TCVN 6101: 1996
ISO 6183: 1990

FIRE PROTECTION EQUIPMENT CARBON DIOXIDE EXTINGUISHING SYSTEMS FOR USE PREMISES DESIGN AND INSTALLATION

(This English version is for reference only)

HA NOI – 2008

Foreword

TCVN 6101: 1996 was identical to ISO 6183:1990.

TCVN 6101: 1996 was prepared by Technical Committee TCVN/TC 21 *Equipment for fire protection and fire fighting*, proposed by Directorate for Standards, Metrology and Quality, and approved by Ministry of Science and Technology.

This standard was transferred in 2008 from Vietnam Standard into Vietnam National Standard under the same identifier number, as stipulated in Section 1, Article 69 of the Law on Standards and Technical Regulations and in Point a, Section 1, Article 6 of Decree No 127/2007/ND-CP of the Government dated 01 August 2007 detailing the implementation of a number of articles of the Law on Standards and Technical Regulation.

Introduction

This Standard is intended for use by those concerned with purchasing, designing, installing, testing, inspecting, approving, operating and maintaining carbon dioxide ($C0_2$) extinguishing systems, in order that such equipment will function as intended throughout its life.

Any automatic carbon dioxide fixed fire-extinguishing system designed and installed in accordance with this Standard may be expected to be effective in operation and reasonably safe in relation to its role. However, in some countries other requirements may need to be met in order to satisfy national or local regulations. Before any installation is planned in detail, the position regarding national or local regulations should be checked. This can normally be done by reference to the authority having jurisdiction.

This Standard applies only to fixed fire-extinguishing systems in buildings and other premises on land. Although the general principles may well apply to other uses (e.g. maritime use), for these other uses additional considerations will almost certainly have to be taken into account and the application of the requirements in this Standard is therefore unlikely to be fully satisfactory.

General information about carbon dioxide as an extinguishing medium is given in annex C. This may be useful background information for those unfamiliar with the characteristics of this medium.

This Standard does not include requirements for pipe fittings, containers, flange bolting, flexible connectors and copper pipes and fittings: these requirements are covered in appropriate national standards.

It is a basic assumption of all technical standards work that each Standard will be used only by persons competent in the field of application with which it deals. This is of particular importance in fire protection. Accordingly it is emphasized that the design requirements given are to be interpreted only by trained and experienced designers. Similarly, competent technicians should be used in the installation and testing of the equipment.

Unless otherwise stated, all pressures are gauge pressures, expressed in bars, with equivalent pressures in pascals.

Fire protection equipment- Carbon dioxide extinguishing systems for use on premises - Design and installation

1. Scope

This Standard lays down requirements for the design and installation of fixed carbon dioxide fire-extinguishing systems for use on premises. The requirements are not valid for extinguishing systems on ships, in aircraft, on vehicles and mobile fire appliances or for below ground systems in the mining industry, nor are they valid for carbon dioxide preinerting systems.

Design of systems where unclosable opening(s) exceed a specified area and where the opening(s) may be subject to the effect of wind is not specified in this Standard. General guidance on the procedure to be followed in such cases is, however, given in 15.6.

2. Normative references

ISO 1182:2002, *Reaction to fire tests for building products — Non-combustibility test*

ISO 4200:1985, Plain end steel tubes, welded and seamless -- General tables of dimensions and masses per unit length

ISO 834:1975, Fire-resistance tests -- Elements of building construction

TCVN 6100:1996 (ISO 5923:1984), Fire protection -- Fire extinguishing media -- Carbon dioxide

3. Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Carbon dioxide fire-extinguishing system

Fixed supply of carbon dioxide permanently connected to fixed piping and nozzles arranged to discharge carbon dioxide into the area being protected in such a manner that the design extinguishing concentration is achieved.

3.2 Total flooding system

Fixed supply of carbon dioxide permanently connected to fixed piping with nozzles arranged to discharge carbon dioxide into an enclosed space or enclosure about the hazard so that the extinguishing concentration can be maintained.

3.3 Local application system

Fixed supply of carbon dioxide permanently connected to fixed piping with nozzles arranged to discharge carbon dioxide directly on to the burning material or identified hazard.

3.4 Automatic

Performing a function without the necessity of human intervention.

3.5 Control device

Device to control the sequence of events leading to the release of carbon dioxide.

3.6 Manual

Requiring human intervention to accomplish a function.

3.7 Operating device

Any component involved between actuation of the system and the release of carbon dioxide.

3.8 Release of carbon dioxide

Opening of container and selector valves leading to the physical discharge of carbon dioxide into the protected area.

3.9 Inhibition time; holding time

Period during which the carbon dioxide at the design concentration surrounds the hazard.

3.10 Authority having jurisdiction

Organization, office, or individual responsible for approving equipment, an installation, a procedure, or a system.

3.11 Selector valve

Device for controlling the passage of carbon dioxide through a pipe manifold to direct it to a pre-selected area of protection.

4 Carbon dioxide

The extinguishing medium used shall be carbon dioxide complying with the requirements of TCVN 6100:1996 (ISO 5932:1984).

Further information on carbon dioxide and its application is contained in annex C.

5 Safety requirements

In any proposed use of carbon dioxide extinguishing systems where there is a possibility that people may be trapped in or enter into the protected area, suitable safeguards shall be provided to ensure prompt evacuation of the area, to restrict entry into the area after discharge, except where necessary to provide means for prompt rescue of any trapped personnel. Such safety aspects as personnel training, warning signs, discharge alarms, and breaching apparatus shall be considered. The following requirements shall be taken into account:

a) provision of exit routes which shall be kept clear at all times and the provision of adequate direction signs;

b) provision of alarms within such areas that are distinctive from all other alarm signals and that will operate immediately upon detection of the fire and release of the carbon dioxide (see clause 6);

c) provision of only outward swinging self-closing doors which shall be openable from the inside even when locked from the outside;

d) provision of continuous visual and audible alarms at entrances, until the atmosphere has been made safe;

e) provision for adding an odour to the carbon dioxide so that hazardous atmospheres may be recognized;

f) provision of warning and instruction signs at entrances;

g) provision of self-contained breathing equipment and personnel trained in its use;

h) provision of a means of ventilating the areas after extinguishing the fire;

i) provision of any other safeguards that a careful study of each particular situation indicates are necessary.

6 Warning alarms

An audible alarm shall be provided on all total flooding systems, and on local flooding systems where dispersal of the carbon dioxide from the system into the room would give a concentration of more than 5 %. The alarm shall sound during any delay period between fire detection and discharge and through- out the discharge.

The sound intensity of the alarm described in 5.b shall be such that it will be heard above the average local noise level; where this is abnormally high, visual indication shall also be provided.

Alarm devices shall be supplied from an energy source sufficient to allow continuous operation of the warning alarm for a minimum of 30 min.

NOTE: Alarms may not be necessary for local application systems, unless the quantity of carbon dioxide discharged relative to the room volume is capable of producing a concentration in excess of 5 %.

7 Automatic shut-down of plant equipment

Before, or simultaneously with, the release of a carbon dioxide system, all equipment capable of causing reignition of flammable material such as heating installations, gas burners, infra- red lamps, etc. shall be automatically switched off.

8 Automatic pressure relief

Automatic pressure relief shall be provided at the highest point of any room which is tightly closed and which would otherwise be subjected to a dangerous increase of pressure when carbon dioxide is introduced.

NOTE — Leakage around doors, windows, ducts and dampers, though not apparent or easily determined, may provide sufficient venting relief for normal carbon dioxide systems without special provisions being made.

For otherwise airtight enclosures, the area necessary for free venting, X, (in square millimetres) may be calculated from the following equation:

$$X = 23.9\frac{Q}{\sqrt{P}}$$

where:

Q is the calculated carbon dioxide flow rate, in kilograms per minute;

P is the permissible strength (internal pressure) of enclosure in bar.

In many instances, particularly when hazardous materials are involved, relief openings are already provided for explosion venting. These and other available openings often provide adequate venting.

9 Electrical earthing

Carbon dioxide extinguishing systems shall be provided with adequate electrical earthing connections.

NOTE: Adequate earthing of the system will minimize the risk of electrostatic discharge. Where the system protects electrical installations, or is housed near or in a building with electrical installations, the system metalwork should be efficiently connected to the main ear- thing terminal of the electrical installation.

10 Precautions for low-lying parts of protected areas

Where it is possible for carbon dioxide gas to collect in pits, wells, shaft bottoms or other low-lying areas, consideration shall be given to adding an odoriferous substance to the carbon dioxide, and/or to providing additional ventilation systems to remove the carbon dioxide after discharage.

NOTE — The carbon dioxide should comply with the requirements of TCVN 6100:1996 (ISO 5923) after addition of any odoriferous substance (see clause 4).

For carbon dioxide container systems the odoriferous substance shall be introduced by proper means into the supply pipe to the protected zone.

11 Safety signs

For all total flooding systems, and those local application systems which may cause critical concentrations, a warning notice shall be displayed on the inside and outside of every door to the protected area.

The notice shall warn that, in case of alarm or discharge of car- bon dioxide, personnel should leave the room immediately and not enter again before the room has been thoroughly ventilated because of the danger of suffocation.

12 Precautions during maintenance work

On automatic total flooding systems, protecting normally unoccupied rooms, provision shall be made for the prevention of automatic discharge during periods of entry by personnel where they may not be able to leave the room during any delay period (see clause 6).

NOTE: This precaution is not usually necessary for local application systems but should be provided where hazardous concentrations may be produced in any area which may be occupied.

13 Discharge testing where there may be explosive mixtures

In circumstances where explosive air/vapour mixtures may be present, the hazard area shall be carefully checked before test discharges are made, due to the possibility of ignition by electrostatic discharge.

14 Basis for design of carbon dioxide systems

The construction of the enclosures to be protected by total flooding carbon dioxide systems shall be such that the carbon dioxide cannot readily escape. The walls and doors shall be capable of withstanding the effects of the fire for a sufficient time so as to allow carbon dioxide discharge to be maintained at the design concentration during the inhibition time.

NOTE: ISO 8341 should be used for the assessment of fire resistance of elements of construction.

Where possible, openings shall be shut automatically and ventilation systems shall be shut down automatically before or at least simultaneously with the initiation of discharge of the carbon dioxide and remain closed.

Where openings cannot be shut and where there is an absence of walls and/or ceilings, additional carbon dioxide shall be provided as specified in 15.6.

When these openings are to the outside atmosphere, where wind conditions may greatly affect the carbon dioxide losses, special precautions should be taken. These cases shall be treated as a special application and may require a discharge test to determine that the proper design concentration has been obtained.

15 Design of total flooding systems

15.1 Factors to be considered

To determine the quantity of the carbon dioxide required, the volume of the room or of the enclosure to be protected shall be taken as a basis. From this volume only solid structural members such as foundations, columns, beams and the like shall be deducted.

The following shall be taken into account:

— room size;

— material to be protected;

— particular hazards;

— openings that cannot be shut;

— ventilation systems which cannot be shut down. There shall be no openings in the floor.

15.2 Determination of carbon dioxide design quantity

The design quantity of carbon dioxide, *m*, in kilograms, shall be calculated using the following formula:

$$m = K_8 \ x\,(0,2\,A \ + \ 0,7\,V)$$

where

$$A = Av = 30\,A_{ov}$$

$$V = V_v + V_z - V_G$$

A_v *is* the total surface area of all sides, floor and ceiling (including the openings A_{ov}) of the enclosure to be protected, in square metres;

A_{ov} is the total surface area of all openings which can be assumed will be open in the event of a fire, in square metres (see 15.6);

V_v is the volume of the enclosure to be protected, in cubic metres (see 15.1);

V_z is the additional volume removed during the inhibition time (see table 1) by ventilation systems which cannot be shut down, in cubic metres (see 15.5);

V_G the volume of the building structure which can be deducted, in cubic metres (see 15.1);

K_B is the factor for the material to be protected which shall be equal to or greater than one (see 15.3 and table 1);

the number 0,2, in kilograms per square metre, comprises the portion of carbon dioxide that can escape;

the number 0,7, in kilograms per cubic metre, comprises the minimum quantity of carbon dioxide taken as a basis for the formula.

For calculation examples, see annex D.

NOTE: The two numbers 0,2 and 0,7 take into account the effect of room size, i.e. the ratio of the room volume (V_v) to room surface area (A_v).

15.3 K_B factor

The material factor K_B shown in table 1 shall be taken into account when designing for combustible materials and particular risks that require a higher than normal concentration.

K_B factors for hazards not listed in section A of table 1 shall be determined by using the cup burner apparatus described in annex C or other test method giving equivalent results.

15.4 Effect of materials with formation of glowing embers

For materials with the formation of glowing embers there are special conditions to be considered. Table 1 gives examples of such materials.

15.5 Effect of ventilation system that cannot be shut down

To determine the quantity of carbon dioxide to be used, the volume of the room (V_v) shall be increased by the volume of the air (V_z) which is charged into or expelled from the room whilst the room is being flooded with carbon dioxide and during the inhibition time stated in table 1.

15.6 Effect of openings (see introduction)

The effect of all openings, including explosion vents in walls and ceiling which will not be shut during a fire, are included in the formula in 15.2 by A_{ov}.

The porosity of the enclosure materials, or leaks around doors, windows, shutters, etc., shall not be considered as openings, as they are already included in the formula.

Openings are not permitted when an inhibition time is required unless additional carbon dioxide is applied to maintain the required concentration during the specified inhibition period.

When the ratio $R = A_{ov}/A_v > 0,03$, the system shall be designed as a local application system (see clause 16). This does not preclude the use of a local application system when R is less than 0,03.

When R is greater than 0,03 and where the openings may be subject to the effect of wind, then practical tests under the likely maximum adverse conditions should be carried out to the satisfaction of the authority having jurisdiction.

15.7 Simultaneous flooding of interconnected volumes

In two or more interconnected volumes where “free flow” of carbon dioxide can take place, or where the possibility of fire spread from one area to the other could occur, the carbon dioxide quantity shall be the sum of the quantities calculated for each volume. If one volume requires greater than normal concentration, the higher concentration shall be used in all interconnected volumes.

15.8 Duration of discharge

The time taken substantially to discharge the calculated design quantity of carbon dioxide, *m* (see 15.2), shall be in accordance with table 2. For fires involving solid materials, for example those listed in table 1 as requiring an inhibition time, the design quantity shall be discharged within 7 mm but the rate shall be not less than that necessary to develop a concentration of 30 % in 2 mm.

Table 1 — Material factors, design concentrations and inhibition times

Combustible material	Material factor K_B	Design CO_2 concentration %	Inhibition time min
A Fires involving gases and liquids[1]			
acetone	1	34	—
acetylene	2,57	66	—
aviation fuel grades 115/145	1,06	36	—
benzol, benzene	1,1	37	—
butadiene	1,26	41	—
butane	1	34	—
butene-1	1,1	37	—
carbon disulfide	3,03	72	—
carbon monoxide	2,43	64	—
coal or natural gas	1,1	37	—
cyclopropane	1,1	37	—
diesel fuel	1	34	—
dimethyl ether	1,22	40	—
dowtherm	1,47	46	—
ethane	1,22	40	—
ethyl alcohol	1,34	43	—
ethyl ether	1,47	46	—
ethylene	1,6	49	—
ethylene dichloride	1	34	
ethylene oxide	1,8	53	—
gasoline	1	34	—
hexane	1,03	35	—
n-heptane	1,03	35	—
hydrogen	3,3	75	—
hydrogen sulfide	1,06	36	—
isobutane	1,06	36	—
isobutylene	1	34	—
isobutyl formate	1	34	—
JP-4	1,06	36	—
kerosene	1	34	—
methane	1	34	—
methyl acetate	1,03	35	—
methyl alcohol	1,22	40	—
methyl butane-I	1,06	36	—
methyl ethyl ketone	1,22	40	—
methyl formate	1,18	39	—
n-octane	1,03	35	—
pentane	1,03	35	
propane	1,06	36	—
propylene	1,06	36	—
quench, lube oils	1	34	—
B Fires involving sc 1) erials[2]			
cellulosic material	2,25	62	20
cotton	2	58	20
paper, corrugated paper	2,25	62	20
plastics material (granular)	2	58	20
polystyrene	1	34	—
polyurethane, cured only	1	34	—
C Special application cases			
cable rooms and cable ducts	1,5	47	10
data handling areas	2,25	62	20
electrical computer installations	1,5	47	10
electrical switch and distribution rooms	1,2	40	10
generators, including cooling systems	2	58	until stopped
oil filled transformers	2	58	—
output printing areas	2,25	62	20
paint spray and drying installations	1,2	40	—
spinning machines	2	58	—

1) [illegible]

2) Fire involving solid materials, usually of an organic nature in which combustion normally takes place with the formation of glowing embers.

15.9 Storage temperatures

High-pressure storage temperatures may range from -20°C to + 50 °C without requiring special methods of compensating for changing flow-rates.

16 Design of local application systems

NOTE: Local application systems are suitable for the extinguishment of surface fires in flammable liquids, gases, and solids where the hazard is not enclosed or where the enclosure does not conform to the requirements for total flooding.

16.1 Carbon dioxide requirements

16.1.1 General

The basic carbon dioxide concentration factor is that which corresponds to a factor $K_B = 1$, i.e. 34 %.

For materials requiring a design concentration over 34 % the basic quantity of carbon dioxide shall be increased by multiplying this quantity by the appropriate material factor given in table 1.K_B factors for hazards not listed in section A of table 1 shall be determined by using the cup burner apparatus described in annex A, or any other method known to give equivalent results.

The design quantity of carbon dioxide required for local application systems shall be based on the total rate of discharge needed to blanket the area or volume protected and the time that the discharge needs to be maintained to ensure complete extinguishment.

For systems with high-pressure storage, the design quantity of carbon dioxide shall be increased by 40% to determine nominal cylinder storage capacity, since only the liquid portion of the discharge is effective. This increase in cylinder storage capacity is not required for the total flooding portion of combined local application/total flooding systems.

Where there are long pipelines or where the piping may be exposed to higher than normal temperatures, the design quantity shall be increased by an amount sufficient to compensate for liquid vaporized in cooling the piping.

16.1.2 Rate of discharge

Nozzle discharge rates shall be calculated by either the surface method or the volume method as covered in 16.2 and 16.3.

The total rate of discharge for the system shall be the sum of the individual rates of all the nozzles or discharge devices used in the system.

16.1.3 Duration of discharge

The time taken substantially to discharge the calculated design quantity of carbon dioxide, *m*, shall be in accordance with table 2. The minimum time shall be increased to compensate for any hazard conditions that would require a longer cooling period to ensure complete extinguishment.

Where there is a possibility that metal or other material may become heated above the ignition temperature of the fuel, the effective discharge time shall be increased to allow adequate cooling time.

16.2 Rate by area method

16.2.1 General

The area method of system design is used where the fire hazard consists primarily of flat surfaces or low level objects associated with horizontal surfaces.

System design shall be based on listing or approval data for individual nozzles. Extrapolation of such data above or below the upper or lower limits shall not be valid.

For a calculation example, see annex D, clause D3.

16.2.2 Nozzle discharge rates

The design discharge rate through individual nozzles shall be determined on the basis of location or projection distance in accordance with specific approvals or listings.

The discharge rate for overhead type nozzles shall be deter- mined solely on the basis of distance from the surface each nozzle protects.

The discharge rate for tankside nozzles shall be determined solely on the basis of throw or projection required to cover the surface each nozzle protects.

Table 2 — Discharge times for surface fires

Values in seconds

System	Carbon dioxide high-pressure installation liquid discharge	Carbon dioxide low-pressure installation	
		Pre-liquid vapour flow time	Liquid discharge time
Total flooding system	max. 60	max. 60	max. 60
Local application system	min. 30	max. 30	min. 30

16.2.3 Area per nozzle

The maximum area protected by each nozzle shall be deter- mined on the basis of location or projection distance and the design discharge rate in accordance with specific approvals or listings.

The same factors used to determine the design discharge rate shall be used to determine the maximum area to be protected by each nozzle.

The area of the hazard protected by individual overhead type nozzles shall be considered as a square.

The area of the hazard protected by individual tankside or linear nozzles shall be either a rectangle or square in accordance with spacing and discharge limitations stated in specific approvals or listings.

Hazards involving deep layer flammable liquid fires shall have a minimum freeboard of 150 mm in order to prevent splashing and to retain a surface concentration when carbon dioxide is applied.

16.2.4 Location and number of nozzles

A sufficient number of nozzles shall be used to cover the entire hazard area adequately on the basis of the unit areas protected by each nozzle.

Tankside or linear type nozzles shall be located in accordance with spacing and discharge rate limitations stated in specific approvals or listings.

Overhead type nozzles shall be installed perpendicular to the hazard and centred over the area protected by the nozzle. Other nozzles shall be installed at angles between 45^0 and 90° from the plane of the hazard surface. The height/distance used in determining the necessary flow-rate and area coverage shall be the distance from the aiming point on the protected surface to the face of the nozzle measured along the axis of the nozzle.

When installed at an angle, nozzles shall be aimed at a point measured from the near side of the area protected by the nozzle, the location of which is calculated by multiplying the aiming factor in table 3 by the width of the area protected by the nozzle.

Nozzles shall be located so as to be free of possible obstructions that could interfere with the proper projection of the discharged carbon dioxide.

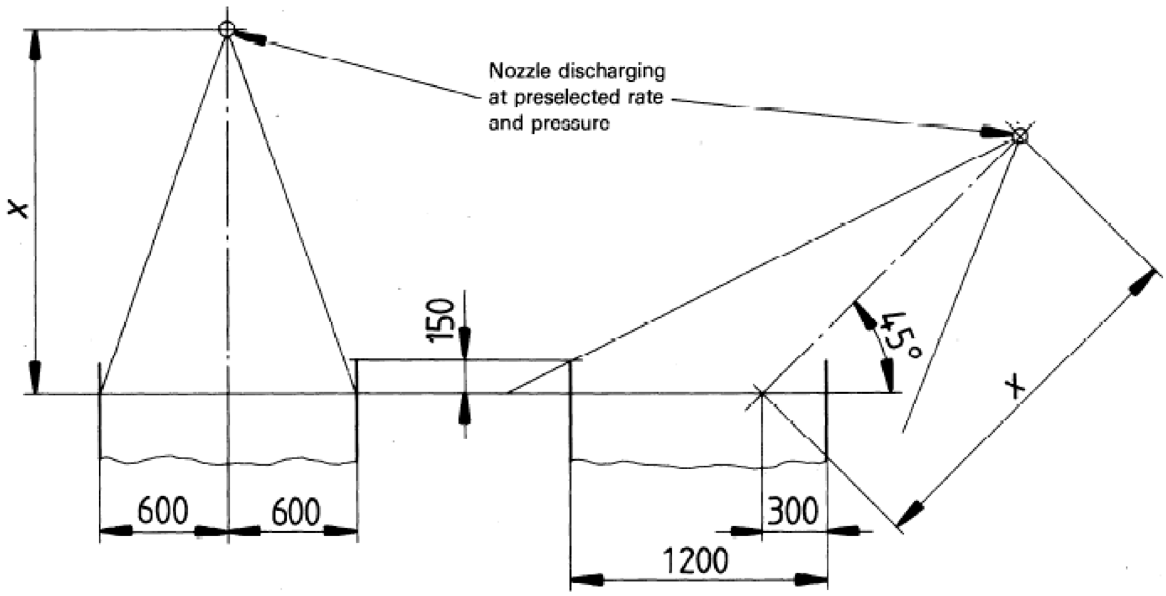
Table 3 — Aiming factors for angular placement of nozzles, based on freeboard 150 mm

Discharge angle[1]	Aiming factor[2]
45° to 60°	1/4
60° to 75°	1/4 to 3/8
70° to 90°	3/8 to 1/2
90° (perpendicular)	1/2 (centre)

1) Degrees from plane of hazard surface.
2) Fractional amount of nozzle coverage area.

For further information, see figure 1.

Dimensions in millimetres



NOTES

1 The diagram shows nozzles discharging at a) 90° with the aiming point at the centre of the protected surface, and at 45°, b) with the aiming point at 0,25 of the width of the protected surface, into a tray containing fuel with a freeboard of 150 mm.

2 x is the preselected height used to determine the flow-rate required.

Figure 1 — Nozzle locations

16.3 Rate by volume method

16.3.1 General

The volume method of system design is used where the fire hazard consists of three-dimensional irregular objects that can- not be easily reduced to equivalent surface areas.

For examples of calculations, see annex D, clauses D1 and D2.

16.3.2 Assumed enclosure

The total discharge rate of the system shall be based on the volume of an assumed enclosure entirely surrounding the hazard.

If the flow is not completely closed special provisions shall be made to take care of bottom conditions.

The assumed walls and ceiling of this enclosure shall be at least 0,6m from the main hazard unless actual walls are involved and shall enclose all areas of possible leakage, splashing or spillage.

No deductions shall be made for any objects within this volume.

A minimum dimension of 1 ,2 m shall be used in calculating the volume of the assumed enclosure.

16.3.3 System discharge rate

The total discharge rate for the basic system shall be not less than 16 kg/mm per cubic metre of assumed volume, unless the assumed enclosure has a closed floor and is partly defined by permanent continuous walls extending at least 0,6 m above the hazard (where the walls are not normally a part of the hazard), in which case the discharge rate may be proportionately reduced to not less than 4 kg/mm per cubic metre for actual walls completely surrounding the enclosure.

16.3.4 Location and number of nozzles

A sufficient number of nozzles shall be used to cover the entire hazard volume adequately on the basis of the system discharge rate as determined by the assumed volume.

Nozzles shall be located and directed relative to objects in the Nozzles shall be located and directed relative to objects in the hazard volume.

The design discharge rates through individual nozzles shall be determined on the basis of location or projection distance in accordance with specific approvals or listings for surface fires.

16.4 Storage temperatures

Special methods of compensating for changing flow-rates shall be applied if the storage temperature of high-pressure containers is less than 0 °C or more than 49 °C.

16.5 Discharge nozzles

The nozzles used shall be listed or approved by the authority having jurisdiction for rate of discharge, effective range, and pattern or area coverage.

NOTE: The supporting data giving requirements and test methods for nozzles is in preparation and will be shown in a future International Standard.

17 Quantity of carbon dioxide to be stored

The determined carbon dioxide quantity required shall be stored so as to be available at all times and not usable for other purposes. Extra quantities of carbon dioxide shall be stored for use with carbon dioxide low-pressure installations in accordance with the following:

a) In order to equalize charge or drain tolerances and gas residues, the quantities of carbon dioxide to be stored for low-pressure systems as determined for the largest extinguishing zone shall be increased by at least 10 %.

b) If there is a possibility that liquid carbon dioxide might remain in the piping between storage container and nozzle-pipe system, the carbon dioxide store shall be increased by this remaining quantity, in addition to the 10 % increase specified in item a) above.

18 Quantity of carbon dioxide to be connected to system as reserve

Under certain circumstances where carbon dioxide systems protect one or more locations, a reserve quantity of 100 % may be required. The reserve supply shall be permanently connected to such systems.

The time needed to obtain carbon dioxide for replenishment to restore systems to the operating conditions shall be considered as a major factor in determining the reserve supply needed.

19 Main items required for detailed design

Carbon dioxide extinguishing systems consist mainly of the carbon dioxide storage either in one or several containers, the selector valves, the release mechanisms and the connected distribution piping and discharge nozzles.

20 Carbon dioxide storage area

20.1 General

NOTE: For storing carbon dioxide, the appropriate national regulations shall be observed.

Storage of carbon dioxide with the proper valves, release mechanisms and further equipment should, if possible, be arranged in one room which is not exposed to fire danger, but which is situated near to the rooms or objects protected by the system and is easily accessible. The storage area shall be protected against the admittance of unauthorized persons.

In certain cases, and when accepted by the authority having jurisdiction, the storage may be located inside the protected rooms.

20.2 High-pressure systems

The container storage area for a high-pressure system shall be so designed that the ambient temperature cannot exceed the appropriate temperature in table 4.

Table 4 — Maximum storage temperature

Filling ratio kg/l	**Maximum ambient temperature 0°C**
0,75	40
0,68	49
0,55	65

NOTE: If it is likely that the ambient storage temperature will be below 0 °C, then special measures may have to be taken in order to comply with the discharge times given in table 3.

20.3 Low-pressure systems

Low-pressure systems shall be designed so that the temperature of the carbon dioxide in the container is kept at a temperature of approximately -18 °C.

NOTE: Suitable measures should be taken to ensure that this temperature is maintained. This means insulating, cooling and/or heating, dependent on the ambient temperature in the storage area. It may be necessary to extract the heat generated by the cooling system.

21 Carbon dioxide containers

21.1 General

NOTE: Apart from the following requirements and the specific requirements for low-pressure containers (see 21.2), there are no further requirements for the construction of gas containers, other than those given in appropriate national standards.

Where the container design does not incorporate a safety pressure relief device then this shall be incorporated in the container valve.

NOTE : This will form the subject of a future International Standard.

21.2 Low-pressure containers

The design shall ensure that the temperature of the carbon dioxide in the container shall be maintained at -18^{+2}_{0} °C and at a pressure of approximately 20 bar[1)] .Means shall be provided continuously to indicate the quantity of carbon dioxide.

An automatic refrigerating system shall ensure that the temperature and pressure of carbon dioxide are kept within the required limits.

On the low-pressure containers, an over-pressure alarm shall be provided which will sound prior to the operation of the safety valves.

The container shall have sufficient insulation to limit the loss of carbon dioxide to not more than 1,5 % (at 3 tonnes to 6 tonnes charge), not more than 0,8 % (over 6 tonnes to 10 tonnes charge) and not more than 0,5 % (over 10 tonnes charge) in 24 h in the event of a failure of the refrigerating system at the highest expected ambient temperature.

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

The container shall be fitted with a pressure gauge and a safety valve.

NOTE: For low-pressure systems care should be taken that the temperature of the carbon dioxide, during the

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1) 1 bar = 0,1MPa

filling of the containers, corresponds to the value necessary for proper functioning of the system.

21.3 Carbon dioxide high-pressure container batteries

In general, the necessary carbon dioxide quantity shall be con- tamed in one battery. The supply to separate distinct hazards may be made from a single battery where there is no likelihood of the fire spreading from one hazard to another. The total quantity of the battery shall correspond to the largest quantity of carbon dioxide required to protect any one room or object.

NOTE: The release systems of the battery and the pipes should be arranged in such a way that each protected zone individually may be flooded with carbon dioxide.

The containers of the battery shall be secured in a fixed position in such a way that no movement occurs when the system is discharging.

Each container shall be replaceable, independently from the other containers. In each pipe connecting the container valve to the manifold, a non-return valve shall be fitted. Removal of any of the containers shall not prevent the remainder of the battery from functioning properly.

Means shall be provided to measure the quantity in each container.

22 Selector valves

If several extinguishing zones are served by one carbon dioxide battery or one container system, a selector valve shall be provided for each extinguishing zone.

Selector valves for cylinder systems shall open automatically before or at the same time as the operation of the cylinder valves.

In low-pressure systems, selector valves shall open automatically and close automatically after discharge of the required quantity of carbon dioxide.

Selector valves shall be installed so as to be protected against fire. At any time it shall be possible to check the correct functioning of the selector valves and their controlling devices.

23 Distribution systems

23.1 Piping shall be of materials that would be classified as non-combustible if tested to ISO 1182 and that have physical and chemical characteristics such that its integrity under stress can be predicted with reliability.

NOTES:

1) Special corrosion-resistant materials or coatings may be required in severely corrosive atmospheres.

2) Flexible piping, tubing or hoses (including connections) will form the subject of a future standard.

23.2 Pipes and pipe connections for low-pressure systems shall be designed for test pressures of 40 bar gauge [1)].

NOTES:

1. High pressure systems will form the subject of a future International Standard. Fittings should comply with appropriate national standards.

Preferably, fittings should be screwed or flanged. Where compression fittings are used, particular care should be taken to ensure correct assembly.

2. Pipes should be selected from ISO 4200.

23.3 Sections of pipe that could be closed at each end, e.g. a pipe section between the container valves manifold and a normally closed selector valve, shall be made of seamless pipe.

23.4 Sections of pipe that incorporate an open end that cannot be under continuous pressure may be of welded pipe except for pipes with a nominal bore larger than 40 mm fed from a low-pressure bulk storage tank.

23.5 Pipe sizes smaller than 50 mm nominal diameter shall not be connected by welding on site.

NOTE: However, factory welded assemblies may be used.

23.6. Flake graphite cast iron fittings shall not be used, since they are susceptible to failure under the temperature and pressure conditions experienced in carbon dioxide systems.

23.7 The piping system shall be securely supported with due allowance for expansion and contraction and shall be sited to minimize exposure to fire, mechanical, chemical, or other damage. Where explosions are possible, the piping system shall be hung from supports that are designed to absorb the probable shock effects.

23.8 In systems where valve arrangements could introduce sections of closed piping, such sections shall be equipped with pressure relief devices.

The pressure setting of the relief device shall be such that maximum pressure attainable does not exceed the criteria indicated in 23.2 but is in excess of the pressure required to maintain normal discharge pressures in the pipeline under flow conditions.

Pressure relief devices shall be designed and so located that the discharge therefore will not injure personnel or otherwise cause damage.

NOTE: Relief device operating pressures are not specified in this standard.

23.9 Where condensation water may form in the pipes, suitable means shall be provided for drainage. These drainage points shall not be accessible to unauthorized persons.

23.10 Pipes shall be free from burrs, rust and other obstructions. Care shall be taken to ensure proper protection against corrosion. Before installing the pipes, they shall be cleaned inside. After installation and before fitting the nozzles, they shall be blown through carefully.

The following formula and the curves developed therefrom, or any other method acceptable to the authority having jurisdiction, shall be used to determine the pressure drop in the pipeline.

The flow-rate, Q, in kilograms per minute, may be calculated as follows:

$$Q^2 = \frac{0{,}8725 \times 10^{-5} \times D^{5{,}25} \times Y}{L + (0{,}04319 \times D^{1{,}25} \times Z}$$

where

D is the inside pipe diameter (actual), in millimetres;]

L is the equivalent length of pipeline, in metres;

Y, Z are factors depending on storage and line pressure, and may be evaluated from the following equations:

$$y = - \int_{p1}^{p} pdp$$

$$Z = - \int_{p1}^{p} \frac{dp}{p} = \ln \frac{P_1}{p}$$

in which

P_1 is the storage pressure in bar (absolute);

p is the pressure at end of pipe line in bar (absolute);

r_1 is the density at pressure p_1 in kilograms per cubic metre;

r is the density at pressure p in kilograms per cubic metre.

In the design of piping systems, pressure drop values can be obtained from curves of pressure versus equivalent length for various flow-rates and pipe sizes (see annex B).

23.12 The release mechanism shall open all the container valves connected to a manifold for one extinguishing zone simultaneously. The release mechanism shall be reliable and its function shall be capable of being checked.

24 Nozzles

NOTE 1 - Nozzles will form the subject of a future standard.

The cross-sections of the openings of the nozzles shall be calculated in accordance with annex B, with a minimum pressure at the entrance to the nozzles and 14 bar for high- pressure systems and 10 bar for low-pressure systems.

The nozzles which discharge the carbon dioxide shall be dimensioned so that it is impossible for the nozzles to get blocked by solid carbon dioxide.

Total flooding systems shall be designed and installed so as to achieve a uniform concentration of carbon dioxide in all parts of the enclosure. Discharge nozzles shall be mounted close to the ceiling.

NOTE 2- It is recommended that for rooms of a height from 5 m to 10 m additional nozzles should be provided at a level of approximately one-third of the room height. For rooms exceeding 10 m height, additional nozzles should be installed at a level of one-third and two-thirds of the room height

Local application system nozzles shall be designed and installed so as to direct carbon dioxide on to the object to be protected without dispersing burning material.

When necessary the nozzles shall be protected against external contamination which could affect their performance.

25 Release mechanisms

25.1 Types of release mechanisms

Systems shall be designed for either

a) automatic and manual release; or

b) manual release only dependent upon the requirements of the authority having jurisdiction.

Operation of the release mechanisms shall cause the complete system to operate including anciliary functions such as indication of alarm devices and shutting down ventilation systems, extract fans, pumps, conveyors, heaters, dampers and shutters, etc.

All devices shall be located, installed, or suitably protected so that they are not subject to mechanical, chemical or other damage which would render them inoperative.

25.2 Automatic release

Automatic systems shall be controlled by an approved automatic fire detection device selected[2)] according to the requirements of the particular hazard.

Where rapid response detectors, such as those for detecting smoke or flame are used, the system shall be designed to operate only after two separate detection signals have been initiated.

[2)] The specific details are not part of this standard but are given in the other standard when applying this standard.

25.3 Manual release

25.3.1 Manual release for total flooding systems shall be located outside the protected room in a position near to the exit(s) from the room. Manual release for local application systems shall be located in a position that is both convenient and safe for the operator.

25.3.2 Manual release devices shall be protected against in- advertent operation by lead-sealed wires or a break glass or quick access cover and be clearly marked to indicate their purpose.

NOTE- If the housing box is protected by a fangible glass front this should be of a type which, when broken, does not leave jagged or sharp edges which might cause injury when the manual release is operated.

25.3.3 The extinguishing zone controlled by the manual point shall be clearly indicated in order that there will be no risk of confusion.

25.4 Types of operation

Release mechanisms shall operate electrically, pneumatically or mechanically.

25.4.1 Electrical

25.4.1.1 The power supply for electrical detection of release devices shall be provided by two independent sources of energy, i.e. a mains supply, with automatic changeover to a standby battery supply in the event of a mains failure.

25.4.1.2 Detection and release circuits shall be automatically monitored and alarms indicating the failure of any monitored device or wiring shall give prompt audible and visual indication. Such alarms shall be distinct from alarms indicating system operation.

25.4.2 Pneumatic

25.4.2.1 As a source of energy, carbon dioxide from the extinguishing system may be used. If another pressurized source is chosen, it shall be used solely for this purpose and its functional service guaranteed.

25.4.2.2 Where gas pressure from pilot containers is used as a means of releasing the remaining containers, the supply and discharge rate shall be designed to release all of the remaining containers simultaneously, and the pilot gas supply shall be continuously monitored and a fault alarm given in the event of excessive pressure loss.

25.4.2.3 Automatically operated detectors and tubing shall be capable of being periodically tested for proper operation.

25.4.3 Mechanical

NOTE- Release systems can be operated mechanically by means of mechanical cables and drop weights.

The control cables shall be run within protective tubes with free running corner pulleys at all changes of direction.

Mechanical control cables shall be capable of being periodically tested for proper operation.

26 Inspection and commissioning

After installation each carbon dioxide fire extinguishing system shall be checked by the manufacturer or his agent to ensure that it will function correctly (see clause 27). A certificate shall be issued to the purchaser covering this test.

After installation detailed instructions shall be given to the staff who will have responsibility for the inspection and maintenance of the system.

27 Functional test

In order to check that the system has been properly installed and will function as specified, a test shall be made for the continuity of piping with free unobstructed flow, such as a puff test with compressed air or carbon dioxide. Additionally, if required by the authority having jurisdiction, a full discharge test may be made. During such a test the discharge time is measured, and determinations made of carbon dioxide concentrations achieved, distribution throughout the hazard area, and holding time.

28 Operating and maintenance instructions

An instruction plate or chart giving directions for the use of the fire-extinguishing system shall be permanently displayed in a clearly visible position and shall be made of substantial and durable material. These instructions shall give full information about operating the system and brief information relating to routine servicing and for replenishing the system after a discharge. The purchaser shall also be provided with a set of operating and maintenance records.

NOTE- Where carbon dioxide containers are disconnected from the system for servicing they should be fully secured and restrained before any work on the valves or release mechanisms is started

Annex A

(normative)

Test procedure for determining carbon dioxide concentrations for flammable liquids and gases

(See also 15.3)

NOTE - Attention is drawn to the fact that work is continuing with this apparatus which may result in some adjustment of the figures in table 1.

A.1 Principle

The cup burner apparatus is used to determine flame extinguishing concentrations for liquids and gases.

The result given is the theoretical minimum carbon dioxide concentration to extinguish the flame. The design concentration is calculated from this figure (see clause A.5). The minimum

design concentration used shall be 34 % which is represented by a K_B, factor of 1.

For flammable material requiring a factor of more than 1, a material factor is applied as shown in table 1 and as used in formula m in 15.2.

For converting the calculated design concentration (obtained by using the test apparatus), to a material factor, K_B the following formula shall be used.

$$K_B = \frac{\ln(1-C)}{\ln(1-C_s)}$$

where

$$C = \frac{\text{design concentration in \%}}{100}$$

$$C_s = \frac{\text{minimum concentration in \%}}{100} = 0{,}34$$

A.2 Apparatus

The apparatus for these measurements is a cup burner arranged as in figure A.I.

A.3 Test procedure for flammable liquids

A.3.1 Place a flammable liquid Sample in the fuel reservoir.

A.3.2 Adjust the adjustable stand under the fuel reservoir to bring the fuel level in the cup to within 1 mm of the top of the cup.

A.3.3 Adjust the electric control circuitry to the cup heating element to bring the fuel temperature to 25^0C, or to 5^0C above the open cup flash Point of the fuel, whichever is higher.

A.3.4 Ignite the fuel by suitable means, preferably which shall not contaminate the fuel under test.

electrical,

A.3.5 Adjust the air flow rate to 40l/min.

A.3.6 Start the flow of the carbon dioxide and increase it slowly until the flame is extinguished. Record the carbon dioxide flow.

A.3.7 Remove approximately 10 ml to 20 ml of fuel from the surface of the cup with a pipette.

A.3.8 Repeat Steps A.3.4 through A.3.6 and average the results.

A.3.9 Calculate the flame extinguishing concentration, TC, as a percentage, as shown in the equation:

$$\mathrm{TC} = \frac{V_F}{40 + V_F} \times 100$$

where V_F is the carbon dioxide flow, in litres per minute.

A.3.10 Increase the fuel temperature to 5^0C below the boiling point of the fuel, or to 200^0C, whichever is lower.

A.3.11 Repeat steps A.3.2 and A.3.4 through A.3.9.

A.3.12 Take the flame extinguishing concentration to be the higher value from the two fuel temperatures.

A.4 Test procedure for flammable gases

A.4.1 The apparatus is modified by filling the cup with glass wool and reinserting a rotameter calibrated for the fuel in place of the fuel reservoir of figure A.1. The rotameter is connected to a source of fuel through an appropriate pressure regulator.

A.4.2 Adjust the fuel flow to produce a linear velocity within the cup of 130 mm/s.

A.4.3 Perform steps A.3.3 through A.3.9.

A.4.4 Increase the fuel temperature to 150 ^{0}C.

A.4.5 Repeat steps A.3.4 through A.3.9.

A.4.6 Take the flame extinguishing concentration to be the higher value from the two fuel temperatures.

A.4.7 If the concentration requirement at the higher temperature exceeds that at the lower temperature by a significant amount, the fuel shall be classified as “temperature sensitive”. The flame extinguishing concentration for temperature-sensitive fuels shall be determined at the maximum temperature existing in the specific protected area.

A.5 Design concentration calculation

Take the design concentration to be the value of the flame extinguishing concentration multiplied by 1,7.

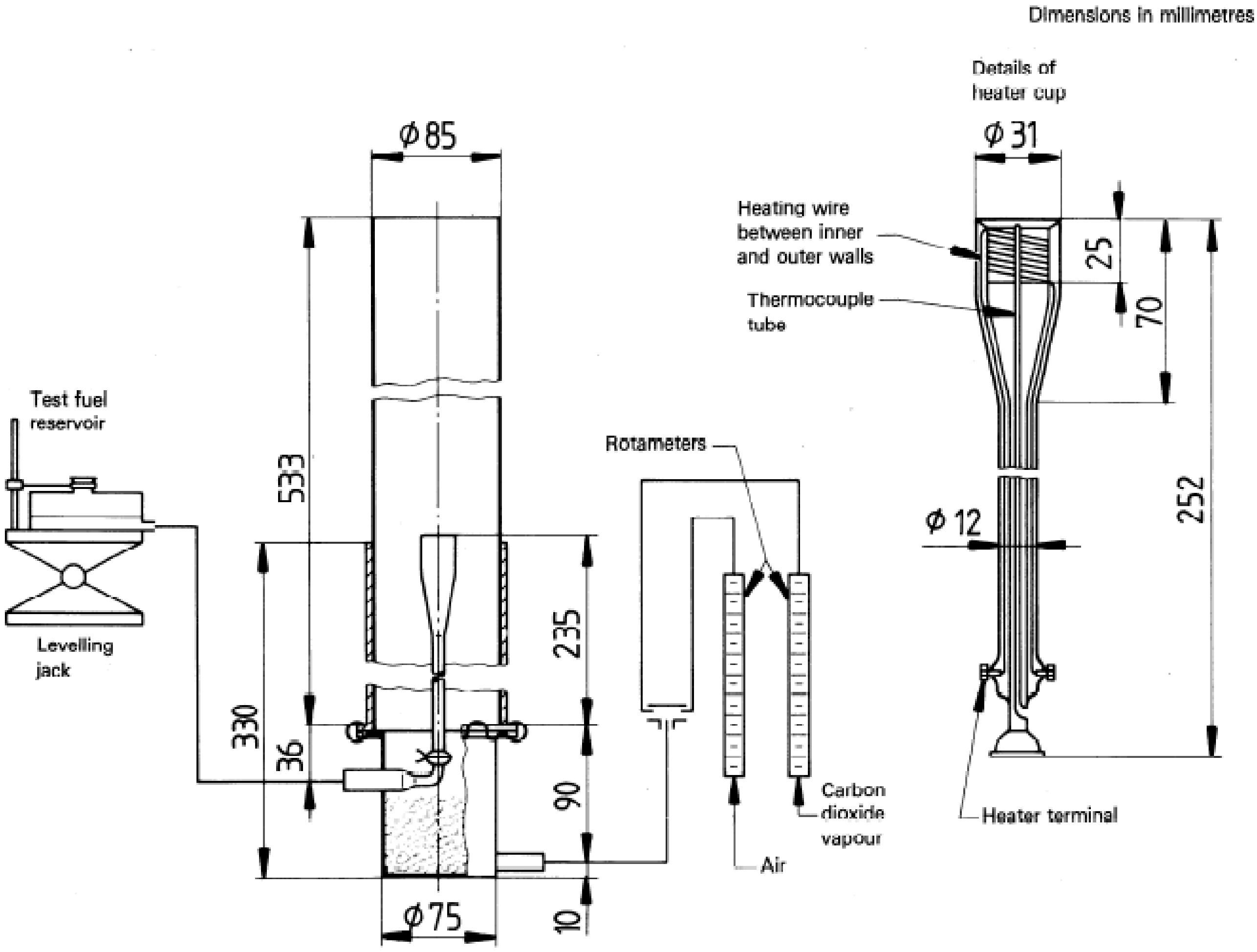

Figure A.1 — Cup burner apparatus

Annex B

(normative)

Carbon dioxide system pipe and orifice size determination

B.l The storage pressure is an important factor in carbon dioxide flow. In low-pressure storage the starting pressure in the storage vessel will drop by an amount depending on whether all or only part of the supply is discharged. Because of this, it will be about 19,7 bar. The flow equation is based on absolute pressure, therefore 20,7 bar is used for calculations necessary for low-pressure systems.

In high-pressure systems, the storage pressure depends on ambient temperature. Normal ambient temperature is assumed to be 21°C. At this temperature, the average pressure in the cylinder during discharge of the liquid Portion will be 51,7 bar approximately. This pressure has therefore been selected for calculations involving high-pressure systems.

Using the above pressure of 20,7 bar and 51,7 bar, values have been determined for the Y and 2 factors in the flow equation. These are listed in tables B. 1 and B.2.

B.2 For practical applications it is desirable to plot curves for each pipe size that may be used. However, it will be noted that the flow equation tan be arranged as follows:

$$\frac{L}{D^{1,25}} = \frac{10^{-5} \times 0,8725Y}{\left(\frac{Q}{D^2}\right)^2} - 0,04319Z$$

Thus, by plotting values of $L/D^{1,25}$ and Q/D^2, it is possible to use one family of curves for any pipe size. Figure B.1 gives flow information for - 18°C storage temperature on this basis.

Figure B.2 gives similar information for high-pressure at 21°C.

These curves tan be used for designing Systems or for checking possible flow-rates. Pressure conditions at any point in a pipeline tan be obtained by calculating Q/D^2 and $L/D^{1,25}$ values. Points may then be plotted on the Q/D^2 curve to obtain starting and terminal pressures. For example, assume the problem is to determine the terminal pressure for a low-pressure

system consisting of a single 50 mm schedule 40 Pipeline with an equivalent length of 152 m and a flow-rate of 454 kg/min.

Q/D^2 and $L/D^{1,25}$ values are first calculated :

$$\frac{Q}{D^2} = \frac{454}{2758} = 0,165 kg / \min\ par\ \mathrm{mm}^2$$

$$\frac{L}{D^{1,25}} = \frac{152}{141,3} = 1,075 m / mm^{1,25}$$

Starting pressure is 20,7 bar and *LID 1,25* = 0, shown in figure B.1 at Si. The terminal pressure is found to be about 15,7 bar at point Ti where the Q/D2 value of 0,165 intersects the L/D 1,25 value at 1,075.

If this line terminates in a single nozzle, the equivalent orifice area must be matched to the terminal pressure in order to control the flow-rate at the desired level of 454 kg/mm.

Referring to table B.8, it will be noted that the discharge rate will be 0,9913 kg/min per square millimetre of equivalent orifice area when the orifice pressure is 15,9 bar. The required equivalent orifice area of the nozzle is thus equal to flow rate divided by the rate per square millimetre.

Table B.1 Values of *Y* and *Z* for low-pressure systems

Pressure		Y	Z
bar	MPa		
20,7	2,7	0	0
20	2	665	0,12
19	1,9	1500	0,295
18	1,8	2201	0,470
17	1,7	2790	0,645
16	1,6	3285	0,820
15	1,5	3696	0,994
14	1,4	4045	1,169
13	1,3	4338	1,344
12	1,2	4584	1,519
11	1,1	4789	1,693
10	1	4962	1,868

Table B.2- Values of Y and Z for high-pressure

Pressure		Y	Z
bar	MPa		
51,7	5,17	0	0
51,0	5,1	554	0,003 5
50,5	5,05	972	0,060 0
50	5	1325	0,082 5
47,5	4,75	3037	0,210
45	4,5	4616	0,330
42,5	4,25	6129	0,427
40	4	7256	0,570
37,5	3,75	8283	0,700
35	3,5	9277	0,830
32,5	3,25	10050	0,950
30	3	10823	1,086
27,5	2,75	11507	1,240
25	2,5	12193	1,430
22,5	2,25	12502	1,620
20	2	12855	1,840
17,5	1,75	13187	2,140
14,0	1,4	13408	2,590

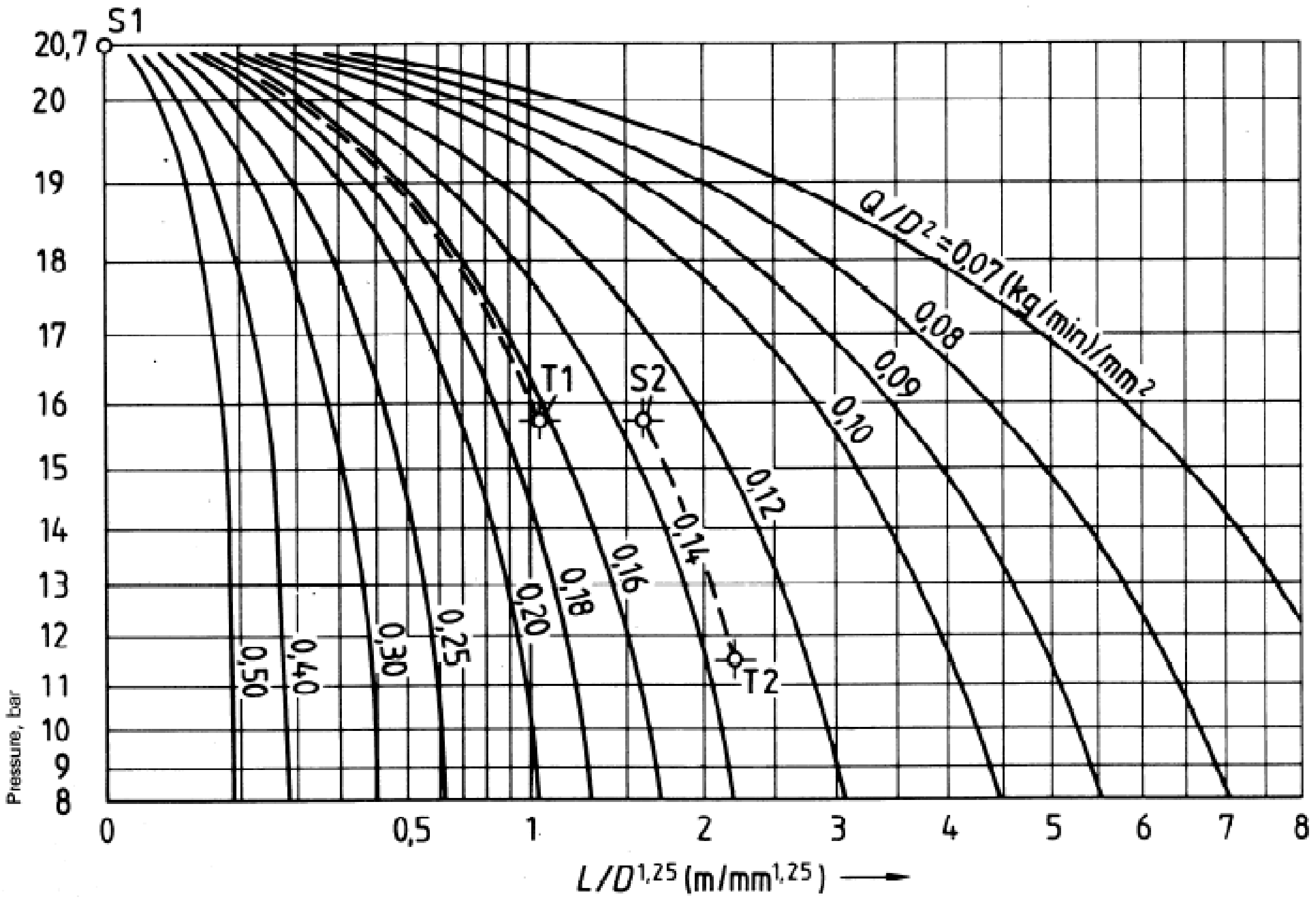

Figure B.1 — Pressure drop in pipeline for 20,7 bar (2,07 MPa) storage pressure

Equivalent orifice area = $\dfrac{454\ \text{kg/min}}{0{,}9913} = 458mm^2$

From a practical viewpoint, the designer would select a standard nozzle having an equivalent area nearest to the computed area. If the orifice area happened to be a little larger, the actual flow-rate would be slightly higher and the terminal pressures would be somewhat lower than the estimated 15,7 bar.

B.3 If, in the above example, instead of terminating with one large nozzle, the Pipeline branches into two smaller pipelines, it will be necessary to determine the pressure at the end of each branch line. To illustrate this procedure, assume that the branch lines are equal and consist of 40 mm schedule 40 pipe with equivalent lengths of 61 mm and the flow in each branch is to be 227 kg/min.

Q/D^2 and $L/D^{1,25}$ values are calculated for the branch pipe:

$$\frac{Q}{D^2} = \frac{227}{1673} = 0{,}136 kg/\text{min per mm}^2$$

$$\frac{L}{D^{1,25}} = \frac{61}{103{,}4} = 0{,}59 mm^{1,25}$$

From figure B.l, the starting pressure of 15,7 bar (terminal pressure of main line) intersects the Q/D^2 line 0,136 at point S2 giving an $L/D^{1,25}$ value of 1,6. The terminal pressure is found by moving down the Q/D^2 line a distance of 0,59 on the $L/D^{1,25}$ scale, i.e. $L/D^{1,25}$ = 1,60 + 0,59 = 2,19 to the point T2 where terminal pressure is 11,4 bar. With this new terminal pressure and flow rate 227 kg/min, the required nozzle area at the end of each branch line is obtained from table B.7 and is approximately 368 mm2.

lt will be noted that this is only slightly less than the single large nozzle example, but that the discharge rate is halved by the reduced pressure.

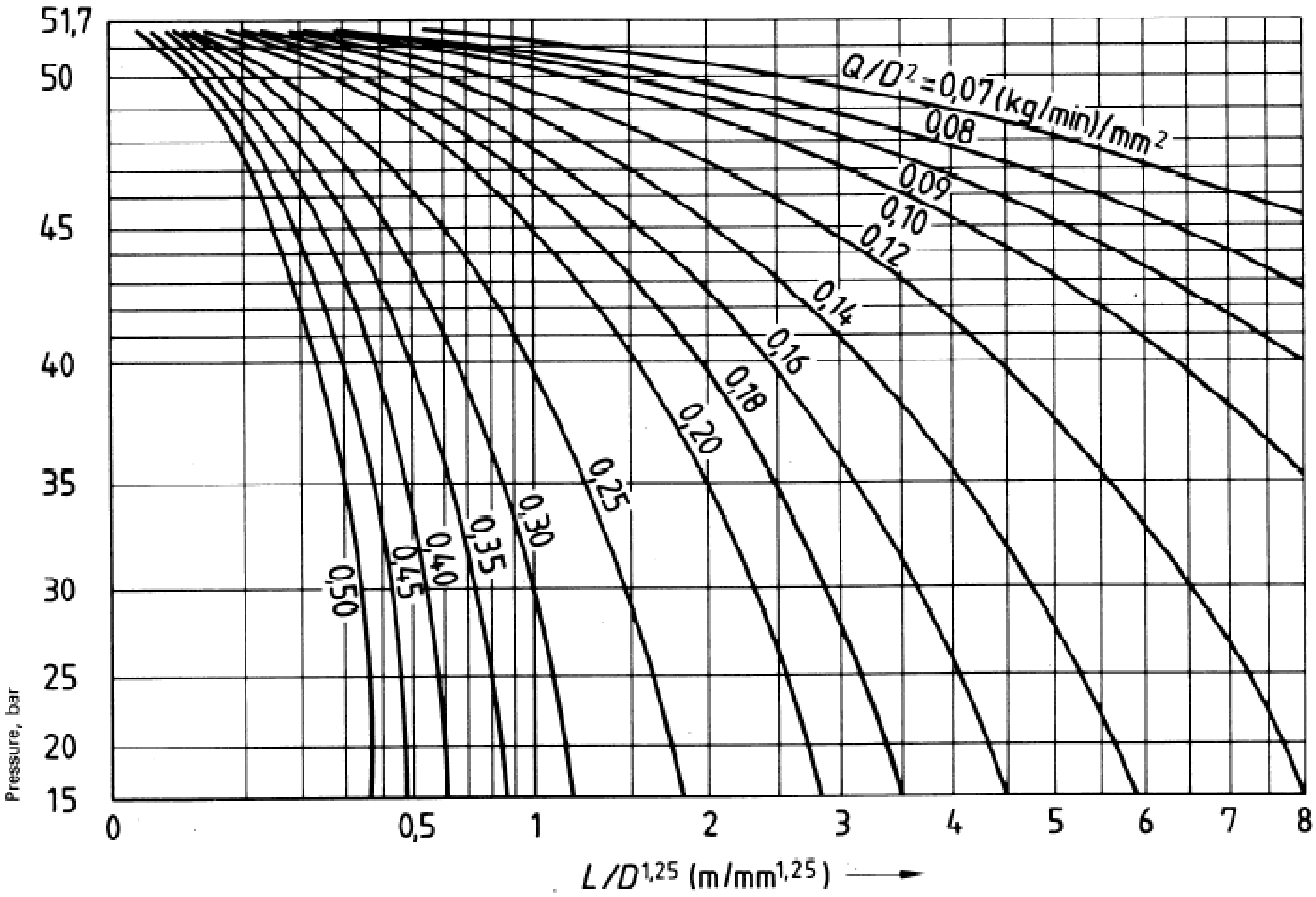

Figure B.2 — Pressure drop in pipeline for 51,7 bar (5,17 MPa) storage pressure

B.4 In high-pressure Systems, the manifold is supplied by a number of separate containers. The total flow is thus divided by the number of containers to obtain the flow-rate from each container. The flow capacity of the container valve and the connector to the manifold will vary with each manufacturer depending on design and size. For any particular valve, dip tube and connector assembly, the equivalent length tan be determined in terms of unit length of Standard pipe size. With this information the flow equation tan be used to prepare a curve of flow-rate versus pressure drop. This provides a convenient method of determining manifold pressure for a specific valve and connector combination.

B.5 Tables B.3 and B.4 list the equivalent lengths of pipe fittings for determining the equivalent length of piping systems. These tables are offered for guidance only. Manufacturers' listed data may also be used. Table B.3 is for threaded joints and table B.4 is for welded joints. Both tables have been prepared for schedule 40 pipe sizes; however, for all practical purposes the same figures tan also be used for schedule 80 pipe sizes.

B.6 For nominal changes in elevation of piping, the change in head pressure is negligible. However, if there is a substantial change in elevation, this factor should be taken into account. The head pressure correction per metre of elevation depends on the average line pressure where the elevation takes place since the density changes with pressure.

Correction factors are given in tables B.5 and B.6 for lowpressure and high-pressure systems, respectively. The correction is subtracted from the terminal pressure when the flow is upward and added to the terminal pressure when the flow is downward. The terminal pressure at the outlet having been determined, appropriately sized nozzles tan now be selected.

For low-pressure systems the discharge rate through equivalent orifices should be based on the values given in table B.7. Design nozzle pressures should be not less than 10 bar.

For high-pressure systems, the discharge rate through equivalent orifices should be based on the values given in table B.8. Design nozzle pressures at 21°C storage should be not less than 14 bar.

Table B.3 — Equivalent length of threaded pipe fittings

Pipe nominal size in	Pipe nominal size mm	Elbow std. 45° m	Elbow std. 90° m	Elbow 90° long radius and tee through flow m	T-side m	Union coupling or gate valve m
3/8	10	0,18	0,4	0,24	0,82	0,09
1/2	15	0,24	0,52	0,3	1	0,12
3/4	20	0,3	0,67	0,43	1,4	0,15
1	25	0,4	0,85	0,55	1,7	0,18
1 1/4	32	0,52	1,1	0,7	2,3	0,24
1 1/2	40	0,61	1,3	0,82	2,7	0,27
2	50	0,79	1,7	1,1	3,41	0,37
2 1/2	65	0,94	2	1,2	4,08	0,43
3	80	1,2	2,5	1,6	5,06	0,55
4	100	1,5	3,26	2	6,64	0,73
5	125	1,9	4,08	2,6	8,35	0,91
6	150	2,3	4,94	3,08	10	1,1

Table B.4 — Equivalent length of welded pipe fittings

Pipe nominal size in	Pipe nominal size mm	Elbow std. 45° m	Elbow std. 90° m	Elbow 90° long radius and tee through flow m	T-side m	Gate valve m
3/8	10	0,06	0,21	0,15	0,49	0,09
1/2	15	0,09	0,24	0,21	0,64	0,12
3/4	20	0,12	0,33	0,27	0,85	0,15
1	25	0,15	0,43	0,33	1,1	0,18
1 1/4	32	0,21	0,55	0,46	1,4	0,24
1 1/2	40	0,24	0,64	0,52	1,6	0,27
2	50	0,3	0,85	0,67	2,1	0,37
2 1/2	65	0,37	1	0,82	2,5	0,43
3	80	0,46	1,2	1	3,11	0,55
4	100	0,61	1,6	1,3	4,08	0,73
6	150	0,91	2,5	2	6,16	1,1

Table B.5 — Elevation correction factors for low-pressure systems

Average line pressure		Elevation correction	
bar	MPa	bar/m	MPa/m
20,7	2,07	0,100	0,010
19,3	1,93	0,077 6	0,007 8
17,9	1,79	0,059 9	0,006 0
16,5	1,65	0,046 8	0,004 7
15,2	1,52	0,037 8	0,003 8
13,8	1,38	0,030 3	0,003 0
12,4	1,24	0,024 2	0,002 4
11,0	1,10	0,019 2	0,001 9
10,0	1,00	0,016 2	0,001 6

Table B.6 — Elevation correction factors for high-pressure systems

Average line pressure		Elevation correction	
bar	MPa	bar/m	MPa/m
51,7	5,17	0,079 6	0,008
48,3	4,83	0,067 9	0,006 8
44,8	4,48	0,057 7	0,005 8
41,4	4,14	0,048 6	0,004 9
37,9	3,79	0,04	0,004
34,5	3,45	0,033 9	0,003 4
31	3,1	0,028 3	0,002 8
27,6	2,76	0,023 8	0,002 4
24,1	2,41	0,019 2	0,001 9
20,7	2,07	0,015 8	0,001 6
17,2	1,72	0,012 4	0,001 2
14	1,4	0,010 2	0,001

Table B.7 — Discharge rate of equivalent orifice area[1] for low-pressure systems

Orifice pressure		Discharge rate
bar	MPa	kg/min per mm^2
20,7	2,07	2,967
20	2	2,039
19,3	1,93	1,67
18,6	1,86	1,441
17,9	1,79	1,283
17,2	1,72	1,164
16,5	1,65	1,072
15,9	1,59	0,991 3
15,2	1,52	0,917 5
14,5	1,45	0,850 7
13,8	1,38	0,791
13,1	1,31	0,736 8
12,4	1,24	0,686 9
11,7	1,17	0,641 2
11	1,1	0,599
10	1	0,54

1) Based upon a standard single orifice having a rounded entry with a coefficient of 0,98.

Table B.8 — Discharge rate of equivalent orifice area[1] for high-pressure systems

Orifice pressure bar	MPa	Discharge rate kg/min per mm²
51,7	5,17	3,255
50	5	2,703
48,3	4,83	2,401
46,5	4,65	2,172
44,8	4,48	1,993
43,1	4,31	1,839
41,4	4,14	1,705
39,6	3,96	1,589
37,9	3,79	1,487
36,2	3,62	1,396
34,5	3,45	1,308
32,8	3,28	1,223
31	3,1	1,139
29,3	2,93	1,062
27,6	2,76	0,984 3
25,9	2,59	0,907
24,1	2,41	0,829 6
22,4	2,24	0,759 3
20,7	2,07	0,689
17,2	1,72	0,548 4
14	1,4	0,483 3

1) Based upon a standard single orifice having a rounded entry with a coefficient of 0,98.

B.7 In high-pressure systems, the delay in achieving equilibrium flow will generally be insignificant. In low-pressure systems, the delay time and amount of carbon dioxide vaporized in cooling the pipe should be calculated and the equilibrium flow rate increased accordingly to deliver the desired quantity within the design time after the start of the discharge.

Delay time, t_d, (low-pressure systems), in seconds and mass, m_v, of carbon dioxide vaporized (low- or high-pressure systems), in kilograms, during this period may be calculated as follows:

$$t_d = \frac{mCp(T_1 - T_2)}{0{,}507Q} + \frac{16850V}{Q}$$

$$m_v = \frac{mCp(T_1 - T2)}{H}$$

where:

m is the mass of piping, in kilograms;

C_p is the specific heat of metal in pipe, in kilojoules per kilogram (C_p= 0,46kj/kg for steel);

T_1 is the average pipe temperature before discharge, in degrees Celsius

T_2 is the average carbon dioxide temperature, in degrees Celsius ((Assume T_2=15,6°C for high pressure and T_2=20,6°C for low pressure installations under normal conditions.);

Q is the design flow rate, in kilograms per minute;

V is the volume of piping, in cubic metres;

H is the latent heat of vaporization of liquid carbon dioxide, in kilojoules per kilogram ($H \approx 150{,}7$ kJ/kg for high pressure and $H \approx 276{,}3$ kJ/kg for low pressure systems.)

Annex C

(informative)

Information on carbon dioxide and its application

The extinguishing medium carbon dioxide is a colourless, odourless and electrically non-conductive inert gas. Carbon dioxide is approximately one and one-half times as heavy as air. 1 kg of liquid carbon dioxide relieved to atmospheric pressure at 0^oC produces approximately 0,51 m^3 of gas. Carbon dioxide is stored in pressure vessels normally as liquefied gas.

Carbon dioxide extinguishes fire principally by reducing the oxygen content in the atmosphere to a point where it will not support combustion.

Carbon dioxide is suitable for extinguishing the following types of fire:

- fires involving liquids or liquefiable solids;

- fires involving gases, except in such cases when after extinguishment an explosive atmosphere may develop due to a continuation of escaping gases;

- under certain conditions, fires involving solid materials, usually of an organic nature in which combustion normally takes place with the formation of glowing embers;

- fires involving live electrical apparatus.

Carbon dioxide is not suitable for fighting fires involving the following materials:

- chemicals containing their own supply of oxygen, such as cellulose nitrate;

- reactive metals and their hydrides (e.g. sodium, potassium, magnesium, titanium and zirconium).

Carbon dioxide concentrations as required for use in extinguishing systems have a suffocating effect and should be regarded as highly dangerous. Therefore the safety requirements given in clause 5 should be strictly observed.

Annex D
(informative)

Calculation examples

D.1 Rate by volume method — Example 1

D.1.1 Hazard

Paint spray booth (requirements for plenum and duct would be a separate calculation; $K_B = 1$).

D.1.2 Actual dimensions

2,44 m wide (open front)
2,13 m high
1,83 m depth

D.1.3 Assumed volume

2,44 m × 2,13 m (1,83 m depth + 0,6 m)[1] = 12,63 m³

D.1.4 Per cent perimeter enclosed

$$\frac{2,44 + 1,83 + 1,83}{2,44 + 2,44 + 1,83 + 1,83} = \frac{6,1}{8,54} \times 100 \approx 71\ \%$$

D.1.5 Discharge rate for 71 % enclosure

4[2] + (1-0,71) × (16-4)[2] = 7,48 kg × minutes per cubic metre

D.1.6 Discharge rate

12,63 (m³) × 7,48 (kg/min per cubic metre) = 94,47 kg/min

D.1.7 Carbon dioxide requirement

94,47 (kg/min) × 0,5 (min) × 1,4 (includes vapour)[3]
= 66,13 kg

D.2 Rate by volume method — Example 2

D.2.1 Hazard

Printer with four sides and top open (no continuous solid walls; $K_B = 1$)

D.2.2 Actual dimensions

1,22 m wide
1,52 m long
1,22 m high

D.2.3 Assumed volume

2,42 m × 2,72 m × 1,82 m = 11,98 m³

D.2.4 Per cent perimeter enclosed

0 %

D.2.5 Discharge rate for 0 % enclosure

16 kg/min per cubic metre[4]

D.2.6 Discharge rate

11,98 (m³) × 16 (kg/min per cubic metre) = 191,7 kg/min

D.2.7 Carbon dioxide requirement

191,7 (kg/min) × 0,5 (min) × 1,4 (includes vapour)[1]
= 134,2 kg

D.3 Rate by area method

D.3.1 Hazard

Quench tank ($K_B = 1$)

D.3.2 Surface dimensions

0,92 m wide
2,13 m long

D.3.3 Nozzle location

Assume that a survey indicates that nozzles can be positioned anywhere from 0,92 m to 1,83 m away from the liquid surface without interfering with the operation.

1) See 16.3.2.
2) See total and minimum specific discharge rates in 16.3.3.
3) See 16.1.1.
4) See specified discharge rate in 16.3.3.

D.3.4 Procedure

From the manufacturer's list[1] of approved nozzles, select the minimum number of nozzles that will cover an area of 2,13 m × 0,92 m. Assume that the list has a nozzle which has a rated coverage of 1,08 m^2 at a height of 1,52 m and a rated flow of 22,3 kg/min. Two nozzles will then cover a length of 2,16 m and a width of 1,08 m.

D.3.5 Total flow-rate

2 × 22,3 (kg/min) = 44,6 kg/min

D.3.6 Carbon dioxide requirement

44,6 (kg/min) × 0,5 min × 1,4 (includes vapour) = 31,2 kg

D.4 Total flooding system

D.4.1 Store-room

Store-room for ethyl alcohol (K_B = 1,34) with an opening (not to be shut) of 2 m × 1 m.

D.4.2 Actual dimensions

16 m long
10 m wide
3,5 m high

D.4.3 Assumed volume

$V_V = 16 \times 10 \times 3{,}5 = 560\ m^3$

D.4.4 Additional volume for ventilation

$V_Z = 0\ m^3$

D.4.5 Deductible volume

$V_G = 0\ m^3$

$V = 560 - 0 - 0\ m^3$

D.4.6 Total surface area of all sides

$A_V = (16 \times 10 \times 2) + (16 \times 3{,}5 \times 2) + (10 \times 3{,}5 \times 2) = 502\ m^2$

D.4.7 Total surface area of all openings

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

D.4.8 Area

$A = 502 + 60 = 562\ m^2$

D.4.9 Carbon dioxide design quantity

$m = 1{,}34 \times (0{,}2\ kg/m^2 \times 562\ m^2 + 0{,}7\ kg/m^3 \times 560\ m^3) = 675{,}9\ kg$

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1) The manufacturer's list of approved nozzles will list a series of rated nozzles with their respective area coverage at a given height above the surface to be protected and a given flow rate in kilograms per minute.