DESIGN MANUAL

SIEX- CO_2

CO_2

LISTED
EX16320

APPROVED
3049949

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1. Introduction

Carbon dioxide CO_2 has been used for many years for the purposes of extinguishing fires arising from inflammable liquids, gases, low voltage electrical equipment, and to a lesser extent for solid combustible material fires such as paper, fabrics and other cellulose materials.

The CO_2 puts out the fire effectively in the majority of cases of combustible materials, except in the case of a few active metals and metallic hydrides, and materials, which, as is in the case of cellulose nitrate contain available oxygen. Other practical limitations of CO_2 are related to the method of use and risks involved with fire protection, which we shall address later.

This design manual shall provide guidelines for the appropriate use of CO_2 in fixed systems for fire extinguishing in accordance with NFPA 12, which serves as a guide for design, installation and function of carbon dioxide systems.

The pipe network SHOULD be checked before installing the CO_2 extinguishing system via the hydraulic flow calculations. Should the specific limits not be adhered to, the system may not provide the correct amount to the extinguishing unit.

2. Design criteria

The complexity of the flow formulas does not allow the application of any simple manual calculation in the case of the CO_2 extinguishing unit. For this reason the flow calculations and the design criteria described in this manual have been included in the carbon dioxide flow calculation software.

> ➢***WARNING****: The CO_2 Extinguisher Flow Calculation Program (software) is the only applicable method for* ***SIEX*** *equipment. No other calculation methods for systems supplied by* ***SIEX*** *shall be accepted.*

The system's designer should be completely familiarised with the SIEX CO_2 extinguisher user manual calculation software as well as the NFPA 12 regulation in order to be able to determine the correct procedures and enter the correct entry parameters into the program. In order to obtain precise results a series of entry parameter limits should be taken into consideration. The majority of these limitations can be found within the program. However, before entering the entry data the system designer should take into account a set of restrictions. This manual describes the main design parameters and the design limitations, which should be considered.

In order to correctly design a system using the SIEX CO_2 system a highly detailed risk study should be carried out analysing the information received for the design. For any design the following steps, as a minimum, must be followed:

-Set risk measurements analysing the connections which can exist with other areas or conducts.
-Risk analysis inspection for protected area.
-Check for leaks or apertures in the protected area.
-Check for room ventilation and the option to disconnect during discharge.
-Check for pneumatic delay and/or pneumatic siren.
-Set type, quantity and location of combustible materials.
-Determine possible ignition sources.
-Determine current ventilation flows and necessary cut-off time.
-Determine maximum and minimum atmospheric temperatures to be expected in area.
-Type of building.
-Determine if the area is occupied and study escape routes.
-Risk classification (for example, risk of explosion etc.).
-Check for pipes, extraction conducts, beams or other building elements.
-Possible location for storage of extinguisher.

-Establish risk as well as necessary design concentration.
-Staff safety measures.
-Calculate quantity of extinguishers needed to provide necessary cover.
-General system design concepts.

2.1. Characteristics of CO_2 Extinguisher

Carbon dioxide possesses many properties, which render it useful for fire extinguishing purposes. It is not combustible and does not react with the majority of substances, and its own pressure means that it can be discharged from its storage cylinder without the need to have nitrogen pressure, as in the case of other extinguishers.

As carbon dioxide is a gas it can penetrate and be distributed throughout all areas that are on fire, either by gas or in solid format known as “snow” or “dry ice”. Furthermore, it is a gas, which does not conduct electricity and therefore, can be used in fires where electrical equipment is present. After discharge it leaves no residue and therefore, does not damage any material upon which it is discharged, eliminating the need for further cleaning.

2.1.1. Thermodynamic properties

Under normal conditions CO_2 is a gas, it easily liquefies by compression and cooling, and can be converted into a solid should it continue to be compressed and cooled.

The effects arising from changes in temperature and pressure upon the physical state of carbon dioxide at a constant volume are the following:

- Above the critical temperature of 31ºC it becomes total gas, irrespective of the pressure, and between –57ºC and the critical temperature of 31ºC the CO_2 in a sealed container can be either a gas or a liquid.

- The pressure is related to the temperature, as long as the liquid and gas states are present. As the temperature and pressure rises, the vapour phase density raises and the liquid phase decreases.

- At 31ºC vapour and liquid densities are equal and the clear separation of the two phases disappears. Above the critical temperature, the CO_2 at high pressure only exists as a gas, with intermediate properties between the normal states of liquid and vapour.

- When the liquid CO_2 is discharged at atmospheric pressure, a portion of it instantly is converted to vapour and the rest is cooled via evaporation and is converted into *dry ice* finely divided (dry ice) at a temperature close to –79ºC. The quantity of CO_2, which is converted to dry ice, depends on the temperature of the stored liquid. Around 46% of the liquid stored at–18ºC is converted into dry ice, compared to 25% for liquid stored at 21ºC.

2.1.2. Discharge properties

A typical discharge of liquid carbon dioxide has a white cloud appearance due to the finely divided dry ice particles transported by the vapour. Due to the low temperature some atmospheric water vapour is produced which causes additional mist which persists for some time after the dry ice particles have been deposited or sublimated. The cooling effect of dry ice is generally beneficial for reducing temperatures after a fire. However, in the case of protecting equipment, which is very sensitive to temperature, direct impacts from strong discharges should be avoided.

2.1.3. Vapour density

Carbon dioxide has a density, which is 1.5 times higher than that of air at the same temperature. Any mix of CO_2 and air is logically heavier than the air at the same temperature. As a result, the air, which contains the highest concentration of CO_2, remains at the lower level while the lowest concentration remains at a higher level.

2.2. Propeties of CO_2 extinguishing

Carbon dioxide is an effective extinguishing agent, mainly because it reduces the oxygen content in the atmosphere via dilution, up to a point where combustion can no longer occur. Under appropriate conditions of control and application it is also has a beneficial freezing effect especially when applied directly to the material that is on fire. The CO_2 acts with two extinguishing systems, by suffocation and by cooling. It is a clean agent which does not damage protected materials and given that it is a gas, expands and penetrates the whole protected area ensuring an adequate extinguishing action.

2.2.1. Suffocation extinguishing

One of the main mechanisms of CO_2, which is particularly beneficial for extinguishing, is the reduction of oxygen. The carbon dioxide can reduce the concentration of O_2 to below the point where combustion can occur and extinguishes the fire via this method. This concentration of the agent should remain below this level for some time during which it ensures that the fire will not start again after being extinguished.

2.2.2. Cooling extinguishing

In a fire the heat is generated by rapid oxidisation of combustible material. Part of this heat is used so that the yet ignited combustible material reaches ignition temperature, while an important amount is lost through radiation and convection, especially in the case of surface fires. Should the atmosphere, which supplies oxygen to the fire, be diluted with CO_2 vapour; the heat generation velocity (oxidisation) is reduced until it is lower than the dissipation velocity.

The minimum concentration of CO_2 necessary to extinguish surface fires, as in the case of combustible liquids, can be determined exactly, as the heat dissipation velocity due to radiation and convection remain almost constant. It is harder to obtain similar data for solid combustible materials as the velocity of heat loss through radiation and convection oscillate widely depending on the shielding effects caused by the physical characteristics of the combustible material.

The effects of rapid cooling are heightened when the device discharges directly upon the combustible material, as for example in an immersion tank full of liquid. With the aim of quickly and completely covering the whole surface of the tank, the device is applied in great quantity. Rapid cooling is preferable in order to avoid re-ignition once the discharge has completed and the air comes into contact again with the combustible surface. The presence of dry ice particles in the discharge current help to achieve a rapid cooling of any surface with which it comes into contact.

2.3. Toxicity

Although carbon dioxide is only slightly toxic it can cause loss of consciousness and even death when encountered in concentration amounts used during the extinguishing of fires. The usual cause is via asphyxiation as opposed to the actual toxic effects of the carbon dioxide. The maximum concentration, which can be tolerated by the majority of people, is 9% without loss of consciousness during a few minutes. Inhalation of a higher concentration could cause the immediate collapse of a person.

2.4. Human safety considerations

Carbon dioxide should not be used in places used by people unless necessary measures are taken which guarantee an evacuation before any discharges take place as described in this manual and the NFPA 12. The same restrictions can be applied to places which aren't normally used by people but which from time to time do certain individuals to carry out maintenance or other such duties use. It will be difficult to guarantee any evacuation should the area be large or should obstacles impede the fire exit route or which use complicated routes. The evacuation will be hampered further should it begin after the discharge has commenced as it could cause a lot of noise and considerably hamper visibility.

The possibility of the release of large volumes of carbon dioxide in low areas without protection, such as basements, tunnels or chambers should be taken into consideration. In this case the suffocating atmosphere would be invisible and may be detected too late.

As the concentration of CO_2 needed to suffocate a fire is dangerous for persons in the flooded area, human protection measures should be commenced when the quantity of the discharged agent in the area, or the volume at which the specific protection system is at, produces a concentration of CO_2 higher than 5% in volume. This is also applicable to areas surrounding the emission zone for specific protection systems as well as adjoining areas to other businesses or protected areas where the possibility of the existence of such concentrations exist. In these cases a locking device shall be required.

The following safety requirements should be met:

- Evacuation routes, which should be kept unhindered at all times and properly signposted.
- A flooded area should not be used as the only escape route to other areas.
- Doors should only be able to be opened outwards, with automatic closure and should be able to be opened from the inside even in the event of being closed from the outside.
- The alarms should be different to any other type of alarm and activate immediately in the case of detecting a fire.
- Continuous alarms should be installed at all entrances until the atmosphere has been made safe.
- The addition of an odoriser should be added to the CO_2 in order to be identified, as it is an odourless gas.
- Emergency signs should be displayed and instructions at all entrances.
- If necessary a supply of breathing equipment should be available and training for use given to all staff.
- Ventilation measures should be available to ventilate areas once the fire has been extinguished.
- CO_2 entering adjacent areas should be taken into consideration, in the event of being able to reach dangerous concentration levels.

Other safety measures which appear in the NFPA 12 regulations and which are not present in this manual should be observed.

2.5. Carbon dioxide applications

Carbon dioxide is appropriate for the extinguishing of fires of certain materials and equipment, which are listed below:

- Inflammable liquids and materials, which, in the case of fire show characteristics similar to those of inflammable liquids.
- Inflammable gases, only in the case of taking measures to avoid the reconstituting mixture of air/gas once the fire has been extinguished.
- Electric and electronic equipment.
- Combustible materials such as wood, paper, textiles etc.
- Turbines.
- Printing machinery.
- Industrial fryers.

Some typical facilities where this type of extinguisher can be used are:

- Transformation centres
- Electric control panels.
- Computer rooms.
- Electric generators.
- Cable galleries.
- Paper archives.
- Paint facilities.
- Ovens and dryers.
- Cooling tanks.
- Turbines.
- Industrial fryers.
- Industrial kitchens.
- Immersion tanks.
- Mixing tanks.
- Conducts.
- Printing presses.
- Marine hazards.
- Printers.
- Electrical generators.
- Dust collection cyclones.

2.6. Carbon dioxide limitations

Carbon dioxide is not an effective extinguishing agent for chemical fires, which have their own oxygen supply, such as cellulose nitrate. Reactive material fires such as sodium, potassium, magnesium, titanium and zirconium, as well as metallic hydrides cannot be extinguished with CO_2, as the metals and hydrides decompose the carbon dioxide.

2.7. Specific types of detection

The types of detection and control panels are installed, tested and maintained meeting with the appropriated standard form NFPA regarding to signalling protection systems (see NFPA 72, *National Fire Alarm Code*). UL listed and FM approved and compatible with Siex's equipment for automatic detection and actuation should be used.

The specific sensors which can be connected to the equipment of an extinguishing system are:

-Smoke detector.
-Heat detector.
-Miltisensor detector.
-Aspirating smoke detector.
-High heat sensor.

As redundant detection system as complementary of the detection systems mentioned above, a mechanical detection system (TK-SIMPLEX or TK-COMPLEX) may be used for the actuation of the extinguishing system (see components manual for detailed information).

3. Calculation of agent via total flooding

3.1. Introduction

Carbon dioxide extinguishing systems via total flooding consist of a storage system of the extinguishing agent (modular cylinder or battery of cylinders) which, through the network of pipes, distribute the gas to the nozzle or nozzles which dispense it in the protected area which extinguishes the fire.

ATTENTION

The total flooding systems via CO_2 cannot be used in areas, which are normally used by people unless the directions and the NFPA12 regulations, which appear in this manual, are strictly adhered to and in accordance with that which has been established by the competent authority.

3.2. Protected area

In the total flooding systems via CO_2 the area should be completely closed off or with the minimum amount of apertures possible which ensures the reach of the design's concentration. In the event of there being apertures in the area which cannot be closed prior to the discharge, an additional discharge is required with the aim of making up for the loss, and never exceeding the quantity required for an area without apertures. If this is not the case local application should be used.
For those cases where deep seated fires occur such as those, which involve solid materials, and with the aim of keeping the agent concentration for a sufficient time to allow for cooling of the combustible material to a temperature below that of re-ignition, apertures shall only be allowed in the roof or areas near to the roof. In those cases where the apertures cannot be closed and which also do not allow for a minimum concentration during the required time to be maintained, these losses of gas can be compensated via the dispensing of an additional agent via an extended discharge (see section 3.7.4).

In the cases where the apertures can cause the fire to spread to other areas these apertures should come with a closure system. If such measures are not possible these annexed areas should be included in the fire protection.

3.3. Ventilation

Given that the efficiency of CO_2 systems as extinguishing agents, which depend on maintaining its extinguishing concentration, gas leaks should be kept to a minimum or be compensated with an additional quantity of gas. Where possible all apertures should come with a closure system, which is activated before or during the discharge.

In cases of forced ventilation it should be preferably disconnected and/or closed before or during the CO_2 discharge or extended discharge.

3.4. Equipment deactivation and locking apparatus

With the aim of avoiding re-ignition sources in the protected space before or during the CO_2 discharge, all measures should be implemented which disconnect all equipment that can cause re-ignition and cut off all those with power supply (fuel, electricity etc) as well as installing any other type of locking device which could be relevant to ensure the system's effectiveness.

3.5. Interconnecting volumes

When two or more volumes are interconnected where an extinguishing agent could take place, the quantity of the extinguishing agent should be the sum of the quantities of one of the volumes. If the design concentration of one of the volumes is higher than the rest, the higher concentration should be used to calculate the other areas.

3.6. Special conditions

Additional quantities of carbon dioxide should be provided to compensate for any special condition, which could adversely affect the extinguishing process.

3.7. Calculations for surface fires

This section corresponds to liquid, gas and inflammable solids fires.

3.7.1. Volume factor

FACTORS K_B FOR LIQUIDS AND GASES	
MATERIAL	**DESIGN CONCENTRATION %**
Acetone	*34*
Acetylene	*66*
Aviation fuel (grade 115-145)	*36*
Benzene	*37*
Butadiene	*41*
Butane	*34*
Butene-1	*37*
Carbon disulphide	*72*
Carbon monoxide	*64*
Natural and coal gas	*37*
Cyclopropane	*37*
Gasoline	*34*
Diethyl ether	*46*
Dimethyl ether	*40*
Dowtherm (heat carrying fluids)	*46*
Ethane	*46*
Ethyl alcohol	*40*
Ethyl ether	*43*
Ethylene	*46*
Bichloride of ethylene	*49*
Ethylene oxide	*34*
Gasoline	*53*
Hexane	*34*
n- Heptane	*35*
Hydrogen	*35*
Hydrogen sulphur	*75*
Isobutane	*36*
Isobutylene	*36*
Isobutyl formate	*34*
JP-4	*34*
Kerosene	*36*
Methane	*34*
Methyl acetate	*34*

Methyl alcohol	*35*
Methyl-butane-1	*40*
Methyl ethyl ketone	*36*
Methyl formate	*40*
n-Hoctane	*39*
Pentane	*35*
Propane	*36*
Propylene	*36*
Toluene	*40*
Lubricating oils and y thermal treatment	*34*

***Table 1. Factor K for liquids* and gases**

The minimum quantity of CO_2 for total flooding is 34%. In any format the required concentration should be increased when there are inflammable liquids and gases. The following table shows the design concentrations for the most representative combustible items.

During a discharge for total volume flooding the carbon dioxide will displace a part of the atmosphere outside of the area concerned, through ventilation and apertures. As a certain amount of the extinguishing agent is lost to the atmosphere, the volume of carbon dioxide necessary to achieve a certain concentration should be higher than that which actually stays within the area concerned.

As a small area has on average more boundary areas (sum of all the areas combined) per closed volume, than a larger area, there could exist higher proportional filters and a higher rate of escape. Therefore, proportionally higher amounts of the extinguisher's agent are discharged to compensate these higher losses. The quantity of carbon dioxide per volume unit is called the "volume factor" and is shown in Table 1.

(Equation 1)

$$W_B = V / f_1 \quad \text{or} \quad W_B = V \times f_2$$

Where: W_B = *quantity of* CO_2 *in kg*

V = *volume of atmosphere in* m^3

f_1 = *volume factor in* m^3/kg

f_2 = *volume factor in* kg/m^3

The volume factor used to determine the quantity of CO_2 needed to protect the area concerned which contains material, which requires a concentration of 34% should be in accordance with Table 2. When the net area volume to be protected is determined the volume of immovable structural elements can be taken away.

VOLUME m^3	f_1 (m^3/kg)	f_2 (kg/m^3)	Quantity Calculated (kg)
Up to 4 m^3	0.086	1.15	-
4 m^3 – 14.2 m^3	0.093	1.07	4.5
14.2 m^3 – 45.3m^3	.99	1.01	1.1
45.3 m^3 – 127.4m^3	1.11	0.9	45.4
127.4 m^3 – 1415 m^3	1.25	0.8	113.5
More than 1415 m^3	1.37	0.74	1135.0
Conducts	0.5	2	-

Table 2. Volume factors (34 % concentration) according to NFPA 12

Example 1: Lets consider a 5 x 4 x 3 m room. Determine the quantity of CO_2 required.

Using the equation $W_B = V / f_1$

Where V is the volume of the area concerned and f_1 is the volume factor in m^3/kg

$V = 5 \cdot 4 \cdot 3 = 60\ m^3$

$f_1 = 1.11\ m^3/kg$

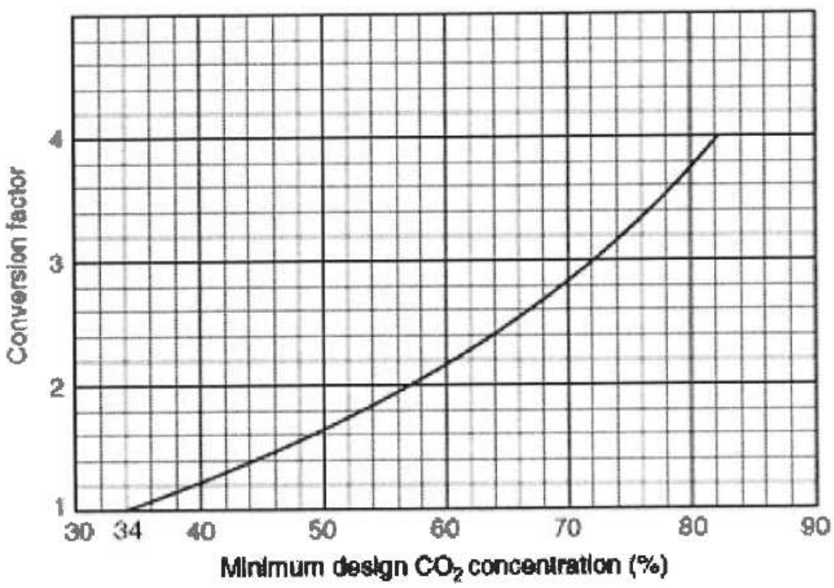
$W_B = V / f_1 = 60\ m^3 / 1.11\ m^3/kg = 54\ kg$

3.7.2. Conducts and channels protection

For protection of conducts and channels via total flooding, a flooding factor of 0.5 m3/kg (8 ft3/lb) or 0.125 lb/ft3 (2.00 kg/m3) should be used. This volume factor, which represents an agent concentration of 65%, does not require the use of a materials conversion factor.
In the cases where, due to the accumulation of combustible material in the conduct or channel an deep seated fire could be provoked so the system should be designed in accordance with the given instructions of the corresponding section.

3.7.3. Material conversion factor

For materials, which require a design concentration higher than 34% the basic quantity of carbon dioxide calculated according to the volume factor (see point 3.7.1.) should increase, multiplying this quantity by the appropriate conversion factor according to the following graph:



Graph 1. Graph 2.3.4 NFPA 12

(Equation 2)

$$W_C = W_B \cdot f_C$$

Where: *W_B = quantity of CO_2 in (kg)*

W_C= quantity of agent given for the equation (kg)
f_C = material conversion factor (graph 1. (Graph 2.3.4. NFPA 12)).

Example 2. Lets consider a 5 x 4 x 3 m room. Acetylene is stored in the room. Determine the quantity of CO_2 necessary.

Via the equation: $W_C = W_B \cdot f_C$

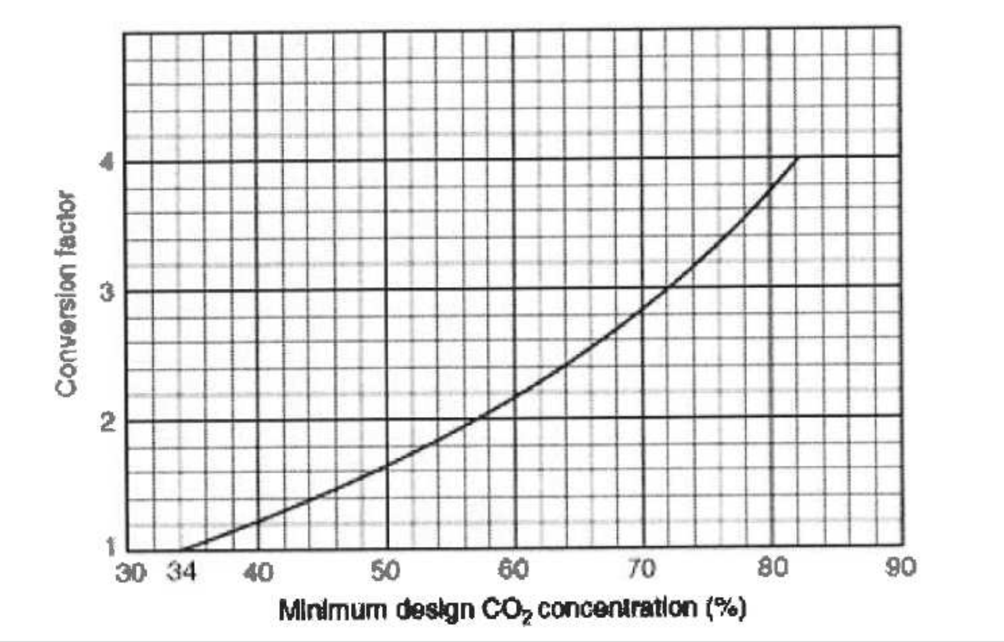
Where W_B is the basic quantity of the agent and f_c is the material conversion factor.

$V= 5 \cdot 4 \cdot 3 = 60\ m^3$

$f_1 = 1.11\ m^3/kg$

$W_B = V / f_1 = 60\ m^3 / 1.11\ m^3/kg = 54\ kg$

Of graph 2.3.4 and taking into account that the acetylene needs a concentration of 66%
We can see that:



For a concentration of 66 % the f_c is of 2.5

$W_C = W_B \cdot f_C = 54\ kg \cdot 2.5 = 135\ kg\ CO_2$

Special conditions

Additional quantities of CO_2 are necessary to compensate for the area's apertures, forced ventilation that could exist and the abnormal temperature variations. Such conditions could adversely affect the CO_2 extinguishing system.

(Equation 3)

$$W_{min} = W_C + W_L + W_V + W_T$$

Where:
W_{min} = *Minimum amount of agent to be supplied (kg)*
W_C = *Quantity of agent for design concentration (kg) Equation 02*
W_L = *Quantity of agent to compensate for apertures (kg) Equation 06*
W_V = *Quantity of agent to compensate for forced ventilation (kg) Equation 07*
W_T = *Quantity of agent to compensate for extreme temperatures (kg) Equation 10*

3.7.4. Openings

Any loss of CO_2 should be compensated through the openings, which, during discharge cannot be closed. The additional quantity shall be equal to the expected quantity of loss of the design concentration during at least 1 minute. This additional quantity of carbon dioxide should be combined with the quantity of the basic design.

The release through the apertures depends on many factors. If there is no forced ventilation, the release shall depend upon the size and location of the apertures. It shall also depend on if there is a release in the upper part of the area concerned which allows the flow of fresh air into the area. As CO_2 is denser than air and in the event of the opening being located in the roof it is possible there will be no or few releases. Alternatively, losses through walls or at ground level can be significant.
In order to maintain constant pressure within the area concerned, fresh air should enter through the same aperture as the carbon dioxide exits. Therefore, the effective area of the aperture is reduced *by a factor of 2.*

(Equation 4)

$$A_L = A_O \ / \ 2$$

Where:

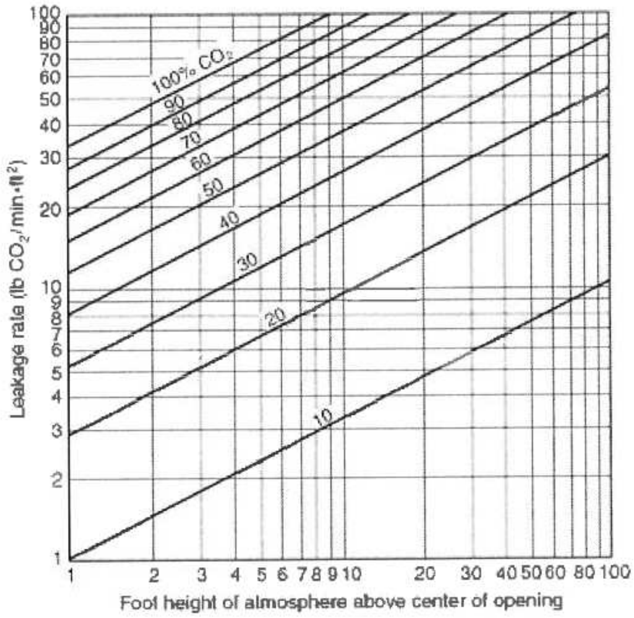
A_L = *effective areas of apertures* (m^2)
A_O = *area of apertures which cannot be closed* (m^2)

The gas flow that can escape through the apertures is determined by using the design concentration, the height from the centre of the aperture to the roof and Graph 2 A-2-3 (b) of the NFPA 12 regulation. In the event of multiple apertures the area's lowest aperture centre line should be used, as this will obtain the least favourable value.

(Equation 5.)

$$q_L = L \times A_L$$

Where:
q_L = *flow of gas losses (kg/min)*
L = *flow of escape of graph 02 (graph A-2-3 (b))* ($kg/min/m^2$)
A_L = *area of effective release* (m^2)



For SI units, 1 ft = 0.305 m; 1 lb/min-ft² = 4.89 kg/min-m².

Graph 2. A-2-3(b) of the NFPA 12

Once the CO_2 release flow is determined the quantity of carbon dioxide, which should be added to compensate for them is calculated via the following method:

(Equation 6)

$$W_L = q_L \cdot t_P$$

Where:

W_L = Quantity of gas to compensate the apertures (kg)
q_L = Flow of gas losses (kg/min)
t_P = duration of discharge ≥ 1 min (min)

Example 3. Determine the loss of gas through an aperture in a wall measuring 1 x 1 m. The mid point of the aperture is at 0.5 metres from the roof and the system is designed for a concentration of 34 %.

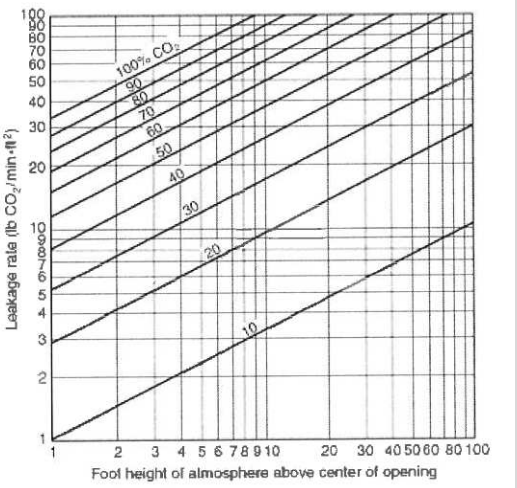
It must be calculated via the equation: $A_L = A_O / 2$

$A_O = 1x\ 1 = 1$

$A_O = 1\ m^2$

$A_L = 1 / 2 = 0.5\ m^2$.
$q_L = L \times A_L$

From the graph we can see that with q_L *at 34 % of the concentration and at a height of 0.5 m (1.64 ft) we obtain a flow of losses (L) of 8 lb /min·ft*^{2} *(39.12 kg/min·m*^{2}*)*



For SI units, 1 ft = 0.305 m; 1 lb/min·ft² = 4.89 kg/min·m².

$q_L = L \times A_L$

$q_L = 39.12 \times 0.5 = 19.56$ *kg/ min*

$W_L = q_L \times t_P = 19.56$ *kg/ min x 1min*

$\boldsymbol{W_L = 19.56}$ **kg**

3.7.5. Forced ventilation

An additional quantity of carbon dioxide should be supplied to make up for any loss of the agent through forced ventilation, which cannot be disconnected before discharge. The quantity of the additional agent is calculated by dividing the quantity of the volume moved by the ventilation system during the discharge design (minimum 1 minute) by the flooding factor.
The resulting quantity is multiplied by the material's conversion factor (see point 3.7.3). Graph. 1 ***(Graph 2.3.4 of the NFPA 12)*** *when* the design concentration required is higher than 34 %

(Equation 7)

$$W_V = q_V \cdot t_P \cdot f_2 \cdot f_c \qquad or \qquad W_V = (q_V \cdot t_P \cdot f_c) / f_1$$

Where:

W_v = *the quantity of the agent to compensate the forced ventilation*
q_v = *ratio of ventilation kg* (m^3 */min)*
t_p = *Duration of protection* ≥ 1 *min*
f_2 = *Volume factor of the table 4* (kg/m^3)
f_1 = *Volume factor of the table 4* (m^3/kg)
f_c = *Conversion factor of material in the Graph 1* ***(Graph 2.3.4 of the NFPA 12)***

Example 4. A room measuring 10 x 8 x 3 m. Determine the additional quantity of CO_2 necessary to compensate a forced ventilation of 28.32 m^3/min that cannot be closed. The design concentration is 34 %, and the discharge has duration of 1 minute.

$W_V = q_V \cdot t_P \cdot f_2 \cdot f_c$

$q_v = 28.32\ m^3/min$

$t_p = 1\ min$

$f_2 = 0.8\ kg/m^3$

$f_c = 1$, *for a concentration of 34%*

$\mathbf{W_v} = 28.32\ m^3/min \cdot 1\ min \cdot 0.8\ kg/m^3 \cdot 1 =$ **22.656 kg of CO_2**

3.7.6. Extreme Temperatures

An additional quantity of the agent should be added to compensate for low or high temperatures.
For places where the normal temperature is above 93 ºC, an increase is needed of 1% of the calculated quantity for each 2.8 ºC from 93 ºC upwards.

<u>For high temperatures:</u>

(Equation 8)

$$\tau_H = \Delta T_{high} / 2.78$$

Where:
τ_H = correction factor for high temperatures
ΔT_{high}= variation of temperature above 93 ºC

For rooms where the atmospheric temperature is lower than 18ºC, a percentage of the CO_2 calculated should be increased with an increase of 0.55 ºC below -18 ºC.

<u>For low temperatures</u> (below -18ºC)

(Equation 9)

$$\tau_L = \Delta T_{low} / 0.55$$

where :
τ_L = correction factor for low temperature
ΔT_{low} = variation of temperature lower than -18 ºC

The compensation factor should be added to the basic quantity of the agent calculated from the volume factor and of all additional quantities.

(Equation 10)

$$W_T = \tau (W_c + W_L + W_v)$$

W_T = quantity of agent to compensate the extreme temperatures (kg)
τ = high or low temperature correction (00)
W_c = quantity of agent calculated
W_L = Quantity of agent to compensate the apertures which cannot be closed (kg)
W_v = Quantity of agent to compensate forced ventilation (kg)

Example 5. A room measuring 4.3 m x 4.3 m and with a height of 3 m has an ambient temperature between -26ºC and 121 ºC. Determine the additional quantity of the additional CO_2 necessary to compensate the extreme temperatures.

The total quantity of the agent for this room is calculated by the following equation:

$$W_T = \tau\,(W_c + W_L + W_v)$$

Where τ is the correction factor for the temperature, W_c is the quantity of the design agent, W_c is the quantity of agent necessary to compensate the losses and W_v is the quantity of the agent to compensate the forced ventilation.

Of the equation

$$W_C = W_B \cdot f_C$$

Where W_B is the basic quantity (34%) and f_c is the material's conversion factor.

W_B = is obtained via the equation $W_B = V \cdot f_2$

Thus:

$V = 4.3 \cdot 4.3 \cdot 3\ m = 55.47\ m^3$

$W_B = 55.47\ m^3 \cdot 0.9\ kg/m^3 = 49.9\ kg$

The material's conversion factor for this risk is: $f_c = 1$ (see curve 02 for 34 %)

$W_c = 49.9 \cdot 1\ kg\ CO_2 = 49.9\ kg\ CO_2$

There are no releases through the apertures, therefore:

$W_L = 0\ kg$

Forced ventilation does not exist, therefore:

$W_V = 0\ kg$

$\tau_H = \Delta T_{high} / 2.78 = (121\text{-}93ºC) / 2.78 = 28 / 2.78 = 10\ \%$

$\tau_L = \Delta T_{low} / 0.55 = (-18 - (-26)\ ºC) / 0.55 = 8 / 0.55 = 14.5\ \%$

as $\tau_L > \tau_H$ so:

$W_T = \tau_L \times (W_c + W_L + W_v) = 0.145 \times 49.9\ kg =$ **7.235 kg de CO_2**

$W = W_{min} + W_T = 49.9 + 7{,}235\ kg =$ **57.25 kg CO_2**

3.7.7. Discharge Flows

For surface fires, the design concentration shall be obtained in 1 minute.

(Equation 11)

$$q_{min} = W_{min} / t_{d,max}$$

Example 6. A room measuring 4 x 4 x 3 m. Determine the minimum flow needed to reach a concentration of 34% in volume within the time limit.

The minimum flow is calculated with the following equation:

$$q_{min} = W_{min} / t_{d,max}$$

Where q_{min} is the minimum discharge flow, W_{min} is the minimum quantity of the agent and $t_{d,\ max}$ is the maximum discharge time.

The minimum quantity of the agent is determined by the following equation

$$W_{min} = W_C + W_L + W_V + W_T$$

Where W_C is the quantity of the agent for the design concentration, W_L is the quantity to compensate for the apertures, W_V is the quantity to compensate for forced ventilation and W_T is the quantity to compensate for extreme temperatures.

Thus:

$W_C = W_B \cdot f_C$

Where W_B is the basic quantity (34 %) and f_c is the material's conversion factor.

W_B is obtained with the following equation

$W_B = V / f_1$

Where V is the volume of the area to be protected and f_1 is the volume factor.

Therefore:

$V = 4 \times 4 \times 3$ m = 48 m^3

W_B = 48 / 1.11 m^3 / kg = 43.24 kg

f_c = 1 for a concentration of 34%

W_C = 43.24 kg x 1 = 43.24 kg

W_L = 0 kg

W_v = 0 kg

W_T = 0 kg

W_{min} = 43.24 kg + 0 kg + 0 kg + 0 kg = 43.24 kg

Therefore, resolving the first equation:

$$q_{min} = W_{min} / t_{d,max}$$

q_{min} = 43.24 kg / 1 min = 43.24 kg/min

3.8. Calculation for deep seated fires

Deep seated fires are a combination of a surface and internal fire within a material's mass. The superficial fire is rapidly extinguished with a sufficient quantity and rapid discharge of CO_2 within the area concerned. However, to extinguish an deep seated fire within a material's mass, a high level of CO_2 should be maintained during a sufficient period to prevent and slow combustion and allow the material to cool to a temperature, which is below re-ignition levels.

There are many other instances apart from superficial fires, which may contain parts of material, which could be considered as deep seated fires.
To determine if a fire is superficial or deep seated we need to take into account various factors which could be: speed of detection in relation to the time of extinguishing, risk importance, quantity of material mass, quantity of fire fighting equipment etc.
To guarantee the extinguishing of a fire without flames the design concentration should be maintained during a minimum of 20 minutes. A longer discharge duration may be necessary depending on the fuel's cooling speed. To achieve this another system of spare cylinders is used which works via an extended discharge which would compensate for any apertures that could not be closed, and for any forced ventilation that could not be switched off at the moment of discharge.

3.8.1. Flooding factors

The concentration of CO_2 for deep seated fires cannot be determined with the same amount of precision as for surface fires. The flooding factor of deep seated fires has been determined through real tests. The design concentrations shown on Table 3 should only be used for the applications named.

For other types of deep seated fires, the flooding factors should be determined via specific tests and justified to satisfy the expected requirements of the competent authorities.

(Equation 12)

$$W_C = V / f_1 \quad \text{or} \quad W_C = V \times f_2$$

W_C = quantity of the agent for the design concentration (kg)

V = volume (m^3)

f_1 = volume factor (m^3/ kg)

f_2 = volume factor (kg /m^3)

Specific Risks	Design concentration (% CO_2)	f_1 (m^3/kg)	f_2 (kg/m^3)
Dry electrical risks ≤ 56.6 m^3	50	0.62	1.60
Dry electrical risks > 56.6 m^3	50	0.75	1.33
Storage of paper, conducts, covered chambers	65	0.50	2.00
Dust collectors, Leather storage	75	0.38	2.66

Table 3. Volume factors for deep seated fires according to NFPA 12,

Note: It is not necessary to apply the material factor in this table as is done for surface fires.

Example 7. Determine the quantity of CO_2 for storage of paper with the following measurements 5 x 10 x 3 m.

From equation 12: $W_C = V / f_1$

Where W_C is the quantity of the basic agent, V is the area-concerned volume and f_1 is the volume factor

$V = 5 \cdot 10 \cdot 3\ m = 150\ m^3$

$f_1 = 0.5\ m^3 / kg$

$W_C = 150\ m^3 / 0.5\ m^3 / kg = 300\ kg\ CO_2$

3.8.2. Special conditions

As in the case of surface fires, deep seated fires need additional quantities of CO_2 to compensate for the room's apertures, forced ventilations as well as extreme temperatures (high or low). This quantity of the compensating agent should be added to the quantity calculated in section 3.7.4. It is therefore obtained in the same way as for surface fires.

3.8.3. Apertures

When any type of aperture exists which is not in the roof or right on the roof's border with the wall and which cannot be closed in the event of an extinguisher being discharged, the losses through them need to be compensated via an additional quantity of CO_2, which should be used via the method described in section 3.7.4. An extended discharge will therefore be necessary with the aim of maintaining the agent's concentration for the duration of the protection, which should be at least 20 minutes.

3.8.4. Forced ventilation

In cases of forced ventilation, which cannot be switched off or closed before or during discharge, an additional amount of should be provided. The method previously explained should be used to calculate the additional amount. This extended discharge may be necessary to allow the extinguishing concentration to be maintained, which should be for at least 20 minutes (see section 3.7.5).

3.8.5. Extreme temperatures

With the aim of compensating for ambient temperatures, which are abnormally high or low in the protected area, an additional amount of carbon dioxide, shall be required. This additional quantity should be calculated in accordance with section (3.7.6.).

3.8.6. Discharge flows

The design concentration for deep seated fires shall be obtained after 7 minutes, but the discharge rate shall not be lower than the amount required to reach 30% in 2 minutes.
In this way the CO_2 needed to reach a concentration of 30% is 0.686 kg/m^3. Therefore, the following equation is valid to calculate the discharge speed necessary to reach that concentration in 2 minutes.

(Equation 13.)

$$q_{30} = 0.343 \cdot V$$

q_{30} = Minimum flow to reach concentration of 30 % (kg/min)

V = volume (m^3)

It should be verified that the discharge takes no more than 7 minutes.

(Equation 14)

$$t_d = W_{min} / q_{30}$$

t_d = Discharge time

W_{min} = Minimum quantity of agent 0

q_{30} = discharge flow to achieve concentration of 30 % (kg /min)

If time t_d calculated in equation 14 is more than 7 minutes, the minimum discharge flow should be increased according to the following equation.

(Equation 15)

$$q_{min} = W_{min} / 7$$

q_{min} = minimum flow (kg/min)

W_m = minimum quantity of agent calculates according to equation 3 (kg).

Example 8. Determine the quantity of CO_2 needed for a paper store room measuring (10 x 15 x 3 m). Also, determine the discharge flow required to reach the concentration of 30 % within 2 minutes and to complete the discharge within 7 minutes.

From the equation 3 we have: $W_{min} = W_C + W_L + W_V + W_T$

Where:

W_{min} *= minimum quantity of agent to be supplied (kg) 0*

W_C *= Quantity of agent for design concentration (kg) 0*

W_L *= Quantity of agent to compensate for apertures (kg) 0*

W_V *= Quantity of agent to compensate for forced ventilation (kg) 0*

W_T *= Quantity of agent to compensate for extreme temperatures (kg) 0*

From Equation 12 we obtain: $W_C = V / f_1$

$W_C = 450\ m^3 / 0.5\ m^3/kg = 900\ kg\ CO_2$

It is not necessary to add CO_2 *to compensate for losses of the agent due to apertures, ventilation or extreme temperatures, therefore:*

$W_L = 0$

$W_V = 0$

$W_T = 0$

$W_{min} = W_C$

With the aim of determining the minimum discharge flow equation 13 is used:

$q_{30} = 0.343 \cdot V$

$q_{30} = 0.343 \cdot V = 0.343 \cdot 450 = 154.35\ kg/min$

The discharge time of less than 7 minutes must be verified:

$t_d = W_{min} / q_{30}$ *(equation 14)*

$t_d = 900\ kg / 154.35\ kg/min = 5.83\ min$

therefore $t_d < 7\ min$

$q_{min} = 154.35\ kg/min$

4. System design

4.1. Occupation

The CO_2 systems should not be installed in rooms, which are normally occupied by people.

Note: The NFPA 12 regulation allows the use of these systems in areas, which are normally occupied, but with certain restrictions.

For any use of carbon dioxide the possibility of the agent being dispersed in an uncontrolled fashion has to be taken into account and the fact that it spreads to adjoining areas, as well as considering the possibility of staff being trapped in dangerous atmospheric conditions. Safety measures must be taken to avoid gas entering into certain areas and ensure the rapid evacuation of staff to prevent them from becoming trapped. In addition, staff that is involved in the use of these systems should have the correct training.

Should staff enter the protected area with carbon dioxide at any time the following safety measures integrated into the extinguishing system should be followed:

- Pneumatic alarm prior to discharge.
- Pneumatic retardant.
- Warning signs should be displayed in accordance with NFPA 12 specifications.
- Warning signs should be displayed in each location where a manual system operation could take place.
- All staff should be informed and instructed regarding accidental discharges.
- In order to avoid accidental discharges a stop valve should be installed.

All safety measures to be adopted can be found in the NFPA 12 paragraph 1-6.1

4.2. Systems with multiple risks

In cases where there are two or more risks located reasonably close to each other, the installation of a single cylinder or battery of cylinders that centralise the storage of carbon dioxide is preferable, directing the agent towards the required area via the use of directional valves. In the case of using this design criteria the system should be calculated in such a way that the quantity of the agent used is sufficient for the largest area or group of risks which are simultaneously protected.

These directional valves are normally closed in such a way that when a fire is detected the directional valve associated to the risk affected opens, with the aim of allowing the agent to flow towards this area.

It is highly recommendable to provide a quantity of reserve agent as advised in this manual.

It is necessary to take into account that given that the directional valves once opened remain open until they are closed again manually, the system is only capable of protecting a certain risk once. Therefore risks, which are independent from one another in a way where fire cannot spread between these different areas and those, which can, should be determined beforehand.

4.3. Pneumatic sirens

It should be taken into consideration that when the pneumatic siren is powered for its carbon dioxide function stored in the cylinders which is to be used for fire extinguishing purposes, the gas used by the siren shall not be discharged within the protected area, and therefore, the device's agent use should be compensated in order to ensure that it discharges the correct quantity of carbon anhydride. The pneumatic siren uses 34.54 g/s.

In this way the quantity of carbon dioxide that should be added to the total agent quantity should be:

$W_S = 34.54 \cdot n \cdot (t_p + t_d)$

Where
W_S = minimum quantity of agent consumed by the siren (g)
n = number of pneumatic sirens
t_p = pneumatic time delay (s)
t_d = agent discharge time (s)

Example 9. Determine the quantity of CO_2 necessary to compensate the consumption of the agent with the pneumatic siren, via a total flooding system (discharge time of 60 seconds) with a delay time of 30 seconds and using a single siren.

Using:

$W_S = 34.54 \cdot n \cdot (t_p + t_d)$

where

n = 1

t_p = 30 seconds

t_d = 60 seconds

$W_S = 34.54 \cdot 1 \cdot (30 + 60) = 3108.6$ g

4.4. Systems with extended discharge

Extended discharges are used in pipe cases where it is necessary to provide protection above and beyond that of a normal duration. This can be done be increasing the initial quantity of the agent used or by using a secondary system.

In all cases the duration of the extended discharge should be specified and accepted by the competent authority and/or the system's owner.

The most common cases where extended discharges are necessary are:

-Risks that contain a liquid with a self-ignition temperature below its boiling point, such as oils used in kitchens which need additional protection duration to allow them to cool sufficiently.

-Risks, which include metallic parts or other materials, which can maintain a certain temperature resulting in a constant source of ignition.

-Those systems protected via a total flooding system that are not able to maintain the minimum design concentration during the set protection time.

4.4.1. Supply of additional agent

The supply of additional agent is used when the CO_2 should be applied with a flow equal to that of the design.

4.4.2. Secondary system

This type of system is used when the agent should be applied with a flow, which is different to that of the initial design. This method is usually used in those cases, which need to maintain the concentration in a risk, which contain leaks and/or significant forced ventilation.

In these cases the main system is calculated to reach the design's quantity of agent in a maximum time of 1 minute, while the secondary system should discharge the CO_2 with a much lighter flow with the aim of compensating for the losses. This secondary system flow is based on the calculations for the apertures that cannot be closed and forced ventilation for total flooding systems.

4.4.3. Common applications

The common applications, which require an extended discharge, are the following:

-Power processing systems that use hot oil.

-Rotary systems such as generators.

4.4.4. Food processing equipment

In the case of equipment used for food processing, a protection system, which allows the oil's temperature to be reduced by 33 ºC below the oil's self-ignition point, should be designed.

In addition, the necessary safety measures should be implemented to avoid any staff present being affected by the agent's discharge, by splashing hot oil, by the fire or by any combustible products. Siex should be consulted in all cases as well as the NFPA 12 regulation and/or the competent authority before creating a design for this type of protection.

4.4.5. Electric rotary equipment

In accordance with the NFPA 12 regulation, a minimum concentration of 30% should be maintained during the equipment's deceleration period and never less than 20 minutes.

4.4.6. Ventilation with re-circulation

In cases where within the risk a ventilation with re-circulation occurs, the NFPA 12 regulation provides adequate directives to determine the quantity necessary for the extended discharge in order to maintain the concentration of 30% during the whole deceleration period. This quantity is based on the deceleration time and the internal volume of the machine with an average release.

4.4.7. Ventilation with valve and without re-circulation

In cases where a ventilation with valve and without re-circulation exist, an additional 35% of the agent should be added to that calculated for systems with ventilation with re-circulation.

4.5. Cylinder batteries

This section is related to the design of the quantity of the extinguisher agent for a battery of cylinders.

4.5.1. Agent supply

All cylinders, which are made up of a battery of cylinders, should be interchangeable and therefore, all be of the same size. So generally the quantity of the agent will be higher than the quantity of the minimum design, which has been calculated for a certain system.

(Equation 16)

$$W_{min\text{-}sist} = W_{min\text{-}TF} + W_{min\text{-}LA} + W_s$$

Where:

$W_{min\text{-}sist}$ = Quantity of minimum supply for the system (kg)

$W_{min\text{-}TF}$ = Quantity of minimum supply for the total flooding part (kg)

$W_{min\text{-}LA}$ = Quantity of minimum supply for the local application part (kg)

W_s = Quantity of agent to be used to operate the siren.

Calculation of the number of cylinders:

$n_{cil} = W_{min\text{-}sist} / W_{cil}$

Where:

n_{cyl} = number of cylinders required

$W_{min\text{-}syst}$ = Quantity of minimum supply of the system (kg)

W_{cyl} = Cylinder capacity (kg)

The quantity of cylinders that follow need to be rounded up to the whole number and calculate the real quantity of the agent which shall be supplied:

$W_{syst} = n_{cyl\text{-}rounded} \cdot W_{cyl}$

Example 10. Determine the real quantity of CO_2 for a total flooding system, which required 530 kg of agent for total flooding, with a delay of 30 seconds and with a pneumatic siren.

Using:

$W_{min\text{-}syst} = W_{min\text{-}TF} + W_{min\text{-}LA} + W_S$

Where

$W_{min,\ TF} = 530$ *kg*

$W_{min\text{-}LA} = 0$ kg

$W_S = 34.54 \cdot n \cdot (t_p + t_d)$

Where

$n = 1$

$t_p = 30$ *seconds*

$t_d = 60$ *seconds*

Therefore:

$W_s = 34.54 \cdot 1 \cdot (30 + 60) = 3108.6$ *g = 3.11 kg*

$W_{min\text{-}syst} = 530 + 3.11$ kg $= 533.11$ kg

Calculation of number of cylinders:

$n_{cyl} = W_{min\text{-}syst} / W_{cyl}$

where

$W_{cvl} = 45.9$ kg

Therefore:

$n_{cyl} = 533.11$ kg / 45.9 kg/cyl = 11. 6 cyl ≈ 12 cyl $= n_{cyl\text{-}red}$

so:

$W_{syst} = n_{cyl\text{-}rounded} \cdot W_{cyl}$

$\mathbf{W_{syst}}$ **=** 12 cyl · 45.9 kg/cyl **= 550.8 kg**

4.5.2. Modular systems

The modular systems can be defined as a design concept where the containers are located throughout or around the protected areas. This maintains the discharge pipes to a minimum but increases the quantity of electrical materials needed to reach the position of each container.

To reduce the quantity of hosing and installation work in large applications, modular distribution is often desirable (or necessary). In some cases, this concept shall be necessary to ensure that the system dispenses the necessary quantity of the agent.

4.5.3. Central storage systems or bottle batteries

The bottle or cylinder batteries can be defined as a design concept where the containers are located at one point and the pipes lead to the protected area from this point, this concept often needs less quantity of electrical material necessary to reach the containers location. This concept can be harder to design due to the increased amount of pipes used and for this same reason the installation work can be more costly.

In any case, this installation is preferable for the customer from an aesthetic point of view as well as being easier to maintain and repair.

4.5.4. Supply of main and reserve agent

A supply system for a secondary extinguisher means a rapid return of the system to its normal operational conditions in the case of having produced a discharge of the agent in the case of fire. Through a system with this aim, the supply of the agent can be switched to a reserve system while the main battery cylinders are refilled. On occasions, the reserve system can be used to carry out a secondary discharge during the same charge.

The reserve agent supply should be equal to the main system and should be connected at all times to the supply network except in those cases where the competent authority states otherwise.

It is highly recommended to have a reserve agent supply in those cases where the only cylinder battery simultaneously protects various risks via the use of directional valves.

4.5.5. Container locations

The CO_2 cylinders shall be located in a separate location (room), without being exposed to an excessive fire risk, but should be as close as possible to the area to be protected. In the case of this not being possible the cylinders should be protected from tampering.

The containers shall **NOT** be located in an area where they can be damaged or be exposed to corrosive chemical products or severe atmospheric conditions. In places where there is the risk of damage or tampering an adequate security locking system shall be required.

The cylinder storage zone should meet the following requirements:

- It should have easy access even in the event of a fire.
- It should be protected from unauthorized access.
- It shall only be used for storage of cylinders.
- Atmospheric temperature shall be kept between -20 ºC and 55 ºC.
- It shall be ventilated.
- It should come with electric lighting.

- Anything installed in the storage area should be protected against heat produced by direct exposure to sunlight or other heat sources.

4.5.6. Storage temperature limits

The **SIEX** CO_2 equipment listed below is designed to operate within the following temperature range -20 to 55° C.

5. Concept of design system

The distribution CO_2 extinguisher agent in the protected area should be carried out via one of the following pipe distribution methods:

1.- *Pre-engineering or balanced system*
2.- *Engineering system*

The method used shall depend on various factors including: installation time, quantity of agent used, economic factors, number of risk areas, space available to house storage containers and customer preferences. For larger projects which have complex pipe networks more than one method will be necessary to face the challenges and therefore, the designer should be familiar with each one of these methods as well as their advantages and disadvantages for any particular application.

5.1. Pre-engineering or balanced systems

The pre-engineering systems are simple balanced flow configurations which are simple to design and need less installation time. The concept of the pre-engineering system minimizes the engineering effort needed to design an effective system via the use of a fixed series of nozzles and clearly defined design criteria. Computerised flow calculations are not required in reference to the nozzle selection, the pipe measurements and their length limitations.

The pre-engineering systems can be designed with the available containers in modular configurations or in cylinder batteries. In 0 an example of how a pre-engineering system would look is shown.

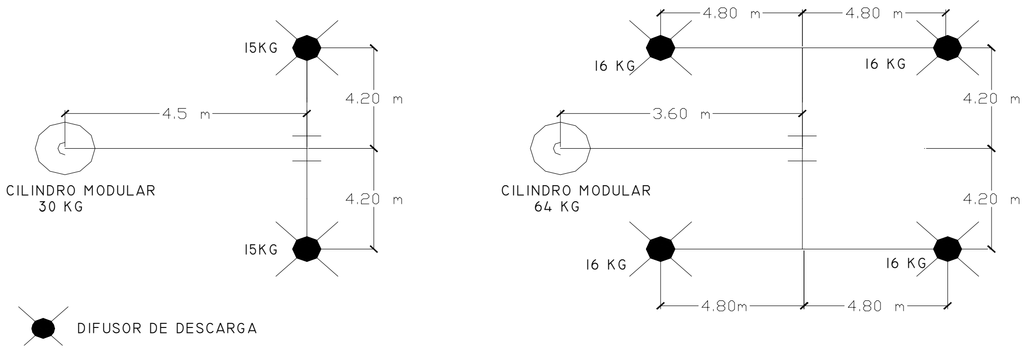


Figure 1. Example of a pre-engineering of balanced system

> ➢ ***NOTE:*** *A pre-designed system is understood to be one in which the pipe network has the same length in all sections and where the nozzles discharge the same quantity of agent.*

5.2. Engineering system

The engineering systems allow the designer to create a network of pipes that adapt to the individual project needs. The pipe configuration can be balanced or unbalanced and the flow separations can vary from one point to the next. This requires a computerised hydraulic flow calculation to make a model for the system and to verify that its function meet the NFPA 12 regulation requirements before installing. That is why, although normally more time is needed for the design process, this concept offers the designer better work flexibility. To make the hydraulic flow calculations a copy of the **SIEX** flow calculation software should be available. The engineering systems can be designed with modular cylinders and batteries of cylinders.

WARNING

The flow calculation software for the CO_2 extinguisher agent is the only calculation method applicable for SIEX equipment. No other calculation method will be accepted for systems supplied by SIEX.

6. Selection of units, cylinders of bottles

6.1. Unit size and filling range

The selection of units is determined by the quantity of CO_2 necessary. The filling density of high-pressure cylinders should be between 0.68* and 0.750 kg/litre of the cylinder volume. Table 4 shows the filling range of all SIEX cylinders as well as the connection valve, length of cylinder diameter and tare of the cylinder. (*Fill density in accordance with NFPA 12 and FM 5420, Sec. 3.2.5.2).

Part Number	Nominal Capacity (litres)	Valve Type	Fill density (kg) 0.68% - 0.75%*		Height Outlet (mm)	Nominal Diameter (mm)
CO2M2UFV-1 CO2M2UFV-2 CO2M2UFV-3	2	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	1.4	1.5	39.9	100
CO2M2UFJ-1 CO2M2UFJ-2 CO2M2UFJ-3	2.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	1.9	2.0	26.9	108
CO2M2UFV-4 CO2M2UFV-5 CO2M2UFV-6	2.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	1.9	2,0	26.9	100
CO2M2UFV-7 CO2M2UFV-8 CO2M2UFV-9	2.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	1.9	2.0	26.9	100
CO2M4UFJ-1 CO2M4UFJ-2 CO2M4UFJ-3	4.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	3.2	3.5	28.2	108
CO2M4UFJ-4 CO2M4UFJ-5 CO2M4UFJ-6	4.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	3.2	3.5	28.2	140
CO2M4UFJ-7 CO2M4UFJ-8 CO2M4UFJ-9	4.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	3.2	3.5	28.2	140
CO2M4UFV-1 CO2M4UFV-2 CO2M4UFV-3	4.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	3.2	3.5	28.2	115
CO2M4UFV-4 CO2M4UFV-5 CO2M4UFV-6	4.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	3.2	3.5	28.2	140
CO2M4UFV-7 CO2M4UFV-8 CO2M4UFV-9	4.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	3.2	3.5	28.2	140
CO2M6UFJ-1 CO2M6UFJ-2 CO2M6UFJ-3	6.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	4.6	5.0	29.6	140
CO2M6UFJ-4 CO2M6UFJ-5 CO2M6UFJ-6	6.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	4.6	5.0	29.6	140
CO2M6UFV-1 CO2M6UFV-2 CO2M6UFV-3	6.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	4.6	5.0	29.6	140
CO2M6UFV-4 CO2M6UFV-5 CO2M6UFV-6	6.7	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	4.6	5.0	29.6	140
CO2M13UFV-1 CO2M13UFV-2 CO2M13UFV-3	13.4	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	9.2	10.0	34.2	140
CO2M13UFJ-1 CO2M13UFJ-2 CO2M13UFJ-3	13.4	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	9.2	10.0	34.2	204
CO2M13UFV-4 CO2M13UFV-5 CO2M13UFV-6	13.4	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	9.2	10.0	34.2	204
CO2M13UFV-7 CO2M13UFV-8 CO2M13UFV-9	13.4	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	9.2	10.0	34.2	204
CO2M26UFJ-1 CO2M26UFJ-2 CO2M26UFJ-3	26.8	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	18.3	20.1	43.3	204
CO2M26UFV-1 CO2M26UFV-2 CO2M26UFV-3	26.8	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	18.3	20.1	43.3	204
CO2M26UFJ-4 CO2M26UFJ-5 CO2M26UFJ-6	26.8	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	18.3	20.1	43.3	229
CO2M26UFV-4 CO2M26UFV-5 CO2M26UFV-6	26.8	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	18.3	20.1	43.3	229

Part Number	Nominal Capacity (litres)	Valve Type	Fill density (kg) 0.68% - 0.75%*		Height Outlet (mm)	Nominal Diameter (mm)
CO2M26UFJ-7 CO2M26UFJ-8 CO2M26UFJ-9	26.8	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	18.3	20.1	43.3	229
CO2M26UFV-7 CO2M26UFV-8 CO2M26UFV-9	26.8	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	18.3	20.1	43.3	229
CO2M26UFV-10 CO2M26UFV-11 CO2M26UFV-12	26.8	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	18.3	20.1	43.3	229
CO2M40UFJ-1 CO2M40UFJ-2 CO2M40UFJ-3	40	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.2	30.0	52.2	204
CO2M40UFV-1 CO2M40UFV-2 CO2M40UFV-3	40.2	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.4	30.1	52.4	204
CO2M40UFJ-4 CO2M40UFJ-5 CO2M40UFJ-6	40	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.2	30.0	52.2	229
CO2M40UFV-4 CO2M40UFV-5 CO2M40UFV-6	40.2	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.4	30.1	52.4	229
CO2M40UFJ-7 CO2M40UFJ-8 CO2M40UFJ-9	40	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.2	30.0	52.2	229
CO2M40UFN-1 CO2M40UFN-2 CO2M40UFN-3	40	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.2	30.0	52.2	229
CO2M40UFV-7 CO2M40UFV-8 CO2M40UFV-9	40.2	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.4	30.1	52.4	229
CO2M40UFN-4 CO2M40UFN-5 CO2M40UFN-6	40	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.2	30.0	52.2	229
CO2M40UFV-10 CO2M40UFV-11 CO2M40UFV-12	40.2	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	27.4	30.1	52.4	229
CO2M67UFB-1 CO2M67UFB-2 CO2M67UFB-3	67.5	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	45.9	50.6	70.9	267
CO2M67UFJ-1 CO2M67UFJ-2 CO2M67UFJ-3	67.5	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	45.9	50.6	70.9	267
CO2M67UFV-1 CO2M67UFV-2 CO2M67UFV-3	67.5	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	45.9	50.6	70.9	267
CO2M80UFJ-1 CO2M80UFJ-2 CO2M80UFJ-3	80	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	54.4	60.0	79.4	267
CO2M80UFB-1 CO2M80UFB-2 CO2M80UFB-3	80	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	54.4	60.0	79.4	267
CO2M80UFV-1 CO2M80UFV-2 CO2M80UFV-3	80	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	54.4	60.0	79.4	267
CO2M80UFV-4 CO2M80UFV-5 CO2M80UFV-6	80	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	54.4	60.0	79.4	267
CO2M80UFV-7 CO2M80UFV-8 CO2M80UFV-9	80	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	54.4	60.0	79.4	267
CO2M100UFV-1 CO2M100UFV-2 CO2M100UFV-3	100	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	68.0	75.0	93	360
CO2M120UFV-1 CO2M120UFV-2 CO2M120UFV-3	120	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	81.6	90.0	106.6	360
CO2M140UFV-1 CO2M140UFV-2 CO2M140UFV-3	140	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	95.2	105.0	120.2	360
CO2M140UFV-4 CO2M140UFV-5 CO2M140UFV-6	140	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	95.2	105.0	120.2	360
CO2M150UFV-1 CO2M150UFV-2 CO2M150UFV-3	150	RGS-MAM-11-1 RGS-MAM-12-1 RGS-MAM-12-1C	102.0	112.5	127	360

Table 4. CO_2 Cylinders

7. Nozzle selection

The selection of nozzles is normally determined by the quantity of CO_2 required compared to the nozzles flow capacity. Other factors such as the surface covered, nozzle availability, obstructions in the discharge flow, etc. can also influence the decision.

7.1. Flow via nozzle

The CO_2 systems discharge over the protected area in a time of 60 seconds in accordance with the requirements of the NFPA 12 regulation. Therefore, the number of nozzles, which are to be installed, should be capable of providing the necessary flow in order to meet this time criteria.

Each nozzle is capable of providing a certain flow range. To determine the number and size of nozzles necessary for each zone Table 5 shall be used.

> ➢ ***NOTE:*** *The table should only be treated as additional information; the pipe and nozzle network* ***SHOULD*** *be verified using the SIEX flow calculation program.*

NOZZLE FLOW RATES	
Ø NOMINAL PIPE	**TOTAL FLOODING 60 sec**
3/8"	1 – 232 kg
1/2"	20 – 403 kg
3/4"	20 – 639 kg
1"	39 – 933 kg
1 ¼"	51.5 – 1503 kg
1 ½"	68.5 – 2389 kg
2"	103 – 3009 kg
2 ½"	322.5 – 9530 kg

Table 5. Nozzle flow rates

7.2. Nozzle coverage

It is important to know the nozzle's maximum coverage when designing a carbon dioxide system in order to determine the quantity of nozzles to be used in the area to be protected for total flooding systems. An area of 174.24 m^2 per 360º nozzle (11 x 11 m) is covered and 60,5m^2 (5,5 x 11 m) for the 180º nozzle, depending on the characteristics of the area are to be covered. For both types of nozzles, the maximum distance to the farthest corner is 7,7 m.

NOZZLE MEASUREMENTS	CONNECTION TYPE
3/8" 1/2" 3/4" 1" 1 ¼" 1 ½" 2" 2 ½"	FEMALE G

Table 6. Nozzle measurements

7.3. Nozzles in total flooding systems

The Siex CO_2 system has four types of nozzles, models FEDRXX of 360º with or without calibrated plates and models FEDRXX180 of 180º, with or without calibrated plates. The maximum spacing for these nozzles is 11.0 metres.

The following table shows the code numbers in accordance with NFPA 12 in function of the 360º nozzle calibrated plate diameter.

Part number	Size	Internal diameter (mm)	Area (mm^2)	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Orifice Code No.
FEDR10	3/8"	1.5	1.770	6.9	3.7
		2.0	3.140	7.9	4.0
		3.0	7.070	10.8	4.7
		4.0	12.570	14.9	5.5
		5.0	19.630	20.1	6.4
		6.0	28.270	26.5	7.3
		7.0	38.480	34.0	8.3
		10.0	78.540	63.5	11.3
		w/o plate		71.3	12.0
FEDR15	1/2"	1.5	1.770	29.8	7.8
		2.5	4.910	31.0	7.9
		3.4	9.080	32.7	8.1
		5.0	19.630	36.9	8.6
		6.0	28.270	40.3	9.0
		7.0	38.480	44.4	9.5
		8.0	50.270	49.1	10.0
		9.0	63.620	54.4	10.5
		10.0	78.540	60.3	11.0
		12.0	113.100	74.1	12.2
		w/o plate		123.6	15.8
FEDR20	3/4"	7.0	38.480	38.0	8.8
		8.0	50.270	45.5	9.6
		9.0	63.620	54.0	10.4
		11.0	95.030	73.9	12.2
		12.0	113.100	85.4	13.1
		13.0	132.730	97.9	14.1
		14.0	153.940	111.4	15.0
		16.0	201.060	141.4	16.9
		18.0	254.470	175.4	18.8
		w/o plate		196.1	19.9
FEDR25	1"	10.0	78.540	56.8	10.7
		12.0	113.100	82.1	12.9
		14.0	153.940	111.9	15.0
		15.0	176.710	128.6	16.1
		16.0	201.060	146.4	17.2
		18.0	254.470	185.4	19.3
		20.0	314.160	229.0	21.5
		22.0	380.130	277.2	23.7
		w/o plate		286.3	24.0
FEDR32	1 1/4"	12.0	113.100	78.1	12.6
		14.0	153.940	112.5	15.1
		16.0	201.060	152.2	17.5

		18.0	254.470	197.1	20.0
		19.0	283.530	221.6	21.2
		20.0	314.160	247.4	22.3
		210	346.360	274.5	23.5
		22.0	380.130	303.0	24.7
		23.0	415.480	332.7	25.9
		24.0	452.390	363.8	27.1
		25.0	490.870	396.2	28.3
		w/o plate		461.3	30.5
FEDR40	1 1/2"	15.0	176.710	114.0	15.2
		18.0	254.470	171.7	18.6
		21.0	346.360	239.9	22.0
		22.0	380.130	265.0	23.1
		24.0	452.390	318.6	25.4
		26.0	530.930	376.9	27.6
		28.0	615.750	439.9	29.8
		29.0	660.520	473.1	30.9
		30.0	706.860	507.5	32.0
		32.0	804.250	579.8	34.2
		34.0	907.920	656.8	36.4
		35.0	962.110	697.0	37.5
		w/o plate		733.2	38.5
FEDR50	2"	18.0	254.470	157.8	17.9
		21.0	346.360	226.0	21.4
		24.0	452.390	304.6	24.8
		32.0	804.250	565.6	33.8
		38.0	1134.110	810.3	40.4
		42.0	1385.440	996.7	44.8
		w/o plate		923.7	43.2
FEDR65	2 1/2"	32.0	804.250	501.9	31.8
		37.0	1075.210	721.6	38.2
		42.0	1385.440	973.2	44.3
		47.0	1734.940	1256.6	50.3
		52.0	2123.720	1571.9	56.3
		57.0	2551.760	1919.0	62.2
		62.0	3019.070	2297.9	68.1
		w/o plate		2925.2	76.8

Table 7. Code number according to NFPA12

In the following table the code numbers as per the NFPA 12 appear in function of the calibrated plate diameter of the nozzle at 180º.

Part number	Size	Internal diameter (mm)	Area (mm^2)	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Orifice Code No.
FEDR10180	3/8"	3.0	7.070	1.4	1.7
		4.0	12.570	3.9	2.8
		5.0	19.630	7.2	3.8
		6.0	28.270	11.1	4.7
		7.0	38.480	15.8	5.6
		w/o plate		52.5	10.3
FEDR15180	1/2"	1.5	1.770	1.0	1.4
		2.5	4.910	2.4	2.2
		3.4	9.080	4.4	3.0
		5.0	19.630	9.3	4.3
		6.0	28.270	13.4	5.2
		7.0	38.480	18.1	6.1
		8.0	50.270	23.6	6.9
		9.0	63.620	29.9	7.8
		10.0	78.540	36.9	8.6
		12.0	113.100	53.0	10.3
		w/o plate		115.8	15.3
FEDR20180	3/4"	7.0	38.480	29.3	7.7
		8.0	50.270	36.3	8.6
		9.0	63.620	44.3	9.5
		11.0	95.030	63.0	11.3
		12.0	113.100	73.8	12.2
		13.0	132.730	85.5	13.1
		14.0	153.940	98.1	14.1
		16.0	201.060	126.2	16.0
		18.0	254.470	158.0	17.9
		w/o plate		175.2	18.8
FEDR25180	1"	10.0	78.540	64.4	11.4
		12.0	113.100	81.1	12.8
		14.0	153.940	100.8	14.3
		15.0	176.710	111.8	15.0
		16.0	201.060	123.6	15.8
		18.0	254.470	149.4	17.4
		20.0	314.160	178.3	19.0
		22.0	380.130	210.1	20.6
		w/o plate		262.1	23.0
FEDR32180	1 1/4"	12.0	113.100	74.6	12.3
		14.0	153.940	98.8	14.1
		16.0	201.060	126.9	16.0
		18.0	254.470	158.6	17.9

		19.0	283.530	175.9	18.8
		20.0	314.160	194.1	19.8
		21.0	346.360	213.2	20.7
		22.0	380.130	233.3	21.7
		23.0	415.480	254.3	22.7
		24.0	452.390	276.3	23.6
		25.0	490.870	299.2	24.6
		w/o plate		449.7	30.1
FEDR40180	1 1/2"	15.0	176.710	99.3	14.2
		18.0	254.470	147.0	17.2
		21.0	346.360	203.3	20.3
		22.0	380.130	224.0	21.3
		24.0	452.390	268.3	23.3
		26.0	530.930	316.5	25.3
		28.0	615.750	368.5	27.3
		29.0	660.520	396.0	28.3
		30.0	706.860	424.4	29.3
		32.0	804.250	484.1	31.3
		34.0	907.920	547.7	33.2
		w/o plate		603.1	34.9
FEDR50180	2"	18.0	254.470	149.3	17.4
		21.0	346.360	207.5	20.5
		24.0	452.390	274.7	23.5
		32.0	804.250	497.7	31.7
		38.0	1134.110	706.8	37.8
		42.0	1385.440	866.1	41.8
		w/o plate		932.6	43.4
FEDR65180	2 1/2"	32.0	804.250	467.3	30.7
		37.0	1075.210	627.5	35.6
		42.0	1385.440	810.9	40.4
		47.0	1734.940	1017.5	45.3
		52.0	2123.720	1247.3	50.2
		57.0	2551.760	1500.3	55.0
		w/o plate		1615.5	57.1

Table 8. Code number according to NFPA12

In the following table the diameters of the plate calibrated of the nozzle at 360º appear in function of the code numbers as per the NFPA 12.

FEDR10			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
4	7.91	3.09	1.98
4.5	10.01	5.94	2.75
5	12.36	9.13	3.41
5.5	14.96	12.66	4.01
6	17.80	16.52	4.59
6.5	20.90	20.72	5.14
7	24.24	25.25	5.67
7.5	27.83	30.12	6.19
8	31.66	35.32	6.71
8.5	35.75	40.87	7.21
9	40.08	46.74	7.71
9.5	44.66	52.96	8.21
10	49.49	59.51	8.70
10.,5	54.56	66.40	9.19
11	59.89	73.62	9.68
11.5	65.46	81.18	10.17
12	71.28	89.07	10.65

FEDR15			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
8	31.66	6.48	2.87
8.5	35.75	16.74	4.62
9	40.08	27.63	5.93
9.5	44.66	39.13	7.06
10	49.49	51.27	8.08
10.5	54.56	64.02	9.03
11	59.89	77.40	9.93
11.5	65.46	91.40	10.79
12	71.28	106.02	11.62
12.5	77.34	121.27	12.43
13	83.66	137.14	13.21
13.5	90.22	153.63	13.99
14	97.03	170.75	14.74

FEDR20			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
7	24.24	16.90	4.64
7.5	27.83	22.55	5.36
8	31.66	28.58	6.03
8.5	35.75	35.00	6.68
9	40.08	41.81	7.30
9.5	44.66	49.01	7.90
10	49.49	56.60	8.49
10.5	54.56	64.58	9.07
11	59.89	72.95	9.64
11.5	65.46	81.70	10.20
12	71.28	90.85	10.76
12.5	77.34	100.39	11.31
13	83.66	110.32	11.85
13.5	90.22	120.64	12.39
14	97.03	131.34	12.93
14.5	104.09	142.44	13.47
15	111.40	153.93	14.00
15.5	118.95	165.81	14.53
16	126.76	178.07	15.06
16.5	134.81	190.73	15.58
17	143.11	203.78	16.11
17.5	151.65	217.21	16.63
18	160.45	231.04	17.15
18.5	169.49	245.26	17.67
19	178.78	259.87	18.19

FEDR25			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
10	49.49	68.49	9.34
10.5	54.56	75.44	9.80
11	59.89	82.73	10.26
11.5	65.46	90.35	10.73
12	71.28	98.32	11.19
12.5	77.34	106.62	11.65
13	83.66	115.26	12.11
13.5	90.22	124.24	12.58
14	97.03	133.57	13.04
14.5	104.09	143.23	13.50
15	111.40	153.23	13.97
15.5	118.95	163.57	14.43
16	126.76	174.25	14.89
16.5	134.81	185.27	15.36
17	143.11	196.62	15.82
17.5	151.65	208.32	16.29
18	160.45	220.36	16.75
18.5	169.49	232.74	17.21
19	178.78	245.45	17.68
19.5	188.32	258.51	18.14
20	198.11	271.90	18.61
20.5	208.15	285.64	19.07
21	218.43	299.71	19.53
21.5	228.96	314.12	20.00
22	239.74	328.88	20.46

19.5	188.32	274.86	18.71
20	198.11	29025	19.22
20.5	208.15	306.03	19.74

22.5	250.77	343.97	20.93
23	262.05	359.40	21.39
23.5	273.57	375.17	21.86
24	285.34	391.29	22.32
24.5	297.36	407.74	22.78
25	309.63	424.53	23.25
25.5	322.15	441.66	23.71
26	334.91	459.13	24.18
26.5	347.93	476.94	24.64

FEDR32			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
11	59.89	91.47	10.79
11.5	65.46	98.09	11.18
12	71.28	105.00	11.56
12.5	77.34	112.20	11.95
13	83.66	119.70	12.35
13.5	90.22	127.50	12.74
14	97.03	135.59	13.14
14.5	104.09	143.97	13.54
15	111.40	152.64	13.94
15.5	118.95	161.62	14.34
16	126.76	170.88	14.75
16.5	134.81	180.44	15.16
17	143.11	190.30	15.57
17.5	151.65	200.45	15.98
18	160.45	210.89	16.39
18.5	169.49	221.63	16.80
19	178.78	232.66	17.21
19.5	188.32	243.99	17.63
20	198.11	255.62	18.04
20.5	208.15	267.53	18.46
21	218.43	279.74	18.87
21.5	228.96	292.25	19.29
22	239.74	305.05	19.71
22.5	250.77	318.15	20.13
23	262.05	331.54	20.55
23.5	273.57	345.22	20.97
24	285.34	359.20	21.39
24.5	297.36	373.48	21.81
25	309.63	388.05	22.23
25.5	322.15	402.91	22.65
26	334.91	418.07	23.07
26.5	347.93	433.52	23.49
27	361.19	449.27	23.92
27.5	374.70	465.31	24.34
28	388.45	481.65	24.76
28.5	402.46	498.28	25.19
29	416.71	515.21	25.61
29.5	431.22	532.43	26.04
30	445.97	549.94	26.46
30.5	460.97	567.75	26.89

FEDR40			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
14	97.03	153.87	14.00
14.5	104.09	163.38	14.42
15	111.40	173.22	14.85
15.5	118.95	183.40	15.28
16	126.76	193.92	15.71
16.5	134.81	204.76	16.15
17	143.11	215.94	16.58
17.5	151.65	227.46	17.02
18	160.45	239.31	17.46
18.5	169.49	251.49	17.89
19	178.78	264.01	18.33
19.5	188.32	276.86	18.78
20	198.11	290.04	19.22
20.5	208.15	303.56	19.66
21	218.43	317.42	20.10
21.5	228.96	331.61	20.55
22	239.74	346.13	20.99
22.5	250.77	360.98	21.44
23	262.05	376.18	21.89
23.5	273.57	391.70	22.33
24	285.34	407.56	22.78
24.5	297.36	423.75	23.23
25	309.63	440.28	23.68
25.5	322.15	457.15	24.13
26	334.91	474.34	24.58
26.5	347.93	491.87	25.03
27	361.19	509.74	25.48
27.5	374.70	527.94	25.93
28	388.45	546.47	26.38
28.5	402.46	565.34	26.83
29	416.71	584.55	27.28
29.5	431.22	604.08	27.73
30	445.97	623.95	28.19
30.5	460.97	644.16	28.64
31	476.21	664.70	29.09
31.5	491.71	685.58	29.54
32	507.45	706.78	30.00
32.5	523.44	728.33	30.45
33	539.68	750.21	30.91
33.5	556.17	772.42	31.36

31	476.21	585.86	27.31
31.5	491.71	604.26	27.74
32	507.45	622.96	28.16
32.5	523.44	641.95	28.59
33	539.68	661.23	29.02
33.5	556.17	680.81	29.44
34	572.91	700.68	29.87
34.5	589.89	720.85	30.30
35	607.12	741.32	30.72

34	572.91	794.97	31.81
34.5	589.89	817.85	32.27
35	607.12	841.06	32.72
35.5	624.60	864.61	33.18
36	642.33	888.50	33.63
36.5	660.31	912.72	34.09
37	678.54	937.27	34.55
37.5	697.01	962.16	35.00
38	715.73	987.38	35.46
38.5	734.70	1012.94	35.91
39	753.92	1038.83	36.37
39.5	773.39	1065.06	36.82
40	793.10	1091.62	37.28
40.5	813.07	1118.51	37.74
41	833.28	1145.74	38.19
41.5	853.74	1173.30	38.65
42	874.45	1201.20	39.11

FEDR50			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
17	143.11	234.63	17.28
17.5	151.65	246.15	17.70
18	160.45	258.01	18.12
18.5	169.49	270.20	18.55
19	178.78	282.73	18.97
19.5	188.32	295.59	19.40
20	198.11	308.79	19.83
20.5	208.15	322.32	20.26
21	218.43	336.19	20.69
21.5	228.96	350.39	21.12
22	239.74	364.92	21.56
22.5	250.77	379.79	21.99
23	262.05	394.99	22.43
23.5	273.57	410.53	22.86
24	285.34	426.40	23.30
24.5	297.36	442.61	23.74
25	309.63	459.15	24.18
25.5	322.15	476.03	24.62
26	334.91	493.24	25.06
26.5	347.93	510.78	25.50
27	361.19	528.66	25.94
27.5	374.70	546.88	26.39
28	388.45	565.43	26.83
28.5	402.46	584.31	27.28
29	416.71	603.53	27.72
29.5	431.22	623.08	28.17
30	445.97	642.97	28.61
30.5	460.97	663.20	29.06
31	476.21	683.75	29.51
31.5	491.71	704.64	29.95
32	507.45	725.87	30.40
32.5	523.44	747.43	30.85

FEDR65			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
31	476.21	772.57	31.36
31.5	491.71	791.68	31.75
32	507.45	811.10	32.14
32.5	523.44	830.82	32.52
33	539.68	850.84	32.91
33.5	556.17	871.18	33.30
34	572.91	891.81	33.70
34.5	589.89	912.76	34.09
35	607.12	934.01	34.49
35.5	624.60	955.57	34.88
36	642.33	977.43	35.28
36.5	660.31	999.60	35.68
37	678.54	1022.08	36.07
37.5	697.01	1044.86	36.47
38	715.73	1067.95	36.87
38.5	734.70	1091.34	37.28
39	753.92	1115.04	37.68
39.5	773.39	1139.05	38.08
40	793.10	1163.36	38.49
40.5	813.07	1187.98	38.89
41	833.28	1212.90	39.30
41.5	853.74	1238.14	39.70
42	874.45	1263.67	40.11
42.5	895.40	1289.52	40.52
43	916.61	1315.67	40.93
43.5	938.06	1342.12	41.34
44	959.76	1368.88	41.75
44.5	981.71	1395.95	42.16
45	1003.91	1423.33	42.57
45.5	1026.36	1451.01	42.98
46	1049.05	1479.00	43.39
46.5	1072.00	1507.29	43.81

33	539.68	769.33	31.30
33.5	556.17	791.56	31.75
34	572.91	814.12	32.20
34.5	589.89	837.02	32.65
35	607.12	860.26	33.10
35.5	624.60	883.83	33.55
36	642.33	907.73	34.00
36.5	660.31	931.97	34.45
37	678.54	956.55	34.90
37.5	697.01	981.45	35.35
38	715.73	1006.70	35.80
38.5	734.70	1032.27	36.25
39	753.92	1058.19	36.71
39.5	773.39	1084.43	37.16
40	793.10	1111.02	37.61
40.5	813.07	1137.93	38.06
41	833.28	1165.19	38.52
41.5	853.74	1192.77	38.97
42	874.45	1220.69	39.42
42.5	895.40	1248.95	39.88
43	916.61	1277.54	40.33
43.5	938.06	1306.47	40.79
44	959.76	1335.73	41.24
44.5	981.71	1365.32	41.69
45	1003.91	1395.25	42.15
45.5	1026.36	1425.52	42.60
46	1049.05	1456.12	43.06
46.5	1072.00	1487.05	43.51
47	1095.19	1518.32	43.97
47.5	1118.63	1549.92	44.42
48	1142.32	1581.86	44.88
48.5	1166.26	1614.14	45.33
49	1190.44	1646.75	45.79
49.5	1214.87	1679.69	46.25
50	1239.56	1712.97	46.70
50.5	1264.49	1746.58	47.16
51	1289.66	1780.53	47.61
51.5	1315.09	1814.81	48.07
52	1340.77	1849.43	48.53
52.5	1366.69	1884.38	48.98
53	1392.86	1919.67	49.44
53.5	1419.28	1955.29	49.90

47	1095.19	1535.89	44.22
47.5	1118.63	1564.80	44.64
48	1142.32	1594.01	45.05
48.5	1166.26	1623.53	45.47
49	1190.44	1653.35	45.88
49.5	1214.87	1683.48	46.30
50	1239.56	1713.92	46.71
50.5	1264.49	1744.66	47.13
51	1289,.66	1775.71	47.55
51.5	1315,09	1807.07	47.97
52	1340.77	1838.73	48.39
52.5	1366.69	1870.70	48.80
53	1392.86	1902.98	49.22
53.5	1419.28	1935.56	49.64
54	1445.95	1968.45	50.06
54.5	1472.87	2001.64	50.48
55	1500.03	2035.14	50.90
55.5	1527.45	2068.95	51.33
56	1555.11	2103.06	51.75
56.5	1583.02	2137.48	52.17
57	1611.18	2172.20	52.59
57.5	1639.59	2207.24	53.01
58	1668.24	2242.57	53.44
58.5	1697.15	2278.22	53.86
59	1726.30	2314.17	54.28
59.5	1755.70	2350.43	54.71
60	1785.35	2386.99	55.13
60.5	1815.25	2423.86	55.55
61	1845.39	2461.04	55.98
61.5	1875.79	2498.52	56.40
62	1906.43	2536.31	56.83
62.5	1937.32	2574.40	57.25
63	1968.46	2612.80	57.68
63.5	1999.85	2651.51	58.10
64	2031.49	2690.53	58.53
64.5	2063.37	2729.85	58.96
65	2095.51	2769.47	59.38
65.5	2127.89	2809.41	59.81
66	2160.52	2849.65	60.24
66.5	2193.40	2890.19	60.66
67	2226.53	2931.04	61.09
67.5	2259.90	2972.20	61.52
68	2293.53	3013.67	61.94
68.5	2327.40	3055.44	62.37
69	2361.52	3097.52	62.80
69.5	2395.89	3139.90	63.23
70	2430.51	3182.59	63.66
70.5	2465.38	3225.59	64.09
71	2500.49	3268.89	64.51
71.5	2535.85	3312.50	64.94

In the following table the diameters of the plate calibrated of the nozzle at 180º appear in function of the code numbers as per the NFPA 12.

FEDR10180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
1	0.49	5.00	2.52
1.5	1.11	6.35	2.84
2	1.98	8.25	3.24
2.5	3.09	10.69	3.69
3	4.45	13.66	4.17
3.5	6.05	17.19	4.68
4	7.91	21.25	5.20
4.5	10.01	25.86	5.74
5	12.36	31.01	6.28
5.5	14.96	36.70	6.84
6	17.80	42.94	7.39
6.5	20.90	49.71	7.96
7	24.24	57.04	8.52
7.5	27.83	64.90	9.09
8	31.66	73,.31	9.66
8.5	35.75	82.26	10.23

FEDR15180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm^2)	Area (mm^2)	Internal diameter (mm)
4	7.91	16.60	4.60
4.5	10.01	21.10	5.18
5	12.36	26.13	5.77
5.5	14.96	31.69	6.35
6	17.80	37.77	6.93
6.5	20.90	44.39	7.52
7	24.24	51.54	8.10
7.5	27.83	59.22	8.68
8	31.66	67.42	9.27
8.5	35.75	76.16	9.85
9	40.08	85.43	10.43
9.5	44.66	95.23	11.01
10	49.49	105.56	11.59
10.5	54.56	116.42	12.17
11	59.89	127.81	12.76
11.5	65.46	139.73	13.34
12	71.28	152.18	13.92
12.5	77.34	165.16	14.50

FEDR20180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm2)	Area (mm2)	Internal diameter (mm)
7	24.24	29.95	6.18
7.5	27.83	35.97	6.77
8	31.66	42.41	7.35
8.5	35.75	49.27	7.92
9	40.08	56.54	8.48
9.5	44.66	64.23	9.04
10	49.49	72.33	9.60
10.5	54.56	80.85	10.15
11	59.89	89.79	10.69
11.5	65.46	99.14	11.24
12	71.28	108.91	11.78
12.5	77.34	119.10	12.31
13	83.66	129.70	12.85
13.5	90.22	140.72	13.39
14	97.03	152.15	13.92
14.5	104.09	164.00	14.45
15	111.40	176.27	14.98
15.5	118.95	188.95	15.51
16	126.76	202.05	16.04
16.5	134.81	215.56	16.57
17	143.11	229.50	17.09
17.5	151.65	243.84	17.62
18	160.45	258.61	18.15

FEDR25180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm2)	Area (mm2)	Internal diameter (mm)
10	49.49	47.66	7.79
10.5	54.56	58.17	8.61
11	59.89	69.18	9.39
11.5	65.46	80.71	10.14
12	71.28	92.76	10.87
12.5	77.34	105.31	11.58
13	83.66	118.38	12.28
13.5	90.22	131.96	12.96
14	97.03	146.06	13.64
14.5	104.09	160.67	14.30
15	111.40	175.79	14.96
15.5	118.95	191.43	15.61
16	126.76	207.57	16.26
16.5	134.81	224.24	16.90
17	143.11	241.41	17.53
17.5	151.65	259.10	18.16
18	160.45	277.30	18.79
18.5	169.49	296.02	19.41
19	178.78	315.24	20.03
19.5	188.32	334.99	20.65
20	198.11	355.24	21.27
20.5	208.15	376.01	21.88
21	218.43	397.29	22.49

18.5	169.49	273.79	18.67
19	178.78	289.39	19.20
19.5	188.32	305.40	19.72

21.5	228.96	419.09	23.10
22	239.74	441.40	23.71

FEDR32180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm2)	Area (mm2)	Internal diameter (mm)
11	59.89	88.41	10.61
11.5	65.46	97.78	11.16
12	71.28	107.57	11.70
12.5	77.34	117.77	12.25
13	83.66	128.39	12.79
13.5	90.22	139.43	13.32
14	97.03	150.89	13.86
14.5	104.09	162.77	14.40
15	111.40	175.06	14.93
15.5	118.95	187.77	15.46
16	126.76	200.89	15.99
16.5	134.81	214.43	16.52
17	143.11	228.39	17.05
17.5	151.65	242.77	17.58
18	160.45	257.56	18.11
18.5	169.49	272.78	18.64
19	178.78	288.41	19.16
19.5	188.32	304.45	19.69
20	198.11	320.92	20.21
20.5	208.15	337.80	20.74
21	218.43	355.09	21.26
21.5	228.96	372.81	21.79
22	239.74	390.94	22.31
22.5	250.77	409.49	22.83
23	262.05	428.46	23.36
23.5	273.57	447.84	23.88
24	285.34	467.65	24.40
24.5	297.36	487.87	24.92
25	309.63	508.50	25.44
25.5	322.15	529.56	25.97
26	334.91	551.03	26.49
26.5	347.93	572.92	27.01
27	361.19	595.23	27.53
27.5	374.70	617.95	28.05
28	388.45	641.09	28.57
28.5	402.46	664.65	29.09
29	416.71	688.63	29.61
29.5	431.22	713.02	30.13

FEDR40180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm2)	Area (mm2)	Internal diameter (mm)
14	97.03	173.02	14.84
14.5	104.09	184.53	15.33
15	111.40	196.45	15.82
15.5	118.95	208.77	16.30
16	126.76	221.50	16.79
16.5	134.81	234.63	17.28
17	143.11	248.16	17.78
17.5	151.65	262.10	18.27
18	160.45	276.44	18.76
18.5	169.49	291.19	19.25
19	178.78	306.34	19.75
19.5	188.32	321.90	20.24
20	198.11	337.86	20.74
20.5	208.15	354.23	21.24
21	218.43	371.00	21.73
21.5	228.96	388.17	22.23
22	239.74	405.75	22.73
22.5	250.77	423.73	23.23
23	262.05	442.12	23.73
23.5	273.57	460.92	24.23
24	285.34	480.12	24.72
24.5	297.36	499.72	25.22
25	309.63	519.73	25.72
25.5	322.15	540.14	26.22
26	334.91	560.96	26.73
26.5	347.93	582.18	27.23
27	361.19	603.80	27,73
27.5	374.70	625.84	28.23
28	388.45	648.27	28.73
28.5	402.46	671.11	29.23
29	416.71	694.36	29.73
29.5	431.22	718.01	30.24
30	445.97	742.06	30.74
30.5	460.97	766.52	31.24
31	476.21	791.39	31.74
31.5	491.71	816.66	32.25
32	507.45	842.33	32.75
32.5	523.44	868.41	33.25
33	539.68	894.89	33.76
33.5	556.17	921.78	34.26
34	572.91	949.07	34.76
34.5	589.89	976.77	35.27
35	607.12	1004.87	35.77
35.5	624.60	1033.38	36.27

36	642.33	1062.30	36.78

FEDR50180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm2)	Area (mm2)	Internal diameter (mm)
17	143.11	244.72	17.65
17.5	151.65	258.21	18.13
18	160.45	272.09	18.61
18.5	169.49	286.36	19.09
19	178.78	301.02	19.58
19.5	188.32	316.07	20.06
20	198.11	331.51	20.54
20.5	208.15	347.34	21.03
21	218.43	363.57	21.52
21.5	228.96	380.19	22.00
22	239.74	397.19	22.49
22.5	250.77	414.59	22.98
23	262.05	432.39	23.46
23.5	273.57	450.57	23.95
24	285.34	469.14	24.44
24.5	297.36	488.11	24.93
25	309.63	507.47	25.42
25.5	322.15	527.22	25.91
26	334.91	547.36	26.40
26.5	347.93	567.89	26.89
27	361.19	588.81	27.38
27.5	374.70	610.13	27.87
28	388.45	631.83	28.36
28.5	402.46	653.93	28.86
29	416.71	676.42	29.35
29.5	431.22	699.30	29.84
30	445.97	722.58	30.33
30.5	460.97	746.24	30.82
31	476.21	770.30	31.32
31.5	491.71	794.75	31.81
32	507.45	819.58	32.30
32.5	523.44	844.82	32.80
33	539.68	870.44	33.29
33.5	556.17	896.45	33.78
34	572.91	922.86	34.28
34.5	589.89	949.66	34.77
35	607.12	976.85	35.27
35.5	624.60	1004.43	35.76
36	642.33	1032.40	36.26
36.5	660.31	1060.77	36.75
37	678.54	1089.52	37.25
37.5	697.01	1118.67	37.74
38	715.73	1148.21	38.24
38.5	734.70	1178.14	38.73
39	753.92	1208.47	39.23
39.5	773.39	1239.18	39.72

FEDR65180			
Orifice Code No.	Equivalent Single-Orifice acc. to NFPA-12 (mm2)	Area (mm2)	Internal diameter (mm)
31	476.21	819.27	32.30
31.5	491.71	845.48	32.81
32	507.45	872.12	33.32
32.5	523.44	899.17	33.84
33	539.68	926.64	34.35
33.5	556.17	954.54	34.86
34	572.91	982.85	35.38
34.5	589.89	1011.59	35.89
35	607.12	1040.74	36.40
35.5	624.60	1070.32	36.92
36	642.33	1100.31	37.43
36.5	660.31	1130.72	37.94
37	678.54	1161.56	38.46
37.5	697.01	1192.81	38.97
38	715.73	1224.49	39.48
38.5	734.70	1256.58	40.00
39	753.92	1289.09	40.51
39.5	773.39	1322.03	41.03
40	793.10	1355.38	41.54
40.5	813.07	1389.16	42.06
41	833.28	1423.35	42.57
41.5	853.74	1457.97	43.09
42	874.45	1493.00	43.60
42.5	895.40	1528.46	44.11
43	916.61	1564.33	44.63
43.5	938.06	1600.63	45.14
44	959.76	1637.34	45.66
44.5	981.71	1674.48	46.17
45	1003.91	1712.03	46.69
45.5	1026.36	1750.01	47.20
46	1049.05	1788.40	47.72
46.5	1072.00	1827.22	48.23
47	1095.19	1866.45	48.75
47.5	1118.63	1906.11	49.26
48	1142.32	1946.19	49.78
48.5	1166.26	1986.68	50.29
49	1190.44	2027.60	50.81
49.5	1214.87	2068.94	51.32
50	1239.56	2110.69	51.84
50.5	1264.49	2152.87	52.36
51	1289.66	2195.47	52.87
51.5	1315.09	2238.48	53.39
52	1340.77	2281.92	53.90
52.5	1366.69	2325.78	54.42
53	1392.86	2370.06	54.93
53.5	1419.28	2414.75	55.45

40	793.10	1270.29	40.22
40.5	813.07	1301.79	40.71
41	833.28	1333.68	41.21
41.5	853.74	1365.96	41.70
42	874.45	1398.63	42.20
42.5	895.40	1431.70	42.70
43	916.61	1465.16	43.19
43.5	938.06	1499.01	43.69
44	959.76	1533.25	44.18
44.5	981.71	1567.88	44.68
45	100.91	1602.90	45.18
45.5	1026.36	1638.32	45.67
46	1049.05	1674.13	46.17
46.5	1072.00	1710.33	46.67
47	1095.19	1746.92	47.16

54	1445.95	2459.87	55.96
54.5	1472.87	2505.41	56.48
55	1500.03	2551.37	57.00

8. Pipe Network design (Engineering systems)

This section refers to the pipe network limitations for all SIEX engineering system configurations with CO_2. This information aims to provide the system designer the information necessary to complete a section of preliminary pipes. The following limitations define the parameters, which have been verified through tests, **but the installation SHOULD NOT begin until the design system has been approved.**

WARNING

The CO_2 extinguisher agent flow calculation program software is the only calculation method applicable for all SIEX equipment. No other calculation method shall be accepted for systems supplied by SIEX

The system designer should be completely familiar with the software in order to establish the correct procedures to enter the entry parameters in the program. In the event of not achieving precise results, a series of limitations for the entry parameters should be analysed. The majority of these limitations can be found in the program. However, there are certain restrictions, which the designer should consider before entering the entry parameters. The following sections describe the main parameters and the design limitations, which should be considered.

8.1. Tees bifurcation ratios

SIEX's CO_2 engineering system has been tested to define the maximum imbalance level, which can be predicted in the tee bifurcations. This value is expressed in terms of the bifurcation ratio in an exit feeder in relation to the other feeder. Each ratio indicated makes reference to a percentage of the total entry flow.

8.2. Central type tee

A central type tee is defined as one, which is configured as a tee shape where two exit feeders switch direction in respect to the entry pipe. Figure 2 and 0.

The bifurcation ratio for a central type tee goes from 10-90% to 50-50%.

This means that the main flow exit has an acceptable range between 50% minimum and 90% maximum, and the secondary flow exit has an acceptable range of between 10% minimum and 50% maximum. These figures are percentages of the total entry flow through a tee.

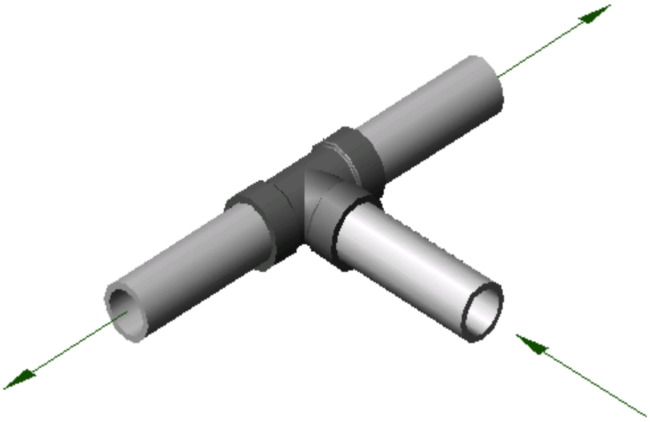


Figure 3.- 50-50% central tee

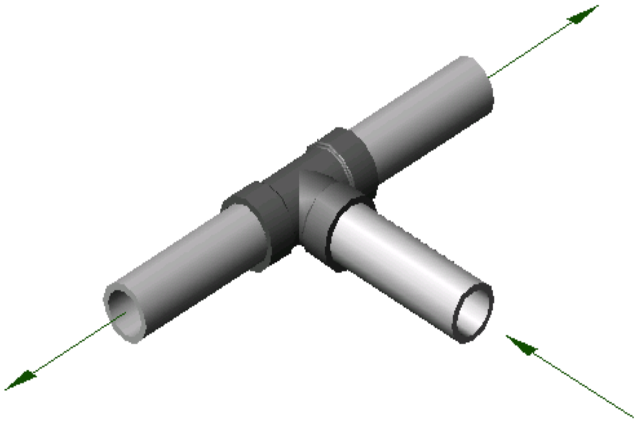


Figure 4- Central tee of 10-90%

8.3. Lateral tee type

A lateral tee type is defined as one, which has a T configuration where one of the exit feeders changes direction in respect of the entry feeder, and the other continues in the same direction as the entry feeder. (Figure 5). The bifurcation ratio for a tee goes 10-30% to 70-90%. This means that the main exit flow (feeder which does not divert in relation to the entry feeder) has an acceptable range of 70% minimum and 90% maximum and which has a secondary flow exit (the feeder which is diverted) with an acceptable range of 10% minimum and 30% maximum. These figures are percentages of the total entry flow through the tee.

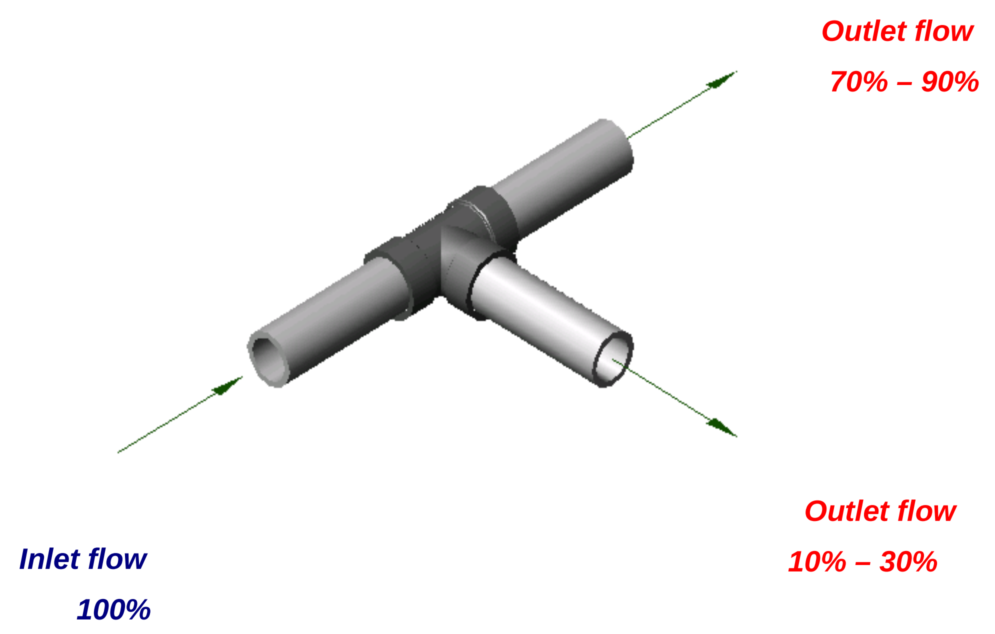


Figure 6. Lateral tees

8.4. Tee orientation

The **SIEX** engineering system with CO_2 has been tested to define the limitations necessary to accurately predict how the system will behave during discharge. The orientation of the tee is an important characteristic in order to maintain consistency in the flow diversion percentages. Therefore, a simple rule **SHOULD** be taken into account in relation to the tees orientation, which appears, on the following page.

1. - *The central tees can have both exists on a horizontal or vertical plane.* ***The entry can be horizontal or vertical pointing upwards or downwards.***

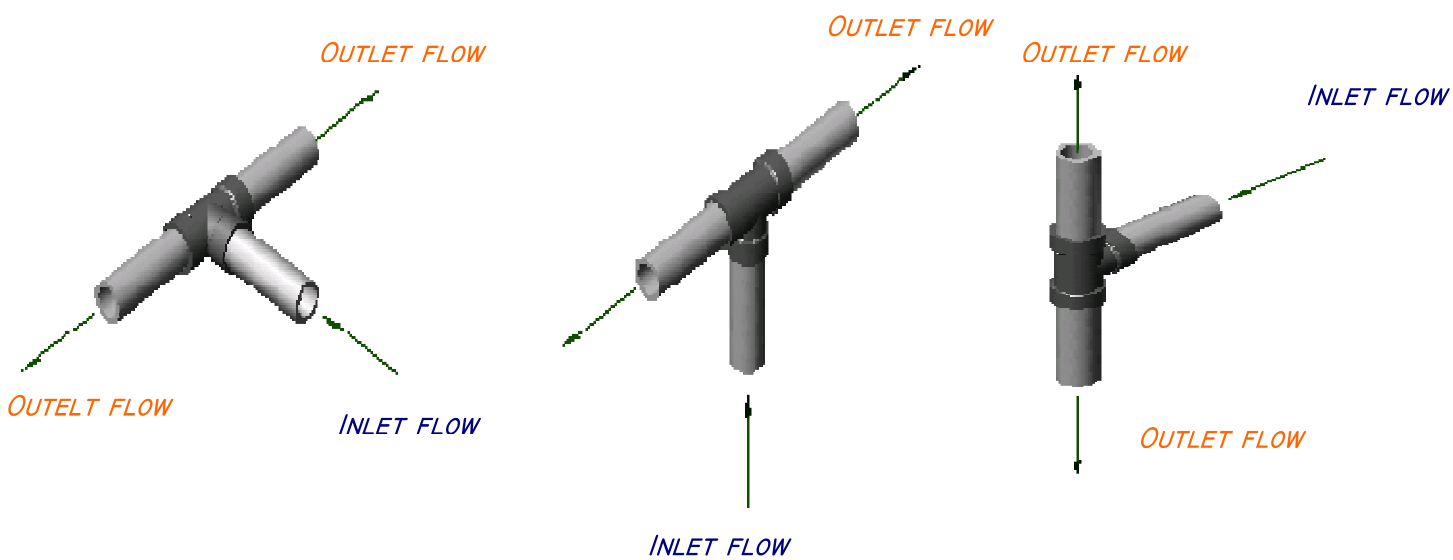


Figure 7

2. - The lateral tees can have the exit and entry on the same horizontal or vertical plane.

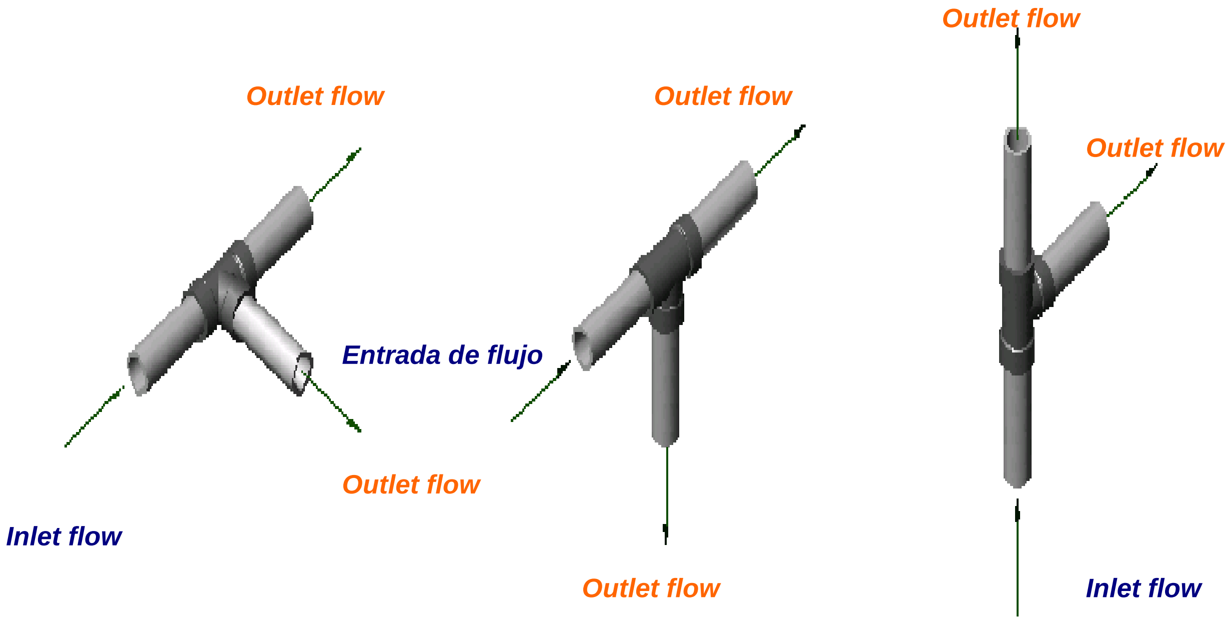


Figure 8.

9. Discharge duration

In total flooding systems the maximum normal discharge time should not exceed 60 seconds. In the case of deep seated fires this shall be 420 seconds (7 minutes).

Therefore, this time requirement must be considered when estimating the pipe sizes. The SIEX flow calculation program chooses the pipe size based on these criteria and as a consequence selects the nozzle size calibration of the nozzle. Through the nozzle discharge sizes with the SIEX program maximum control over discharge time is achieved.

10. Vent or relief vent area design

CARBON DIOXIDE extinguishers reduce the amount of oxygen to a point where combustion can no longer occur. The quantity of agent discharged in the area generates a positive pressure in the area, removing air from it. This means that it is necessary to use a vent or relief system to avoid structural damage to the area concerned and to equipment therein.

To avoid damage to the facilities or to staff therein, the vent devices should not direct air to other areas, which are outsize of the zone to be extinguished, they should always direct towards fresh air.

The vent conduct should be designed to ensure that the fire does not spread to other areas. The vent device should close completely once the pressure discharge has been completed. It is preferable for the device to have its own electrical power and should be able to open and close automatically, as well as each flooding zone being equipped with its own vent device.

Therefore, in order to avoid structural damage in the protected area the provision of a relief or vent system should be addressed as in many cases the quantity of carbon dioxide to be extinguished is approximately equal to 50% of the area's volume and therefore, if the area is completely airtight the pressure would increase by around 50%.

10.1. Excess pressure relief vent system design

For the sizing of these devices it is essential to take into account this manual's guidelines. Therefore the working pressure, design concentration and quantity of the agent to be discharged, the existing escape area, allowed excess pressure, discharge time and specific gas volume. As a general rule the maximum tolerated excess pressure is 1 milibar. However, in the case of the customer providing higher values in function of the area's structural resistance evaluated by the customer, these shall be the ones to be taken into account when making the calculation.

The calculation of the aperture area for pressure relief shall be determined via the equations provided in appendix A9 of the CEA 4007: 1997-08 technical specifications for carbon dioxide.

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10.2. Equations for calculation of carbon dioxide excess pressure relief vent aperture.

The equation used for the determination of the area required for pressure relief is the following:

(Equation 17)

$$A = \frac{239 \cdot Q}{\sqrt{P}}$$

Where:
A: Area of aperture (mm^2).
Q: Mass flow of agent (kg/min).
P: Maximum excess pressure allowed in area concerned (kPa).