located outside of and as close as possible to the equipment being protected. They may be located in the same room as the protected equipment. They shall be secured against damage and unauthorised tampering.

11.5.12 Piping and hoses

Piping shall be fabricated from galvanised steel or equivalent material. Piping shall be routed and affixed within the equipment in such a way that no damage can arise from temperature fluctuations or vibration. Hoses for flexible connections shall be no longer than necessary and shall be used only where piping would not be suitable.

11.5.13 Selection and arrangement of the nozzles

If the nozzle cross section is smaller than 7 mm^2, then the nozzle shall be fitted with a filter. Nozzle orifices shall have a minimum diameter of 1 mm. The nozzles shall be arranged so that a concentration sufficient to extinguish a fire can be built up throughout the equipment. The nozzles shall be designed and positioned so that devices sensitive for cooling are outside the immediate vaporisation zone.

11.5.14 Control

11.5.14.1 The automatic extinguishing control system shall be automatically activated when the fire alarm is given.

11.5.14.2 It shall be possible to initiate the flooding manually in each flooding zone. The manual control devices shall be clearly marked.

11.5.15 Personnel safety

Due to the fact that the extinguishant is applied selectively and in limited volumes in equipment protection systems, no concentrations which could be hazardous to personnel will as a rule be developed, this is in contrast to room protection concepts. Measures for personnel safety like delay devices and alarm devices will be necessary when flooding in one or several extinguishing zones within a single room will create a CO_2 concentration of more than 5% by volume.

11.5.16 Installation in the unit

11.5.16.1 If modifications, changes or reconstruction of the equipment should be necessary, then the measures required shall be co-ordinated in each individual case between the:

- user,
- equipment manufacturer,
- installer of the equipment protection system.

11.5.16.2 Permanent modifications (e.g. holes) which must be made to install fire protection components, and the associated fastening components in the equipment being protected, shall be avoided to the greatest possible extent, or carried out in such a way that the function of the device is not affected. In the same way, maintenance work shall not be hindered any more than is necessary. Details are to be co-ordinated with the equipment manufacturer.

11.5.16.3 Sensitive electronic devices can be destroyed by electrostatic discharge. The manufacturers regulations for handling devices susceptible to electrostatic voltages shall therefore be observed, in so far as this is required in a particular item of equipment.

11.5.16.4 If components must be installed in equipment the emission of high-frequency electromagnetic radiation shall not exceed the permissible maximum values. The electromagnetic compatibility of the systems, one with another, shall be assured.

11.5.16.5 Piping in units equipped with full screening shall be fastened with the units housing so as to be coaxial connected. The connection to the housing panel is to be made by using a screw and a toothed lock-washer. To ensure sufficient screening, the length of the piping inside the unit shall be at least three times the diameter of the access opening.

11.5.17 Operation

11.5.17.1 Should modifications, changes or reconstruction of the equipment be necessary then the measures required are to be co-ordinated in each individual case between the:

- user,
- equipment manufacturer,
- installer of the equipment protection system.

11.5.17.2 Malfunction reports from equipment protection systems shall be indicated and, if necessary, transmitted so that rectification of the malfunction by the responsible service organisation can be initiated. The user is to co-ordinate the work required.

11.5.17.3 The installer shall be notified after every activation of the equipment protection system to enable him to inspect the system and restore operational readiness.

11.5.18 Inspections

11.5.18.1 Flooding tests are normally not necessary during acceptance tests. If smoke tests are needed to check the fire detection system or the arrangement of the detectors, then non-corrosive test gases are to be used.

11.5.18.2 The user has to make, at least quarterly, visual checks and spot checks of the function of the equipment protection system. Functional checks are limited to those components outside the equipment which will not adversely affect operations.

11.5.19 Maintenance

The maintenance of all the components in the equipment protection system shall be carried out by the installer at the following intervals:

- at least once every six months for components outside the equipment,
- at least once a year for components inside the equipment.

Work requiring intervention in the equipment shall be carried out in co-operation with the manufacturer and the user. The manufacturer’s specifications concerning devices susceptible to electrostatic discharges are to be observed.

12 Electrostatic spraying of flammable liquid and powder coating materials

12.1 Fields of application

This section specifies the additional requirements for the fire protection of electrostatic spraying of flammable liquid and powder coating materials, especially for the protection of:

- electrostatic liquid coating plants for vehicle coating,
- electrostatic liquid coating plants using omega-technique,
- electrostatic liquid coating plants for other applications,
- manually operated electrostatic powder coating plants,
- automatically operated electrostatic powder coating plants.

If, instead of CO_2, other extinguishing agents are used for the equipment protection system, these specifications shall be applied in an analogous way, provided that the extinguishing systems are proved to have the same extinguishing efficiency; this has to be proved by fire and extinguishment tests.

12.2 General

Electrostatic coating systems and their near vicinity are exposed to special fire risks. Specific fire protective measures are necessary due to simultaneous presence of:

- flammable material of ignitable concentration (powder clouds or finely sprayed liquid coating

materials),
- pressurized air,
- the ignition hazard of the electrostatic energy always present during normal operation.

The fire extinguishing installations of coating plants mainly consist of two parts: the booth extinguishing system and the equipment extinguishing system.

The equipment extinguishing system prevents the propagation of a fire and possible subsequent explosions by the use of specific protective measures (early detection, cut-off and local extinguishment).

Equipment extinguishing systems, however, cannot serve as a substitute for a booth extinguishing system.

The schematic drawings in appendix 13 show examples for equipment protection for spraying devices in powder coating plants and in liquid lacquer coating plants.

12.3 Planning

The booth extinguishing system shall be designed according to the CEA Specifications for CO_2 fire extinguishing systems, unless otherwise indicated.

Equipment extinguishing systems shall be planned and installed according to these specifications by an approved installer (approved for this kind of fire detection and extinguishing system) using approved, compatible components (see appendix 12). Approval is given by the insurers.

The design of the fire protection plan shall be co-ordinated by the parties concerned (manufacturer of the coating plant, user, insurers and the companies installing the fire detection and fire alarm system and the fire extinguishing system).

In general the fire protection plan of a coating plant depends on the following factors:

- Internal and external fire and explosion hazards,
- safety of personnel,
- economic importance,
- interruption of production,
- time for replacement,
- size and location of building, constructional separation and technical equipment,
- size and arrangement of the plant,
- automatic or manual operation of the coating plant,
- fire protection measures present,
- further protective devices (e.g. for explosion protection) present.

In order to ensure a thorough fire protection, parts of plant components belonging to the equipment, e.g. filter, cyclones, supply and exhaust ducts of ventilation system, shall also be included in the protection concept.

12.4 Definitions

Spraying equipment: Components forming the spraying system within a coating plant (including spraying devices, ducts containing supply pipes, electrical cables etc.).

Equipment protection (object protection): Protection of spraying equipment by means of fire detection and extinguishing systems.

Equipment detection system: Fire detection system for early detection of fires in the equipment.

Equipment extinguishing system: Fire extinguishing system designed for selective discharge of fire extinguishing agent into the equipment (e.g. spraying device).

Booth: Whole enclosure of the coating plant.

Booth protection: Protection of the complete coating plant (internal space of the booth, including all plant components).

Booth extinguishing system: Fire extinguishing system for discharge of fire extinguishing agent into the whole coating plant.

12.5 Normative references

CEA Specifications for connection pipes and flexible hoses (CO_2: CEA 4013, inert gases: CEA 4017)

CEA specifications for CO_2 fire extinguishing systems - planning and installation (CEA 4007)

CEA specifications for fire detection systems - planning and installation

DIN EN 50176	Automatic electrostatic spraying installations for flammable liquid spraying material
DIN EN 50177	Automatic electrostatic spraying installations for flammable coating powder
DIN EN 50110-1	Operation of electrical installations
DIN EN50110-2	Operation of electrical installations (national annexes)

References for information:

DIN VDE 0833-3	Specification for alarm systems for fire, intrusion and hold-up - Requirements for intruder and hold-up alarm systems
DIN VDE 0105-3	Operation of power installations - Supplementary specifications for rail-borne and trackless vehicles
DIN VDE 0105-4	Operation of power installations - Supplementary requirements for fixed electrostatic spraying equipment
DIN VDE 0165	Installation of electrical apparatus in hazardous areas
VDMA 24371-2	Surface treatment technology - Machines and plants for surface treatment technology - Guidelines for electrostatic coating with plastic powders - Implementing examples

Safety regulations of the German "Berufsgenossenschaften" (for information):

ZH 1/206	Regulations related to safety and health protection: Use of fire extinguishing systems with oxygen replacing gases

ZH 1/250	Safety regulations for electrostatic spraying of flammable liquid coating materials using manual spraying devices
ZH 1/251	Safety regulations for electrostatic spraying of flammable liquid coating materials using stationary spraying devices
ZH 1/443	Safety regulations for electrostatic spraying of flammable powder coating materials using manual spraying devices
ZH 1/444	Safety regulations for electrostatic spraying of flammable powder coating materials using stationary spray plants

12.6 Fire detection and alarm systems

12.6.1 Design

The fire detection and alarm system shall be selected and adopted considering the operational conditions of the equipment. The following factors shall be taken into account:

- operational and environmental conditions (e.g. high voltage, temperature, humidity, mist of lacquer, powder clouds, aerosols, vapours, radiation, powder deposits, fire and explosion hazards),
- mode of operation of the coating plant (e.g. manual or automatic operation, accessibility)
- type of ventilation.

The detectors shall not reduce the operational safety of the protected devices and shall not hinder maintenance works.

In case of inadmissible soiling of detector optics an automatic cleaning and/or monitoring device of the optics is required.

12.6.2 Selection and arrangement of fire detection devices

Because of the very rapid flame propagation to be expected within coating plants, special approved flame detectors shall be used for equipment protection.

Additionally other types of fire detection devices and fire detectors, e.g. for booth protection, could be applied, depending on protection scheme and hazards.

12.6.2.1 Electrostatic liquid coating plants

In electrostatic liquid coating plants fire detection devices shall be located at least at:

- Spraying devices,
- cavities in the course of supply lines, like enclosed supports of portal-type plants, enclosed supply ducts and colour change housings of side and top plants.

Flame detectors used at spraying devices shall be arranged in such a way to detect fires at an early stage at the spraying devices in all operational positions possible.

Flame detectors used in colour change housings shall be arranged in such a way to monitor all points

- inside the colour change housing as well as
- inside the cavities to be protected.

12.6.2.2 Electrostatic powder coating plants

In electrostatic powder coating plants fire detection devices shall be located at least at:

- Spraying device,
- powder exhaust ducts,
- powder recovery plant.

Flame detectors used at spraying devices shall be arranged in such a way to detect fires at an early stage at the spraying devices in all operational positions possible.

Flame detectors used in powder exhaust ducts shall be, with consideration of their characteristics and of the local conditions, installed in such a way to monitor the total cross section of the supply duct in a safe way, even in case of maximum throughput of materials. Here it could be necessary, depending on the cross section of the supply duct, to place detectors not only on the periphery, but also in different planes.

In some cases, the protection of powder recovery plants can be ensured by other preventative protection measures.

12.6.3 Detection zone

The detectors used for protection of booth and equipment shall be connected to separate control circuits.

Note: In case of two line or two detector dependency, coincidence detection, for activation of the booth extinguishing system, the detection zone of the equipment detection system can be used as one of the two loops for activation of the booth extinguishing system in accordance with the CEA specifications for fire detection systems, planning and installation.

12.6.4 Alarm and control system

The alarm and control system shall be tested according to the CEA specifications for electrical automatic control and delay devices.

The following systems shall be automatically activated by detectors:

- local alarm,
- activation of equipment extinguishing system,
- auxiliaries such as shut-off of
  - supply of coating materials or powder coating materials and solvents,
  - high voltage,
  - powder recovery plant,
  - ventilation system of powder coating plants.

An automatic shut-off of ventilation system of liquid coating plants, the complete electrical supply and the conveyors shall be adapted to the individual operational requirements.

The background lighting of the coating plant shall remain operative.

The fire alarm should be transmitted to a permanently manned position.

In addition, manual activation of the equipment extinguishing system shall be possible. The manual activation devices shall be arranged outside the coating plant within its near vicinity, and shall be marked clearly.

In case of manual activation of the booth extinguishing system, the equipment extinguishing system shall also be activated.

Procedures shall be defined for actions (manual and automatically) to be followed after each alarm.

12.6.5 Electrical power supply

Power supply for fire detection and control systems of the equipment extinguishing system shall be installed in accordance with CEA specifications for fire detection systems with the following modifications:

Power supply for fire detection and control systems of the equipment extinguishing system shall be ensured for at least 4 hours. After these 4 hours, alarm devices in the area of the equipment extinguishing system with the highest energy demand shall be operative for at least 30 minutes.

Emergency power plants, if present, shall be connected with the power supply of the fire detection and control systems. This requirement does not substitute the internal emergency power supply of the fire alarm system.

12.7 Extinguishing system

12.7.1 Extinguishing agent

The following requirements in 12.7.2 to 12.7.8 are related to the extinguishing agent CO_2.

For the equipment protection system, CO_2 shall be used in gaseous form.

12.7.2 Quantity of extinguishing agent

The company installing the fire alarm and extinguishing system shall verify the quantity of extinguishing agent required for successful extinction of spraying devices to the insurers. Verification shall be carried out according to appendix 11 for the spraying devices used in the coating plant.

The calculation of the quantity of extinguishing agent to be stored shall be based on the actual flow rates belonging to the actual nozzle pressures at the spraying devices (see also 12.7.3) and a discharge time of at least 10 s. The storage shall be sufficient for at least 5 extinction processes before the indication from the weighing device.

Thus the quantity of extinguishing agent is calculated based on the following formula:

$$Q = Q_{SP} * \cdot t \cdot n \cdot A_L + Q_S \qquad (1a)$$

$$Q_S = 10 \cdot Q_{SP} * \cdot t \cdot n \qquad (2a)$$

Q_S shall fulfil the following relation in any case:

$$Q_S \geq V_{cont} \cdot \rho_{CO_2} + Q_{SP} * \cdot t \cdot n \qquad (3a)$$

where

Q = CO_2-quantity [kg]
Q_{SP} * = Flow rate of CO_2 at the spraying device [kg/s]
t = discharge time [s], for the calculation of the quantity of extinguishing agent it

shall be assumed t = 10 s

n = number of spraying devices

A_L = number of extinction processes (= at least 5)

Q_S = minimum quantity at indication from weighing device[kg]

V_{cont} = Volume of the storage container(s) [m^3]

ρ_{CO_2} = density of gaseous CO_2 at room temperature and the related vapour pressure [kg/m^3]

(e.g. 15 °C and p = 50,9 bar, thus ρ_{CO_2} = 158 kg/m^3)

Note: To ensure that CO_2 for at least one extinction process can be taken out of the CO_2 container without difficulties due to the decrease of temperature and pressure in the container, approximately 10 times this quantity shall be in the container. This is the basis for factor 10 in equation (2).

So the minimum quantity of extinguishing agent is calculated with the following formulas:

$$Q = Q_{SP} * \cdot 10\,s \cdot n \cdot 5 + Q_S \tag{1b}$$

with

$$Q_S = 10 \cdot Q_{SP} * \cdot 10\,s \cdot n \tag{2b}$$

and

$$Q_S \geq V_{cont} \cdot \rho_{co_2} + Q_{SP} * \cdot 10\,s \cdot n \tag{3b}$$

For an estimation of the quantity of fire extinguishing agent a flow rate of 0,02 kg/s per spraying device can be assumed.

Ducts containing paint supply lines, like enclosed supports of portal plants, enclosed supply ducts and colour change housings of side and top plants, as well as in case of powder extraction ducts and powder recovery plants, a concentration factor (K_B) of 1,2 shall be used. A concentration of 40 % (vol.) CO_2 shall be established after at maximum 30 s and shall be maintained for at least 15 s simultaneously at all points of the flooding zone.

The quantity of CO_2 to be stored for one flooding zone is determined by the total quantity of CO_2 required for all objects (calculation zones of one flooding zone) to be protected plus 10 %.

Several objects (e.g. top machine, side machines) to be protected could be grouped to one flooding zone.

12.7.3 Pressure of fire extinguishing agent

For equipment extinguishing systems, the pressure of the fire extinguishing agent shall fulfil both of the following requirements:

- At the interface to coating equipment the pressure of fire extinguishing agent of the protection system of spraying devices shall be at least 2 bar above the switching pressure of the component concerned (e.g. OR-valve).
- The minimum pressure required at the spraying devices results from the minimum pressure determined in the fire and extinguishment tests. Plus an additional safety pressure of 2 bar.

12.7.4 Storage of fire extinguishing agent

For the equipment protection of coating plants, the extinguishing agent shall be used in gaseous form. Therefore storage containers shall not have a dip tube.

The quantity of CO_2 in the CO_2-containers shall be monitored by a weighing device.

The weighing device shall at least give an indication in case of obtaining the calculated minimum quantity Q_S calculated according to 7.2.

If one fire extinguishing system includes more than five separate flooding zones at least one time the maximum required quantity of CO_2 to be stored (according to 12.7.2) shall be available as reserve. This reserve shall be able to supply every flooding zone. Quantities of CO_2 according to 12.7.2 and the reserve quantities can be stored together.

The weighing device shall at least give an indication in case of obtaining the calculated reserve quantity. Then the quantity of fire extinguishing agent to be stored shall be replaced immediately.

CO_2 containers shall be installed outside the coating plant and as near to the coating plant to be protected as possible. They shall be safeguarded against damage and unauthorized access.

The ambient temperature shall not be lower then the temperature in the extinguishing tests according to appendix 11 and the filling factor shall not be higher then in the extinguishing tests.

12.7.5 Discharge time

The total discharge time is equal to the duration of detection of flames by the detectors plus a post extinction time of at least 5 s.

12.7.6 Pipes, hoses and joints

Pipes shall be made of galvanized steel or any other material of equivalent quality. They shall be installed and mounted to prevent damage due to variations in temperature and vibration.

Hoses for flexible joints installed behind the magnetic valve up to the spraying device shall correspond at least to the CEA specifications for connection pipes and flexible hoses, shall not be longer as necessary and shall only be used, if pipes are not appropriate. These hoses shall be designed for pressures according to 7.3.

12.7.7 Nozzles

If the nozzle's orifice is smaller than 7 mm^2 the nozzle shall be equipped with a filter. The minimum diameter of nozzles shall be 1 mm.

Nozzles shall be arranged and designed in such a way to allow the generation of concentration sufficient for extinction. The use of openings for shaping air or other devices servicing the coating process is only permitted if the efficiency is proved by a fire and extinction test.

Nozzles shall be safeguarded against pollution. This protection shall not hinder the CO_2 flow; the type and application of protection shall be certified by the insurers.

12.7.8 Personnel safety

Measures for protection of persons, like delay devices and reliable actuation of alarm are only required, if, due to actuation of one or more extinction area, a CO_2-volume-concentration of more than 5 % could be built-up within the working and traffic area. National regulations related to personnel safety shall be observed.

Actuation of fire extinguishing systems shall be displayed by a local acoustical alarm (visual alarm could be optional).

12.8 Modification of coating plant or parts of it

In case of required measures, modifications or alterations of the coating plant or parts of it, the individual measures shall be co-ordinated by

- the user,
- the manufacturer of the coating plant,
- the company installing the fire extinguishing system

Permanent modifications inside the coating plant due to installation of components of the fire extinguishing system shall be prevented or shall be carried without impairment of function of the coating plant. Maintenance measures shall not be hindered. The details shall be co-ordinated with the manufacturer of the device.

During installation of fire protection systems the sensitive electronic components of the equipment could be influenced or damaged by electrostatic discharges. This is especially applicable for high-voltage components. Therefore, the manufacturer's installation regulations specific for these devices shall be observed in case of components with hazard of electrostatic damage (EMC).

12.9 Operation

Daily inspection of the coating plant including the fire extinguishing system shall be carried out according to the prescriptions of the company installing the fire alarm and extinguishing system.

The user or the person charged by the user shall ensure safe operation of the fire extinguishing system by instructing the personal working in this area. Personnel shall be instructed at least once a year.

Operators shall be instructed according to the safety regulations for CO_2 fire extinguishing systems before commencing to work. A written report on this instruction is required.

Automatic shut-off of the coating plant shall be ensured in case of shut-off or malfunction of the fire extinguishing system.

Registration of malfunctions of the fire extinguishing system shall be displayed and passed to a permanently manned position; the responsible installer shall eliminate the displayed malfunction immediately. The user shall order the required works.

12.10 Inspection and maintenance

The fire extinguishing systems shall be approved after commissioning and inspected annually by an inspector approved by the insurers.

The fire extinguishing system shall be maintained twice a year by the company installing the fire extinguishing system. Shorter maintenance intervals may be required by specific operational conditions or by prescriptions of authorities.

During inspection and maintenance, the whole function of the fire extinguishing system shall be verified. Especially the exact function of nozzles which are connected to the stored quantity of fire extinguishing agent by hoses or which are exposed to increased hazard of pollution shall be verified by use of pressurized air or extinguishing gas.

Appendix A 1
The properties of CO_2

The extinguishing efficiency of CO_2 is due primarily to the reduction of the oxygen content in the air to a value at which the fire is no longer self-sustaining. The cooling effect of CO_2 is minimal, when compared to this smothering effect. Once a fire has been extinguished it may be necessary, in order to prevent re-ignition, to maintain the CO_2 concentration until hot objects have had time to cool down.

Carbon dioxide is a colourless, odourless, non-corrosive and electrically non-conductive gas with a density approximately 50% greater than air. It is generally stored in the liquid phase, under pressure.

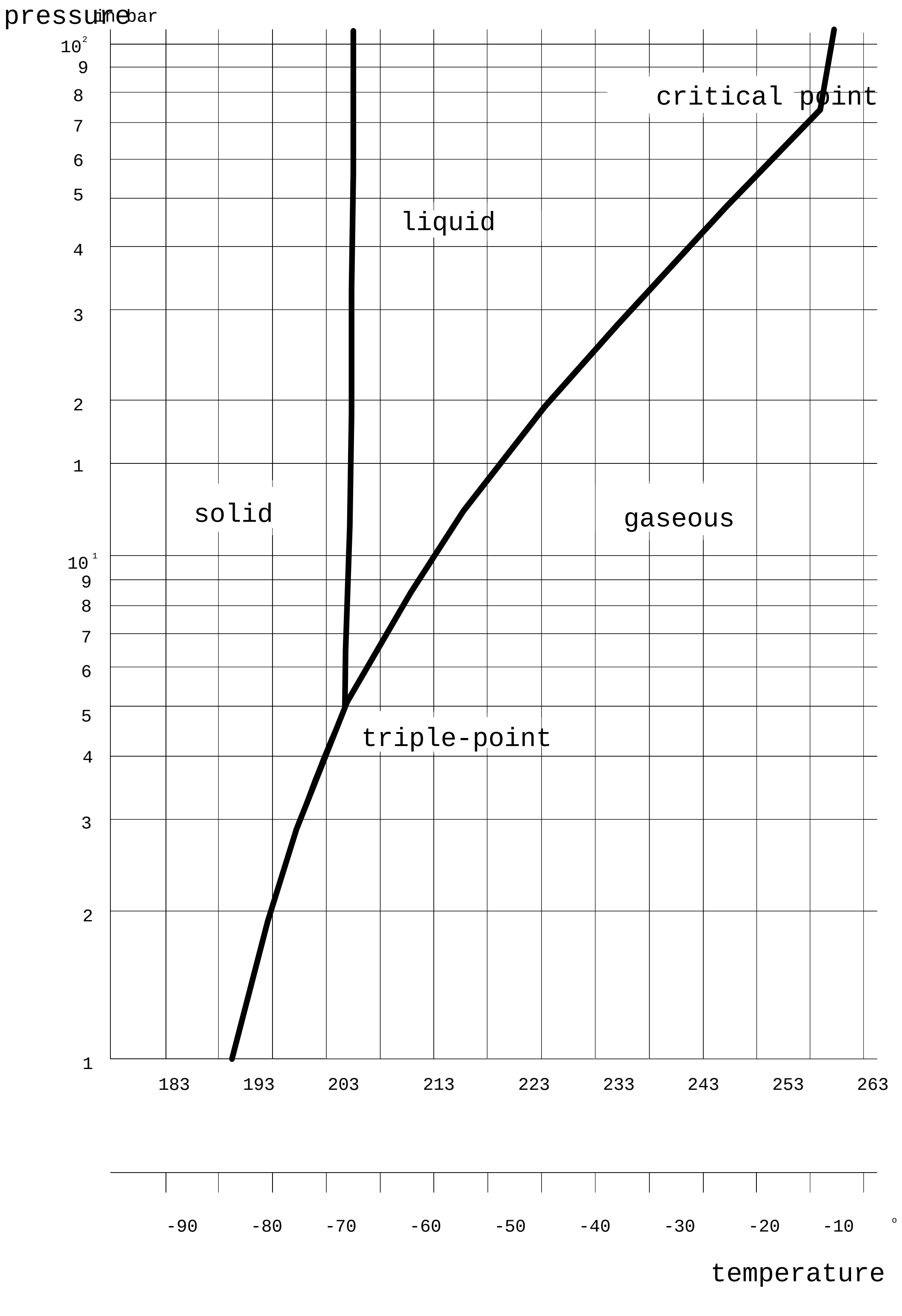
A few of the most important properties of CO_2 are listed below:

Carbon dioxide

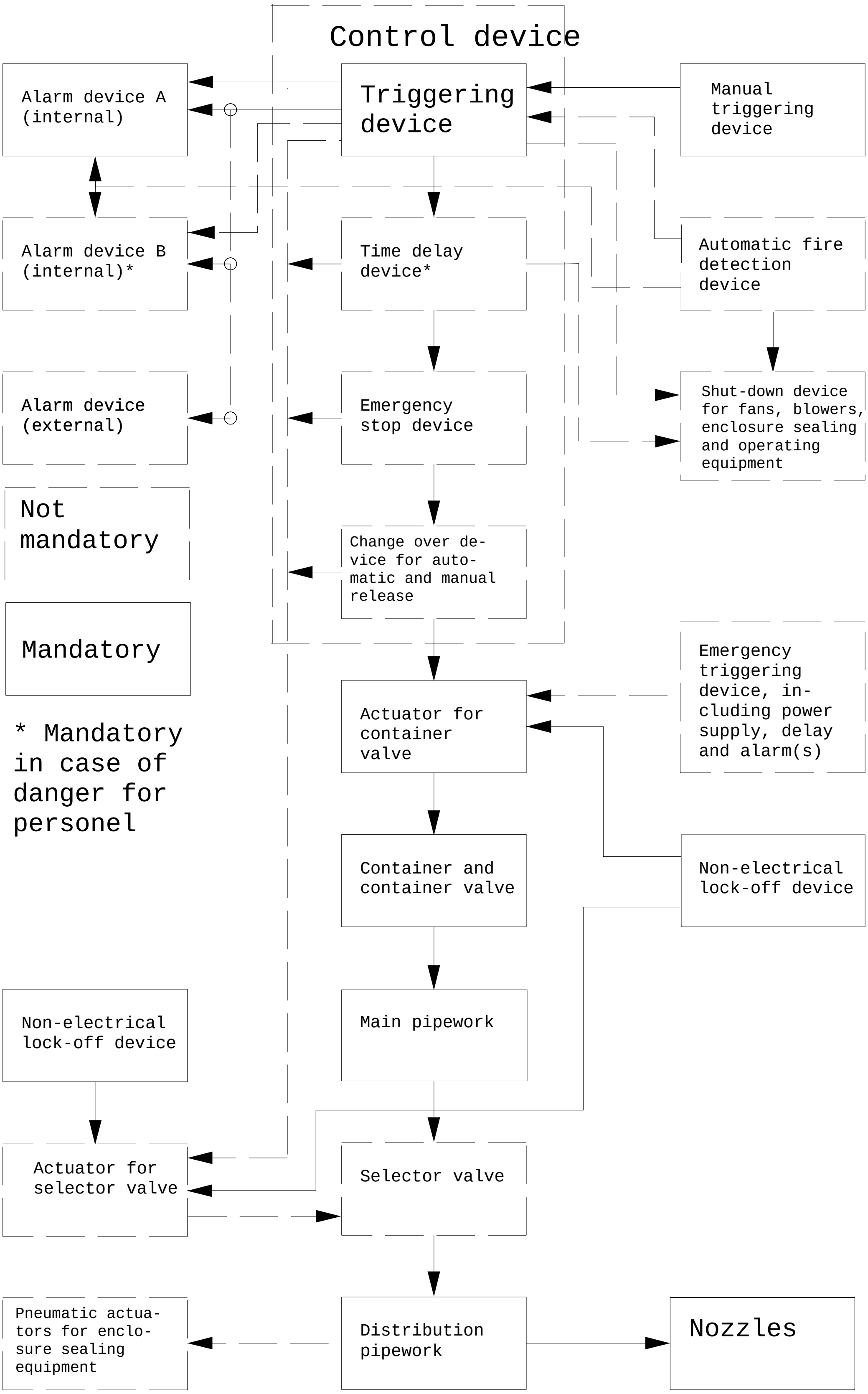
Chemical formula		CO_2
Molecular weight		44.0 g/mol
Density at 0 C and 101 kPa (abs)		1.98 kg/m^3
Relative density compared with air		1.5
Triple point:		-56.6 C
		517.8 kPa (abs)
Critical point:		31.0 C
		7.375 MPa (abs)
Pressure at	-18 C	2.07 MPa (abs.)
	+21 C	5.86 MPa (abs)

Notes: 1 bar = 100 kPa = 0.1 Mpa

The correlation between temperature and pressure in CO_2 (at phase equilibrium) is illustrated in the following graph.


pressure in bar
10²
9
8
7
6
5
4
3
2
1
10¹
9
8
7
6
5
4
3
2
1
critical point
liquid
solid
gaseous
triple-point
183
193
203
213
223
233
243
253
263
-90
-80
-70
-60
-50
-40
-30
-20
-10
°
temperature

Appendix A 2
Block diagram for CO_2 Systems



Appendix A 3
Components

The following listed components shall be approved.

1 Automatic control devices

   a) electrical control

   b) non-electrical control

2 Manual control devices

3 Delay devices

4 High pressure container valves, assemblies and actuators

5 High and low pressure selector valves and their actuators

6 Non-electrical lock-off devices

7 Nozzles

8 Hoses and container connecting pipes

9 Fire detection devices

10 Pressure switches and switch-type pressure gauges

11 Weighing devices

12 Alarm devices

13 Non-return valves and check valves

14 Low pressure container isolating valves

15 Safety valves

16 Odorisers

17 Pipe hangers (if not in accordance with these specifications)

18 Emergency stop devices

19 Pressure gauges

20 System approval

21 Calculation method

Appendix A 4
Test procedure for determining carbon dioxide concentrations for flammable liquids and gases

This appendix corresponds to ISO 6183:1990, Annex A.

Appendix A 5
Structural construction of the enclosure

	Scope	Protected zone	Requirement	fulfilled by
1	Buildings or parts of buildings and their contents shall be protected from fires both inside and outside	Complete building or part of, excluding permissible exceptions (see explanation to A 5)	Enclosure shall be gas tight* and ensure protection from fires in the neighbourhood	Structural or space separation
2	The contents of a room shall be protected from fires both inside and outside	Room	Enclosure (walls, floor and ceiling) shall be gas tight* and ensure protection from fires in the neighbourhood	90 min fire separation according to national specifications, if the adjoining rooms are not protected by approved extinguishing installations
3	The contents of a room shall be protected from fires inside	Room	Enclosure (walls, floor and ceiling) shall be gas tight*	30 min fire separation according to national, specifications or non-combustible material
4	A closed object shall be protected from fires inside	Closed object	Enclosure (walls, floor and ceiling) shall be gas tight*	30 min fire separation according to national specifications, or non-combustible material
5	An open object shall be protected from fires	Open object	None	

** see clause 2.1.3*

Explanation to appendix A5

Appendix A5 shows in table form the relation between the scope of a CO_2 installation and the structural requirements. The underlying principle is based on the same ideas which have to be considered for the development of a protection concept.

Example: The contents (material value) of a room shall not suffer a total loss.

1	2
Fire occuring inside	Fire occuring outside

Protection against 1 (risk from inside):

By means of a CO_2 installation and gas tightness of a room the protection target is fulfilled.

Protection against 2 (Risk from outside):

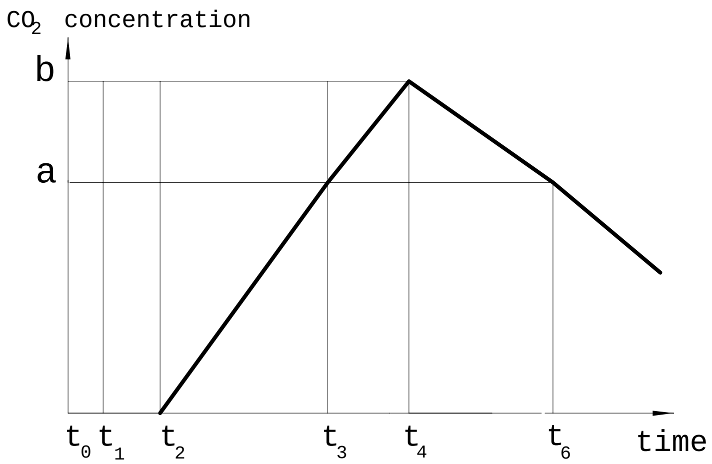
Measures as described above cannot ensure fulfilment of the protection target; structural measures are necessary and shall be assessed as a function of the risk.

The table details the minimum requirements and under the heading « fulfilled by » describes the methods which may be used basically. These two columns will have to be adapted to the type of internal or external risk.

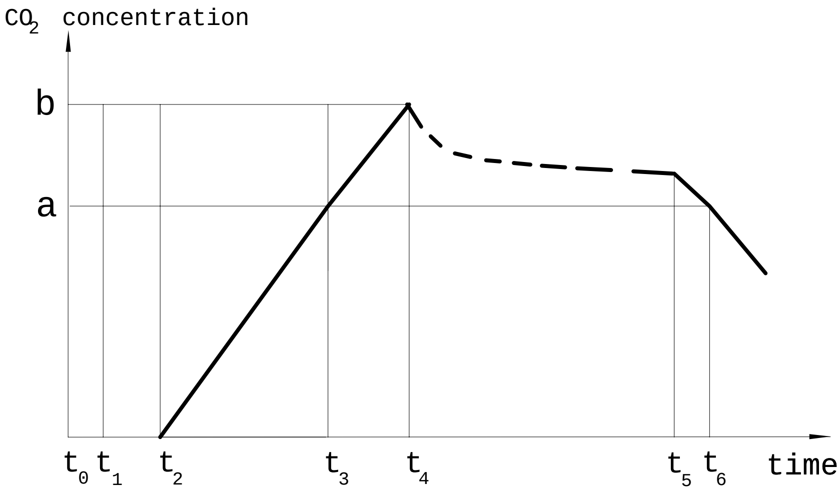
Permissible exceptions

- Rooms that are protected by other approved extinguishing installations.
- Wet process rooms cut off by 90 min fire separations meeting national specifications. The authorities shall be contacted.
- Lavatories constructed of non-combustible materials and with no combustible storage inside. This exception does not apply to dressing rooms.
- Offices and flats with a maximum area of 150 m^2 cut off by 90 min rated fire walls meeting national specifications.
- Staircases that contain no combustible materials.

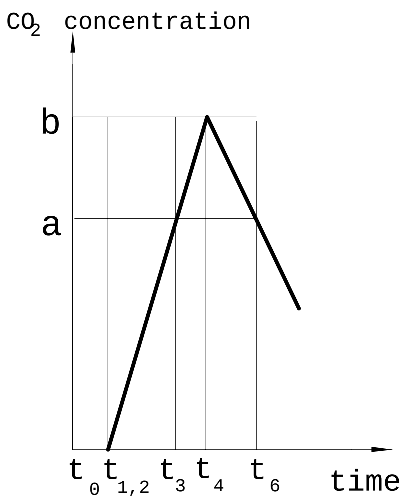
Appendix A 6
Time - concentration diagram of the discharge



Flooding without secondary flooding



Flooding with secondary flooding



Flooding without pre-warning time

$t_0 - t_1$: delay, caused by the system
$t_1 - t_2$: pre-warning time
$t_2 - t_3$: development time for effective extinguishing concentration
$t_2 - t_4$: time to develop maximum concentration
$t_3 - t_6$: holding time
$t_4 - t_5$: duration of secondary flooding
t_0 : moment of response of fire detection or manual triggering device
t_1 : response of alarm device
t_2 : discharge of extinguishing agent
t_3 : achievement of effective extinguishing concentration
t_4 : completion of build-up flooding
t_5 : completion of secondary flooding
t_6 : concentration falls below effective extinguishing concentrati
a : design concentration, given in table 1, 2 or 3
b : maximum achieved concentration

Appendix A 7
Calculation formula for the design of the pipework

A7.1 The pressure drop along the pipe system

The pressure drop of a flowing mixture along a pipe with the length z is calculated as following

$$\Delta p = \Phi_L^2 \times \Delta p_L + \rho_H \times g \times z \times \sin\gamma \qquad (1)$$

with:

$$\Delta p_L = \lambda \times \frac{\rho_L}{2} \times w_L^2 \times \frac{z}{D}$$

$$\Delta p_G = \lambda \times \frac{\rho_G}{2} \times w_G^2 \times \frac{z}{D}$$

$$\Phi_L^2 = 1 + (\Gamma^2 - 1) \text{ x } \{B\ (X_L \text{ x } X_G)^{\frac{2-n}{2}} \quad X_G^{2-n}\}$$

$$\Gamma^2 = \frac{\Delta p_G}{\Delta p_L}$$

$$B = \frac{20 \text{ x } \Gamma + 2\ (1 - 2^{1-n})}{\Gamma^2 - 1}$$

n = 0.25

λ = friction coefficient of the single-phase (recommendation for rough pipes: relation of Colebrook)

Remark: The friction coefficient λ in the equation (1) is corresponding to the single-phase flow and either it can be taken from pipe specific information or it can be determined experimentally with simple measurements of water pressure drop.

A7.2 The local phase change

The CO_2 which flows out of the storage container is in the so-called saturation state; this means that the pressure corresponds to the vapour pressure of the liquid temperature. During the flow in the pipe system a pressure drop takes place, to which the liquid temperature adapts. Thereby energy for the evaporation of fluid CO_2 is available.

Ignoring the initial energy supplied by the pipe system which has an ambient temperature, the thermodynamic process in the flowing mixture corresponds to an adiabatic expansion.
The differential enthalpy equation leads to the following differential equation for the vapour fraction in the pipe:

$$\frac{d\,x_g}{d\,T} = x_g \cdot \frac{C_{pG} - C_{pL}}{h_L - h_G} + \frac{C_{pL}}{h_L - h_G} + \frac{1}{T(v_L - v_G)}$$

$$. \left[x_G \,.\, v_G\,(1 - \beta_G \,.\, T) + (1 - x_G)\,.\, v_L(1 - \beta_L \,.\, T)\right] \qquad (2)$$

with $x_G = 0$ at $T = T_0$.

T (T_{SAT}) corresponds to the local saturation temperature in the pipe and can be ascertained by the calculation of pressure drop (1) and by the curve of vapour pressure.

A7.3 The working pressure point in the CO_2 container

When fire extinguishing systems are engineered the pressure drop in the pipe system and the nozzle inlet pressure (which is coupled with the pipe system) must be fixed at a reference value of the container pressure. But during the expansion process the pressure in the pipe system falls, so that the choice of a reference pressure must be arbitrary. Because of the critical rate of flow the choice of such a reference or so-called « working » pressure point is justified. Due to the critical flow phenomenon the mass discharge remains independent of the container pressure during the fluid emitting phase. At the same time the nozzle inlet pressure shows a nearly linear behaviour during this decisive expansion phase.

Because of these two phenomena it is permissible to choose the pressure, which occurs when half the weight in CO_2 has flowed out of the nozzles as the so-called working pressure point. Proceeding from this working pressure point both the pressure drop in the pipe system and the nozzle flow rate are determined.

To calculate the working pressure point in the storage container the enthalpy balance can also be used. For the working pressure point, the actual container temperature T_A can be found by integration of the differential equation.

$$T_A = T_o + \frac{1}{a} \times \ln \left(\frac{\frac{1}{2} - \frac{M_R}{M_o} + b}{1 + b} \right) \qquad (3)$$

with:

$$a = \frac{C_{pL} \times \rho_L - C_{pG} \times \rho_G}{\Delta h \times \rho_G}$$

$$b = \frac{C_{pG} \times \rho_G + \frac{M_M}{M_0} \times C_{pM} \times \rho_L}{C_{pL} \times \rho_L - C_{pG} \times \rho_G}$$

$M_R = CO_2$ - mass in the pipe

M_M = mass of the container wall

$M_0 = CO_2$ - mass at the beginning

The enthalpy balance is based on the supposition that the state of saturation in the storage container is maintened. Consequently the working pressure point can be found by the relation for the actual container inside temperature T_A with the help of the vapour pressure curve.

$$P_A = P_{SAT}(T_A) \qquad (4)$$

A7.4 The universal calculation set-up for the nozzle pressure drop

The nozzles for the distribution of CO_2 in protected areas are differently constructed and installed. Because of the establishment of a calculation method that covers all nozzle designs, a universal analytical model must also be made available that can cover all nozzle designs.

It can be supposed that the flow homogenises and that no velocity slip between the phases occurs when the two-phase mixture flows in the nozzle. Consequently it may be calculated with the homogenous density ρ_H and with the (to the density corresponding) homogenous velocity w_H.

$$\frac{1}{\rho_H} = \sum_K \frac{x_K}{\rho_K} \qquad (5)$$

$$w_H = \frac{M^*_{TOT}}{A \times \rho_H} \qquad (6)$$

with:

A = cross section of all nozzle orifices (m^2)

M^*_{TOT} = total mass flow (kg/s)

X_K = mass fraction of the phase K (-)

ρk = density of phase K (kg/m^3)

The so-called nozzle inlet pressure is set for the as certainment of the substance data of the mixture.

The pressure drop of a nozzle can be described by the following term:

$$\Delta p_{nozzle} = k_1 \times Re_H^{k_2} \times n_B^{k_3} \times \left(\frac{D_R}{D_B}\right)^{k_4} \times w_H^{\bar{k}_5} \times \rho_H^{\bar{k}_6} \qquad (7)$$

with:

$\bar{k}_5 = 2+k_5 \text{ x } \varepsilon_L \text{x}(1-\varepsilon_L)$

$\bar{k}_6 = 1+k_6 \text{ x } \varepsilon_L(1-\varepsilon_L)$

$k_1, k_2, k_3, k_4, k_5, k_6$: resistance coefficients for one nozzle type

$$Re_H = \frac{w_H \times \rho_H \times D_B}{\mu_H} \text{ : homogeneous Reynolds number}$$

$$\mu_H = \sum x_K \times \mu_K \text{ : homogeneous viscosity}$$

$$\varepsilon_L = x_L \frac{\rho_H}{\rho_L}$$

with:

D_B = diameter of the nozzle orifice .... (m)
D_R = diameter of the supply-connection .... (m)
μ_K = viscosity of the phase K .... (kg/ms)

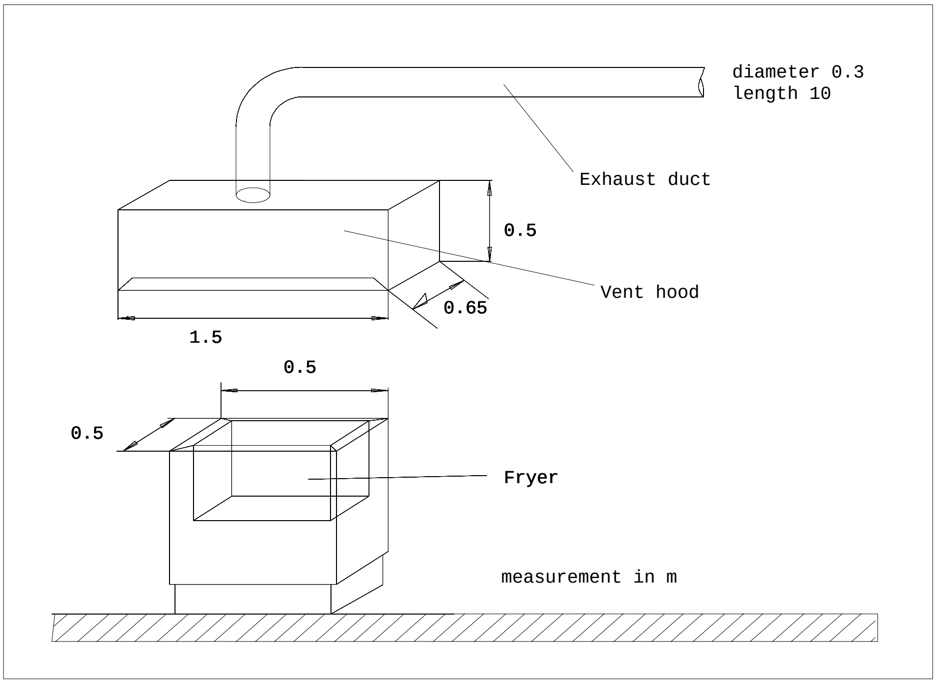
Index of symbols

A	:	area ....m^2
β	:	heat expansion coefficient 1/K
C_P	:	specific heat ....J/kg K
D	:	diameter .... m
g	:	acceleration due to gravity .... m/s^2
h	:	specific enthalpy ....J/kg
M	:	mass .... kg
M*	:	mass flow .... kg/s
ρ	:	pressure ....Pa
v	:	specific volume .... m^3/kg
w	:	velocity .... m/s
x	:	mass transport fraction .... -
z	:	length .... m
γ	:	horizontal angle .... -
ε	:	room volume fraction .... -
λ	:	resistance coefficient of pipe .... -
P	:	density .... kg/m^3
μ	:	viscosity .... kg/ms
ϕ	:	two-phase multiplier .... -

Subscripts

A	:	actual
G	:	gas/vapour
K	:	phase K
M	:	metal
SAT	:	saturation
B	:	orifice (drill hole)
H	:	homogeneous
L	:	liquid
R	:	pipe
0	:	start

Appendix A 8
Calculation examples for the protection of deep-fat fryers and associated vent hoods and ducts



CO_2 design quantity for extractor hood

Vent hood:

V_{T1} = 1.5 m x 0.65 m x 0.5 m = 0.49 m^3

A_{T1} = 2 x 1.5 m x 0.65 m + 2 x 0.5 m x 0.65 m + 2 x 1.5 m x 0.5 m = 4.10 m^2

A_{OT1} = 1.5 m x 0.65 m = 0.98 m^2

Exhaust duct:

V_{T2} = 0.785 x (0.3 m)^2 x 10 m = 0.71 m^3

A_{T2} = 3.14 x 0.3 m x 10 m = 9.42 m^2

A_{OT2} = 0.785 x (0.3 m)^2 = 0.07 m^2

Total:

$V_T = V_{T1} + V_{T2}$ = 0.49 m^3 +0.71 m^3 = 1.20 m^3

$A_T = A_{T1} + A_{T2}$ = 4.10 m^2 + 9.2 m^2 = 13.52 m^2

$A_{OT} = A_{OT1} + A_{OT2}$ = 0.98 m^2 + 0.07 m^2 = 1.05 m^2

$$Q = \left(\left(0.2\,\mathrm{kg}/\mathrm{m}^2\right) \times \frac{A_T + 30A_{TO}}{V_T + V_Z} + 0.75\,\mathrm{kg}/\mathrm{m}^3\right) \times K_B \times (V_T+V_Z)$$

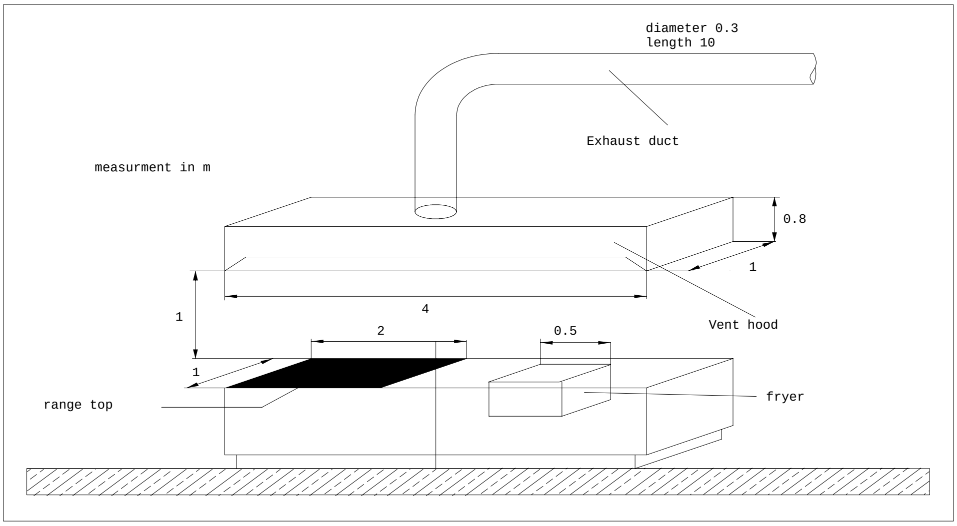
$$Q = \left(\left(0.2^{kg}/m^2\right) \times \frac{13.52m^2+30 \times 1.05m^2}{1.2m^3 + 0m^3} + 0.75^{kg}/_{m3}\right) \times 1 \times (1.2m^3 + 0m^3) = 9.90kg$$

CO_2 design quantity for the deep-fat fryer

Fryer fat:

$A = 0.5\ m \times 0.5\ m = 0.25\ m^2$

$$Q = 0.25\ m^2 \times 64\ {}^{kg}/_{m^2} = 16\ kg$$



CO_2 design quantity for extractor and range top

Vent hood:

$V_{T1} = 4\ m \times 1\ m \times 0.\ m = 3.20\ m^3$

$A_{T1} = 4\ m \times 1\ m + 2\ m \times 1\ m + 2 \times 4\ m \times 0.8\ m + 2 \times 1\ m \times 0.8\ m = 14.00\ m^2$

$A_{OT1} = 2\ m \times 1\ m = 2\ m^2$

Exhaust duct:

$V_{T2} = 0.785 \times (0.3\ m)^2 \times 10\ m = 0.71\ m^3$

$A_{T2} = 3.14 \times 0.3\ m \times 10\ m = 9.42\ m^2$

$A_{OT2} = 0.785 \times (0.3\ m)^2 = 0.07\ m^2$

Range top:

$V_{T3} = 2\ m \times 1\ m \times 1\ m = 2\ m^3$

$A_{T3} = 2\ m \times 1\ m + 2 \times 1\ m \times 1\ m + 2 \times 2\ m \times 1\ m = 8\ m^2$

$A_{OT3} = 2 \times 1\ m \times 1\ m + 2 \times 2\ m \times 1\ m = 6\ m^2$

Total:

$V_T = V_{T1} + V_{T2} + V_{T3} = 3.20\ m^3 + 0.71\ m^3 + 2\ m^3 = 5.91\ m^3$

$A_T = A_{T1} + A_{T2} + A_{T3} = 14\ m^2 + 9.42\ m^2 + 8\ m^2 = 31.42\ m^2$

$A_{OT} = A_{OT1} + A_{OT2} + A_{OT3} = 2\ m^2 + 0.13\ m^2 + 6\ m^2 = 8.13\ m^2$

$$Q = \frac{\left((0.2\ kg/m^2) \times A_T + 30\ A_{TO} + 0.75\ kg/m^3\right) \times K_B \times (V_T + V_Z)}{V_T + V_Z}$$

$$Q = \frac{\left((0.2\ kg/m^2) \times 31.42\ m^2 + 30 \times 8.13\ m^2 + 0{,}75 kg/m^3\right) \times 1 \times (5.91 m^3 + 0 m^3)}{5.91\ m3 + 0\ m} = 59.5 kg$$

CO_2 design quantity for the deep-fat fryer

Fryer fat:

$A = 0.5\ m \times 0.5\ m = 0.25\ m^2$

$Q = 0.25\ m^2 \times 64\ {kg}/{m^2} = 16\ kg$

Appendix A 9
Pressure relief openings for CO_2 protected rooms

Equation for the calculation of the pressure relief opening:

$$A = \frac{M_{CO_2}^{*} \cdot v_{CO_2}}{\sqrt{\Delta p \cdot v_{HOM}}} \cdot C_2$$

A9.1 Pressure drop through an opening

$$\Delta p = C_1 \cdot \frac{\rho_{HOM}}{2} \cdot w_{HOM}^{2} \qquad (1)$$

The resistance coefficient C_1 for openings is depending on the geometry of the opening and in most cases it is situated in the following range:

$0{,}5 < C_1 < 2{,}5$.

A9.2 Mass flow through an opening

$$M_{HOM}^{*} = V_{HOM}^{*} \cdot \rho_{HOM} \qquad (2)$$

A9.3 Volume flow through an opening

$$V_{HOM}^{*} = A \cdot w_{HOM} \qquad (3)$$

A9.4 Homogenous mixture density, homogenous specific volume

$$\frac{1}{\rho_{HOM}} = \frac{x_{air}}{\rho_{air}} + \frac{x_{CO_2}}{\rho_{CO_2}}$$

$$\rho_{HOM} = \varepsilon_{air} \cdot \rho_{air} + \varepsilon_{CO_2} \cdot \rho_{CO_2}$$

$$\frac{1}{\rho_{HOM}} = v_{HOM}$$

Assumption:

The volume flow of the extinguishing gas $V^{*}_{CO_2}$ is equivalent to the relief volume flow : V_{HOM}

$$V_{CO_2}^{*} = V_{HOM}^{*}, \quad V_{CO_2}^{*} = \frac{M_{CO_2}^{*}}{\rho_{CO_2}}$$

A9.5 Rearranging for calculating the surface of the relief opening:

(3) rearranged for A:

$$A = \frac{V_{HOM}^{*}}{w_{HOM}} \qquad (4)$$

(2) rearranged for V_{HOM}^{*} :

$$V_{HOM}^{*} = \frac{M_{HOM}^{*}}{\rho_{HOM}} = \frac{M_{CO_2}^{*}}{\rho_{CO_2}} \qquad (5)$$

(1) rearranged for w_{HOM} :

$$w_{HOM} = \sqrt{\frac{2 \cdot \Delta p}{C_1 \cdot \rho_{HOM}}} \qquad (6)$$

(5) and (6) set into (4):

$$A = \frac{\dfrac{M_{CO_2}^{*}}{\rho_{CO_2}}}{\sqrt{\dfrac{2 \cdot \Delta p}{C_1 \cdot \rho_{HOM}}}} \qquad (7)$$

Rearranging and simplifying of equation (7):

$$A = \frac{\dfrac{M_{CO_2}^{*}}{\rho_{CO_2}}}{\sqrt{\dfrac{2 \cdot \Delta p}{C_1 \cdot \rho_{HOM}}}} = \frac{M_{CO_2}^{*} \cdot \sqrt{C_1 \cdot \rho_{HOM}}}{\rho_{CO_2} \cdot \sqrt{2 \cdot \Delta p}}$$

With the coefficient C_2

$$C_2 = \sqrt{\frac{C_1}{2}}$$

the pressure relief surface is found to be

$$A = \frac{M_{CO_2}^{*} \cdot \sqrt{\rho_{HOM}}}{\rho_{CO_2} \cdot \sqrt{\Delta p}} \cdot C_2 = \frac{M_{CO_2}^{*} \cdot v_{CO_2}}{\sqrt{\Delta p \cdot v_{HOM}}} \cdot C_2$$

C_1 can be equated with 2 in case of openings with a high flow resistance (e.g. louvers which get into 45^o). This simplifies the formula, because then C_2 is equated with 1.

Index of symbols:

A	= opening surface	m^2
M^*	= mass flow	kg/s
Δp	= allowable pressure increase in the enclosure	Pa
v	= specific volume	m^3/kg
V*	= volume flow	m^3/s
w	= flow velocity	m/s
x	= mass fraction	≤ 1
ε	= volume fraction	≤ 1
ρ	= density	kg/m^3

Subscripts:

HOM = subscript for homogenous mixture

CO_2 = subscript for CO_2

Example

A room system brings 300 kg CO_2 into a protected volume within a discharge period of 60 s. The CO_2 quantity was calculated for an extinguishing concentration of 34 % by volume. The enclosure is lightweight constructed with glazing and it can be exposed to a maximum over pressure of 100 Pa.

$$A = \frac{M_{CO_2}{}^* \cdot v_{CO_2}}{\sqrt{\Delta p \cdot v_{HOM}}}$$

With

$$M_{CO_2}{}^* = \frac{300\ kg}{60\ s} = 5\ \frac{kg}{s}$$

$$\Delta p_{max} = 100 Pa$$

$$v_{CO_2} = 0.506\ \frac{m^3}{kg}$$ at 0 C, 1013 mbar

$\rho\ CO_2 = 1.977\ \frac{kg}{m^3}$ at 0 C, 1013 mbar

$$\rho_{HOM} = \varepsilon_{air} \cdot \rho_{air} + \varepsilon_{CO_2} \cdot \rho_{CO_2}$$

$$\rho_{HOM} = (0 \cdot 66 \cdot 1 \cdot 29 + 0 \cdot 34 \cdot 1.977)\ \frac{kg}{m^3} = 1.52\ \frac{kg}{m^3}$$

at 0 C, 1013 mbar

$V_{HOM} = 0.656\ \frac{m^3}{kg}$ at 0 C, 1013 mbar

it follows

$$A = \frac{5 \cdot 0.506}{\sqrt{100 \cdot 0.656}}\ m^2 = 0.312\ m^2$$

Appendix A10
Example for the design of pipes and pipe connections

A10.1 For the selection of pipes the publication « AD - Merkblatt W 10 - Werkstoffe für tiefe Temperaturen, Eisenwerkstoffe » - (materials for low temperatures, ferrous materials) - shall be taken into consideration. Only pipes according to table A10.1 shall be used.

A10.2 The wall thickness shall be calculated according to DIN 2413 «Geltungsbereich I» (ISO/DIS 10400-1989) and «Merkblatt W 10». The pipe dimensions shall be selected according to DIN 2448/DIN 2458 (ISO 4200-1985) and shall have normal wall thickness as a minimum.

A10.3 For all pipes of low pressure systems and the nozzle pipework of high pressure systems a certificate according to EN 10204 is necessary. In the certificate the design of the pipes according to the necessary working pressure shall be confirmed.

A10.4 The design of manifolds and distribution pipes in accordance with the necessary working pressure shall be confirmed in a factory certificate according to EN 10204. All materials used shall be specified in the certificate.

A10.5 The installed pipes between container and selector valves shall be pressure tested with water for 60 minutes according to the test pressure listed in table A10.1.

A10.6 Only qualified welders, examined according to EN 287 Part 1 (DIN 8560-G-RIm or DIN 8560-E-RIm, for the material St 35.8 class RII) shall do welding work. The welded seams shall be in accordance to class CS or BK of DIN 8563.

A10.7 Fittings shall be designed for the possible working pressures and be suitable for use under low temperature (ca. -50 C) conditions according to table A10.2.

A10.8 All pipe sections between container and selector valve shall be stamped by an authorised person to allow identification even when installed. Manifolds and distribution pipes could be stamped as a unit by an authorised person if identification of the unit according to the factory certificate is possible.
Each welding seam shall be marked with a stamp by the welder, to permit a clear identification between the seam and welder.

The fittings shall be marked with a red colour point and stamped with the letter « D ».

Section	**Working pressure in bar**	**Test pressure in bar[1)]**	**Type of pipe**	**Standard**	**Material**	**Quality class**	**Certificate according to EN 10204**
High pressure systems between container and selector valve[2)]	120	160	seamless seamless welded welded	DIN 1629 DIN 17175 DIN 1629 DIN 17177	St 37.0 St 35.8 St 37.0 St 37.8	 I I	3.1.B 3.1.B 3.1.B 3.1.B
High pressure systems downstream the selector valve	60	80	seamless welded	DIN 1629 DIN 1629	St 37.0 St 37.0		2.2 2.2
Low pressure systems between container and selector valve2), downstream the selector valve	25	40	seamless welded	DIN 1629 DIN 1629	St 37.0 St 37.0		2.2 2.2

Table A10.1 : Requirements for pipes

1) *The tightness of the pipes shall be tested by a pressure test with water according to the pipe standard or a adequate test such as x-rays.*

2) *Appropriate pressure relief valves shall prevent the increase of the working pressure in the case of an untightness of the container valve.*

Working pressure in bar	**Test pressure* in bar**	**Fitting according to**	**Material**	**Certification according to EN 10204**
120	160	DIN 2950	GTW-40-05	2.2

Table A10.2: Requirements for fittings

** If the fitting is hydraulically type tested with 300 bars pressure this test can be omitted.*

Appendix A11
Fire and extinction tests on electrostatic spraying devices for powder coating materials and liquid lacquers

A11.1 Test arrangement

Figures A11.1 to A11.3 show a schematic view of the required test arrangement. The spraying devices and the control systems used shall comply with those currently used in the coating plant. Table A11.1 shows the test criteria.

A11.2 Test criteria

Substances sprayed	Standard epoxy-polyester mixture and A 1 - solvent
Type of spraying device	Type used for the correspondent application. In some cases, approval of similar types is possible without individual test.
Tested object	For tests with spraying devices for powder coating materials: Steel box, open fronted, having the dimensions 800 mm x 600 mm x 300 mm; for tests with spraying devices for liquid lacquers: component of car body, e.g. mudguard, door,
Distances	Distance between spraying device for powder coating materials and tested object shall be 300 mm, 500 mm and 800 mm. For tests with spraying device for liquid lacquers, a distance of 300 mm is sufficient.
Preburning time	The preburning time after response of the detector is 3 s.
Extinction time	The total extinction time is equal to the duration of flame detection plus a post extinction time of 5 s.
Number of tests	Every test shall be carried out with and without tested object (steel box, car body component). For tests with spraying devices for powder coating materials the different distances between spraying device and tested object shall also be verified.

Table A11.1: test criteria

A11.3 Test description

In order to carry out fire and extinction tests the spraying devices shall be mounted with fire detection, alarm and fire extinguishing systems. In order to simulate the maximum number of spraying devices, one nozzle shall be installed as bypass of the spraying device. Before beginning the test, it shall be verified that this nozzle complies with the number of spraying devices to be simulated and that the splitting of the CO_2 mass flow is correct between nozzle and spraying device. For the approval, the number of spraying devices determined by the test is reduced by two for safety reasons.

The maximum possible length of ducting for system to be approved with appropriate diameters shall be installed for the test between solenoid valve and spraying device.

The minimum possible length of ducting for system to be approved with appropriate diameters shall be installed for the test between storage container and solenoid valve to ensure worst case situation for taking gas phase out of the container.

The storage container shall be the size for use in real installations, shall have the maximum filling factor that will be used for real installations and they shall be conditioned at the lowest anticipated ambient temperature for a minimum of 16 hours prior to conducting the test. This is to ensure worst case situation for the possibility of taking gaseous CO_2 from the container.

The temperature in the test room shall be 20°C +5°C/-10°C.

The tests shall be conducted in an enclosure that meets the following requirements:

- distance between spraying device and backward wall: at least 0,1 m,
- distance between test object and surrounding walls: at least 1 m, in spraying direction at least 2 m.

The powder coating materials are sprayed by the spraying device to be tested. The mixture shall be such that the most vigorous flame is generated. The powder is supplied by a standard supply device. Here, the maximum characteristics of the spraying device shall be observed.

At the spraying devices for liquid lacquer A 1-solvents are sprayed. The use of liquid lacquer could be neglected, since the rinsing process during colour change during which a high quantity of solvents is sprayed, is, with regard to fire prevention, the most hazardous state of operation. By supply of pressurized air to the turbine in order to reach the maximum speed of rotation the spraying device shall reach the maximum admissible operational pressure according to the manufacturer for fine atomization of solvents. The solvent shall be supplied to the spraying device via a supply device with adjustable pressure. The pressure shall be adjusted within the admissible range according to the manufacturer's indications in order to generate the most vigorous flame.

Starting at a horizontal distance of 200 mm from the powder cloud or solvent mist, a high-voltage igniter shall be introduced into the powder cloud or solvent mist until ignition occurs.

Under test conditions, the supply of powder and solvents is not shut-off simultaneously with actuation of fire extinguishing agent.

During the fire and extinction tests, after response of the detector actuation of the fire extinguishing system is delayed by 3 s (preburning time).

The efficiency of the fire extinguishing system is considered to be proven if the fire is extinguished within 3 s after the preburning time.

The extinction time of 3 s mentioned above shall be measured by optical sensors.

It shall be ensured, that the reaction time between ignition of flame and response of the electrical actuation valve is < 150 ms.

The container shall not be empty after the test (including the post extinction time of 5 s).

The report shall include at least the following information:

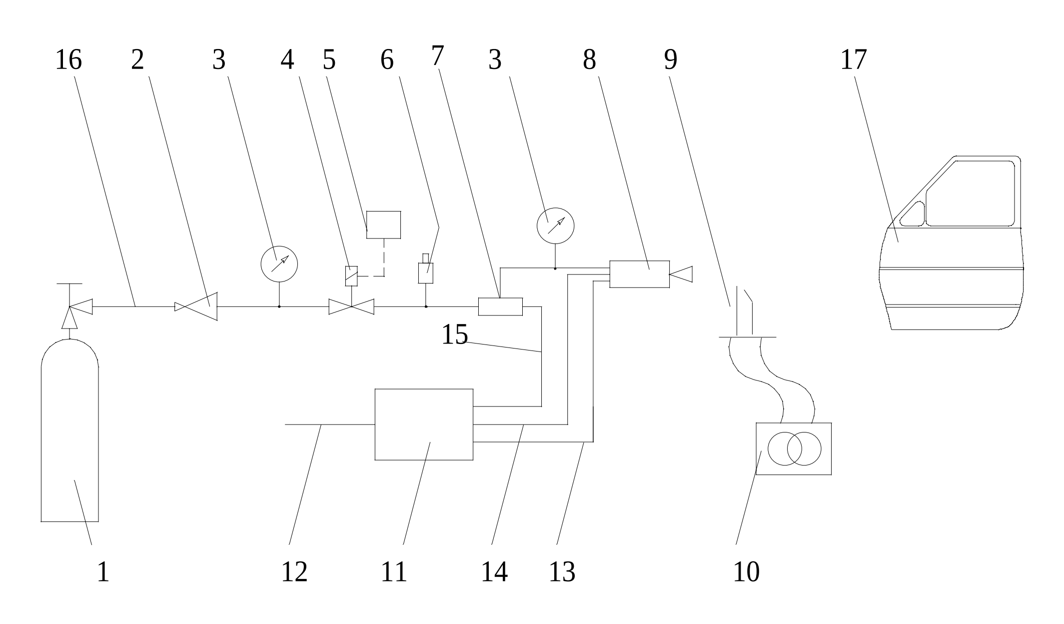
- description of test enclosure including room temperature (before the test),
- description of the products used in the test (spraying device (engineering drawings etc.) and related devices, piping with diameters and lengths, valves, nozzle, type of solvent or powder, detection and triggering system),
- number of spraying devices that are simulated by the nozzle,
- storage conditions of the containers (volume of the container, filling factor, temperature) before

the test,

- pressure at solenoid valve and spraying device during the test,
- quantity of CO_2 discharged during the test (weighing of the container before and after the test) for calculation of the mass flow at the spraying device,
- discharge time
- reaction time between ignition of flame and response of the electrical valve,
- preburning time,
- extinguishing time.

Figure A11.1:

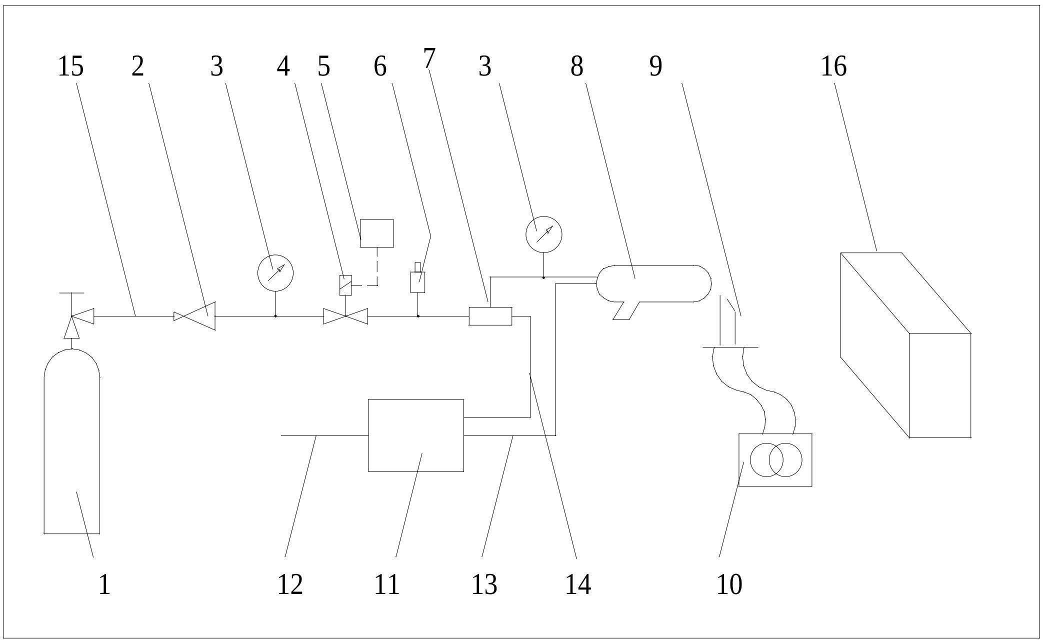
Test arrangement for verification of extinguishing efficiency for liquid coating plants



1 Container for fire extinguishing agent
2 Pressure reducing valve
3 Pressure gauge
4 Magnetic valve
5 Electronic control device
6 Nozzle simulating different numbers of spray guns
7 OR-valve
8 High rotational atomizing device
9 High voltage igniter
10 High voltage supply
11 Supply device for drive air and shaping air, as well as for solvents
12 Supply of pressurized air
13 Duct for solvents
14 Drive air duct
15 Shaping air duct
16 Extinguishing agent duct
17 Car-component

Figure A11.2:

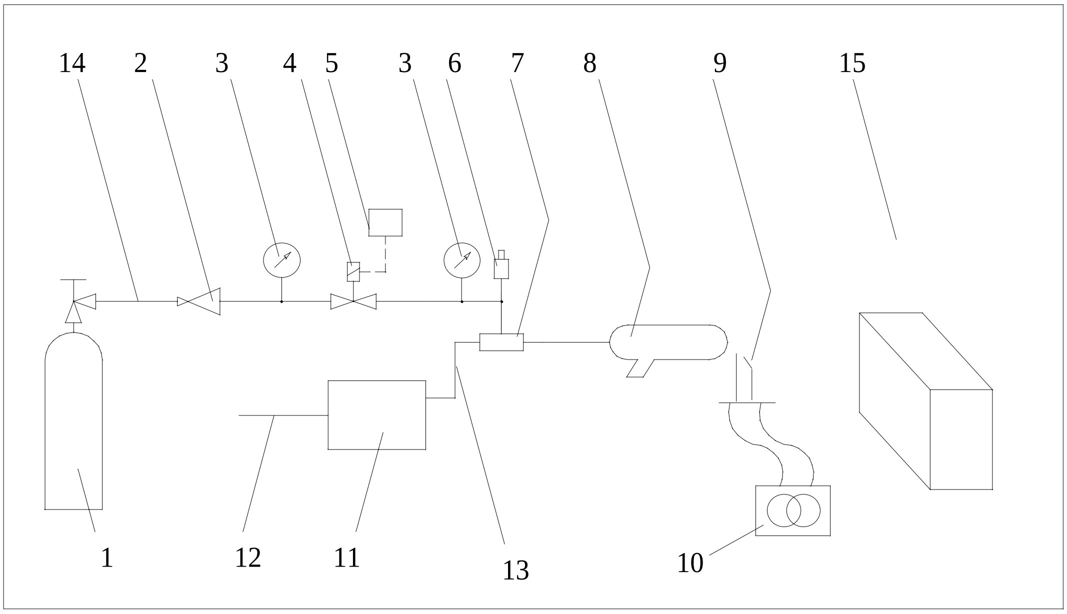
Test arrangement for verification of extinguishing efficiency at powder spray guns, supply of extinguishing agent via ducts for atomizing/shaping air



1 Container for fire extinguishing agent
2 Pressure reducing valve
3 Pressure gauge
4 Magnetic valve
5 Electronic control device
6 Nozzle simulating different numbers of spray guns
7 OR-valve
8 Powder spray gun
9 High voltage igniter
10 High voltage supply
11 Supply device for atomizing/shaping air, as well as for powder coating materials
12 Supply of pressurized air
13 Powder supply duct
14 Atomizing/shaping air duct
15 Extinguishing agent duct
16 Steel box

Figure A11.3:

Test arrangement for verification of extinguishing efficiency at powder spray guns, supply of extinguishing agent via powder supply duct



1 Container for fire extinguishing agent
2 Pressure reducing valve
3 Pressure gauge
4 Magnetic valve
5 Electronic control device
6 Nozzle simulating different numbers of spray guns
7 OR-valve
8 Powder spray gun
9 High voltage igniter
10 High voltage supply
11 Supply device for powder coating materials
12 Supply of pressurized air
13 Powder supply duct
14 Extinguishing agent duct
15 Steel box

Appendix A12
Components for extinguishing systems for coating systems with electrostatic spraying of flammable liquid and powder coating materials

The following listed components shall be approved - in addition to the list in CEA 4007 - for this application.

1. Solenoid valves
2. Weighing device (in accordance with CEA draft GEI 6 N84/B, but with suitable range)
3. System (in accordance with CEA draft GEI 6 N108/B)

Appendix A13
Example for equipment protection in powder coating and liquid lacquer coating plants

Figure A13.1: Example for equiment protection in a powder coating plant

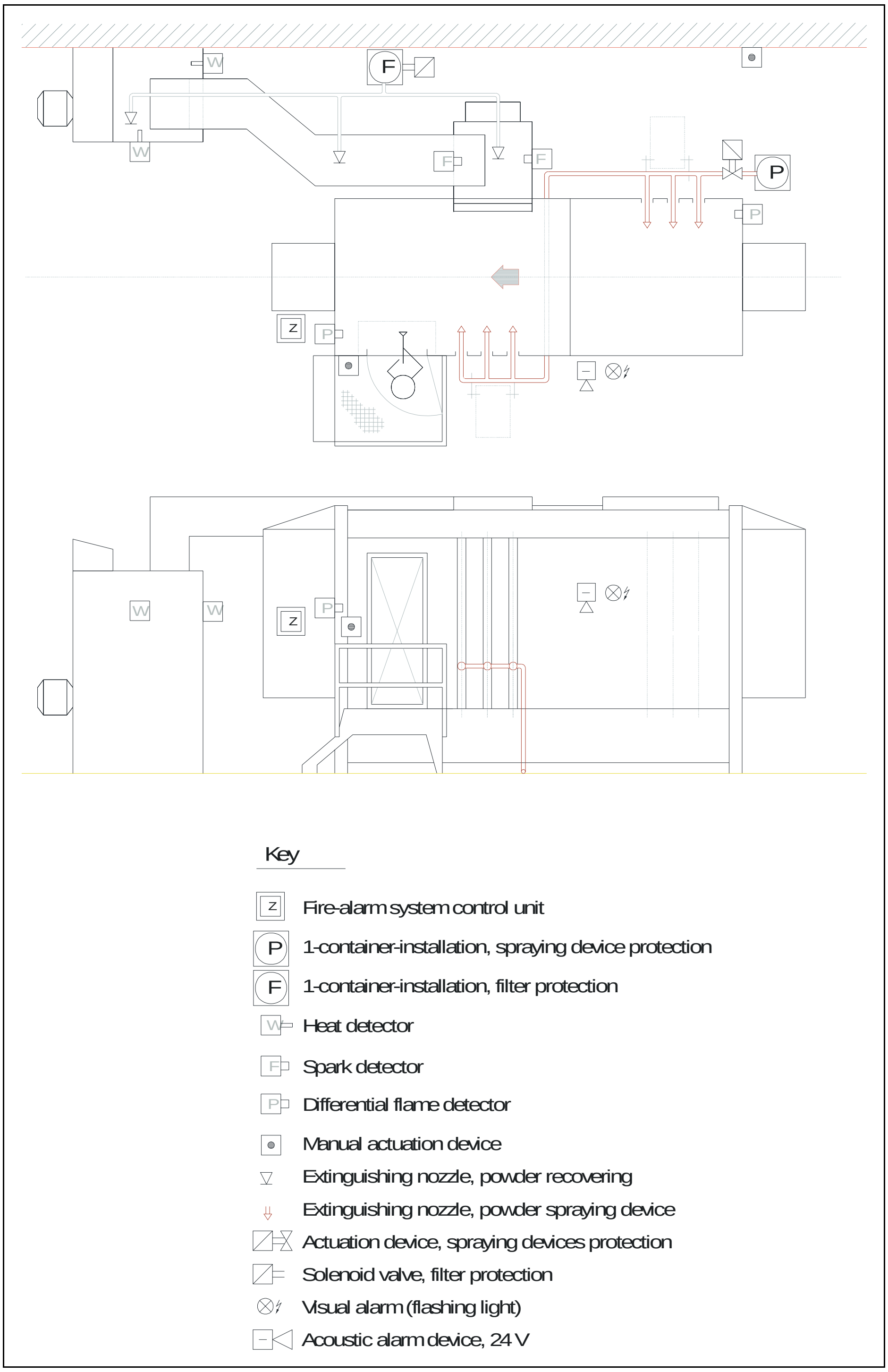


Figure A13.2: Example for equiment protection in liquid lacquer coating plants