Kidde Fire Protection

High Pressure Carbon Dioxide Fire Protection Equipment

DESIGN MANUAL

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TABLE OF CONTENTS

Chapter **Page**

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

This manual describes the design principles to be used on all carbon dioxide (CO_2) systems.

General requirements and design criteria are based on British Standard (BS) 5306 Part 4, but on some occasions National Fire Protection Association (NFPA) 12 may be used as the base document.

Detailed information on components is given in the individual CO_2 Engineering Data Sheets.

The importance of proper design cannot be over stressed as design concentrations and application rates are critical for successful extinguishing.

The recommendations given in this document represent the best known technical data, but while the aim has been to anticipate all considerations, the recommendations should be applied in practical situations with discretion and due regard to local circumstances.

Full requirements for the design of CO_2 fire fighting systems are given in BS5306 Part 4.

1 TOTAL FLOODING SYSTEMS

CO_2 total flooding systems are based on creating an extinguishing concentration of CO_2 within an enclosed space containing the combustible materials. The quantity of CO_2 is determined by applying an appropriate flooding factor to the volume being protected.

The efficiency of a total flooding system depends upon maintaining the concentration for as long as possible, so before total flooding can be considered as a method of extinguishing, the protected space must be reasonably well enclosed. It is always advisable for an integrity test to be conducted to verify the rate of leakage.

A fixed supply of CO_2 is permanently connected to fixed piping and discharge nozzles are arranged to discharge CO_2 into the protected space.

1.1 Examples of Hazards

Rooms, vaults, enclosed machines, ovens, dust collectors, floor and ceiling voids and fume extraction ducts.

1.2 Type of Fires

Fires that can be extinguished by total flooding methods are:

(a) Surface fires that can be extinguished quickly, such as those involving flammable liquids and vapours.

(b) Deep seated fires that require cooling time in order to be extinguished, e.g. fires involving bulk paper and other solids.

1.3 Where CO_2 is NOT Effective

(a) Materials that contain their own oxygen supply and liberate oxygen when burning, e.g. cellulose nitrate.

(b) Reactive metals e.g. sodium, potassium, magnesium, titanium, zirconium, uranium and plutonium.

(c) Metal hydrides.

While CO_2 may not extinguish these fires, it will not react dangerously or increase the burning rate. CO_2 will protect adjacent combustibles and will also extinguish fires of other materials in which the reactive metals are often stored.

Example:

(a) Sodium stored or used under Kerosene.

(b) Cellulose nitrate in a solvent.

(c) Magnesium chips covered with heavy oil.

2 CO_2 REQUIREMENTS FOR SURFACE FIRES

2.1 Basic Quantity

Multiply the volume to be protected (cubic metres) by the appropriate volume factor given in Table 1.

The answer will be in kilograms of CO_2. This will protect an enclosure containing materials requiring a design concentration of up to 34%.

The volume to be used is the gross volume of the enclosure but you are permitted to deduct permanent, impermeable elements of the building structure i.e. beams, stanchions, solid stairways and foundations.

Table 1 Volume Factors

Volume of Space m^3		Volume Factor kg CO_2/m^3	Calculated Minimum kg
	<4	1.15	
>4	<14	1.07	4.5
>14	<45	1.01	16.0
>45	<126	0.90	45.0
>126	<1400	0.80	110.0
>1400		0.74	1100.0

» ***NOTE 1 Table 1 Volume Factors, must ONLY be used for SURFACE FIRES*.**

» ***NOTE 2 For DEEP SEATED FIRES refer to Chapter 3.***

Example:

Room: 6 m x 9 m x 3m = 162 m^3

162 m^3 x 0.80 kg/m^3 = 129.6 kg

2.2 Uncloseable Openings

Openings shall be arranged to close automatically before or simultaneously with the start of the CO_2 discharge. This can be done by self-closing door devices, fire curtains or steel shutters, refer to Data Sheet 811-5000.

If it is not possible to seal the opening it is permissible for small openings to remain open provided they do not exceed the limits shown below, and are compensated by the addition of extra carbon dioxide.

2.2.1 Limits of Uncloseable Openings

The maximum area permitted is the smaller result of the following calculations:

(a) An area in square metres, which is numerically equivalent to 10% of the volume in cubic metres.

(b) 10% of the total area of all sides, top and bottom in square metres.

When uncloseable openings exceed this limitation, the system should be designed by a local application method.

2.2.2 Compensation

Additional gas at the rate of *5* kg/m^2 of opening.

Where necessary this quantity should be multiplied by the appropriate Material Conversion Factor (MCF), refer to Section 2.3.

The additional quantity should be discharged through the regular pipework system and the flow rate increased accordingly so that the additional quantity is discharged within the time specified in BS5306 Part 4.

2.3 Material Conversion Factor

For materials requiring a design concentration over 34%, the basic quantity of carbon dioxide calculated, i.e. the result of using Table 1, plus the addition for losses through limited openings, shall be increased by multiplying this quantity by the appropriate conversion factor in Table 2.

The most hazardous material in the enclosure must be selected no matter what the quantity of that material.

For materials not listed consult Kidde Fire Protection as the design concentration may have to be determined by test.

Example:

Room: 6 m x 9 m x 3 m high = 162 m^3
162m^3 x 0.80kg/m^3 = 129.6kg
Uncloseable opening = 1.0 m^2 = 5.0 kg
Basic quantity = 134.6 kg
If room contains butadiene as the most hazardous material: MCF = 1.3
134.6 kg x 1.3 = 175kg

Table 2 Minimum Carbon Dioxide Concentration for Extinction

Material	**Minimum Design CO_2 Concentration (%)**	**Material Conversion Factor**
Acetaldehyde	34	1.0
Acetylene	66	2.5
Amyl Acetate	34	1.0
Acetone	31	1.0
Amyl Alcohol	34	1.0
Benzol, Benzene	37	1.1
Butadiene	41	1.3
Butane	34	1.0
Butyl Acetate	34	1.0
Butyl Alcohol	34	1.0
Carbon Disulphide	66	2.5
Carbon Monoxide	64	2.4
Coal Gas or Natural Gas	37	1.1
Cyclopropane	37	1.1
Diesel Fuel	34	1.0
Dowtherm	46	1.5
Ethane	40	1.2
Ethyl Ether	46	1.5
Ethyl Alcohol	43	1.3
Ethylene	49	1.6
Ethylene Dichloride	25	1.0
Ethylene Oxide	53	1.75
Hexane	35	1.1
Hydrogen	74	3.2
Isobutane	36	1.1
Kerosene	34	1.0
Lube oils	34	1.0
Methane	30	1.0
Methyl Alcohol	40	1.2
Paint	34	1.0
Pentane	35	1.1
Petroleum Spirit	34	1.0
Propane	36	1.1
Propylene	36	1.1
Quench, Lube Oils	34	1.0
Tar	34	1.0
Toluol	34	1.0
Turpentine	34	1.0
Transformer Oil	34	1.0

For materials not listed please contact Kidde Fire Protection

2.4 Temperature Correction

Additional quantities of CO_2 are needed to compensate for the effects of abnormal temperature.

Hazards which operate at temperatures above 100°C may be more likely to re-ignite so it is necessary to hold the extinguishing concentration for a longer period to assist cooling.

Add 2% carbon dioxide for each 5°C above 100°C.

Example:

Oven: 3 m x 1.5 m x 1.8 m = 8.1 m^3
If the normal working temperature is 204°C:
204-100 = 104/5 = 20.8
20.8 x 2% = 41.6%
8.1m^3 x 1.07 kg/m^3 = 8.66 (basic quantity) x 1.416 (temp correction)
= 12.26 kg

CO_2 has a lower expansion ratio at lower temperatures so it will be more dense and leakage would be greater than normal.

Where the normal temperature of the enclosure is below -20°C, add 2% of CO_2 for each 1°C below -20°C.

Example:

Refrigerated space:
3 m x 6 m x 3 m = 54 m^3 with a normal operating temperature of -23°C.
23°C - 20°C = 3°C x 2% = 6%
54 m^3 x 0.90 kg/m^3 = 48.6 kg (basic quantity) x 1.06 (temp correction)
= 51 .5 kg

If an addition has been made to the basic CO_2 quantity to compensate for openings or application of an MCF, the total quantity should be used in place of the basic quantity in the above examples.

2.5 Forced Ventilation

When forced air ventilation systems are used, they shall, if possible, be shutdown before, or simultaneously, with the start of the CO_2 discharge. If this cannot be done, additional CO_2 must be applied.

If there is a short run down time but the quantity of air removed is significant, additional CO_2 must be applied. The additional CO_2 must be discharged within the time specified in BS5306 Part 4.

For calculation purposes the volume of air removed in one minute will be replaced with CO_2 at the design concentration being used.

Example:
Refer to the example in Section 2.3.
Assume the room has 30 m^3 of air removed by the ventilation system in one minute.

30 m^3 x 0.80 kg/m^3 = 24 kg x 1.3 (MCF) = 31.2 kg **+** 175.0 kg (original) = 206.2 kg

Services such as heating, fuel supplies, paint spraying, conveyors etc. must also be shutdown before or simultaneously, with the CO_2 discharge.

2.6 Interconnected Volumes

In two or more interconnected volumes where free flow of CO_2 can occur, the CO_2 quantity shall be the sum of the quantities calculated for each volume, using its respective volume factor. If one volume requires greater than normal concentration, the higher concentration shall be used for all interconnected volumes.

2.7 Venting for Surface Fire Systems

Leakage around doors and windows often provides sufficient pressure relief without special arrangements being required. It is possible to calculate the area of free venting needed for very tight enclosures but it is recommended you provide the customer with the formula and CO_2 flow rate so that his architect can take the responsibility.

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

where:
X is the free venting area (in mm^2).
Q is the calculated carbon dioxide flow rate (in kg/min).
P is the permissible strength (internal pressure) of enclosure (in bar).

3 CO_2 REQUIREMENTS FOR DEEP SEATED FIRES

3.1 Basic Quantity

Multiply the volume to be protected (cubic metres) by the flooding factor given in Table 3.

Example:

Paper documents storage room:
6m x 6m x 3m high = 108m^3
108 m^3 x 2 kg/m^3 CO_2 = 216 kg

3.2 Openings

Total flooding systems protecting solid materials cannot tolerate the degree of openings permitted for surface fire protection.

The design concentration must be maintainable over a long period, so low level openings are not practicable. Small openings at or near the ceiling are ideal because:

(a) Compensation for losses involves only reasonable quantities of additional CO_2.

(b) They allow the escape of hot gases.

(c) They prevent pressure increases that can stress the enclosure structure.

Any openings that cannot be closed shall be compensated for by the addition of CO_2 equal in volume to the expected loss during the extinguishing and holding time.

3.3 Forced Ventilation

When forced air ventilation systems are used, they shall, if possible, be shutdown before, or simultaneously, with the start of the CO_2 discharge. If this cannot be done, additional CO_2 must be applied.

If there is a short run down time but the quantity of air removed is significant, additional CO_2 must be applied. The additional CO_2 must be discharged within the time specified in BS5306 Part 4.

For calculation purposes the volume of air removed in one minute will be replaced with CO_2 at the design concentration being used.

Example:

Assume the room has 30 m^3 of air removed by the ventilation system in one minute:
30 m^3 x 2 kg/m^3 = 60 kg + 216 kg (original) = 276 kg

Services such as heating, fuel supplies, paint spraying, conveyors etc. must also be shutdown before or simultaneously, with the CO_2 discharge.

3.4 Interconnected Volumes

In two or more interconnected volumes where free flow of CO_2 can occur, the CO_2 quantity shall be the sum of the quantities calculated for each volume, using its respective volume factor. If one volume requires greater than normal concentration, the higher concentration shall be used for all interconnected volumes.

Table 3 Hazard Factors

Based on an expansion ratio of 0.52 m^3/kg at a temperature of 10°C.

Hazard	**Design Concentration (%)**	**Flooding Factors (kg/m^3)**
Electrical equipment.		
Enclosed rotating equipment		
Dry electrical wiring		
Electrical insulating materials	50	1.35
Computer installations *		
Central processing areas and equipment	53	1.50
Data processing		
Tape controlled machinery		
and tape storage	68	2.25
Stores		
Record stores and archives for		
paper documents		
Ducts and covered trenches	65	2.00
Fur storage vaults		
Dust collectors	75	2.70
General		
Cocoa		
Leather		
Silk		
Wool	63	1.78
Coal		
Coffee		
Cork		
Cotton		
Peanuts		
Rubber		
Soybean		
Sugar	75	2.70

* See also BS 6266.

» ***NOTE 1*** *Flooding factors for other deep seated fires should be agreed with Kidde Fire Protection.*

» ***NOTE 2*** *Table 1 Volume Factors, is not applicable for deep seated fires and must not be used.*

3.5 Extended Discharge

In some instances it may be necessary to have an extended discharge for leakage compensation with a rate of flow that is considerably slower than that required for initial fire extinguishing. A typical example is the protection of rotating electrical machinery, i.e. alternators and generators, where an initial concentration has to be achieved in a short time and a minimum concentration of 30% during a specified deceleration period, which should be held for 20 minutes.

Two separate banks of CO_2 containers and distribution piping are used in this case, the 'initial' bank discharging at a fast rate and the 'extended' bank discharging at a slow rate.

Table 4 is used to determine the quantity of CO_2 to maintain minimum concentration.

The quantities are based on the nett internal volume of the machine and the deceleration time assuming average leakage.

For non re-circulating machines with relief vents, add 35% to the quantities shown in Table 4.

3.5.1 Venting for Deep Seated Fire Systems

Leakage around doors and windows often provides sufficient pressure relief without special arrangements being required. It is possible to calculate the area of free venting needed for very tight enclosures but it is recommended you provide the customer with the formula and CO_2 flow rate so that his architect can take the responsibility.

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

where:
X is the free venting area (in mm^2).
Q is the calculated carbon dioxide flow rate (in kg/min).
P is the permissible strength (internal pressure) of enclosure (in bar).

Table 4 Extended Discharge Gas Quantities for Enclosed Circulation: Rotating Electrical Machines

Carbon Dioxide Required		5 mm		10 mm		15 mm		20 mm		30 mm		40 mm		50 mm		60 mm	
kg	lb	m^3	ft^3	m^3	ft^3	m^3	ft^3	m^3	ft^3	m^3	ft^3	m^3	ft^3	m^3	ft^3		ft^3
45	100	34	1 200	28	1 000	23	800	17	600	14	500	11	400	9	300	6	200
68	150	51	1 800	43	1 500	34	1 200	28	1 000	21	750	17	600	14	500	11	400
91	200	68	2 400	55	1 950	45	1 600	37	1 300	28	1 000	24	850	18	650	14	500
113	250	93	3 300	69	2 450	57	2 000	47	1 650	37	1 300	30	1 050	23	800	17	600
136	300	130	4 600	88	3 100	68	2 400	57	2 000	47	1 650	37	1 300	28	1 000	20	700
159	350	173	6 100	116	4 100	85	3 000	71	2 500	57	2 000	47	1 650	34	1 200	26	900
181	400	218	7 700	153	5 400	108	3 800	89	3 150	71	2 500	57	2 000	45	1 600	34	1 200
204	450	262	9 250	193	6 800	139	4 900	113	4 000	88	3 100	74	2 600	60	2 100	45	1 600
227	500	306	10 800	229	8 100	173	6 100	142	5 000	110	3 900	93	3 300	79	2 800	62	2 200
250	550	348	12 300	269	9 500	210	7 400	173	6 100	139	4 900	119	4 200	102	3 600	88	3 100
272	600	394	13 900	309	10 900	244	8 600	204	7 200	170	6 000	147	5 200	127	4 500	110	3 900
295	650	436	15 400	348	12 300	279	9 850	235	8 300	200	7 050	176	6 200	156	5 500	136	4 800
319	700	479	16 900	385	13 600	314	11 100	266	9 400	230	8 100	204	7 200	181	6 400	159	5 600
340	750	524	18 500	425	15 000	350	12 350	297	10 500	259	9 150	232	8 200	207	7 300	184	6 500
363	800	566	20 000	464	16 400	385	13 600	329	11 600	289	10 200	261	9 200	232	8 200	207	7 300
386	850	609	21 500	503	17 750	421	14 850	360	12 700	320	11 300	289	10 200	258	9 100	229	8 100
408	900	651	23 000	541	19 100	456	16 100	391	13 800	350	12 350	317	11 200	285	10 050	255	9 000
431	950	697	24 600	581	20 500	491	17 350	422	14 900	379	13 400	346	12 200	312	11 000	278	9 800
454	1 000	739	26 100	620	21 900	527	18 600	453	16 000	411	14 500	374	13 200	337	11 900	303	10 700
476	1 050	782	27 600	666	23 300	564	19 900	484	17 100	442	15 600	402	14 200	364	12 850	326	11 500
499	1 100	824	29 100	697	24 600	596	21 050	515	18 200	470	16 600	430	15 200	389	13 750	351	12 400
522	1 150	867	30 600	736	26 000	632	22 300	547	19 300	501	17 700	459	16 200	416	14 700	374	13 200
544	1 200	912	32 200	773	27 300	667	23 550	578	20 400	532	18 800	487	17 200	442	15 600	399	14 100
567	1 250	954	33 700	813	28 700	702	24 800	609	21 500	562	19 850	515	18 200	467	16 500	422	14 900
590	1 300	1 000	35 300	852	30 100	738	26 050	641	22 650	592	20 900	544	19 200	494	17 450	447	15 800
612	1 350	1 042	36 800	889	31 400	773	27 300	673	23 750	623	22 000	572	20 200	521	18 400	472	16 650
635	1 400	1 087	38 400	929	32 800	809	28 550	705	24 900	654	23 100	600	21 200	548	19 350	496	17 500
658	1 450	1 130	39 900	968	34 200	844	29 800	736	26 000	685	24 200	629	22 200	575	20 300	520	18 350
680	1 500	1 172	41 400	1 008	35 600	879	31 050	767	27 100	715	25 250	657	23 200	600	21 200	544	19 200

4 DISCHARGE RATES FOR TOTAL FLOODING SYSTEMS

The importance of the following calculations is that pipe and nozzle sizes are based on the desired flow rate, refer to Chapter 9.

0.52 m^3/kg @ 10°C

0.54 m^3/kg @ 20°C

0.56 m^3/kg @ 30°C

4.1 Surface Fires

For surface fires the design concentration will be achieved in one minute.

Example:

Room requiring 1,000 kg of CO_2.
This would be the basic quantity calculated, plus all additions but not including any special addition for cooling purposes, refer to Section 2.4.
1,000 kg of CO_2 ÷ by one minute
Flow rate = 1000 kg/min

4.2 Deep Seated Fires

For deep seated fires the design concentration will be achieved within seven minutes but the rate will not be less than that required to develop a concentration of 30% in two minutes.

This would be the basic quantity calculated, plus all additions but not including an extended discharge.

Example:

Paper documents storage room:
6 m x 6 m x 3 m high = 108 m^3
108 m^3 x 2 kg/m^3 of CO_2 = 216 kg
30% Vol = 32.4 m^3
32.4 in^3 ÷ 0.56 m^3/kg (expansion 30°C) = 57.85 kg ÷ 2
Flow rate = 29 kg/min
Flow time = 216 ÷ 29 = 7.45 minutes
To ensure a flow time of 7 minutes
Use 216 ÷ 7 = 31 kg per minute

Most calculations produce a flow time of between four and seven minutes, the last step shows what to do if seven minutes is exceeded.

5 NOZZLE DISTRIBUTION

For flooding rooms use discharge horn nozzles Part No K61793 or K61792, refer to Data Sheet 811-9148, depending upon flow rate required.

Nozzles should spaced approximately 6 m apart.

For rooms up to *5* m high, install nozzles at a height of *2.5* m and angle of 45°. Average throw approximately 4 m.

For rooms between *5* and 10 m high, install at 2/3 height up from floor.

For rooms with high stacking or rooms over 10 m high, it may be necessary to install at 1/3 and 2/3 levels.

Obstructions: If obstructions interfere with efficient distribution it may be necessary to use more nozzles than specified above, or even locate nozzles at ceiling level.

To protect the nozzle in dirty conditions use Part No. K5814, refer to Data Sheet 811-9139.

To inject CO_2 into ducts use nozzle Part No. K13045, refer to Data Sheet 811-9151.

6 LOCAL APPLICATION SYSTEMS

Local application systems are used for extinguishing surface fires in flammable liquids, vapours and shallow solids, where the hazard is not enclosed or where the degree of enclosure does not conform to the requirements for total flooding.

In carbon dioxide local application systems, CO_2 is discharged directly into the *fire.* The efficiency of the system depends on the CO_2 contacting the burning surface at the required rate of flow. Correct discharge horn nozzle positioning is critical.

Quantities of CO_2 must not be determined by using Table 1.

6.1 Examples of Hazards

Dip tanks, quench tanks, printing presses, textile machinery, coating machinery, spray booths, kitchen ranges and hoods etc.

6.2 General

The important point is that the hazard shall be isolated from other hazards and the entire hazard protected simultaneously, so that fire is prevented from spreading to unprotected areas and a re-flash from unprotected areas is not possible.

For example, in a six stand printing press simultaneous protection would be given to all printing stands, the drying boxes, the ink supply containers, and the flammable vapour extract duct. Similarly in an industrial food processing environment, simultaneous protection is given to the cooking oil surfaces, the burner compartment, the fume hood and extraction duct.

Any service likely to affect the efficiency of the CO_2 discharge must be interlocked with the system so as to automatically shut down. This would include ventilating fans, conveyors, flammable liquid pumps, mixers, heaters, dryers, sprayers etc.

6.3 CO_2 Quantities

The quantity of CO_2 to be used in a local application system can be determined by either of two methods depending upon the hazard construction, but there are various factors that are common to both.

The amount of CO_2 required is computed by multiplying the total nozzle discharge rate by the time the discharge is required to be maintained.

For high pressure systems, the computed quantity of CO_2 is increased by 40% to compensate for the fact that only 70% of the cylinder content is discharged as a liquid and considered effective.

If a combination of total flooding and local application protection is being given, this increase is not needed for the total flooding portion. The discharge rate for the total flooding portion can be calculated by dividing the quantity required for total flooding by the factor 1.4 and by the time of the local application discharge in minutes.

6.3.1 Duration of Discharge

The minimum, effective liquid discharge time is 30 seconds.

This is increased if inherently hot surfaces or materials require a longer time to assist in cooling and to prevent re-ignition.

The standard does not specify the prolonged discharge time so this must be decided by the designer taking into account the temperature involved and local site considerations, but somewhere between one and three minutes is usually adequate.

The minimum discharge time for Carbon Dioxide being applied to liquids that have an auto-ignition temperature that is lower than their boiling temperature shall be 3 min.
For example when protecting a kitchen range a prolonged discharge is given to the cooking oil surface (3 minutes) but only 30 seconds to other associated areas.

6.3.2 Material Conversion Factor

A MCF is applied when appropriate, as specified in Section 2.3. The increased quantity of CO_2 has to be discharged during the 30 second minimum period.

Example:

Local application portion:
Flow rate (kg/min) x discharge time (mins) x 1.4 x MCF = kg of CO_2 required
e.g. 100 kg/min x 0.5 x 1.4 x 1.5 (Ethyl Ether)
=100 x 0.7x 1.5
= 105kg
plus 150 kg for a 90 second discharge for cooling = 315 kg in total and discharged at a rate of 150 kg/min

Total flooding portion:
Quantity of CO_2 required is determined by the total flooding method

$$\text{Flow rate} = \frac{\text{Quantity of } CO_2}{1.4 \times \text{discharge time}}$$

e.g. 14 kg of CO_2 is for a Total Flooding portion of a combined Local Application minus Total Flooding system (discharge time 0.5min)

$$\text{Flow rate} = \frac{14\text{ kg}}{1.4 \times 0.5} = \frac{14}{0.7} = 20\text{ kg/min}$$

The foregoing information relates to high pressure storage containers of which the majority of systems comprise.

If a low pressure bulk storage tank is employed, the 1.4 liquid flow factor is omitted.

Also the pre-liquid flow time, which is a feature of low pressure systems must not be included as part of the 30 second liquid discharge time.

» **NOTE** *Only liquid discharge is effective in a local application system.*

7 RATE BY AREA METHOD

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

When flammable liquid fires are to be extinguished, a minimum freeboard of 150 mm is necessary.

7.1 CO_2 Quantity

The maximum area protected by each discharge horn and the amount of CO_2 required varies with the distance of the horn from the surface being protected. The greater the distance, the larger the area covered and quantity of CO_2 required.

The portion of a hazard surface protected by each horn is based on its 'side of square' coverage.
Nozzle sizes are selected for their area coverage and flow rate so as to minimise the amount of CO_2 required.

See Table 5 for details of horn height, area coverage and CO_2 quantity combinations.

Table 5 Horn Selection and CO_2 Quantity

Part Nos. K5814 up to N8, refer to Data Sheet 811-9139.

Part Nos. K61793 up to N12 and K61792 up to N18, refer to Data Sheet 811-9148.

Coated Surface (m)		Discharge Horn		Liquid Surface (m)	
Area (m^2)	Side of Square	Height (m)	Rate (kg/min)	Area (m^2)	Side of Square
1.17	1.08	0.60	14.0	0.84	0.91
1.23	1.11	0.68	15.7	0.88	0.94
1.30	1.14	0.76	17.3	0.93	0.96
1.36	1.17	0.84	19.3	0.98	0.99
1.43	1.19	0.91	20.5	1.02.	1.01
1.50	1.22	0.99	21.6	1.07	1.03
1.56	1.25	1.07	23.6	1.11	1.05
1.62	1.27	1.14	25.2	1.16	1.08
1.69	1.30	1.22	26.8	1.20	1.09
1.76	1.33	1.30	28.4	1.25	1.12
1.82	1.35	1.37	30.0	1.30	1.14
1.86	1.37	1.45	31.6	1.35	1.16
1.95	1.40	1.52	33.2	1.39	1.18
2.01	1.42	1.60	34.8	1.44	1.20
2.08	1.44	1.67	36.4	1.49	1.22
2.15	1.46	1.75	38.0	1.53	1.23
2.21	1.48	1.83	39.5	1.58	1.26
2.28	1.50	1.90	41.1	1.62	1.27
2.34	1.53	1.98	42.7	1.67	1.29
2.41	1.55	2.06	44.3	1.72	1.31
2.47	1.57	2.13	46.0	1.76	1.33
2.54	1.59	2.21	47.5	1.81	1.34
2.60	1.81	2.29	49.1	1.86	1.36
2.60	1.61	2.36	50.7	1.86	1.36
2.60	1.61	2.44	52.3	1.86	1.36
2.60	1.61	2.51	53.9	1.86	1.36
2.60	1.61	2.59	55.5	1.86	1.36
2.60	1.61	2.67	57.0	1.86	1.36
2.60	1.61	2.74	58.6	1.86	1.36

» **NOTE** *Interpolations are not permitted.*

7.2 Horn Dispositions

Hazard conditions often restrict the positioning of discharge horns but to use Table *5* accurately, horns must be installed perpendicular to the hazard and centred over the area to be protected. They may also be installed at angles between 45 and 90° to the plane of the hazard. The 'height' used in determining the necessary flow rate and area coverage is the distance from the aiming point on the protected surface to the face of the horn measured along the axis of the horn.

See Figure 1 for a typical example.

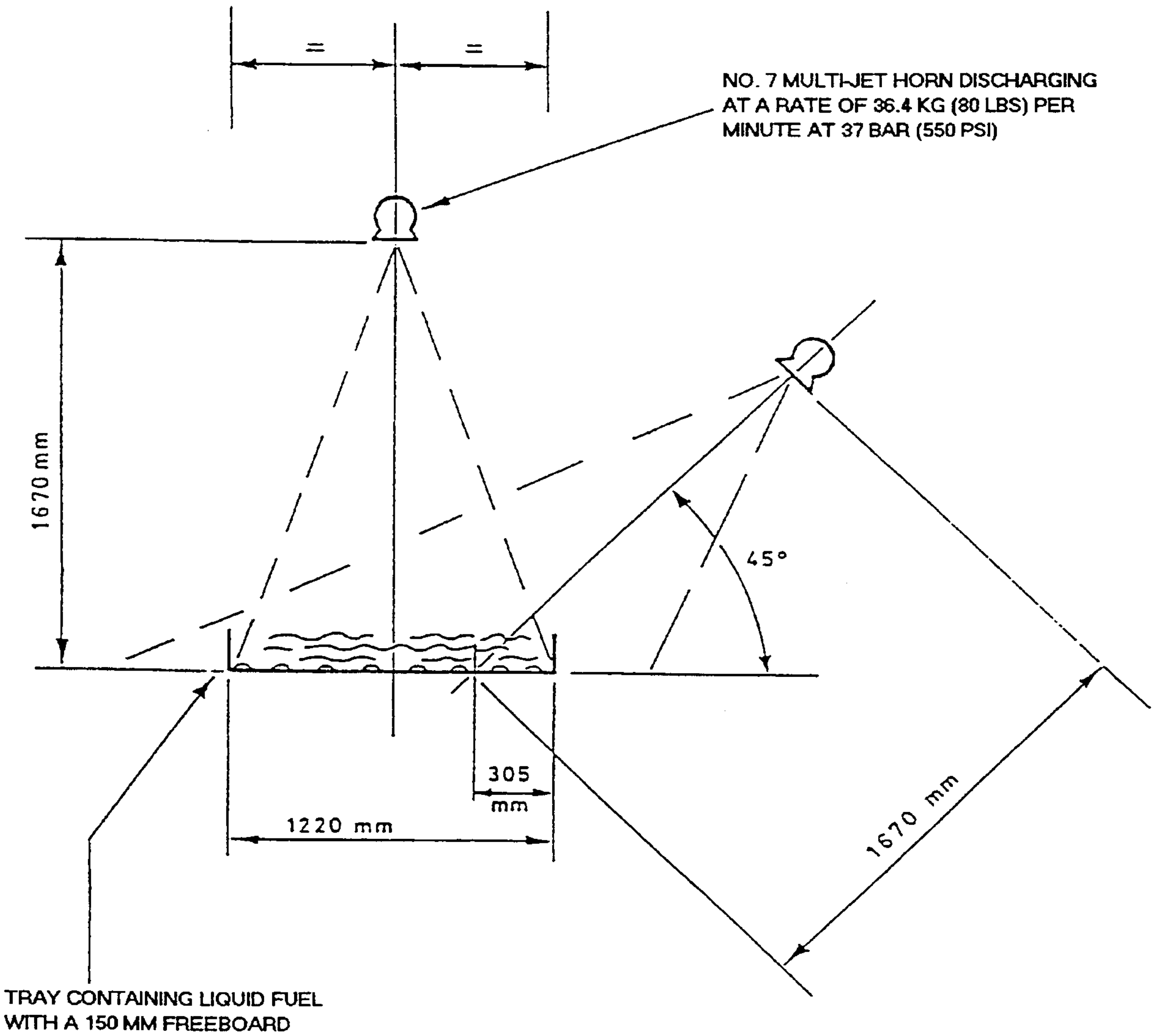

Figure 1 Aiming Position for Angled Discharge Horns

The aiming point is measured from the near side of the area protected and is located by multiplying the fractional aiming factor in Table 6 by the width of the area protected by the horn.

Table 6 Aiming Factors for Nozzles Installed at an Angle (based on 150 mm Freeboard)

Discharge Angle (See Note 1)	Aiming Factor (See Note 2)
45 to 60°	174
60 to 75°	1/4 to 3/8
75 to 90°	3/8 to 1/2
90° (perpendicular)	1/2 (centre)

» ***NOTE 1*** *Degrees from plane of hazard surface.*
» ***NOTE 2*** *Fractional amount of nozzle coverage area.*

It is important that horns are located so that the discharge is not obstructed and their alignment is not easily disturbed.

Discharge horns must be located so as to develop an extinguishing concentration over coated stock that may be extending over a protected surface, e.g. freshly dipped items hanging on a conveyor line. In these circumstances additional horns may be required for this specific purpose, particularly if stock extends more than 600 mm above a protected surface.

Note the increase in area coverage that is given in Table 5 for coated surfaces compared with liquid surfaces.

The effects of severe air currents and draughts shall be compensated for by adjusting horn locations or by providing additional horns to suit the expected conditions.

Example:

Hazard: Quench Tank
Material: Quench Lube Oil
MCF: 1
Surface dimensions: 0.92 m x 2.13 m

Horn Location. The site survey has shown that discharge horns can be positioned anywhere from 0.92 m to 1.83 m above the liquid surface without interfering with plant operations.

Design Aim. To select a combination of horn height, area coverage and flow rate to adequately cover the area with the minimum CO_2 quantity.

Procedure. Consider the size to be protected. What is the minimum number of horns that could be used to cover a length of 2.13 m of liquid surface?

Answer. Two horns with a side of square each of 1.08 m. This selection also satisfies a width of 0.92 m since it is less than 1.08 m, and also an area of 1.95 m² since it is less than can be protected by the two horns selected.

Horns required. Two located centrally above the liquid surface pointing down from a height of 1.14m.

Flow rate. 2 x 25.2 kg per minute **=** 50.4 kg/min

CO_2 required. $\frac{50.4 \quad \times 1\ (\text{MCF})\ 1\ 4}{2}$ (liquid flow for 0.5 min) = 50.4 x 0.7 = 35.3 kg

This provides the basic CO_2 quantity for the minimum permitted length of time but the discharge time at the calculated flow rate could be increased for cooling to prevent reignition.

8 RATE BY VOLUME METHOD

The assumed volume method of system design is used where the fire hazard consists of three dimensional irregular objects that cannot easily be reduced to equivalent surface areas, or where the degree of enclosure does not conform to the requirements for total flooding.

8.1 Assumed Enclosure

The total discharge rate of the system is based on the volume of hypothetical enclosure surrounding the hazard.

The assumed enclosure must have a closed floor.

The assumed walls and ceiling of the 'enclosure' shall be at least 0.6 m from the main hazard unless actual walls are involved, and they must enclose all areas of possible leakage, splashing or spillage.

No deduction from the assumed volume shall be made for solid objects within this volume. A minimum dimension of 1.2 m shall be used in calculating the assumed volume.

8.2 CO_2 Quantity

The total discharge rate for the basic system shall be 16 kg/min per m^3 of assumed volume.

If the assumed enclosure is partly defined by permanent continuous walls extending at least 0.6 m above the hazard, the discharge rate may be proportionately reduced to not less than 4 kg/min per m^3 for the actual walls completely surrounding the hazard. See Figure 2 for quickly deciding the appropriate discharge rate.

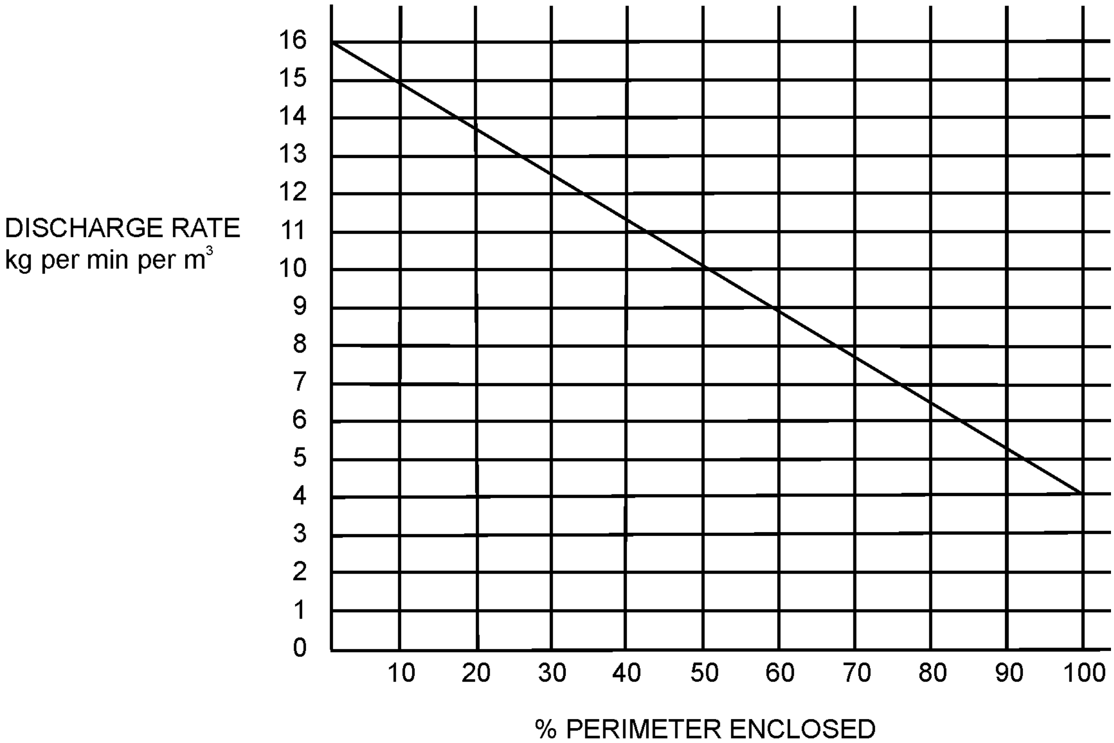

Figure 2 Discharge Rate, per kg per min per m^3

8.3 Horn Dispositions

A sufficient number of horns must be used to adequately cover the entire hazard volume and they must be located and directed so as to retain the CO_2 in the hazard volume by suitable co-operation between horns and objects making up the hazard volume.

If forced draughts or air currents are anticipated they must be compensated for by a suitable disposition of the discharge horns.

To ensure that discharge horns are not located so remote from the risk as to be ineffective, and not so close to liquids as to cause splashing, a check can be made by using Table 6.

Example:
If horn, Part No. K61792, with a flow rate of 52.3 kg/min, was selected it should be located approximately 2.44 m from the surface it is protecting.

Example 1

Hazard: Paint Spray Booth (ignoring extract duct for this calculation)
Actual dimensions: 2.44 m wide (open front) x 2.13 m high x 1.83 m deep
Assumed volume: 2.44 m x 2.13 m x 2.43 m (1.83 m deep + 0.6 m) = 12.63 m^3
Percent Perimeter enclosed =

$$\frac{244 + 1.83 + 183}{2.44 + 2.44 + 1.83 + 1.83} = \frac{6.1}{8.54} = 71\%$$

Discharge rate for 71% enclosure: from Figure 2 = 7.5 kg/min m^3
Discharge rate: 12.63 m^3 x 7.5 kg/min m^3 = 94.73 kg/min
CO_2 required: 94.73 kg/min x 0.7 = 66.3 kg x MCF (1.0)

Example 2

Hazard: Printer with 4 sides and top open (no continuous solid walls and ignoring extract duct for this calculation).
Actual dimensions: 1.22 m wide x 1.52 m long x 1.22 m high (this is the maximum hazard outline).
Assumed volume: 2.42 m (1.22 + 0.6 + 0.6) x 2.72 m (1.52 + 0.6 + 0.6) x 1.82 m (1.22 + 0.6) = 11.98 m^3
Percent perimeter enclosed: Zero
Discharge rate for 0% enclosure: 16 kg/min m^3
Discharge rate: 11.98 m^3 x 16 kg/min m^3 = 191.7 kg/min
CO_2 required: 191.7 kg/min x 0.7 = 134.2 kg x MCF (1.0)

» ***NOTE*** *The assumed volume method of system design always needs more gas than the rate by area method, so to be competitive it is always worth considering if the risk can be protected by the area method. Example 2 can, but Example 1 cannot.*

9 PIPE SELECTION

The selection of the various grades of pipe and fittings in order to meet the duties imposed by operating pressures arid temperatures is made by complying with BS 5306 part 4 or NFP A 12 as appropriate.

9.1 Rate of Application

Also see to Chapter 4.

Where advancement of flame is potentially rapid, as in surface fires, the CO_2 discharge must be comparably fast to minimise damage.

Where the spread of fire is potentially slow, such as deep seated fires in solid materials, more emphasis is placed on maintaining a fire suppression concentration for a lengthy period of time to allow time for cooling.

Where the spread of fire may be faster than normal for the type of fire expected, or where high values, or vital machinery or equipment are involved, rates higher than the stated minimums may be used.

Where a hazard contains materials that will produce both surface and deep seated fires, the rate of application should be at least the minimum required for surface fires.

9.2 Pipe Size Estimates

Hydraulic pipe size calculations are accurately determined by using the Kidde Fire Protection CO_2 Computer Calculation Program. However, for estimating for a quotation, only a reasonably accurate result is needed and this can be achieved by using Table 7.

Table 7 Pipe Size Estimates

Metric

Flow Rate (kg/min)	Estimated Pipe Size Nominal bore (mm)
Up to 123	20
124 to 177	25
178 to 363	32
364 to 545	40
546 to 1045	50
1045 to 1363	65

Imperial

Flow Rate (lbs/min)	Estimated Pipe Size Nominal bore (inches)
Up to 270	¾
271 to 390	1
391 to 800	1¼
801 to 1200	1½
1201 to 2300	2
2300 to 3000	2½

Examples

(a) A surface fire where the design concentration has to be achieved in one minute. If a space requires 300 kg of CO_2, the flow rate from the main manifold would be 300 kg/min and the size of the feed pipe would be 32 mm bore.

If the system used 4 discharge horns in a balanced distribution system, the feed pipe would branch into two pipes each flowing at 150 kg/min and would be sized 25 mm bore.

» ***NOTE*** *The design concentration would include any extra CO_2 for losses through openings and that demanded by the MCF but would not include any extra CO_2 allowed for cooling. This would be allowed to discharge at the same rate and would extend the discharge time beyond one minute.*

The same philosophy applies in a local application system except that the minimum discharge time is 30 seconds, which may be extended beyond this time to discharge any extra CO_2 added for cooling.

(b) A deep seated fire where the design concentration has to be achieved within seven minutes, but a concentration of 30% (must be achieved within) two minutes.

When an order has been received, a Contract Engineer would calculate the flow rate accurately, as shown in Section 4.2.

For estimating purposes it is sufficient to adopt a short cut method.

To determine the flow rate divide the volume protected by:
3 if in cubic metres and answer in kg/min.
51 if in cubic feet and answer in lbs/min.

(c) In an extended discharge system where the CO_2 quantity is derived from Table 4, it is simply necessary to divide the quantity of CO_2 required by the length of time of the extended discharge to determine the flow rate.

9.3 Nozzle Sizes

These are determined by use of the Calculation Program, and nozzle orifice sizes are drilled according to Data Sheet 811-9148.

A point to bear in mind is that the maximum number of discharge horns that can be fed by one container is 11 – N3.

The larger the nozzle orifice the smaller the number of horns that can be used, i.e. only one N11

10 STORAGE CONTAINER LOCATION

It is important to get a commitment from a prospective client about the location of storage containers because this will affect the installation of pipe, detection lines and cabling, and remote pull controls.

The containers shall be located in a secure area and arranged so that they are readily accessible for inspection, testing, recharging and other maintenance.

Containers shall be located as near as possible to the space they protect. They may be located within the protected space, but must not be exposed to a fire in a manner that is likely to impair system performance. If located within the protected space the manual/pneumatic actuator can be used to provide a means of mechanically operating the system from outside the protected space. The chosen location should provide protection from mechanical, chemical, electrical and other types of damage. Suitable guards or enclosures should be provided when necessary, as required by an appropriate risk analysis. The floor at the container location must be suitable for withstanding the loading exerted by the containers.

The containers must not be exposed to the direct rays of the sun. When excessive temperature variations are expected, suitable enclosures shall be provided.

The general ambient storage temperatures should not exceed the following:

(a) For total flooding systems:
not greater than 55ºC or less than -18ºC.

(b) For local application systems:
not greater than 46ºC or less than 0ºC.

» ***NOTE*** *The minimum storage temperature for local application is higher than that allowed for total flooding systems because the discharge area limit tests were carried out at a minimum temperature of 0ºC and to operate at lower temperatures would cause the figures in Table 5 to be incorrectly applied.*

11 DISTRIBUTION VALVES

When the multiple hazards are located reasonably close together they can be protected with a single bank of containers with the CO_2 being directed to the hazard on fire by opening the appropriate distribution valve on a distribution valve manifold.

When using this method it is important to consider the list below:

(a) The amount of CO_2 is sufficient for the largest hazard.

(b) There is only one supply of agent so it must not be possible for fire to spread from one zone to another.

(c) Any number of zones can be protected by a single bank of containers but Insurers' rules generally limit the number to 5.

(d) A reserve supply of CO_2 should be considered.

12 AUTOMATIC OPERATION

Systems should preferably be operated automatically by a detection system which is appropriate to the risk.

Where applicable, e.g. slow burning hazards, the requirements of BS5839 should be observed.

13 MANUAL CONTROL

All systems must be fitted with a manual release facility.

Refer to Data Sheet 841-5027.

13.1 Manual Release

When mechanically operated pull-handles are used the following limitations apply:

Maximum length of cable =45 m

Maximum number of corner pulleys = 10

Maximum number of sets = 1

All mechanical functions must be tested upon completion of the installation to ensure proper performance.

14 ALARMS

System condition indicators should be provided as appropriate to the surroundings.

(a) A total flooding systems should have indicators located outside the entrance doors to show:

CO_2 Discharged - red lamp
Manual Control only - green lamp
Automatic and Manual Control - amber lamp

These indications may not always be necessary for a local application system.

(b) Additional alarms may be needed to be transmitted to remote locations including a Central Station, and other system conditions may be required such as:

System Totally Disabled - amber lamp
Fire - red flashing lamp
System Operated - red steady lamp
Supply Healthy - green lamp

Warning labels are required to be located alongside manual release points, refer to Data Sheet 811-9225, and located on all entrance doors, refer to Data Sheet 811-9237.

Depending upon the size and complexity of the site or system, instructional wall charts may be needed.

Operating and Maintenance manuals should always be provided.

Audible alarms should be provided as appropriate to the type of system and protected area, but at least to the requirements of B5306 Part 4.

Where BS5839 is not a requirement, local alarms may be mains operated provided the supply can be guaranteed.

15 ELECTROSTATIC DISCHARGE

WARNING

CO_2 FIRE EXTINGUISHING SYSTEMS MUST NOT BE USED FOR INERTING EXPLOSIVE ATMOSPHERES.

16 DETECTION

Automatic detection systems used with CO_2 extinguishing systems should comply with appropriate Codes of Practice, these include:

1. BS5839 - Fire Detection and Alarm Systems in Buildings.

2. BS6266 - Data Processing Installations.

3. FOC Rules.

4. This Manual.

» ***NOTE*** *Attention is drawn to the considerably higher concentration of detectors required by BS6266 when protecting computer suites.*

This philosophy should not be extended into other areas of protection without prior consultation with Kidde Fire Protection.

The following guidance is given for use when designing systems using pneumatic detection systems.

16.1 Pneumatic Detection - Heat Actuated Devices

16.1.1 General

Heat Actuated Devices (HADs) are heat detectors and the following general points must be considered before using the devices.

(a) It is always necessary to determine that the minimum expected quantity of fuel is sufficient to produce a significant rise in the ambient temperature.

(b) Heat detection should never be used where the fire can be of a smouldering, or primarily smoke producing type.

(c) Height reduces the efficiency of heat detectors: it takes a larger floor level fire to actuate a detector in a tall room, than a room with a height of only 3 m.

(d) Where the passage of smoke or hot gas from a position to a detector is disturbed by a ceiling obstruction (such as a beam) having depth greater than 450mm, then the obstruction should be treated as a wall for the purposes of detector location.

(e) Rate-of-rise systems are recommended only for Class B flammable liquid, or exceptionally fast burning Class A types of hazards.

(f) Fixed temperature systems should be used where rapid changes in temperature are the norm, such as forced hot air ovens, kitchens, boiler houses, lantern lights, etc. The operating temperature of the detector should be about 30ºC above the maximum working temperature. Be aware that capillary tubing can act as a rate-of-rise detector so routes outside the rapid change area must be found.

(g) Detectors fitted in lantern lights should be protected from direct sunlight and fitted at least 50 mm below the glass.

16.1.2 Location of HADs on Smooth Flat Ceilings

(a) Distance between detectors and walls.

(i) HADs shall be spaced no more than 10 m apart.

(ii) Where ceilings are level, the distance between the wall and the nearest detector should not exceed one half the distance allowed between detectors.

(iii) With sloped ceilings, (slope more than 1 in 10) and apexed ceilings, consult Kidde Fire Protection.

(b) Height of detector above the hazard.

Where detectors are place more than 7 m above the hazard, consult Kidde Fire Protection for guidance on the spacing of detectors.

(c) Number of detectors on one circuit:

(i) There shall be no more than six HADs on any one detection circuit or control head.

(ii) The maximum length of 1/8” (3mm) O.D. tube per detection circuit is 210 m.

Each HAD is equivalent to 30 m of 1/8” (3mm) O.D. tube:

1 HAD + 180 m tube

2 HAD + 150 m tube

3 HAD+ 120 m tube

4 HAD + 90 m tube

5 HAD + 60 m tube

6 HAD + 30 m tube

(d) Reducing the risk of accidental discharge:

(i) Care should be taken to prevent unwanted discharges as a result of normal ambient or operating conditions. This includes most forced air sources such as exhaust systems, unit heaters and air conditioning systems; as well as the opening of oven or furnace doors, opening doors from the protected area or a heating system able to rapidly raise the temperature of the hazard. Similarly consider the effect of locating detectors adjacent to fresh air inlets that will dilute heat build up.

(ii) Where portions of a single hazard have different temperature characteristics, the HAD’s in each section shall be installed on a separate cell of a check valve unit.

16.1.3 Fixed Temperature HAD

(a) Fixed temperature HAD's employ a meltable alloy slug are available for a limited range, contact Kidde Fire Protection.

Select an operating temperature that is at least 30ºC above the maximum expected temperature.

17 SAFETY REQUIREMENTS

Suitable safeguards are necessary to protect people in areas where the atmosphere may be made hazardous by a carbon dioxide fire extinguishing system.

The principal risk is from suffocation. The effects of toxicity are usually not considered a life hazard.

17.1 Total Flooding Systems

Entry into a protected space may only be made when the system is on manual control and automatic release has been prevented.

If a CO_2 protected room is normally occupied by people a normally closed valve should be fitted into the feed pipe so that a malicious or accidental release at the container bank is stopped from discharging into the room. The valve should only open when demanded by the detectors or by a manual release unit.

The condition of the valve should be automatically monitored and indicated. CO_2 trapped in the feed pipe should be indicated by means of a pressure switch and a locked closed valve fitted so that the CO_2 can be safely vented to atmosphere.

A time delay may be used, but only in addition to an isolation device, refer to Chapter 14 for alarm signals.

17.2 Local Application Systems

An isolating device to prevent automatic release is not necessary, if it can be shown that following a risk analysis a hazardous concentration cannot be created within the total volume of the room containing the local application system. A time delay and pre-discharge alarm is acceptable to the Health and Safety Executive in this circumstance.

A concentration in excess of 10% on the nett volume could be considered hazardous to some people.

Concentrations below 5% are harmless to the majority of people.

The facility provided on system actuators and control heads for totally disabling a system are not to be used as a normal ‘entry to space isolating device’.

18 FACTORY MUTUAL RULES

Kidde Fire Protection has official approval of its CO_2 equipment by Factory Mutual (FM) Insurance. These are generally similar to NFPA 12 rules, with some variations.