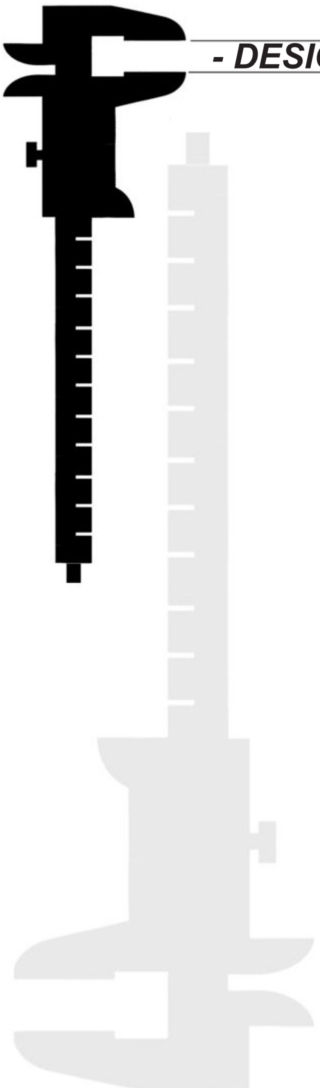


- DESIGN MANUAL -

INERT-SIEX™ CFT-541

(Constant Flow Technology)
at 2900 & 4350 PSI
(200 and 300 BAR) - IG-541

LISTED
EX27097

INDEX

1. DESIGN

The design criteria explained in this design manual are based on the requirements of the NFPA 2001, ISO 14520, EN-UNE 15004.

The design of the pipework MUST be verified by means of hydraulic flow calculations before installing the IG-541 system. If the specific limitations are not adhered to, it is possible that the system will not deliver the necessary quantity of extinguishant.

1.1. Design criteria

The complexity of flow formulas does not allow the use of a simple manual calculation method in the case of IG-541 extinguishant. For this reason, the flow calculations and design criteria described in this manual have been included in the software for clean agent flow calculations.

ATTENTION: The IG-541 extinguishing agent flow calculation program (software) is the only calculation method applicable with SIEX equipment. No other calculation method is accepted for systems supplied by SIEX.

System designers must fully familiarise themselves with this manual. For the use of the software for the calculation, it is necessary to take into account a series of limitations for these input parameters in the software to obtain accurate results. The majority of these limitations are to be found in the program. However, before inputing the data, the system designer needs to take a series of restrictions into account. This manual describes the main design parameters and limitations which need to be considered. To design a INERT-SIEX™ CFT-541 system the following steps must be followed:

1. Carrying out of a risk analysis and inspection in the protected area,
2. Establishing the necessary design concentration,
3. Determining if there are risks to people in the enclosure (safety measures),
4. Calculating the quantity of extinguishant needed for the risk,
5. Determining if there are leaks or openings from the protected area.
6. General system design concepts.

1.2. Properties of IG-541 extinguishant

IG-541 is a colourless, odourless, electrically non-conductive gas with a density approximately the same as that of air. It is an inert gas mixture consisting nominally of 52 % nitrogen, 40 % argon and 8 % carbon dioxide, with the following mixture specification (based on 8 % carbon dioxide with tolerance of +-5 %).

Property	Requirement		
	Argon	Nitrogen	Carbon dioxide
Purity	99,997 % by volume, min.	99,99 % by volume, min.	99,5 % by volume, min.
Water percent	4 × 10–6 by mass, max.	5 × 10–6 by mass, max.	10 × 10–6 by mass, max.
Oxygen	3 × 10–6 by mass, max.	3 × 10–6 by mass, max.	10 × 10–6 by mass, max.

Table 1: IG-541 specifications

Property	Unit	Value
Molecular mass	—	34,0
Boiling point at 16.38 psi (1,013 bar) (absolute) a	ºF (°C)	-320.8º F (–196)
Freezing point	ºF (°C)	-109.3 (–78,5)
Critical temperature	ºF (°C)	—
Critical pressure	psi (bar) abs a	—
Critical volume	in3/mol (cm^3/mol)	—
Critical density	lb/in3 (kg/m^3)	—
Vapour pressure 68ºF (20 °C)	psi (bar) abs	2204.57
Liquid density 68ºF (20 °C)	lb/in3 (kg/m^3)	—
Saturated vapour density 68ºF (20 °C)	lb/in3 (kg/m^3)	—
Specific volume of superheated vapour at 16.38psi (1,013 bar) and 68ºF (20 °C)	ft^3/lb (m^3/kg)	11.164 (0,697)
Chemical formulas	N2	52 % by volume
	Ar	40 % by volume
	CO2	8 % by volume
Chemical names	Argon Nitrogen Carbon dioxide	
a 1 bar = 0,1 MPa = 105 Pa; 1 MPa = 1 N/mm^2 .		

Table 2: Physical properties of IG-541

1.3 Uses and limitations

IG-541 Extinguishant is suitable for the following Classes of Fire:

- Class A: A fire in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.
- Class B: A fire in flammable liquids, combustible liquids,etroleum greases, tars, oils, oilbased paints, solvents, lacquers, alcohols, and flammable gases.
- Electrical risks (Class C): A fire that involves energized electrical equipment.

However, precautions must be taken with some materials since IG-541 extinguishant is not effective for:

Chemical products with their own oxygen supply, such as cellulose nitrate. Class D fires (combustion of metals); reactive metals such as lithium, sodium, potassium, titanium, etc, some of which can react violently,
Radioactive elements such as uranium and plutonium.

1.4 Safety of personnel

IG-541 is a suitable system for use in areas occupied by people and can be designed for concentrations above the NOAEL (43%). For spaces with an Oxygen level of 12% or greater the limited exposure time for humans is 5 minutes.
These systems can also be designed for a concentration which exceeds the NOAEL (43%) and is below the LOAEL (52%) (with an Oxygen level between 12% and 10%) provided that the exposure

time does not exceed 3 minutes:

Concentrations exceeding the LOAEL are permitted only in areas that are not normally occupied by personnel – provided that they can escape the area in 30 seconds or less. No unprotected personnel shall enter the area during agent discharge.

In areas that are normally occupied by personnel where egress takes longer than 30 seconds the design concentration CANNOT exceed the LOAEL concentration of 52% by volume.

Concentrations exceeding the 62% (corresponding to an oxygen concentration of 8 % or lower) are permitted in unoccupied areas when the personal is not exposed to this low oxygen concentration.

• NOAEL (No Observed Adverse Effect Level): highest concentration which has not been observed any adverse physiological or toxic effect.

• LOAEL (Lowest Observed Adverse Effect Level): lowest concentration which has been observed an adverse physiological or toxic effect.

PROPERTIES	VALUE
NOAEL	43 %
LOAEL	52 %

Table 3: Security percentage for IG-541

1.4.1 Risk analysis and inspection of the protected area

The first and most important step in designing an extinguishing system using IG-541 clean agent is to carefully analyse the risk to be protected. Use the instructions in the NFPA 2001 (US standard), ISO 14.520 and UNE-EN 15004 standards as a design guide.

BASIC CONCEPTS WHICH MUST BE KNOWN:

1) CLASS OR TYPE OF RISK
2) TYPE OF FIRE PRODUCED (CLASS A, B or C)
3) ENVIRONMENTAL CONDITIONS (TEMPERATURE, HU MIDITY, CORROSION, ETC)
4) PRESENCE OF PEOPLE IN THE ROOM DURING THE DISCHARGE (OCCUPIED AREA)
5) OPENINGS WHICH REMAIN OPEN DURING DISCHARGE
6) SYSTEM OF OPERATION UNDER NORMAL CONDITIONS AND AFTER THE DISCHARGE OF THE IG-541 EXTINGUISHANT,
7) PROTECTED AREA ACCESS (EVACUATION ROUTES, EVACUATION TIME, ETC)
8) TYPE OF CONSTRUCTION OF THE PROTECTED AREA (DOORS, FIRE RESISTANT WALLS, ETC)
9) VOLUME OF THE COMPARTMENT TO BE PROTECTED
10) MAXIMUM HEIGHT OF THE ENCLOSED AREA TO BE PROTECTED
11) FALSE FLOORS AND CEILINGS IN THE ENCLOSED AREA
12) LOCATION OF THE EXTINGUISHING SYSTEM (CYLINDERS OR BANKS)
13) ANY OTHER SPECIAL CONSIDERATION TO BE TAKEN INTO ACCOUNT WHICH MAY AFFECT THE RISK

1.4.2 Determining the design concentration needed for the hazard to be protected

The design concentration is based on the extinguishing concentration plus a safety factor which varies according to the Class of Fire and the standard to be applied.

For Class A fires a safety factor of 30% is added for ISO-14520 or UNE-EN 23570 and 20% for NFPA 2001. On the other hand, for Class B fires, 30% is added for ISO-14520, UNE-EN 23570 and NFPA 2001. For class C fires, a safety factor of 35% is added according to NFPA 2001. The extinguishing concentrations are based on laboratory tests using standardised methods in accordance with the standard. Difficult environments or those which require intrinsically safe or Ex-proof equipment will be considered as special cases and would need to be studied in detail before completing the system design.

1.4.3 Calculation of the percentage concentration

As explained above, the majority of fires are normally included in one of the two categories (Classes A and B), although at times they may be a combination of the two. The designer needs to take into account the type of fire to establish the correct design concentration and so determine the quantity of extinguishant needed. The three types of fires which will be considered in this manual are:

- Class A: Wood, paper, clothing or anything which leaves an ash residue after combustion
- Class B: For flammable liquids
- Class C: For electrical risks

A guide is given below to determine the appropriate percentage extinguishant concentration according to the hazard.

1.4.4 Class A fires or Electrical Risks and n-heptane risks

a) According to NFPA 2001:
The design concentrations given in table 4 are for 69.8ºF (21ºC). The values for Class B are for heptane. The values for the design for class A have a safety factor of 1,2, the values for the design of class B have a safety factor of 1,3. The class C fires correspond to the minimum concentration for Class A fire plus a safety factor of 1,35.

FUELS	EXTINGUISHING %	MINIMUM DESIGN %
Class A surface fires [2)]	27,69	33,23
Class B	27,90	36,27
Class C	27,69	37,38

Table 4: IG-541 nominal design and extinguishing concentrations

b)) According to ISO 14520 and UNE-EN 15004:
The design concentration for Class A fires and electrical hazards is 39.9 % according to ISO 14520 – UNE-EN 15004, and it is different for Class B fires.
The systems protecting hazards which contain Class B flammable hazards and for n-heptane, can be designed with a concentration of 41.2%. (According to ISO 14520 and UNE-EN 15004).

FUEL	EXTINGUISHING %	MINIMUM DESIGN %
Class A surface fires [2)]	30,7	39,9
Class B [1)]	31,7	41,2
Higher Hazard Class A	[a)]	39,9

NOTES:
[1)] See 7.5.1.3 of the Standard ISO 14520-1
[2)] Values based on the Standard UNE-EN 15004, Annex B, according to the cup burner method.
[a)] The minimum design concentration for Higher Hazard Class A fuels shall be the higher of the Surface Class A or 95 % of the Class B minimum design concentration.

Table 5: Design and extinction concentrations for IG-541 taken from the Standards ISO 14520 and UNE-EN 15004

1.4.5 Safety guidelines

The safety guidelines in this section are as specified in NFPA 2001, ISO 14520 and UNE-EN 15004. During the evaluation of the project, Designers must take into account the occupation of the protected areas and must bear in mind any hazard to people who might be in the enclosure due to the discharge of the extinguishant. They must make the necessary adjustments and to state any appropriate recommendations.

The terms “NOAEL” and “LOAEL” which appear in Table 6 are defined below:

- NOAEL (No Observed Adverse Effect Level): the highest concentration at which no adverse physiological or toxic effect has been observed.
- LOAEL (Lowest Observed Adverse Effect Level): the lowest concentration at which an adverse physiological or toxic effect has been observed.

For spaces with an Oxygen level of 12% or greater the limited exposure time for humans is 5 minutes The maximum concentration must not exceed 52% and the minimum must not be lower than 43 % (corresponding to the LOAEL and NOAEL values for the IG-541 Extinguishant, 12% and 10% residual oxygen, see Table 6) and the exposure time of 3 minutes must not be exceeded.

Concentrations exceeding the LOAEL are permitted only in areas that are not normally occupied by personnel – provided that they can escape the area in 30 seconds or less. No unprotected personnel shall enter the area during agent discharge. Where egress takes longer than 30 seconds, but less than 1 minute, the design concentration CANNOT exceed the LOAEL concentration of 52% by volume.

Concentrations exceeding the 62% (corresponding to an oxygen concentration of 8 % or lower) are permitted in unoccupied areas when the personal is not exposed to this low oxygen concentration.

PROPERTIES	VALUE
NOAEL	43 %
LOAEL	52 %

Table 6: Toxicological information for IG-5451 according to NFPA-2001, according to ISO 14520 and UNE-EN 15004

NOTE: Systems designed to exceed NOAEL (43%) will must installed in accordance with the NFPA 2001 standard.

The maximum concentration may exceed 52% (LOAEL) without the need to install a lock-off device since there is no risk to people in an unoccupiable area.

1.4.6 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 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).

1.4.7 Calculation of extinguishant quantity

The necessary steps to establish the estimated quantity of IG-541 to protect the hazard areas, according to the NFPA-2001, ISO 14520 and UNE-EN 15004, are shown below.

1.4.8 Determining the volume of the hazard

The first step in designing the system for IG-541 Extinguishant is to determine the volume of the space to be protected. Flooding will be total, therefore the area to be flooded is considered to be a closed area without openings so that the extinguishing concentration established can be achieved and maintained.

Depending on the layout of the enclosure to be protected, for example an enclosure with several sectors or zones, may need to be divided into such sectors to later obtain the total volume of the enclosure, which will be the sum of the zones or sectors, possibly such as false ceilings, false floors, cable ducts, etc. These are considered to be enclosures adjacent to the risk and hence would need to be flooded with simultaneous discharges. Should the false ceiling and floors have very high structural strength, it might be possible to consider them as independent hazards.

As a general rule, the volume used to calculate the quantity of IG-541 needed must be based on the empty space (gross volume). Some additional considerations must be taken into account:

The space occupied by fixed objects or parts of the structure discountable as the Extinguishant cannot penetrate them can be subtracted from the protected volume.

Any volume open from the space to protected (e.g. ducts without a draft regulator, openings which cannot be closed at the time when the discharge occurs, etc).

NOTE: Any object which can be moved out of the protected space MAY NOT be subtracted from the volume considered

1.4.9 Determining the Extinguishant

This calculation must be based on two significant criteria: the ambient temperature of the enclosed space and the design concentration, as explained in this manual.

To determine the quantity of extinguishant needed to produce the design concentration level, the volume of the hazard is multiplied by the factors indicated in the following formula:

$$W = 2{,}303 \cdot \frac{V_S}{S} \cdot \text{Log10}[100/(100-C)] = \frac{V_S}{S} \cdot \text{Ln}[100/(100-C)]$$

(Reference in NFPA 2001, ISO 14520, UNE-EN 15004)

Where:

- W = Weight of extinguishant lb (kg)
- V = Volume of the hazarad to be protected ft^3 (m^3)
- C = Design concentration (% by volume)
- S = Specific volume ft^3/lb (m^3/kg). Specific volume of superheated IG-541 vapour at 14692.31 psi (1.013 bar), according to the expression:

$$S = k_1 + k_2 \cdot x \cdot T$$

Where:

- Where:
- k1 =9.8579 (0.65799)
- k2 =0.02143 (0.00239)
- T = temperature ºF (°C)

An Exercise is carried out below to determine the quantity of IG-541 Extinguishant needed.

ATTENTION: Any variation in the volume of the risk to cover or the addition or removal of fixed elements not included in the original design will affect the concentration of the agent. In such cases the system will need to be recalculated to achieve the appropriate design concentration.

EXAMPLE: Let us assume that we have an enclosure with a volume of 13145,89 ft^3 (372.25 m^3), with an ambient temperature of 68ºF (20 °C) and a design concentration of 37.97 %. The minimum temperature expected for this enclosure in exceptional cases is +41ºF (+5ºC).

We know that:

- C (Design concentration) = 39.9 %
- V (Volume) = 13145,89 ft3 (372.25 m3)
- S = 9.8579+ 0.02143X 41ºf =4.0317 ft3/lb (0.65799+0.00239x5°C = 0.6699 m3/kg) (5ºC is the minimum expected temperature regardless the usual ambient temperature. The calculation must be done at the minimum expected temperature in order to consider the worse case.)

Substituting these values in the expression:

$$W = 2.303 \cdot \frac{372.25}{0.6719} \cdot Log_{10}\left[100/(100-40.3)\right] = 623.68 \text{ lb}$$

$$W = 2.303 \cdot \frac{372.25}{0.6699} \cdot Log_{10}\left[100/(100-39.9)\right] = 282.9 \text{ kg}$$

In this risk area we need 630.081 lb (282.9 kg) of IG-541.

Another calculation method for the quantity of Extinguishant, and one which is much quicker, is to use Table 7 directly. (Reference NPFA 2001, Table A-5.5.2.) (Reference UNE-EN 15004-10, Table 3) (ISO 14520-15, Table 3). The quantities for total flooding are shown in the table based on Formula 1. To determine the quantity of extinguishant needed to produce the desired concentration level, the volume of the hazard is multiplied by the factor from the appropriate table (e.g.: 13145.89 ft^3 ***x 3.243 [39.9% @ 5 °C] = 7085.537*** m^3 ***/ 10.730*** ft^3***/lb = 661.364 lb.) (e.g.: 372.25*** m^3 ***x 0.539 [39.9% @ 5 °C] = 200.64*** m^3 ***/ 0,06699*** m^3***/kg = 299.99 kg.) (The minimum value for the temperature given in the table is -40ºF (-40ºC))***

Temperature	Specific vapour volume	IG-541 volume requirements per unit volume of protected space, V/V (m3/m3). This information refers only to IG-541, and may not represent any other products containing argon as component. Design concentration (by volume)							
T °C	S (m3/kg)	34%	38%	42%	46%	50%	54%	58%	62%
–40	0,5624	0,521	0,600	0,684	0,773	0,870	0,975	1,089	1,214
–30	0,5863	0,500	0,575	0,656	0,742	0,834	0,935	1,044	1,165
–20	0,6102	0,481	0,553	0,630	0,713	0,802	0,898	1,003	1,119
–15	0,6221	0,471	0,542	0,618	0,699	0,786	0,881	0,984	1,098
–10	0,6341	0,463	0,532	0,606	0,686	0,772	0,864	0,966	1,077
–5	0,646	0,454	0,522	0,595	0,673	0,757	0,848	0,948	1,057
0	0,658	0,446	0,513	0,584	0,661	0,744	0,833	0,931	1,038
5	0,6699	0,438	0,504	0,574	0,649	0,730	0,818	0,914	1,019
10	0,6819	0,430	0,495	0,564	0,638	0,717	0,804	0,898	1,001
15	0,6938	0,423	0,486	0,554	0,627	0,705	0,790	0,882	0,984
20	0,7058	0,416	0,478	0,545	0,616	0,693	0,777	0,868	0,968
25	0,7177	0,409	0,470	0,536	0,606	0,682	0,764	0,853	0,951
30	0,7297	0,402	0,462	0,527	0,596	0,670	0,751	0,839	0,936
35	0,7416	0,395	0,455	0,518	0,586	0,660	0,739	0,826	0,921
40	0,7536	0,389	0,448	0,510	0,577	0,649	0,727	0,812	0,906
45	0,7655	0,383	0,441	0,502	0,568	0,639	0,716	0,800	0,892
50	0,7775	0,377	0,434	0,494	0,559	0,629	0,705	0,787	0,878
55	0,7894	0,371	0,427	0,487	0,551	0,620	0,694	0,776	0,865
60	0,8014	0,366	0,421	0,480	0,543	0,610	0,684	0,764	0,852
65	0,8133	0,361	0,415	0,473	0,535	0,601	0,674	0,753	0,840
70	0,8253	0,355	0,409	0,466	0,527	0,593	0,664	0,742	0,827
80	0,8492	0,345	0,397	0,453	0,512	0,576	0,645	0,721	0,804
90	0,8731	0,336	0,386	0,440	0,498	0,560	0,628	0,701	0,782
100	0,897	0,327	0,376	0,429	0,485	0,545	0,611	0,683	0,761

Temperature	Specific vapour volume	IG-541 volume requirements per unit volume of protected space, V/V, pie3/ pie3. This information refers only to IG-541, and may not represent any other products containing argon as component. Design concentration (by volume)							
T ºF	S (pie3/lb)	34%	38%	42%	46%	50%	54%	58%	62%
–40	9.001	0.524	0.603	0.686	0.802	0.873	0.977	1.096	1.218
–30	9.215	0.513	0.590	0.672	0.760	0.855	0.958	1.070	1.194
–20	9.429	0.501	0.576	0.657	0.743	0.836	0.936	1.046	1.166
–10	9.644	0.490	0.563	0.642	0.726	0.817	0.915	1.022	1.140
0	9.858	0.479	0.551	0.628	0.710	0.799	0.895	1.000	1.116
10	10.072	0.469	0.539	0.615	0.695	0.782	0.876	0.979	1.092
20	10.286	0.459	0.528	0.602	0.681	0.766	0.858	0.958	1.069
30	10.501	0.450	0.517	0.590	0.667	0.750	0.840	0.939	1.047
40	10.715	0.441	0.507	0.578	0.653	0.735	0.824	0.920	1.026
50	10.929	0.432	0.497	0.566	0.641	0.721	0.807	0.902	1.006
60	11.144	0.424	0.487	0.555	0.628	0.707	0.792	0.885	0.987
70	11.358	0.416	0.478	0.545	0.616	0.693	0.777	0.868	0.968
80	11.572	0.408	0.469	0.535	0.605	0.681	0.762	0.852	0.950
90	11.787	0.401	0.461	0.525	0.594	0.668	0.749	0.836	0.933
100	12.001	0.393	0.453	0.516	0.583	0.656	0.735	0.821	0.916
110	12.215	0.386	0.445	0.507	0.573	0.645	0.722	0.807	0.900
120	12.429	0.380	0.437	0.498	0.563	0.634	0.710	0.793	0.884
130	12.644	0.373	0.430	0.489	0.554	0.623	0.698	0.779	0.869
140	12.858	0.367	0.422	0.481	0.544	0.612	0.686	0.766	0.855
150	13.072	0.361	0.415	0.473	0.535	0.602	0.675	0.754	0.841
160	13.287	0.355	0.409	0.466	0.527	0.593	0.664	0.742	0.827
170	13.501	0.350	0.402	0.458	0.518	0.583	0.653	0.730	0.814
180	13.715	0.344	0.396	0.451	0.510	0.574	0.643	0.718	0.801
190	13.930	0.339	0.390	0.444	0.502	0.565	0.633	0.707	0.789
200	14.144	0.334	0.384	0.437	0.495	0.557	0.624	0.697	0.777

Table 7: Quantities of IG-55 for flooding

1.4.10 Correction factors for altitude

The design quantity of IG-541 needs to be adjusted so as to compensate for ambient pressures which vary by over 11% (equivalent to a change of 39370 in (1,000 m) in elevation) with respect to the pressure at sea level (14.692 psi (1.013 bar) absolute) since the pressure is lower at greater altitude and therefore the quantity of extinguishant needed will be less.

To compensate for these effects, the quantity of extinguishant needed must be adjusted by means of the correction factors indicated in Table 8. (Reference: NFPA 2001 Table 5.5.3.3)

Altitude, Ft (km)	Enclosure pressure, mm Hg (psia)	Atmospheric correction
-3000 (-0,92)	840 (16,25)	1,11
-2000 (-0,61)	812 (15,71)	1,07
-1000 (-0,30)	787 (15,23)	1,04
0.00 (0,00)	760 (14,71)	1,00
1000 (0,30)	733 (14,18)	0,96
2000 (0,61)	705 (13,64)	0,93
3000 (0,92)	678 (13,12)	0,89
4000 (1,22)	650 (12,58)	0,86
5000 (1,52)	622 (12,04)	0,82
6000 (1,84)	596 (11,53)	0,78
7000 (2,13)	570 (11,03)	0,75
8000 (2,45)	550 (10,64)	0,72
9000 (2,74)	528 (10,22)	0,69
10000 (3,05)	505 (9,77)	0,66

Table 8: Correction factors for altitude

Hence, the quantity of extinguishant is determined by multiplying the quantity of extinguishant obtained by the correction factor in cases where this needs to be applied.

1.4.11 Determining the actual concentration at the maximum temperature

The concentration level expected at the maximum temperature in the risk also needs to be calculated. This is a necessary step when designing systems for occupied spaces to evaluate the system requirements dealt with before in an appropriate manner. It is mandatory to calculate the concentration at the minimum expected temperature for the enclosure, which gives the minimum concentration.

To determine the concentration expected at the maximum temperature, the following formula may be used:

$$W=2{,}303\cdot \frac{V_S}{S}\cdot \mathrm{Log10}[100/(100-C)]= \frac{V_S}{S}\cdot \mathrm{Ln}[100/(100-C)]$$

Where:

- W = Weight of extinguishant lb (kg)
- V = Volume of the hazarad to be protected ft^3 (m^3)
- C = Design concentration (% by volume)
- S = Specific volume ft^3/lb (m^3/kg). Specific volume of superheated IG-541 vapour at 14692.31 psi (1.013 bar), according to the expression:

$$S = k_1 + k_2 \cdot x \cdot T$$

Where:

- k1 =9.8579 (0.65799)
- k2 =0.02143 (0.00239)
- T = temperature ºF (°C)

EXAMPLE: Let us assume that we have an enclosure with a volume of 10559,089 ft^3 (299 m^3) with 390.22 lb (177 kg) of extinguishant and an ambient temperature of 68ºF (20 °C). The minimum expected temperature is 32ºF (+5ºC). What will be the actual concentration in the enclosure?

- S = 11.358 ft3/lb (0.7906 m^3/kg) (from Table 7 at 70ºF (20 °C).)
- V = 10559,089 ft^3 (299 m^3)
- W = 390.22 lb (177 kg)

$$C = 100 - \frac{100}{e^{\frac{m \cdot S}{V}}} = 100 - \frac{100}{e^{\frac{390.2 \cdot 1\ .17064}{10559.089}}} = 34{,}24\%\ \%$$

- Actual concentration

$$C = 100 - \frac{100}{e^{\frac{m \cdot S}{V}}} = 100 - \frac{100}{e^{\frac{177 \cdot 0.708}{299}}} = 34{,}24\ \%$$

- Actual concentration

As mentioned above, the minimum concentration in the enclosure is given by the minimum expected temperature. It is necessary to check that the minimum expected concentration (at the minimum temperature) has a value, equal or higher, than the design concentration for the hazard.

- S = 10.74073 ft^3/lb (0,67186 m^3/kg) (from table 7 at 41ºF (5ºC))
- V = 10559,089 ft^3 (299 m^3)
- W = 390.22 lb (177 kg)

$$C = 100 - \frac{100}{e^{\frac{m \cdot S}{V}}} = 100 - \frac{100}{e^{\frac{390.2 \cdot 0\ .74073}{10559.089}}} = 32{,}78\ \%$$

- Actual concentration

$$C = 100 - \frac{100}{e^{\frac{m \cdot S}{V}}} = 100 - \frac{100}{e^{\frac{177 \cdot 0.67186}{299}}} = 32{,}78\ \%$$

- Actual concentration

1.4.12 Leaks or openings in the protected area

The physical characteristics of the protected spaces must be taken into account when a design is produced for an IG-541 system. Open areas must be closed and, if they cannot be, these openings must be kept to a minimum to prevent extinguishant leaking into neighbouring spaces (which would reduce the effectiveness of the system in extinguishing the fire).

Simply adding a greater quantity of extinguishant is not only not very practical, but also ineffective. Hence all openings need to be sealed or equipped with automatic closures.

Forced ventilation systems must be disconnected or shut off automatically if their continued operation would affect the agent’s capacity to extinguish the fire. It is not necessary to disconnect internal recirculation ventilation systems, but it is advisable. Draft regulators must be of the “low smoke” or 100% closure type to ensure adequate sealing and prevent leaks. When the ventilation system is not disconnected or regulated, the associated ducting and ventilation units must be considered to be part of the total volume of the hazard in establishing the quantity of extinguishant needed.

To reach and maintain the desired concentration for sufficient time for the emergency personnel to respond, all protected enclosures must be sealed. Under normal circumstances the extinguishant will extinguish the fire quickly so limiting possible damage caused by the fire and the production of dangerous decomposition products. Consequently, it is fundamental that the protected area is constructed so as to prevent any leak from the protected spaces.

Some guidelines are given below on controlling gas leaks from the hazard.

Doors: All doors which lead to or from the perimeter of the protected area must be fitted with seals at the bottom, for insulation around the doorjamb and around the latch and closure mechanisms. Double doors will also need to have insulating mouldings to prevent leaks between the doors and a coordinator to ensure the appropriate closure sequence. Doors which cannot be kept shut normally must be fitted with mechanical and magnetic closures which will unblock the doors should the alarm be triggered.

Ducting: All ducting which enters or leaves the protected area must be insulated and sealed. Closures must be of spring or motorised type to cut off the air 100% when the system is activated.

Air ventilation/duct: It is recommended that all the air duct or ventilation units be shut down when the alarm is triggered to prevent leaks to other zones. If the air duct units cannot be disconnected, the volume of the corresponding ducting must be added to the total volume of the protected space and more extinguishant must be added to compensate for this additional volume.

Break-throughs: All holes, cracks, openings or break-through in the walls which define the perimeter of the protected area must be sealed. This includes some less obvious leakage zones such as gutters and pipe and drain casings. To prevent leaks, it must be ensured that drains have collectors full of a product which does not evaporate.

Walls: All the walls which define the perimeter of the protected area must extend from side to side and be sealed at the top and the bottom and inside. When the walls do not extend from side to side, partition walls will be installed to achieve the desired sealing characteristics.

Air brick walls: Porous walls made from air bricks must be sealed or the IG-541 extinguishant will leak out.

NOTE: It is essential when designing a gas extinguishing system to be familiar with or to thoroughly examine hazard. An essential aspect is to examine any openings through which extinguishing gas might escape.

SIEX has the necessary machinery available to carry out tests to determine the integrity of the enclosure. This test is known as a “Door fan test”. Similar conditions are generated in this test to those which would occur during the discharge of the extinguishant. It is then possible to check if the concentration is maintained during the hold time set by the standard.

The Integrity Test in the enclosure by means of fan pressurisation must be carried out in accordance with the requirements of the manufacturer and the NFPA2001 Annex C and UNE-EN 15004 Annex E.

1.4.13 System design concept

Distribution of IG-541 extinguishant in the protected area must be carried out by means of one or more of the following pipe distribution systems.

Engineered system,
Modular system (engineered),
Central storage system or banks of bottles (engineered).

The method used will depend on several factors, including: installation time, amount of extinguishant used, economic factors, number of protected areas, space available to locate the storage containers and the client’s preferences. For larger projects with more complex pipe networks more than one method will be required to tackle the challenges posed, so designers must familiarise themselves with each of these methods as well as their advantages and disadvantages for any specific application.

1. Engineered system

Engineered systems allow a designer to create a customised pipework to adapt to the individual needs of the project. The pipe configurations can be balanced or unbalanced and the flow separations within the system can vary from one point to another. This requires a computer hydraulic flow calculation to create a model of the system and verify if its operation complies with the requirements of the NFPA 2001, ISO-14520 and UNE-EN-15004 before installation. Consequently, although more design time is usually needed, this concept offers the designer greater working flexibility. To carry out the hydraulic flow calculations you will need a copy of SIEX’s flow calculation software. Engineered systems can be designed with modular cylinders and banks of cylinders.

2. Modular systems

Modular systems can be defined as a design concept where the containers are located throughout or around the protected areas. These keep the needs for discharge pipes to a minimum, but increase the quantity of electrical materials needed to reach the position of each container.

To reduce the quantity of piping and the installation work in large applications, it is often desirable (or necessary) to use a modular distribution. In some cases this concept will be necessary for the system to make the required quantity of extinguishant pass.

3. Centralised systems or banks of bottles

Bottle or cylinder bank systems 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 requires more discharge piping, but needs less electrical materials to reach the container location. This concept can be more complicated to design due to the increase in piping involved and the installation work will tend to be more expensive for the same reason.

In any case, this type of installation will be preferable for the client from the aesthetic point of view as well as usually being easier to maintain and repair.

ATTENTION
The IG-541 extinguishant flow calculation program (software) is the only calculation method applicable with SIEX equipment. No other calculation method is acceptedfor systems supplied by SIEX.

1.5 Selection of containers, cylinders or bottles

The selection of the containers is normally determined by the quantity of IG-541 needed, considering the filling ranges permitted for the different cylinder sizes. However, other factors can also influence the decision, such as the system design concept, the location of the containers and flow calculation limitations.

1.5.1 Container size and filling range

All the containers must be filled within the filling range permitted by the NFPA 2001, ISO-14520, UNE-EN-15004 and another standards like EN, EEC, ADR, DOT and UL (2127). The filling densities recommended by SIEX are shown in ANNEX 1 in system components manual.

The filling ranges for the various cylinders offered by SIEX are collected below in ANNEX 2, in system components manual along with the valve connection, cylinder length, diameter and tare. For inert gas agents in a multiple container system connected to a manifold, all containers supplying the same manifold outlet for distribution of the same agent shall be interchangeable and of one select size and charge.

1.5.2 Location of containers

The location and type of storage container depend on several considerations:

1) Extinguishant quantity: The extinguishant storage container selected must have sufficient capacity to store the total volume of extinguishant necessary for the extinguishing system.

2) Type of system: Each zone must be protected either by several small containers with independent nozzles, or by a group of cylinders (bank) of greater capacity which discharge through a pipework with 1, 2, 3, 4 or more nozzles, depending on the needs of the enclosure to be protected.

3) Pipe lengths: In systems with large pipe structures the pressure drop may be too large for the selected layout and configuration. In some cases it may be necessary to relocate the containers closer to the zones to be protected. It also may be necessary to divide the pipework into smaller configurations with separate containers.

4) Container type: The type of container required for the installation must be taken into account (cylinder capacity).

5) Accessibility for maintenance: The containers shall be mounted in such a way as to facilitate maintenance and access to both the container and its contents. In general, the larger the container, the more difficult it will be to separate it from the system to carry out maintenance or repairs. However, it may also be difficult to gain access to small containers when they are located in false floors, under a computer bench or in false ceilings above the same computer bench.

6) Floor loading: This factor must be considered when selecting the location for the containers. When the loads are excessive it will be necessary to relocate the containers to an appropriate location.

7) Proximity: The IG-541 containers must be located as close as possible to the protected area. Preferably this will be outside the enclosure, although they can also be located inside the enclosure if the placement enables the risk of exposure to fire and explosion to be minimised.

8) Environmental effects: The containers shall NOT be located where they can be subject to physical damage, exposure to chemical products or severe atmospheric conditions. An appropriate enclosure will be needed in places where there is a risk of damage or unauthorised handling.

1.5.3 Storage temperature limitations

SIEX´s equipment for IG-541 listed below is designed to operate within a temperature range of -4 to 122ºF (-20 to 50 °C).

ATTENTION

The calculation program for the clean agent is designed for an operating temperature between +50ºF and 122ºF (+10ºC and +50ºC). Consequently, the usage temperature for the cylinder must be within the same range of temperatures. If the cylinder operating or storage temperature is outside of this range, an insufficient quantity of IG-541 will discharge through one or more nozzles.

The containers must be located as close as possible to the protected space. The range of storage temperatures for the cylinders is -4 to 122ºF (-20 to 50 °C). It may be necessary to heat or cool the cylinder storage area to keep the temperature within this range.

2. DISTRIBUTION PIPING AND FITTINGS

This section refers to design by computer calculations systems with pipework. Examine the planned configuration to ensure that the pipework and nozzles do not interfere with objects in the hazard area, and make any necessary changes before proceeding with the installation. The pipework and fittings must comply with the limitations detailed below:

2.1 Piping

All the installed piping must be in accordance with the latest requirements included in NFPA-2001, ISO-14520 and UNE-EN 15004. They must be of non-combustible material, and have physical and chemical characteristics that guarantee their integrity under the stresses to which they will be subjected. For the wall thickness calculation we must take into account that they have to withstand a pressure equal to that of the extinguishing gas when stored at 122 ºF (50ºC).

Acceptable piping includes galvanised or black steel to pipe Standard ANSI B31.1. The types of pipe that must not be used are cast iron, steel pipes to ASTM A 120 specifications and all non-metallic pipes.

ATTENTION
The calculation program for the clean agent has been investigated and validated for the types of fittings, types of pipe and pipe inside diameters included in this manual.
When the specified limitations are not maintained there is the risk that the system will not supply the required quantity of extinguishing agent.

Working pressure at 122ºF (50ºC) with IG-541	
(filled at 2900 psi (200 bar))	3408.38 psi (235 bar)
(filled at 4351 psi (300 bar))	5221psi (360 bar)

Table 9

2.2 Equivalent lengths

The resistance coefficients for the system equipment are implemented in the validated software.

IG-541	
Dip tube - hose - check valve	Equivalent length in (m)
RGS-MAM-RD9/11 W21,8x1/14” outlet	34.21 (0.869)
RGS-MAM-RD9/11 ¾” G outlet	51.57 (1,314)

Table 10

2.3 Pipe layout (engineered systems)

2.3.1 Pipe joints (fittings)

The mode of joining the pipes must meet the most recent requirements of the NFPA 2001, ISO-14520 and UNE-EN 15004.

Piping must be installed according to the isometric drawing included in the design. All pipe sizes, dimensions and qualities indicated on the drawing must be observed, since changing the sizes or dimensions of the pipework could result in improper operation of the system. If a modification is necessary it must be considered beforehand.

The pipework must comply with the requirements of the table. The following kinds of seamless steel pipe of grade ASTM A-106 B are recommended*:

Connection by welded fittings:

Pipe size	Working pressure	Pipe Class
3/8”	942.74psi (65 bar)	Sch 40 or higher welded joint
1/2”		
¾”		
1”		
1 ¼”		Sch 80 or higher welded joint
1 ½”		
2”		
2 ½”		
3”		
4”		

**In accordance with ANSI B-36-10*

Connection with threaded fittings:

Pipe size	Working pressure	Pipe Class
3/8”	942.74psi (65 bar)	Sch 40 threaded joint
1/2”		
¾”		
1”		
1 ¼”		Sch 40 or higher threaded joint
1 ½”		
2”		
2 ½”		
3”		
4”		

- The fittings, whether threaded or welded, must be rated 3000 lb upstream of the pressure reducer.
- Downstream of the pressure reducer the fittings must be a minimum of 1000 lb rated.
- Pipes of nominal diameter less than or equal to 2” must not be welded in situ.
- Connections carried out in situ must be threaded.

- The installation must be earthed.
- The piping paint colour must be red (RAL 3000).

When 3000 lb threaded fittings are used they must meet the requirements of the ANSI B.16.11 standard.

When 3000 lb welded fittings are used they must meet the requirements of the ANSI B.16.9 standard.

2.3.2 Branching ratios at tees

SIEX´s engineered systems for IG-541 have been proven to define the maximum level of imbalance which can be predicted in tee branches. This value is expressed in terms of the branch ratio at an outlet as the relationship of one with the other. Each ratio indicated refers to a percentage of the total incoming flow.

a) Bull head tee

A bull head tee type is defined as a tee configuration in which the two outlet branches change direction with respect to the inlet branch **Figures 1-2**

The branch ratio for a bull head tee type ranges from 30-70 to 50-50.

This means that the output from the main flow has an acceptable range which varies from 50% as a minimum to 70% as a maximum and the output from the secondary flow has an acceptable range between 30% as a minimum and 50% as a maximum. These proportions are percentages of the total incoming flow to the tee.

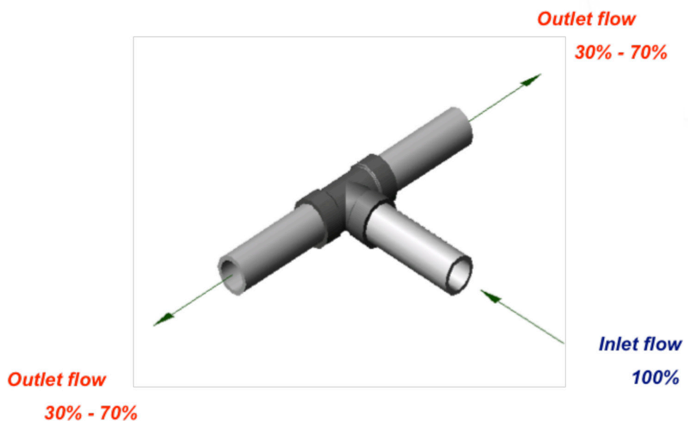


Figure 1 – 30-70% bull head tee

b) Side tee

A side tee type is defined as a tee configuration where one of the branches changes direction with respect to the input and the other continues in the same direction as the input. (Figure 2)

The branch ratio for a side tee goes from 10-90 to 90-10. This means that the outlet from the main flow (the branch which does not diverge with respect to the inlet) has an acceptable range which varies from 10% as a minimum to 90% as a maximum and the outlet from the secondary flow (the branch which diverges) has an acceptable range between 10% as a minimum and 90% as a maximum. These proportions are percentages of the total incoming flow to the tee.

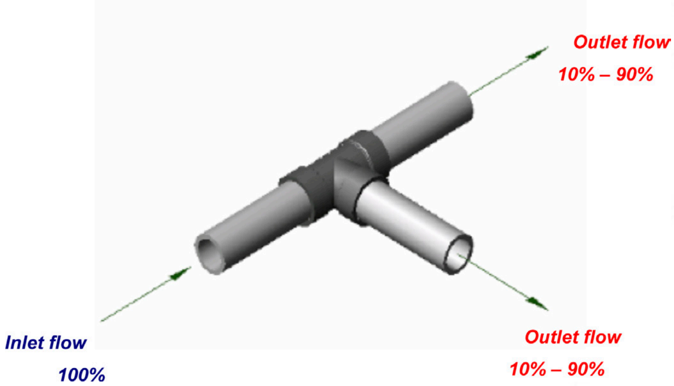
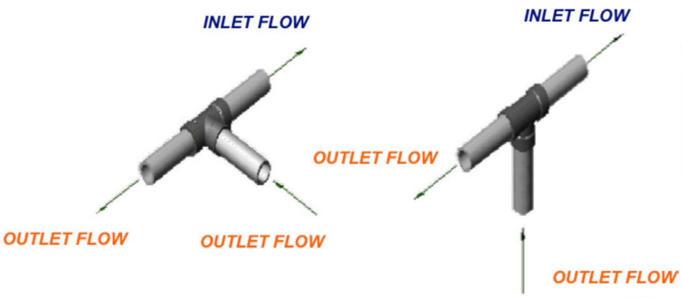


Figure 2 – side tee

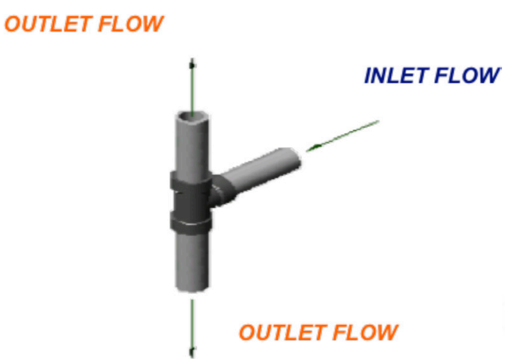
c) Tee orientation

SIEX engineered system with IG-541 has been proven to define the necessary limitations to precisely predict how the system will behave when a discharge occurs. The tee orientation is an important characteristic in maintaining the consistency of the flow diversion percentages. Therefore, simple rules MUST be taken into account with respect to the orientation of the tees, as presented bellow.

1. Bull head tees may have both outlets in the horizontal or vertical plane. The inlet can be horizontal or vertical from above or below.

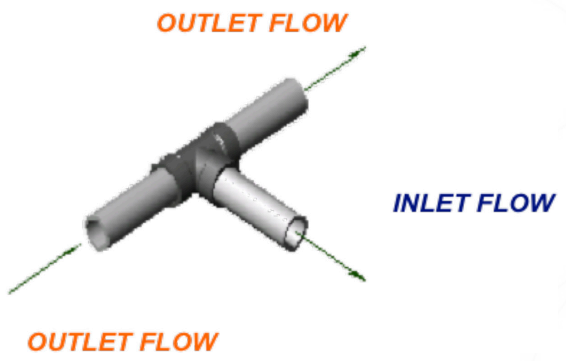


V Correct
Figure 3– bull head tee

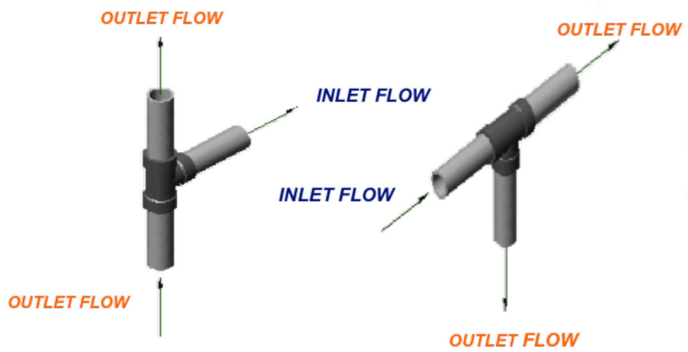


V Correct
Figure 4 – bull head tee

2. Side tees may have the inlet and both outlets in the vertical or horizontal plane.



V Correct
Figure 5– side tee



V Correct
Figure 6 – side tee

3. Elbows before the tee branches installed to separate hazards must be located at a minimum distance of 10 times the nominal pipe diameter before the branch.

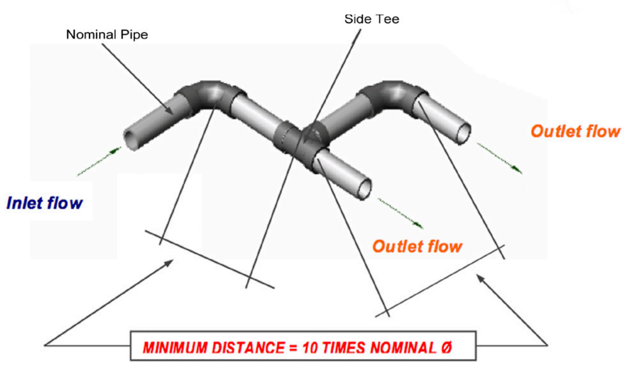


Figure 7

4. Tee branches to separate hazards fed from a common supply pipe must be separated by a minimum of 10 times the pipe diameter.

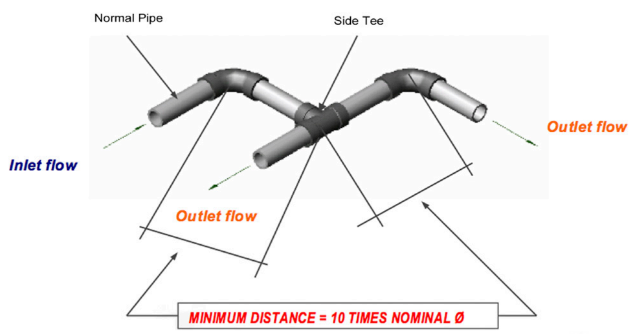


Figure 8

5. Pipe reductions before tee branches must be installed at a minimum distance of 10 times the pipe diameter. These reductions must be of the concentric type.

2.3.3 Agent percentage in the piping

SIEX items of equipment for IG-541 are pressurised systems which are autopressurized (inert gases at 2900 and 4350 psi (200 and 300 bar)) to drive the extinguishant through the pipe network to the protected compartment. Hence, a size (volume) limit needs to be set for the associated pipework to ensure that the agent is sent to the protected compartment within the permitted period of time for discharge. This is a “floating” limit which depends on the size and fill weight of the cylinders or bottles involved. This makes it a design limit which is difficult to identify, but it is usually associated with very large pipe systems and with configurations with multiple tees. This limitation is therefore defined such that: the ratio of agent in the piping is to be as large as possible to reach at least the minimum working pressure in the nozzle.

2.3.4 Time to arrival of the agent

The time needed for the agent IG-541 to arrive at each nozzle must have a maximum difference of 2,00 seconds. For example, if the gas takes two (2) seconds to arrive at the first nozzle (the closest nozzle to the cylinder), the arrival time at the other nozzles must not exceed three 4,00 seconds.

2.3.5 Time to emptying of the agent

The time needed for the agent IG-541 to discharge at each nozzle must have a maximum difference of 2,00 seconds. For example, if the agent takes 3 seconds to empty through the first nozzle, the emptying time through the rest of the nozzles must not exceed 5,00 seconds.

2.3.6 Estimation of pipe sizes (Engineered systems)

To determine the appropriate size in each pipe section, this is selected based on the design flow rate for each pipe section. The size selection depends on the design flow quantity carried by each of the different pipework branches. It must be done using the software. (*see Table 11 – Estimation of pipe diameter. This table is only for guidance and it includes two of the most representative starting pressures).

APPROXIMATE PIPE DIMENSIONING

NOMINAL PIPE DIA.	IG-541
3/8”	0 – 282.51 ft^3 (0–8 m^3)
1/2”	317.83-565.03 ft^3 (9–16 m^3)
3/4”	600.35-1165.38 ft^3 (17 – 33 m^3)
1”	1200.70-1695.10 ft^3 (34 – 48 m^3)
1 1/4”	1730.41-2860.48 ft^3 (49 – 81 m^3)
1 1/2”	2895.80-4590.91 ft^3 (82 – 130 m^3)
2”	4626.22-8475.52 ft^3 (131 – 240 m^3)
2 1/2”	8510.83-13490.20 ft^3 (241 – 382 m^3)
3”	13525.52-21188.80 ft^3 (383 – 600 m^3)
4”	21224.12-30370.62 ft^3 (601 – 860 m^3)

Table 11: Estimation of pipe diameter

EXAMPLE: Starting from a pipe network which discharges 2842,832 ft^3 (80.5 m^3) through four nozzles at 4350 psi (300 bar), what will be the section in the different branches?.

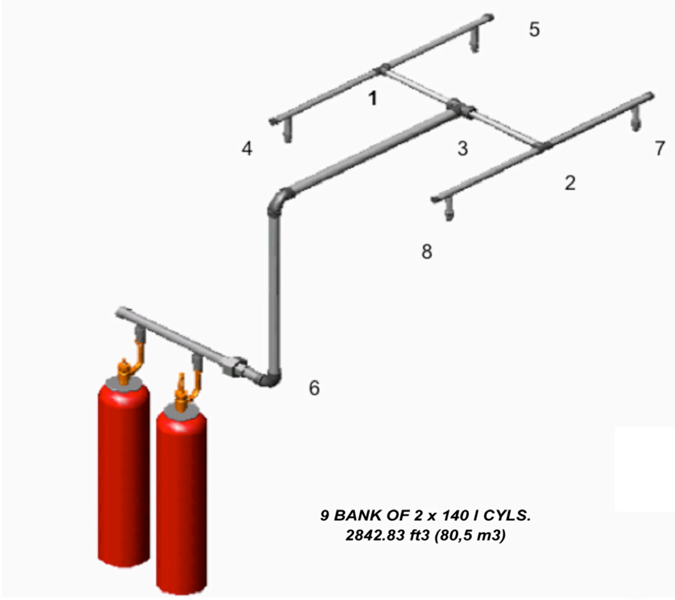


Figure 9

DESIGN FLOW	CHARGED SYSTEM	PIPE DIA.
SECTION 1-2	2842.83 ft^3 (80,5 m^3)	1 1/4"
SECTION 2-3	1421.41 ft^3 (40.25 m^3)	1"
SECTION 3-4	710.70 ft^3 (20.125 m^3)	3/4"
SECTION 3-5	710.70 ft^3 (20.125 m^3)	3/4"
SECTION 2-6	1421.41 ft^3 (40.25 m^3)	1"
SECTION 6-7	710.70 ft^3 (20.125 m^3)	3/4"
SECTION 6-8	710.70 ft^3 (20.125 m^3)	3/4"

Table 12

2.3.7 Piping characteristics

The wall thickness of the pipe is calculated as a function of the pressure at the maximum storage temperature in the bottle, this being not less than 122ºF (50 °C), in accordance ASME B31.1. These storage pressures are presented in the table below.

Working pressure at 122ºF (50ºC) (2900 psi (200 bar) charge)	3408.38 psi (235 bar)
Working pressure at 122ºF (50ºC) (4351 psi (300 bar) charge)	5221.35 psi (360 bar)

Table 13

Fittings must have a rated working pressures equal to or greater than the maximum pressure in the cylinder at 122ºF (50ºC) when this is at its maximum fill density for the agent used.

2.3.8 Reducers

All reductions in the pipe size must be made using reducing fittings such as concentric reducers. Double elbow reducers are not acceptable.
The system installation drawings (calculation software) must be taken as a reference for sizes and lengths of pipes.

2.3.9 Cleaning

All pipe sections must be fitted and assembled with the appropriate sealants, e.g. Teflon tape or paste (in the case of threaded pipe). All rough edges and residual oils must be removed afterwards.

2.3.10 Threads

It is recommended that Teflon tape be used, applied only to the male threads of the pipe. When Teflon paste is used, impregnate at least one turn of the male thread and one of the female thread. The threads of all the pipes and fittings must be properly sealed. Threads must meet ANSI B1.20.1 or ISO 7-1.When 3000 lb fittings with NPT threads are used, ensure that the pipes also have NPT threads.

2.4 Installation

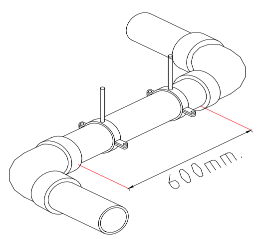
All piping must be installed in line with industry best practice. The pipework must be secured with supports that allow for its expansion and contraction.

DISTANCES BETWEEN PIPE SUPPORTS

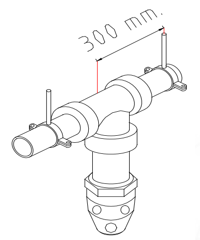
Pipe diameter DN (mm)	15	20	25	32	40	50	65	80	100	125
Pipe diameter (inches)	1/2”	3/4”	1”	1 1/4”	1 1/2”	2”	2 1/2”	3”	4”	5”
Maximum distance between supports in (m)	59.05 (1.5)	70.86 (1.8)	82.68 (2.1)	94.48 (2.4)	106.29 (2.7)	133.85 (3.4)	137.79 (3.5)	145.67 (3.7)	169.29 (4.3)	188.98 (4.8)

Table 14 a y b

- Supports must be located between elbows that are 23.62 in (600 mm) apart (see figure A).
- Supports must be fitted 11.81 in (300 mm) from any discharge nozzle (see figure B).
- Supports must be secured to structures capable of supporting the pipework.



A (23.62 in)



B (11.81 in)

Figure 10

2.5 Electrical clearances

Where electrical conductors are present, the minimum distances stipulated in the High Voltage Regulations must be observed (ANSI C2, NFPA 70 or 29CFR 1910, Subpart S). Should it not be possible to comply with these distances, approved insulators must be fitted to the pipes. It is recommended that the system pipework be earthed in order to discharge any static electricity generated during the discharge of the extinguishing agent (IG-541).

3. NOZZLE SELECTION

The selection of nozzles is generally determined by the quantity of IG-541 required related to the capacity of the nozzles to allow the flow to pass. Other factors such as the area covered, nozzle layout, obstructions to the discharge duct, etc. can also influence the decision.

3.1 Type of system

Designers must take into account the type of system they are going to use. This manual is intended only for engineered systems.

3.2 Flow through the nozzle

The majority of IG-541 systems discharge into the protected space in 60, (in any case the maximum discharge time to achieve the 95% of the design concentration is 60 seconds. Other countries and/or authorities may have supplemental requirements to those mentioned above, and therefore must be consulted) following the requirements of the NFPA 2001, as supplemented by ISO-14520 and UNE-EN 15004 as applicable.

Therefore, the number of nozzles installed must be capable of carrying the required flow to comply with this time criterion. To get a fast and effective fire extinguishment and to reduce products of thermal decomposition, extending the discharge times above 60 seconds is not recommended

Each nozzle is capable of carrying a certain range of flow. Table 15 will be used to determine approximately the number and size of the nozzles needed for each area.

NOTE: The Table must be considered as additional information. The design of the pipe network and the nozzles MUST be verified the SIEX flow calculation program.

The data in Table 15 must not be used for the design of an engineering system. This table is only for guidance and it includes two of the most representative staring pressures.

FLOW RATES IN NOZZLES

NOMINAL PIPE DIA.	DESIGN FLOW RATE (Min. – Max.)
3/8”	0 – 282.51 ft^3 (0–8 m^3)
1/2”	317.83-565.03 ft^3 (9–16 m^3)
3/4”	600.35-1165.38 ft^3 (17 – 33 m^3)
1”	1200.70-1695.10 ft^3 (34 – 48 m^3)
1 1/4”	1730.41-2860.48 ft^3 (49 – 81 m^3)
1 1/2”	2895.80-4590.91 ft^3 (82 – 130 m^3)
2”	4626.22-8475.52 ft^3 (131 – 240 m^3)

Table 15: Flow rates in nozzles

EXAMPLE: We have a compartment to protect with 18010.49 ft^3 (510 m^3) of extinguishant stored at 2900 psi (200 bar). How many nozzles do we need and of what diameters?

Table Flow Rate, we see that the maximum design possible for a 2” nozzle is 9534.96 ft^3 (270 m^3), therefore a minimum of three 2” nozzles is needed, giving a flow through each nozzle of 6003.49 ft^3 (170 m^3).

3.3 Types of nozzles

The IG-541 extinguishant distribution within the area to be protected is carried out through the discharge nozzles. Two different nozzle models are available – R°-180 and R°-360:

1.- R°-180 or wall nozzle: The R°-180° or wall nozzle is designed to be installed around the wall for the protected area so that the discharge is directed away from the wall where it is installed. These nozzles have 7 outlet orifices at two levels. Each level has a different angle of inclination to improve gas distribution.

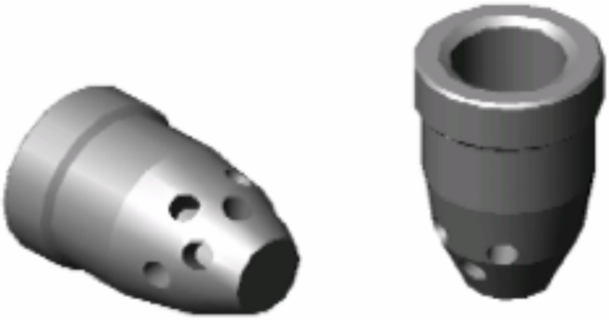


Figure 11 – R°-180 nozzle

2. R°-360 or ceiling nozzle: The R°-360° or ceiling nozzle: is designed to be installed in the centre of the protected area. These nozzles have 8 outlet orifices at two levels. Each level has a different angle of inclination to improve gas distribution.

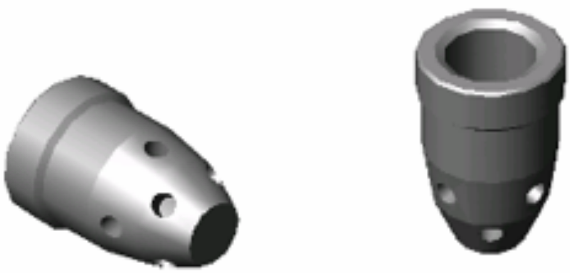


Figure 12 – R°-360 nozzle

The minimum orifice area which may be used for R°-180° or 360° nozzles for an engineered system is 2.2% of the transverse pipe section. The maximum orifice area must be less than 96.4% of the transverse section of the pipe. A computer flow calculation program must therefore be used to select the appropriate nozzles to comply with the limitations of the orifice area (maximum/minimum) and with the minimum pressure restriction of 6.16 bar in the nozzle of 360° and 89.343 psi (6.22 bar) in the case of the nozzle of 180°.

WARNING

SYSTEM INSTALLATION MUST NOT START UNTIL THE FINAL PIPE NETWORK DESIGN HAS BEEN VERIFIED USING THE SIEX FLOW CALCULATION PROGRAM

3.4 Nozzle coverage

It is important to know the maximum coverage of the nozzles when designing a system with IG-541 so as to determine how many nozzles need to be used in the protected compartment. Each nozzle model (R°180 or R°-360) has been verified for its coverage area limitations.

The maximum area coverage for each nozzle is described as the distance in a straight line from the nozzle to the farthest corner of the protected space. Figures 13 and 14 show the maximum areas of coverage for R°-180° and R°-360° nozzles.

360° and 180° nozzle models can be located a maximum of 3.93 in (100 mm) below the ceiling (or the highest protected point when the nozzles are stacked). Additionally, the 180° nozzles can be located a maximum of 3.93 in (100 mm) from the wall.

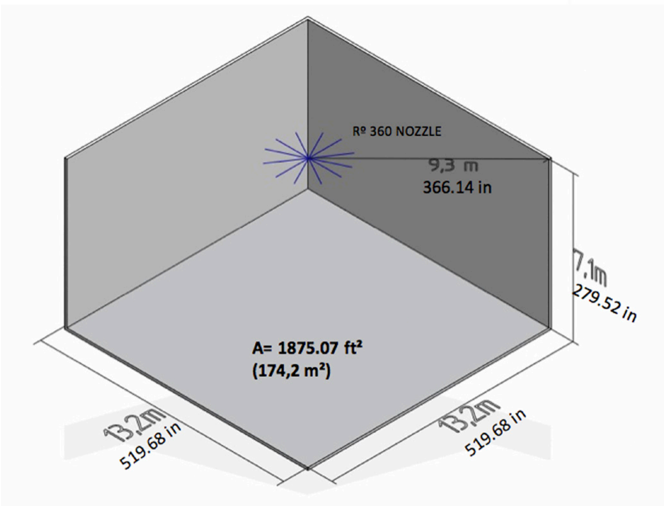


Figure 13 – Radius of coverage for the R°-360 nozzle

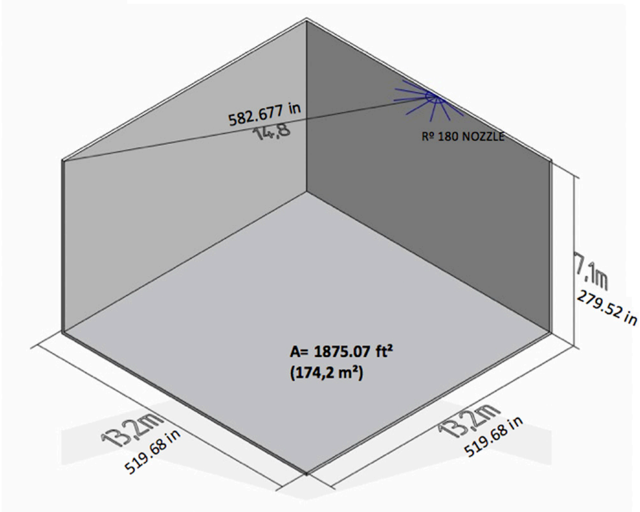


Figure 14 – Radius of coverage for the R°-180 nozzle

The nozzle sizes available are shown in Table 16.

NOZZLE SIZE	CONNECTION TYPE
3/8”	FEMALE G
1/2”	
3/4”	
1”	
1 1/4”	
1 1/2”	
2”	

Table 16: Nozzle sizes

3.5 Nozzle location

Nozzles must be located symmetrically or almost symmetrically within the protected area. The 360° nozzles are designed to be located above or close to the centre line of the protected area to discharge towards the perimeter of the area covered.

The system designer must locate the nozzles on the floor plan and verify that the whole protected area is appropriately covered with no blind spots.

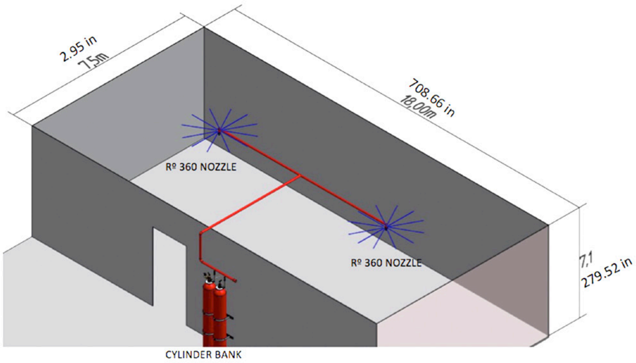


Figure 15

However, the location of the 180° nozzles is different as they are designed to be located around the perimeter of the protected area to discharge towards the opposite side as shown in the plan view. The maximum distance from the wall MUST NOT be greater than 100 mm measured from the centre of the nozzle to the wall.

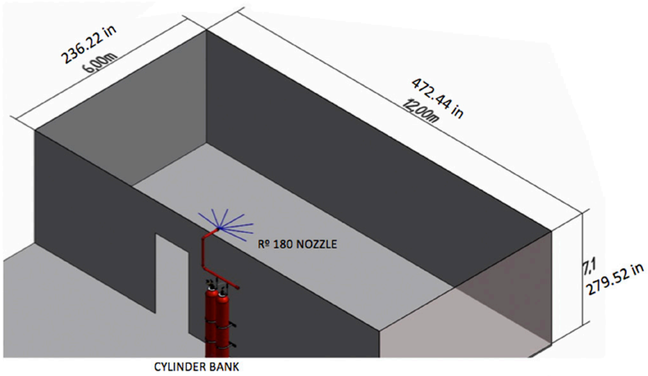


Figure 16

A series of guidelines presented below must be taken into account in locating the nozzles.

NOTE: ALL DISCHARGE NOZZLES MUST BE LOCATED A MAXIMUM OF 3.94 in (100 MM) BELOW THE CEILING:

1. Rº180 or wall nozzle:
- Compartment height of 11.81 to 0.28 in (300 to 7,100 mm):
Coverage = 1875.07 ft2 (174,2 m2) (for example = 519.68x519.68 in (13,2x13,2 m))
- Must be installed in the protected compartment so that the discharge is directed away from the wall.

2. Rº360 or ceiling nozzle:
- Compartment height of 11.81 to 0.28 in (300 to 7,100 mm):
Coverage = 1875.07 ft2 (174,2 m2)
(for example = 519.68x519.68 in (13,2x13,2 m))

NOTE: In false floors or ceilings with heights between 5.90 and 11.81 in (150 and 300 mm) a lower coverage per nozzle must be established as these areas are normally full of cables, supports, etc, a reduction of the coverage space must be considered when there may be obstacles which impede the uniform distribution of the IG-541 in the whole area. Please, consult SIEX for further guidance.

3.6 Maximum elevation differences in pipe runs

There is not maximum elevation difference between horizontal pipe runs or nozzles.

3.7 Maximum coverage height

The maximum ceiling height when using either R°-180° or R°-360° nozzles with IG-541 is 279.52 in (7,1 metres) . A double height or additional level of nozzles will be needed for room over 279.52 in (7,1 metres) high. Therefore, when the compartment to be protected exceeds this height nozzles must be installed at several levels (elevations).

EXAMPLE: We need to protect a compartment up to 8 metres high. Therefore, the lowest level of nozzles MUST be located at a maximum height of 279.52 in (7,1 m) and the second (upper) level of nozzles MUST be located a maximum of 3.94 in (100 mm) from the ceiling.

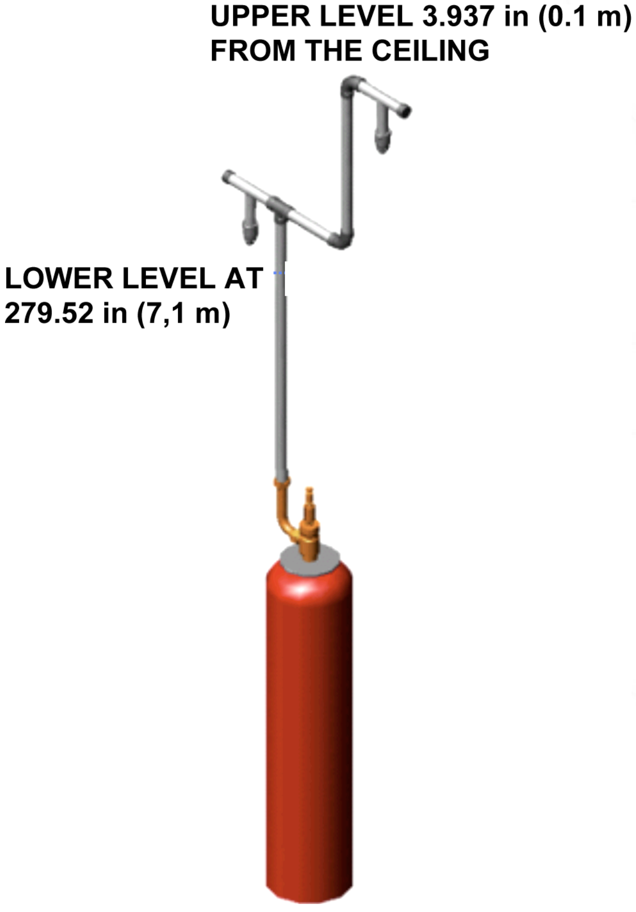


Figure 17. Example of pipework at two discharge levels

3.8 Obstructions to nozzle discharge

It must be taken into account when there are racks, shelves, partitions and tall items of equipment in the protected compartments which may represent an obstacle to the gas discharge through the nozzles when extinguishant discharge occurs. Hence, the "route" of the discharge from the nozzles must be taken into account when the number of nozzles required is determined.

All the permanent solid obstructions which could interfere with the "line of sight" of the discharge route must be considered as separate areas. All the nozzles must be located in such a way that the discharge route reaches all the extremes of the protected space.

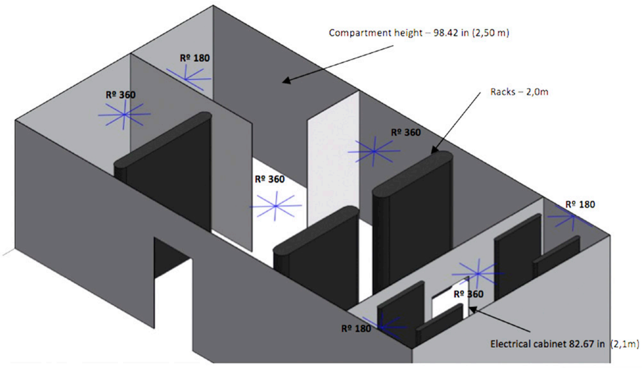


Figure 18 – Nozzle distribution

4. SUMMARY OF THE STEPS TO FOLLOW TO CALCULATE A IG-541 SYSTEM

After the explanation given previously in this manual, we are going to carry out a small exercise in which all the steps to be followed for the design of an IG-541 system are brought together.

EXAMPLE: You wish to protect a DP room 157.48 in (4 m) long by 118.11 in (3 m) wide and 98.42 in (2.5 m) high with an ambient temperature of 68ºF (20 °C). It also has a 15.74 in (0.40 m) high false ceiling, which is also to be protected.

1. The type of fire is determined and this determines the design concentration according to the standard. In this case there will be a Design Concentration of 40.3%.(Acording to ISO-14520) The compartment will be occupied by people, therefore the NOAEL must not be exceeded.

2. Calculate the quantity of extinguishant necessary for each area to be protected, assuming the areas are flooded simultaneously.

$$W = 2{,}303 \cdot \frac{V_S}{S} \cdot \mathrm{Log10}[100/(100-C)] = \frac{V_S}{S} \cdot \mathrm{Ln}[100/(100-C)]$$

Where:
- W = Weight of extinguishant lb (kg)
- V = Volume of the hazarad to be protected ft^3 (m^3)
- C = Design concentration (% by volume)
- S = Specific volume ft^3/lb (m^3/kg). Specific volume of superheated IG-541 vapour at 14692.31 psi (1.013 bar), according to the expression:

$$S = k_1 + k_2 \cdot x \cdot T$$

Where:
- k1 = 9.8579 (0.65799)
- k2 = 0.02143 (0.00239)
- T = temperature ºF (°C)

Substituting all the values in the above expression we obtain:

$$W_{room} = 2{,}303 \cdot \frac{1059.44}{11.309} \cdot Log_{10}[100/(100\text{-}41.9)] =$$

$$\frac{1059.44}{11.309} \cdot Ln[100/(100\text{-}41.9)] = 47.62 \text{ lb}$$

$$W_{false\ ceiling} = 2{,}303 \cdot \frac{169.51}{11.309} \cdot Log_{10}[100/(100\text{-}41.9)] =$$

$$\frac{169.51}{11.309} \cdot Ln[100/(100\text{-}41.9)] = 7.628 \text{ lb}$$

$$W_{total} = W_{room} + W_{false\ ceiling} =$$
$$47.62 + 7.628 \text{ lb} = 55.33 \text{ lb} = 626.48 \text{ ft}^3$$

$$W_{room} = 2{,}303 \cdot \frac{30.0}{0.706} \cdot Log_{10}[100/(100\text{-}39.9)] =$$

$$\frac{30.0}{0.706} \cdot Ln[100/(100\text{-}39.9)] = 21.6 \text{ kg}$$

$$W_{false\ ceiling} = 2{,}303 \cdot \frac{4.8}{0.706} \cdot Log_{10}[100/(100\text{-}39.9)] =$$

$$\frac{4.8}{0.706} \cdot Ln[100/(100\text{-}39.9)] = 3{,}46 \text{ kg}$$

$$W_{total} = W_{room} + W_{false\ ceiling} =$$
$$21.6 + 3.46 \text{ kg} = 25.1 \text{ kg} = 17.74 \text{ m}^3$$

In this example the altitude correction factor will not be considered; it is assumed to be at sea level.

3. Now select the cylinders, since these are determined as a function of the quantity of extingui-shant needed, although we also know that other factors can be of influence, such as their location, the flow calculation limitations, etc.

In this case we have 66.74 ft^3 (18.89 m^3) which will be stored in a 18.16 gal (80 l) bottles 6287.29 ft^3 (23.8 m^3).

CYLINDER TYPE	MAX. FILL PRESSURE	MAX. CHARGE
18.16 gal (80 l)	4350.13 psi (300 bar)	811.88 ft^3 (22.99 m^3)

Table 1

4. Once the bottles have been decided we choose the nozzles. Nozzles must be placed in the main room area. We will discharge 840.48 ft^3 (23.8 m^3).
We know that the coverage of each nozzle is about 519.69x 519.6 9in (13,2 x 13.2 m), so only one nozzle is needed. Rº-360 nozzles will be chosen (*see Section 3.5)

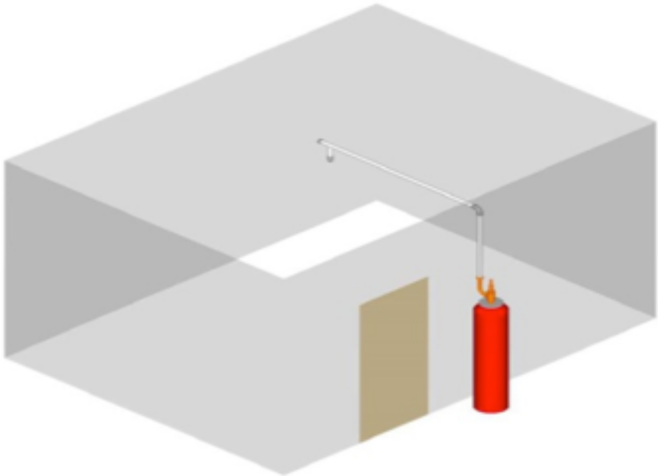


Figure 19 – Pipe network layout

5. These are guidelines for making an approximate calculation of the nozzles needed as well as their diameter, but as has been stated, SIEX has flow calculation software for INERT-SIEX™ CFT-541™ extinguishant which is the only calculation method applicable to SIEX equipment.

5. SOTWARE DISCHARGE CALCULATION

The application of IG-541 fire extinguishing systems requires a good knowledge of the flow processes in an expanding gas. This calculation method takes into account the single phase flow in IG-541-installations and is qualified by measurements in the laboratory.

The calculation software is able to calculate IG-541 installations of very different constructions. Special files contain the characteristic values of the components for the installation as valves, nozzles and pipe-types. These data are adapted to SIEX specific requests. The resistance coefficients of valves and nozzles have been determined in the laboratory.

The calculation software allows a simultaneous calculation up to 21 zones with 450 pipe system sections and 200 nozzles.

The calculation software has been tested with DIN 2440, SCHEDULE 40, SCHEDULE 80 and SCHEDULE 160 pipes with accessories of 300 lb, 600 lb and 3000 lb.

In the case of systems with selector valves, that is, a single cylinder or a cylinder bank which protects several hazards simultaneously, each hazard is required to be calculated independently with the software. The use of the selector valves has no effect on the hydraulic calculation in terms of equivalent length or pressure drop, but the effect related to the dead volume of the selector valve manifold in relation to the total volume of the pipe network must be considered. The limit of the ratio between the volume of the selector valves which are not opened in case of actuation of the system and the inner volume of the system piping shall be observed. Additional information of the limits can be found in section about the “Selector valves (SVD)” in “System components manual”.

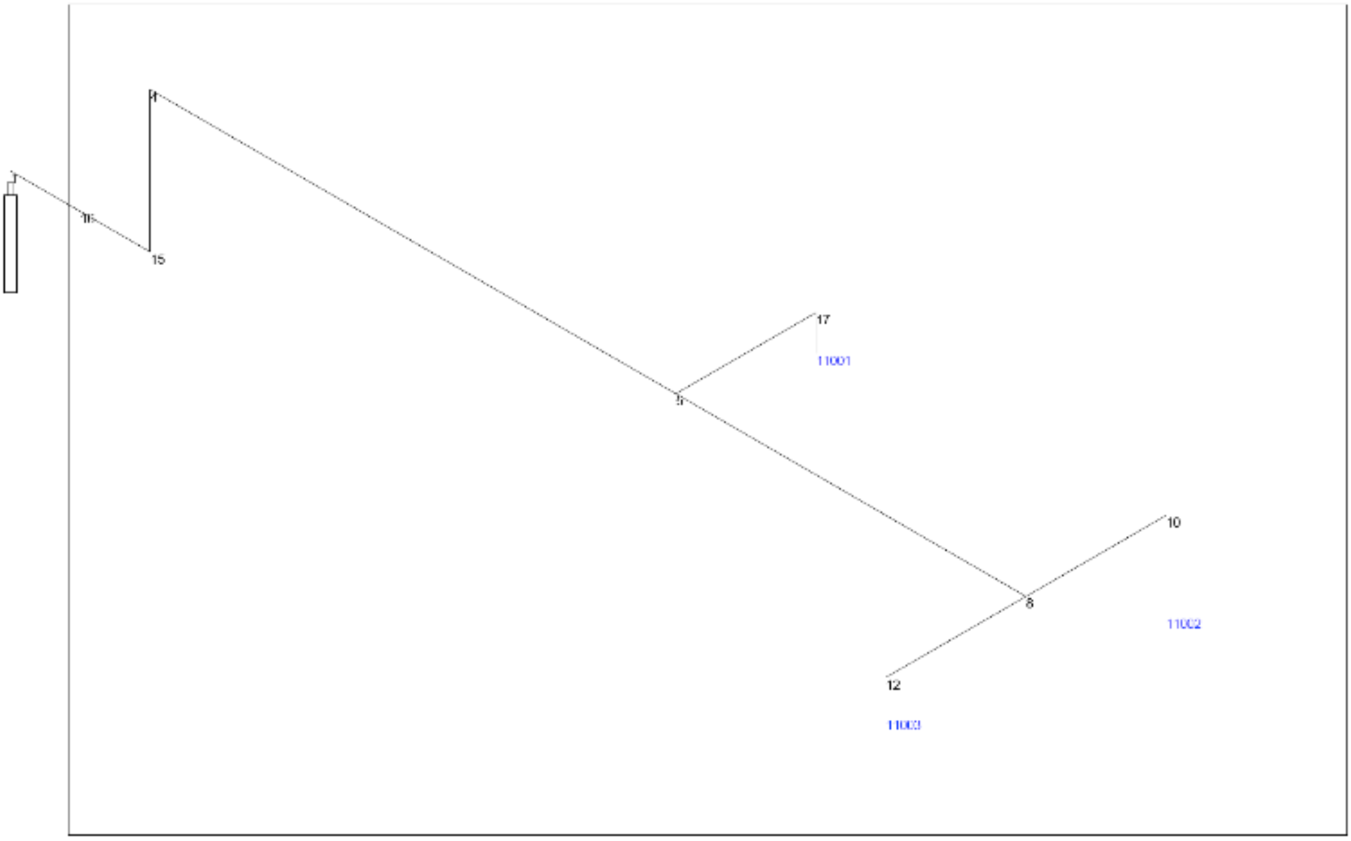
Version: 1.01
Licenced to: *Siex 2001*
File: example IG-541 RV00.prj - Results

Page: 1
09/03/2015

Project:	
Project-No:	
Building:	
Object:	
Contractor:	
Owner:	
Project engineer:	
Date:	10/03/2015
Regulation rule for calculation of IG541 quantities:	ISO 14520-1
Altitude above sealevel:	0 m
Atmospheric correction factor:	1,000
Pipe catalogue:	pipes new.rkl
Component catalogue:	
Nozzle catalogue:	nozzles_inert_gases UL_FM rv01.noz

Error messages:

No error detected



Input Data: Pipe System

Section-No:	Starting-node	Endnode Nozzle	Length [m]	Height [m]	Pipetype	Pipe Dn [mm] **	Fitting *	Component code	Component coefficient	Nb of container IG541 quantitiy
1	0	1	0,10	0,10	42	0,0 #		-	1202,0000	1
2	1	16	1,00	0,00	10	0,0 #	E	-	-	
3	16	15	1,00	0,00	13	0,0 #		-	-	
4	15	4	2,00	2,00	13	0,0 #	E	-	-	
5	4	5	3,00	0,00	13	0,0 #	E	-	-	
6	5	8	2,00	0,00	13	0,0 #	T-0deg	-	-	
7	8	10	2,00	0,00	13	0,0 #	T-90deg	-	-	
8	10	11002	0,50	-0,50	13	0,0 #	E	-	-	0,00
9	8	12	2,00	0,00	13	0,0 #	T-90deg	-	-	
10	12	11003	0,50	-0,50	13	0,0 #	E	-	-	0,00
11	5	17	2,00	0,00	13	0,0 #	T-90deg	-	-	
12	17	11001	0,50	-0,50	13	0,0 #	E	-	-	0,00

* C=Component, B=Bend, T=T-Piece, E=Elbow, P=Pressure control valve
** If a pipe diameter is equal zero see the extra table of the calculated diameters
# This pipe is not in the pipe catalogue

Legend of pipetypes

Type	Pipeclass	Pipe roughness
42	Schedule 160	hose
10	DIN-2440	smooth
13	DIN-2440	black pipe

Nozzle data:

No.	Calculation zone	Orifice diameter [mm]
11002	New calculation zone	9,5
11003	New calculation zone	9,5
11001	New calculation zone	9,0

Legend of nozzles:

Type	Number of orifices	C1	C2	C3	C4	C5	C6
1 FEDR	1	0,04630	-0,00999	-0,06126	0,00000	0,00000	0,00000

Version: 1.01
Licenced to: *Siex 2001*
File: example IG-541 RV00.prj - Results

Page: 3

09/03/2015

Calculation zone data:

Calculation of design quantity:

Zone	Total volume [m^3]	Volume of building parts [m^3]	Calculated volume [m^3]	Max. Over-pressure [mbar]	Design temp. [degC]	Extinguish-conc. [% Vol]	Design factor	Design conc. [% Vol]	Design quantity [kg]
1 New calculat	70,5	0,0	70,5	100,000	20,0	30,7	1,30	39,9	50,88

Regulation rule for calculation of IG541 quantities: ISO 14520-1

Altitude above sealevel: 0,0 m
Atmospheric correction factor: 1,000
IG541 volumes and volume flows are based on a density of 1,000 kg/m³

IG541 storage input data:

Container volume: 140,0 l
Container filling pressure: 300,0 bar
Container filling temperature: 15,0 degC
Storage temperature: 15,0 degC
Supplement factor: 1,00
Number of containers: 1

Discharge time (input value): 60,0 s

Version: 1.01
Licenced to: *Siex 2001*
File: example IG-541 RV00.prj - Results

Page: 4

09/03/2015

Calculation results:

IG541 design data:

Design quantity:	50,88 kg
Minimum storage quantity:	50,88 kg
Container pressure:	300,0 bar
IG541-quantity in one container:	58,1 kg
Number of containers:	1
Actual storage quantity:	58,1 kg

System information:

Max. pressure downstream control valve:	48,0 bar
Total network volume:	6,4 l
Ratio of volume of pipework to volume of storage:	4,6 %
Ratio of volume of pipework between storage and first T-piece to total network volume:	64,9 %

Discharge time in the calculation zones	
New calculation zone	59,5 s

Calculated pipe network parameters

No.	Inlet node	Outlet node	Inner-diameter [mm]	Minimum Pressure [bar]	Maximum Pressure [bar]	Average Pressure [bar]	Minimum mass flow [kg/s]	Maximum mass flow [kg/s]	Average mass flow [kg/s]
1	0	1	29,5	6,4	27,1	17,7	0,31	1,09	0,80
2	1	16	27,2	6,3	27,1	17,6	0,31	1,09	0,80
3	16	15	27,2	6,2	26,6	17,3	0,32	1,10	0,80
4	15	4	27,2	6,0	26,2	16,9	0,32	1,10	0,80
5	4	5	27,2	5,6	25,2	16,0	0,32	1,10	0,80
6	5	8	21,6	5,3	23,6	15,1	0,21	0,73	0,53
7	8	10	16,0	4,9	22,3	14,1	0,10	0,37	0,27
8	10	11002	16,0	4,6	20,5	13,1	0,10	0,37	0,27
9	8	12	16,0	4,9	22,3	14,1	0,10	0,37	0,27
10	12	11003	16,0	4,6	20,5	13,1	0,10	0,37	0,27
11	5	17	16,0	5,3	23,6	15,0	0,11	0,37	0,27
12	17	11001	16,0	5,0	22,2	14,1	0,11	0,37	0,27

This pipe is not in the pipe catalogue

Nozzle parameters:

No.	Calculation zone	Nozzle type	Orifice diameter [mm]	Pipe size	Orifice area to pipe area ratio [%]
11002	New calculation zone	FEDR	9,5	1/2	35,3
11003	New calculation zone	FEDR	9,5	1/2	35,3
11001	New calculation zone	FEDR	9,0	1/2	31,6

Arrival time at nozzles

Nozzle	Arrival time [s]	Maximum imbalance time [s]
11002	0,19	0,03
11003	0,19	0,03
11001	0,16	0,03

Discharged quantities at discharge time 60,0 s

No.	Calculation zone	Design quantity [kg]	Discharged quantity [kg]	Nozzle	Diameter [mm]	Design quantity [kg]	Discharged quantity [kg]
1	New calculation zone	47,613	47,762	11002	9,500	15,871	15,934
				11003	9,500	15,871	15,934
				11001	9,000	15,871	15,895

Version: 1.01
Licenced to: *Siex 2001*
File: example IG-541 RV00.prj - Results

Page: 5

09/03/2015

Gas concentration at dischearge time 60,0 s

No.	Calculation zone	O2 Conc. [%]	N2 Conc. [%]	Ar Conc. [%]	CO2 Conc. [%]
1	New calculation zone	13,0	68,2	15,8	3,0

Discharged quantities at the end of discharge 87,9 s

No.	Calculation zone	Design quantity [kg]	Discharged quantity [kg]	Nozzle	Diameter [mm]	Design quantity [kg]	Discharged quantity [kg]
1	New calculation zone	50,876	53,627	11002	9,500	16,959	17,894
				11003	9,500	16,959	17,894
				11001	9,000	16,959	17,838

Gas concentration at dischearge time 87,9 s

No.	Calculation zone	O2 Conc. [%]	N2 Conc. [%]	Ar Conc. [%]	CO2 Conc. [%]
1	New calculation zone	12,2	67,3	17,2	3,3

Pressure relief openings

No.	Calczone	Maximum Flow [kg/s]	Resistance Coefficient	Max. overpressure [Pa]	Net open area [m²]
0	New calculation zone	1,10	2,00	100,0	0,08

6. INSTALLATION AND MAINTENANCE

Installation and maintenance must be executed according to INERT-SIEX™ CFT-541 Installation manual and maintenance manual.