GUIDE FOR

FIRE PROTECTION AND DETECTION SYSTEM CALCULATIONS

FM-200/ Novec-1230/CO2 System

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GAS-BASED FIRE SUPPRESSION SYSTEM

HFC-227ea & FK-5-1-12

(FM200 & NOVEC 1230)

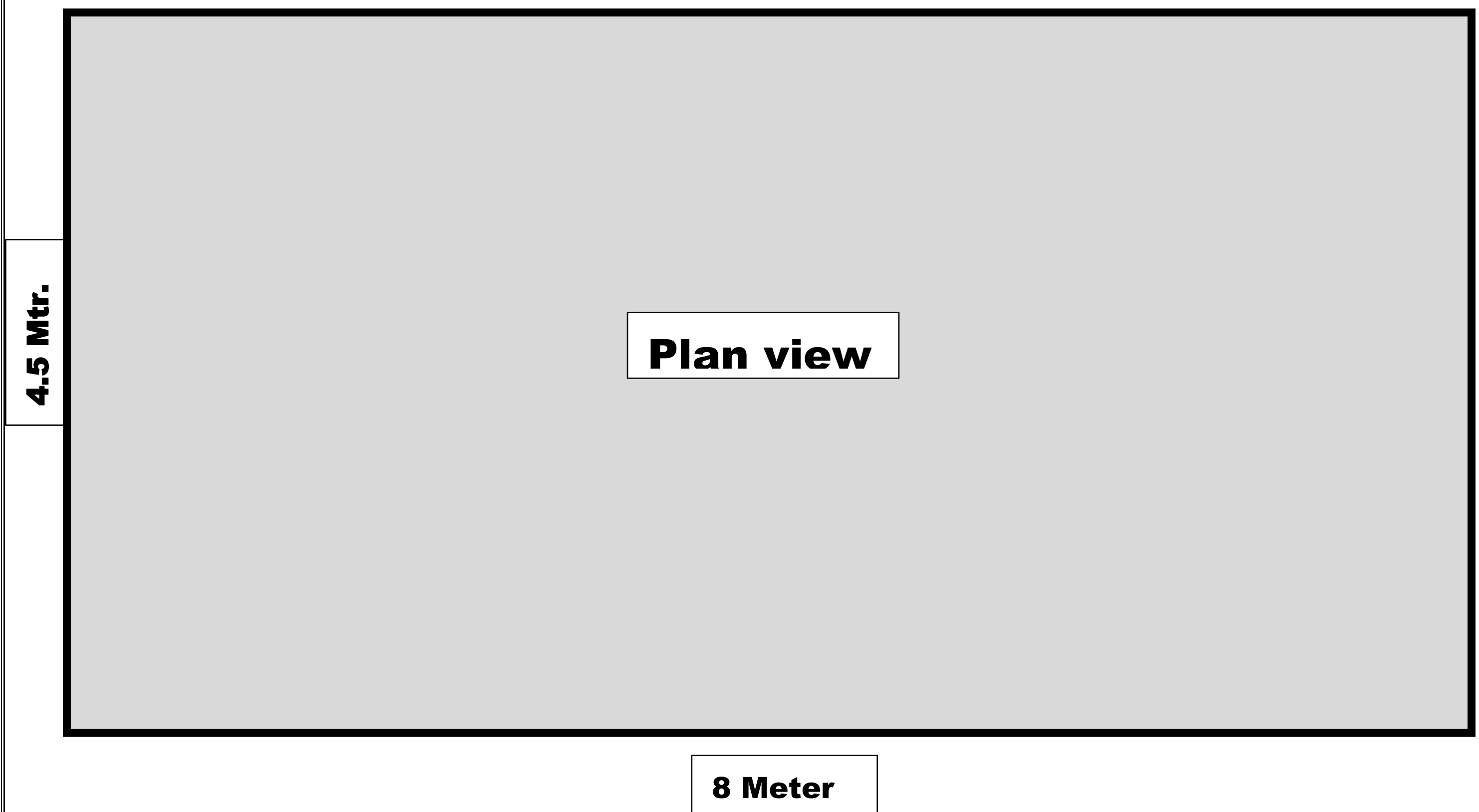
CO2 System

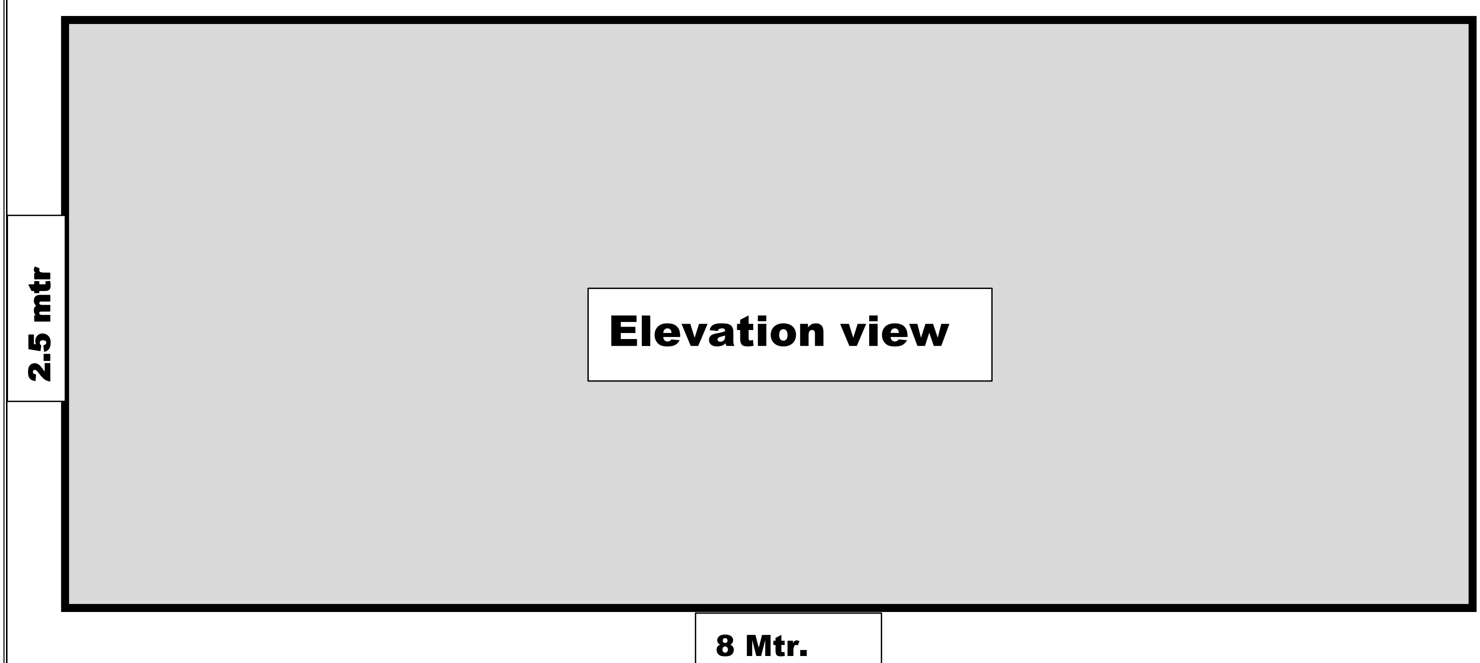
A Step-by-Step design Procedure

Design Process

1. Define the Hazard
2. Determine Design Concentration
3. Determine the Net Hazard Volume
4. Determine Extinguishing agent Quantity
5. Check the maximum reach concentration
6. Determine number and size of agent containers
7. Establish maximum Discharge time
8. Determine nozzle size and quantity to deliver required concentration at required discharge time to ensure mixing
9. Determine pipe sizes and pipe run(Pipe Sizing & Flow Calculation)
10. Evaluate compartment over/underpressurization and provide venting if required.
11. Establish minimum agent hold requirements and evaluate compartments for leakage.

Example Project -1 : A Computer Room





Step -1 : Define Hazard

Type of Hazard : Computer Room (Surface Class A)

Min. Hazard Temprature : 20 C

Max. Hazard Temprature : 30 C

Step -2 : Determine Design Concentration

FM-200

Agent	Heptane MEC (NFPA 2001, 2008) (%)	Class A design concen. NFPA 2001/UL (%)	Ratio Class A design to MEC (NFPA)	Class A design concen. (ISO 14520) (%)	Ratio Class A design concen. to MEC (ISO 14520)	Ratio Class A design NFPA 2001 to ISO 14520
Halon 1301	3.4[a]	5[b]	1.47	–	–	–
CO_2	23[a]	>34[c]	1.48	–	–	–
HFC-227ea	6.7	6.25–7.0	0.93–1.04	7.9	1.2	0.79–0.88
HFC-125	8.7	8.0	0.92	11.2	1.3	0.71
HFC-23	12.9	16.8–18	1.3–1.4	16.3	1.26	1.03–1.1
FK-5-1-12	4.5	4.2	0.93	5.3	1.17	0.79
IG-541	31	34.2	1.1	36.5	1.17	0.94
IG-55	35	37.9	1.08	40.3	1.15	0.94
IG-01	42	–	–	41.9	1.0	–
IG-100	31	–	–	40.3	1.3	–

Design Concentraction © = Min. Concentraction*1.2

C = 7 x 1.2 = 8.4 %

Select min Design Concentraction from this table based appropriate design standard

For our example we will select NFPA 2001 and design concentraction of 7 % (as we should select highter of extinguishing concentration)

Step -3 : Determine Net Hazard Volume

V = l x b x h

V = 8 x 4.25 x 2.5

V(Gross)= 85 Cubic Meter.

Volume of Any Impermiable Member such as Fixed Solid objects etc.

V1 = 0 Cubic Meter (assuming there is no such member in the room)

V(net) = V – V1 = 85 – 0 = 85 Cubic Meter.

Altitude : 1500 Mtr.

Specific Volume(S)= k1+k2xT

S = 0.1268+ 0.0005133 x 20

S = 0.136266

Generic name	Trade name	k_1 English units	k_2 English units	k_1 SI units	k_2 SI units
Halocarbons					
Halon 1301	Halon 1301	2.2062	0.005046	0.1478	0.00057
HFC-23	FE-13	4.7302	0.010699	0.3168	0.0011942
HFC-125	FE-25	2.722	0.006376	0.1828	0.0007085
HFC-227ea	FM 200	1.879775	0.0046625	0.1268	0.0005133
HFC-236fa	FE-36	2.0978	0.00514	0.1413	0.00058
FK-5-1-12	Novec-1230	0.9856	0.002441	0.0664	0.0002743
Inert gases					
IG-01	Argon	8.40299	0.018281	0.5612	0.002054
IG-55	Argonite	9.8809	0.0214956	0.65979	0.0024134
IG-100	NN-100	11.976	0.02606	0.7997	0.002927
IG-541	Inergen	9.858	0.02143	0.659	0.00241

Step -4 : Determine Agent Quantity

Agent Quantity (w) = $\frac{V}{S}\left(\frac{C}{100-C}\right)$

Agent Quantity (w) = $\frac{85}{0.1362}\left(\frac{8.4}{100-8.4}\right)$

Agent Quantity (w) = (624.08)x (0.09170)

$\boxed{W = 57.23 \text{ kg}}$

This Quantity is at sea Level

Altitude		
Feet	Meters	Correction factor
3000	914	0.90
4000	1219	0.86
5000	1524	0.83
6000	1829	0.80
7000	2134	0.77
8000	2438	0.74
9000	2743	0.71
10,000	3048	0.69
11,000	3353	0.66
12,000	3658	0.64
13,000	3962	0.61
14,000	4267	0.59
15,000	4572	0.56

Agent

Quantity @ 1500 mtr.

W = 57 /0.83 $[aboveTable]$

W = 68 kg.

$\boxed{W = 68\ kg}$

This Quantity is at 1500 mtr.

This is the Altitude of this Hazard

Step -5 : Check reached concentration @ Min. & Max Tempratures.

$$C = 100 \frac{\left(\frac{wxs}{V}\right)}{\left(\frac{wxs}{V}\right) + 1}$$

Where;

Q = Agent quantity supplied from the system [kg]

V = hazard volume [m^3]

s = specific vapor volume [m^3/kg] = k1+k2*T

T = Min./Max. hazard temperature [°C]

S = k1+k2xT

S = k1+k2x20

S = 0.1268+ 0.0005133 x 20

S = 0.1362 for min. Temp.

S = k1+k2xT

S = k1+k2x30

S = 0.1268+ 0.0005133 x 30

S = 0.1423 for Max. Temp.

$$C = 100\frac{\left(\frac{68x0.1326}{85}\right)}{\left(\frac{68x0.1326}{85}\right)+1}$$

$$C = 100\frac{(0.08424)}{(0.08424)+1}$$

$C = 7.7\%$ @ 20 C Min. Temp.

$$C = 100\frac{\left(\frac{54x0.1423}{85}\right)}{\left(\frac{54x0.1423}{85}\right)+1}$$

$$C = 100\frac{(0.09040)}{(0.09040)+1}$$

$C = 8.29\%$ @ 30 C Max. Temp

Lets check if this concentraction is Safe for occupied space

TABLE 17.7.6 NOAEL and LOAEL Values for Halocarbon Clean Agents

Halocarbon Clean Agent	*NOAEL (Agent % by Volume)*	*LOAEL (Agent % by Volume)*
FC-3-1-10	40.0	>40.0
FK-5-1-12	10.0	>10.0
HCFC Blend A	10.0	>10.0
HFC Blend B	5.0	7.5
HCFC-124	1.0	2.5
HFC-125	7.5	10.0
HFC-227ea	9.0	>10.5
HFC-23	30.0	>30.0
HFC-236fa	10.0	15.0
FIC-13I1	0.2	0.4

*Concentration @ 30°C is less than NOAEL (9%) – **okay for occupied space.***

Step-06 : Determination of number & Size of Container

Using DOT Container chart

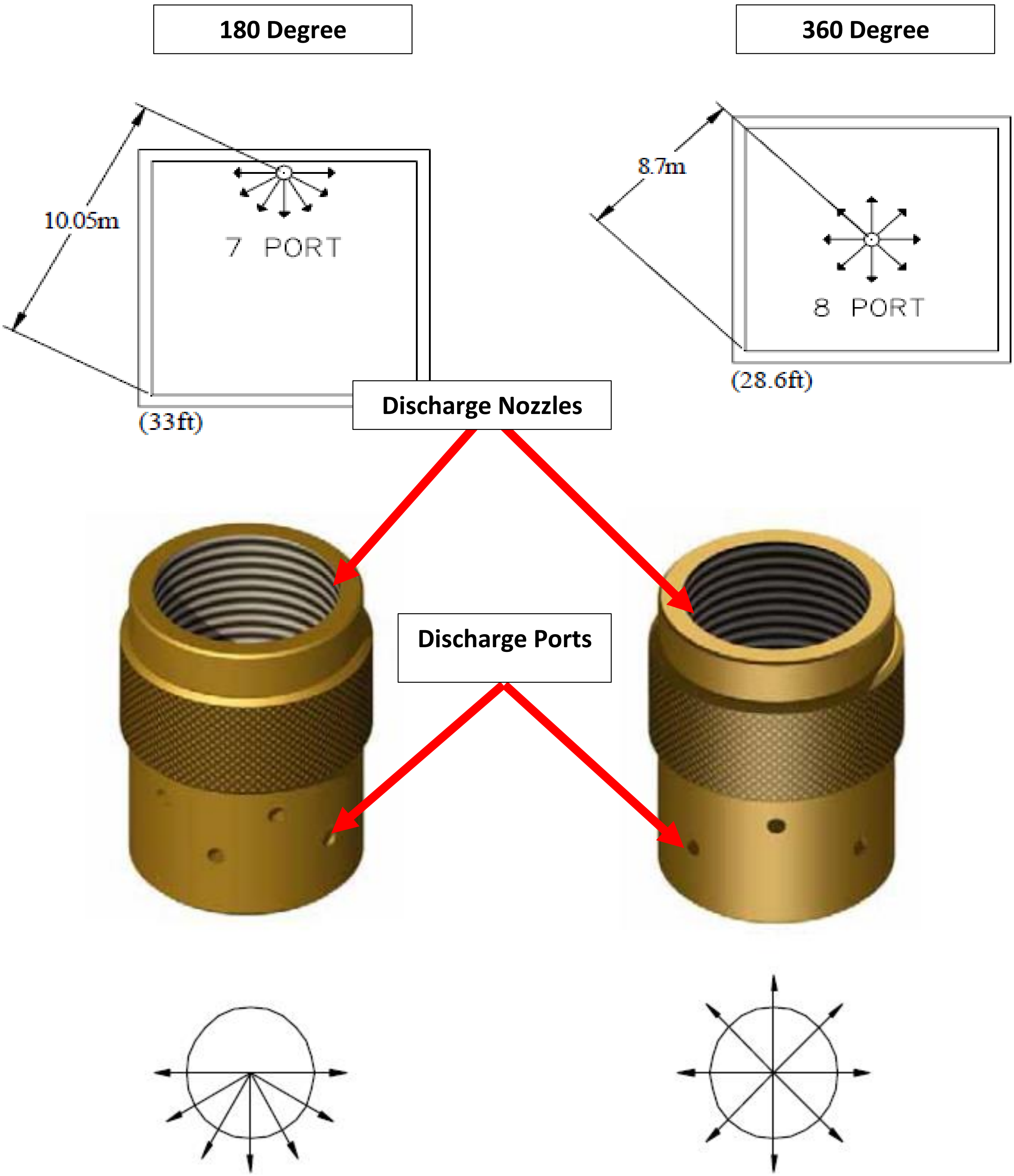
Part No. (Nominal Volume)		Minimum and Maximum Fills		Valve Size		Height from floor to outlet (nominal)		Diameter		Nominal Tare Weight	
		kg	(lbs)	mm	(in)	mm	(in)	mm	(in)	kg	(lbs)
303.205.026	(4.5 litre)	2.3 to 4.5	(5 to 10)	25	(1")	280	(11")	178	(7")	7.7	(17)
303.205.015	(8 litre)	4.0 to 8.0	(9 to 18)	25	(1")	304	(12")	254	(10")	14.8	(32.6)
303.205.016	(16 litre)	8.0 to 16.0	(18 to 35)	25	(1")	502	(19.8")	254	(10")	18.4	(40.6)
303.205.017	(32 litre)	16.0 to 32.0	(35 to 71)	25	(1")	833	(32.8")	254	(10")	26.1	(57.5)
303.205.030	(40 litre) *	20.0 to 40.0	(44 to 88)	50	(2")	1352	(53.2")	227.2	(9")	52.2	(115)
303.205.018	(52 litre)	26.0 to 52.0	(58 to 115)	50	(2")	596	(23.5")	406	(16")	49.1	(108.3)
303.205.031	(67.5 litre) *	33.8 to 67.5	(75 to 149)	50	(2")	1526	(60")	265	(10.4")	81.6	(180)
303.205.032	(80 litre) *	40.0 to 80.0	(88 to 176)	50	(2")	1685	(66.3")	276	(11")	95.3	(210)
303.205.019	(106 litre)	53.0 to 106.0	(117 to 234)	50	(2")	1021	(40.2")	406	(16")	71.8	(158.3)
303.205.020	(147 litre)	73.5 to 147.0	(162 to 324)	50	(2")	1354	(53.3")	406	(16")	89.9	(198.2)
303.205.021	(180 litre)	90.0 to 180.0	(198 to 397)	50	(2")	1634	(64.3")	406	(16")	105.8	(233.2)
303.205.022	(343 litre)	171.5 to 343	(378 to 756)	80	(3")	1466	(57.7")	610	(24")	207	(456)

Note :Unless a hydraulic flow calculation is done, approximate 80% of the max. filling should be used to determine a container size (Recommanded practices from Manufacturers)

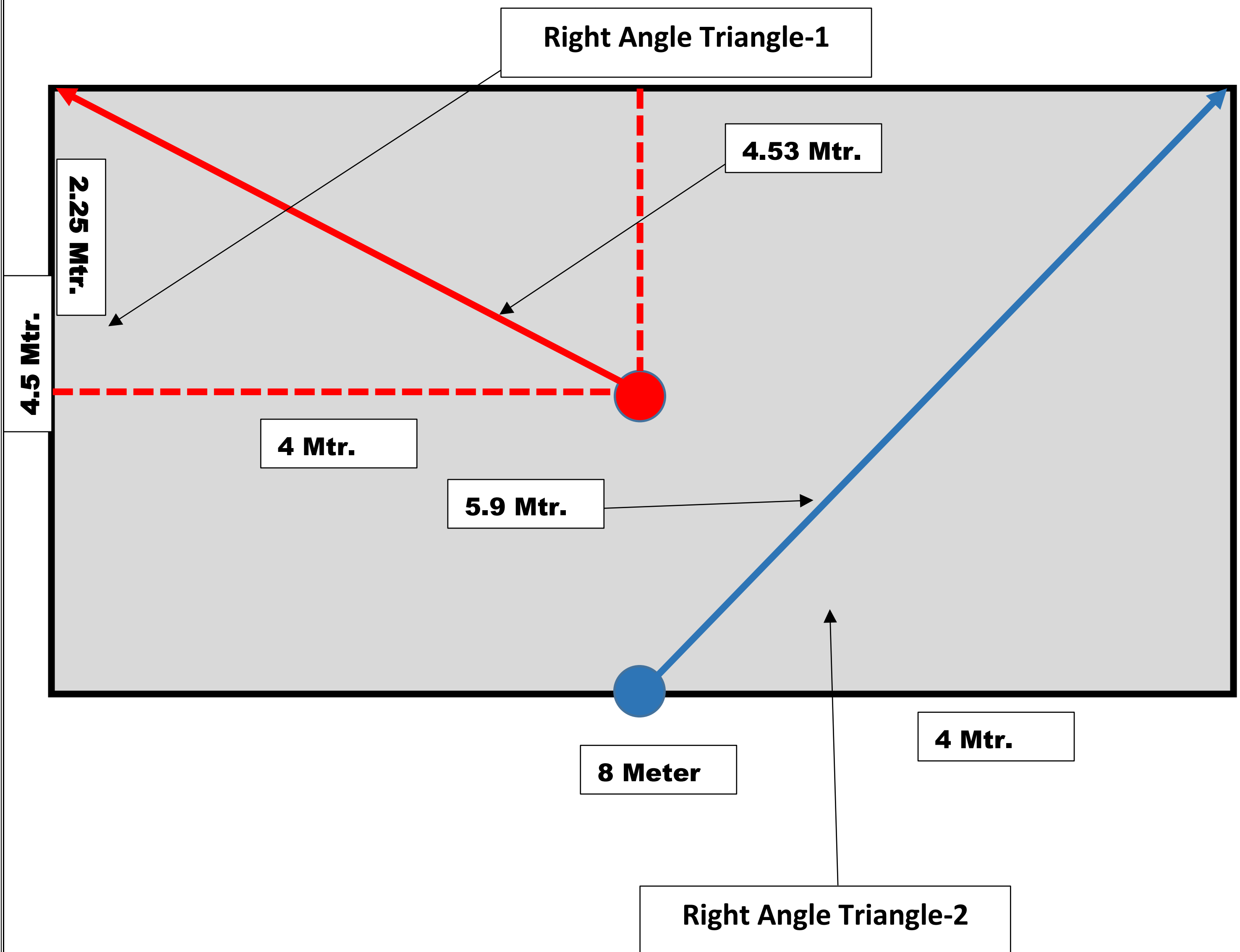
1 x 52 litre containing 41 kg of FM 200 is selected

Step-07,08 : Establish maximum Discharge time & Determine nozzle size and quantity to deliver required concentration at required discharge time to ensure mixing

	180 Deg Pattern	360 Deg. Pattern
No. of Ports	7	8
Available Size	15/20/22/32/40/50 mm	
Max area of Coverage	95.3 Sq. Mtr	95.3 Sq. Mtr
Max Discharge Radius	10.05 Mtr	8.7 Mtr.
Max. Coverage Height	4.87 Mtr.	4.87 Mtr.
Min. Void height (Sub-floors & false ceilings)	300 mm	300 mm
Max. Distance from wall(Measured from centre of the nozzle to the wall.)	300mm	
Min Distance from Wall(Measured from centre of the nozzle to the wall.)	50mm	
Max. Distance below the ceiling	300mm	300mm
Max. Distance between Nozzle and Container outlet (if nozzles are located only above the container)	9.1 Mtr	9.1 Mtr.
Max. Distance between Nozzle and Container outlet (if nozzles are located only below the container)	9.1 Mtr	9.1 Mtr.


180 Degree
360 Degree
10.05m
7 PORT
(33ft)
8.7m
8 PORT
(28.6ft)
Discharge Nozzles
Discharge Ports

Check the Nozzle Coverage vs Max. Allowed coverage :



Actual Coverage Radius is within Max. allowed Coverage Radius

4.53 Mtr for 360° - Okay

5.9 Mtr for 180° - Okay

Check Height of Hazard Area vs Max. Allowed coverage height :

4.25 Mtr. < 4.87 Mtr.- Okay

1 Nozzle 180° or 1 nozzle 360° is possible

Determine Size of Pipe & Number of Nozzles :

Number of Nozzles = $\frac{Volume of Hazard}{Coverage Area of Each Nozzole}$

Number of Nozzles(360° or 180°) = $\frac{85}{95.3}$

Number of Nozzles(360° or 180°) = 0.89 Say 1 Nos

Discharge Time = 10 Sec.

Agent Quantity = 48 Kg

Select higher size than required Discharge rate using table

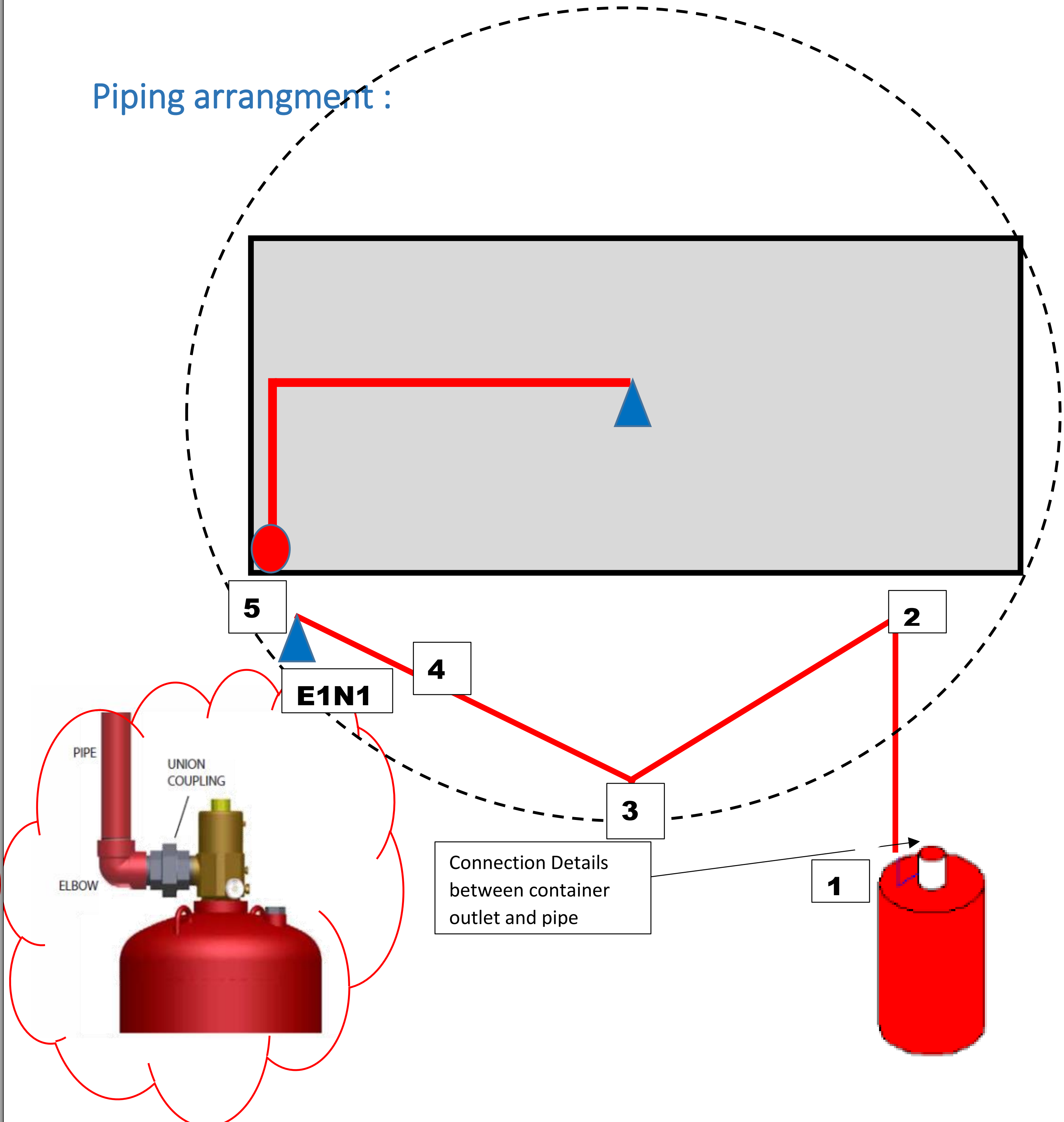
Discharge rate = 4.8 kg/ Sec.

Pipe Size mm (in)	Minimum flow rate kg/s (lb/s)	Maximum flow rate kg/sec.(lb/s)
10 (3/8)	0.272 (0.60)	0.907 (2.00
15(1/2)	0.454 (1.00)	1.361 (3.00)
20 (3/4)	0.907 (2.00)	2.495 (5.50)
25 (1)	1.588 (3.50)	3.855 (8.50)
32 (1 1/4)	2.722 (6.00)	5.67 (12.50)
40 (1 1/2)	4.082 (9.00)	9.072 (20.00)
50 (2)	6.35 (14.00)	13.61 (30.00)
65 (2 1/2)	9.072 (20.00)	24.95 (55.00)
80 (3)	13.61 (30.00)	44.92 (99.00)
100 (4)	24.95 (55.00)	56.7 (125.00)
125 **(5)**	40.82 (90.00)	90.72 (200.00)
150 (6)	54.43 (120.00)	136.1 (300.00)

Estimated pipe size = 32 mm (1¼")

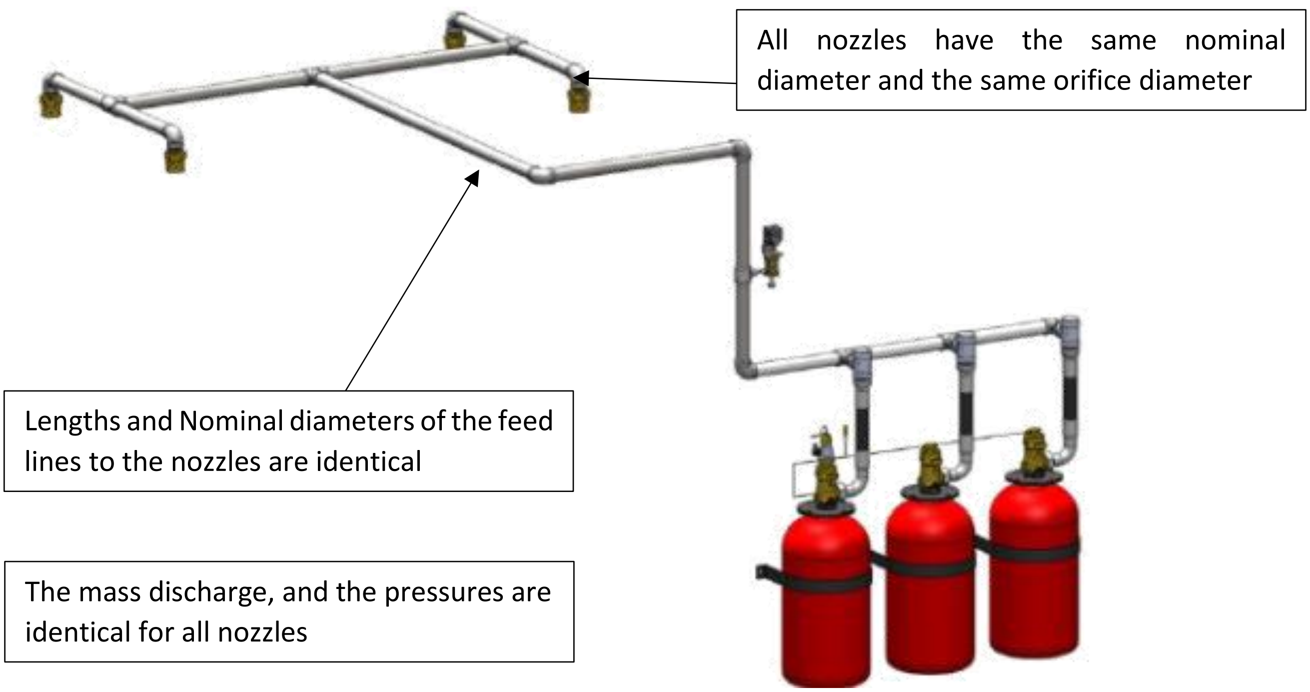
Step-09 : Piping Arrangment

Piping arrangment :



Important Parameters :

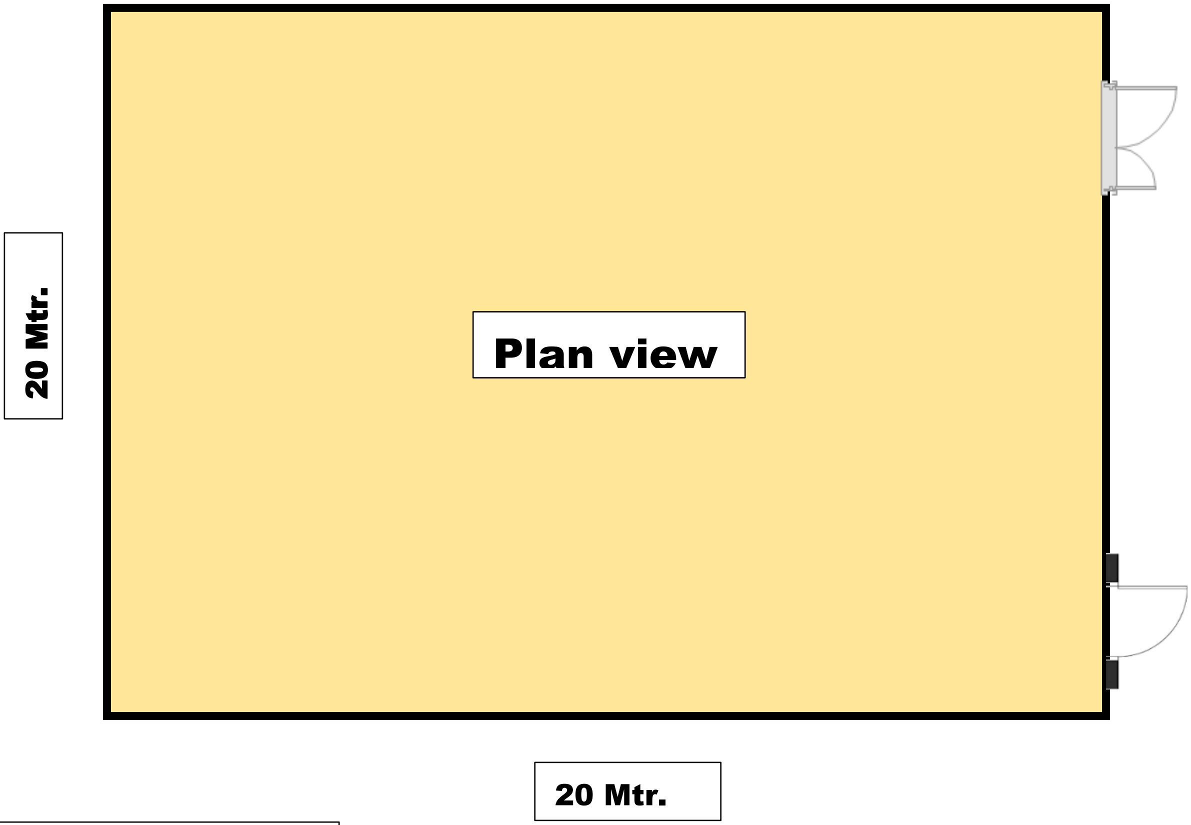
Piping System must be balanced (*A balanced system has the actual and equivalent pipe lengths from container to each nozzle within 10% of each other and has equal design flow rates at each nozzle)*



- 80% maximum agent in pipe
- 4.87 bar (70.6 psi) minimum nozzle pressure
- Between 6 - 10 seconds discharge time.
- 10 - 30 % side tee split.
- 30 -70 % bull tee split.
- 0.5 kg/L(31.2lbs/ft3) - 1.0 kg/L(62.4lbs/ft3) fill density.
- Max. liquid arrival time imbalance of 1.0 seconds.
- Maximum liquid run out time of 2.0 seconds.
- Maximum nozzle height is 4.87m (16.0ft)

- Minimum of 10% agent in pipe before first tee.
- Maximum of 20 nozzles per system.
- Maximum of 10 enclosures per system.
- The ratio between the nozzle area and the pipe cross sectional area immediately preceding the nozzle is limited to a minimum of 0.20 (20%) and a maximum of 0.80 (80%).

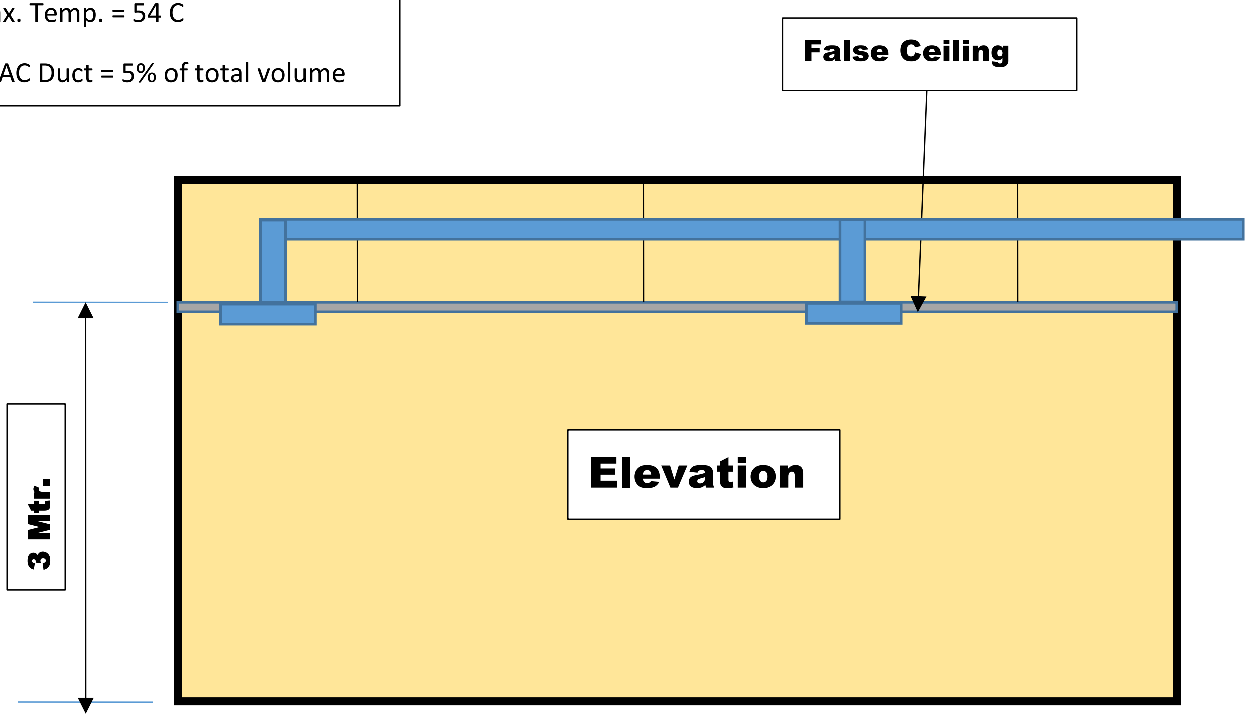
Example Project -2



Min. Temp = 20 C

Max. Temp. = 54 C

HVAC Duct = 5% of total volume

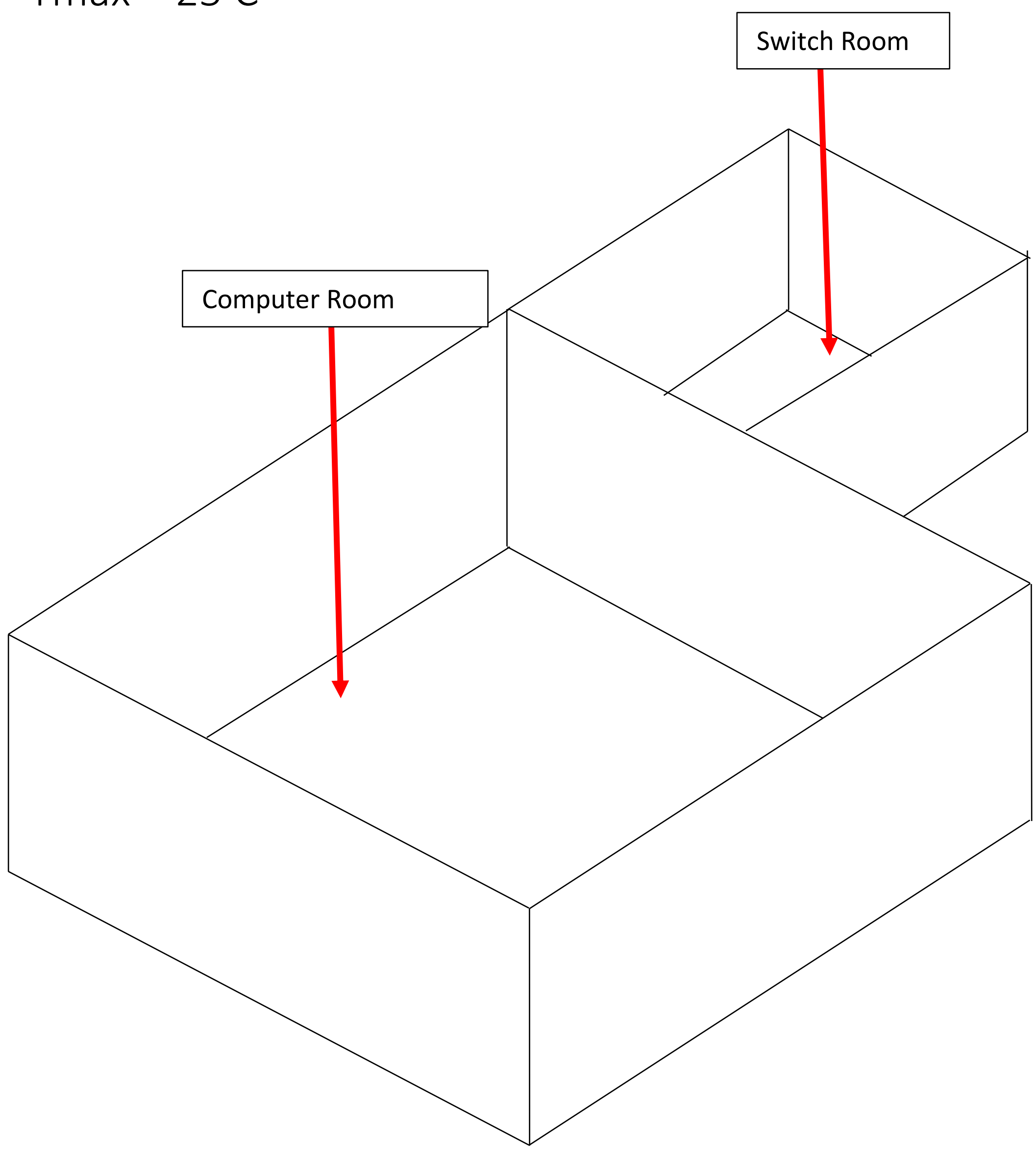


Example Project -3

Calculation for two rooms with the following dimensions:

Switch Room: 6.9 x 7 x 2.5 = 120.7m3
Computer Room: 12 x 16 x 2.83 = 543.3m3

Tmin = 20 C
Tmax = 25 C



Example Project -4

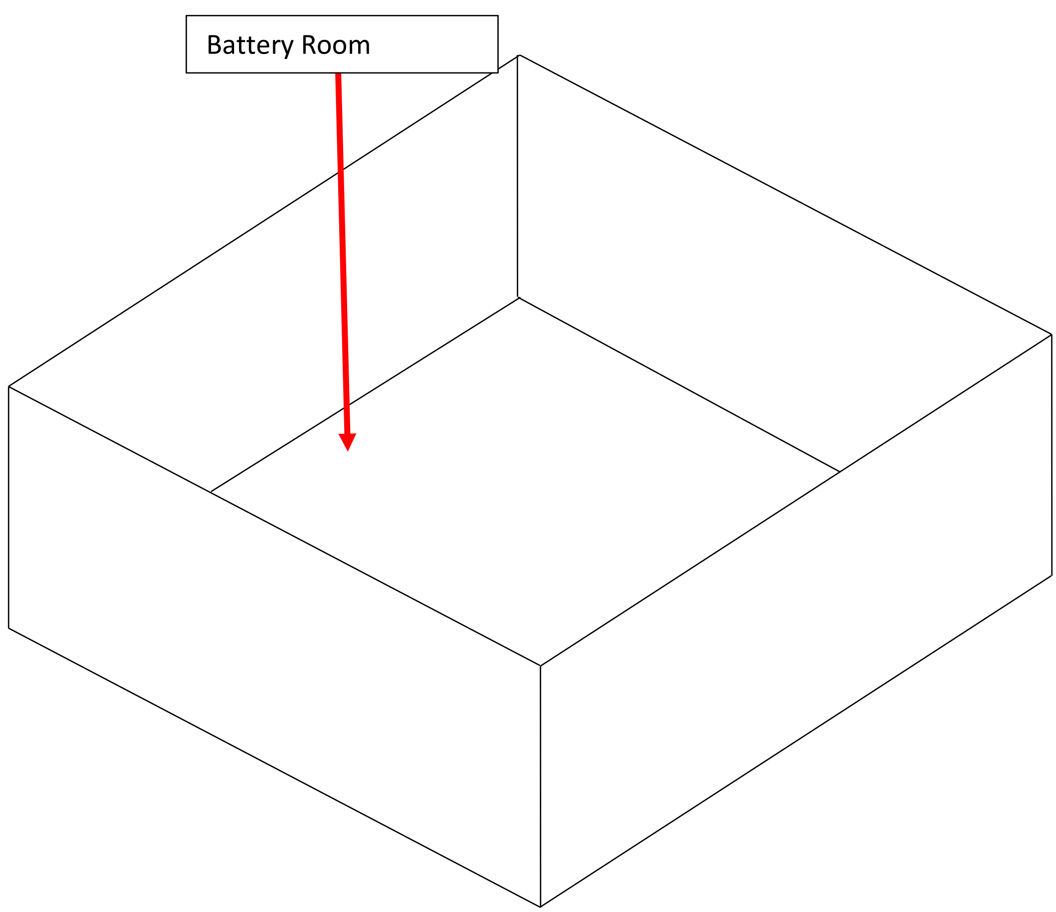
Calculation for a Battery room with the following dimensions & details:

Room to be Protected by Novec 1230 (FK-5-1-12/Propellant N2)

Computer Room Volume: = 170.70 m3

Non Permeable Volume = 0 m3

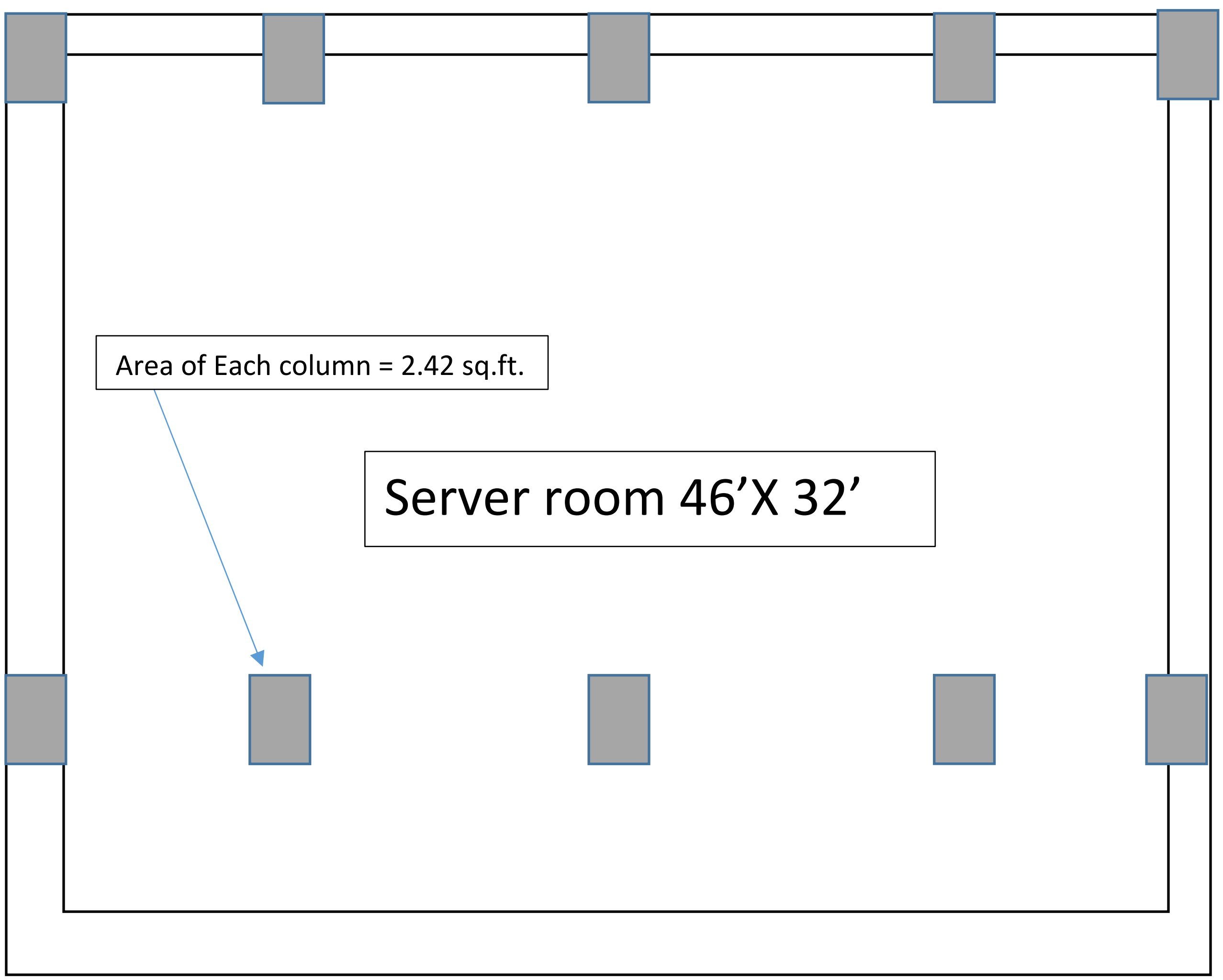
Tmin = 21 C
Tmax = 21 C



Example Project -5

Calculation for a Server room with the following dimensions & details:

Room to be Protected by Novec 1230 (FK-5-1-12/Propellant N2)



CO2 DESIGN QUANTITY FOR SURFACE FIRES

1. Define the Hazard
2. Determine Min. Extinguishing Concentration(MEC)
3. Determine Design Concentration(DC)
4. Determine the Net Hazard Volume
5. Determine Base Design Quantity
6. Determine additional CO2 quantity for special condition.

6a. Material Conversion Factor (MCF)

6b. Uncloseable Openings

6c. Ventilation System

6d. Temprature Extereme

7. Determine Final Design Quantity.

CO2 DESIGN QUANTITY FOR DEEP SEATED FIRES(Smoldering Combustion)

1. Define the Hazard
2. Determine Min. Extinguishing Concentration(MEC)
3. Determine Design Concentration(DC)
4. Determine the Net Hazard Volume
5. Determine Base Design Quantity
6. Determine additional CO2 quantity for special condition.

6a. Material Conversion Factor (MCF)

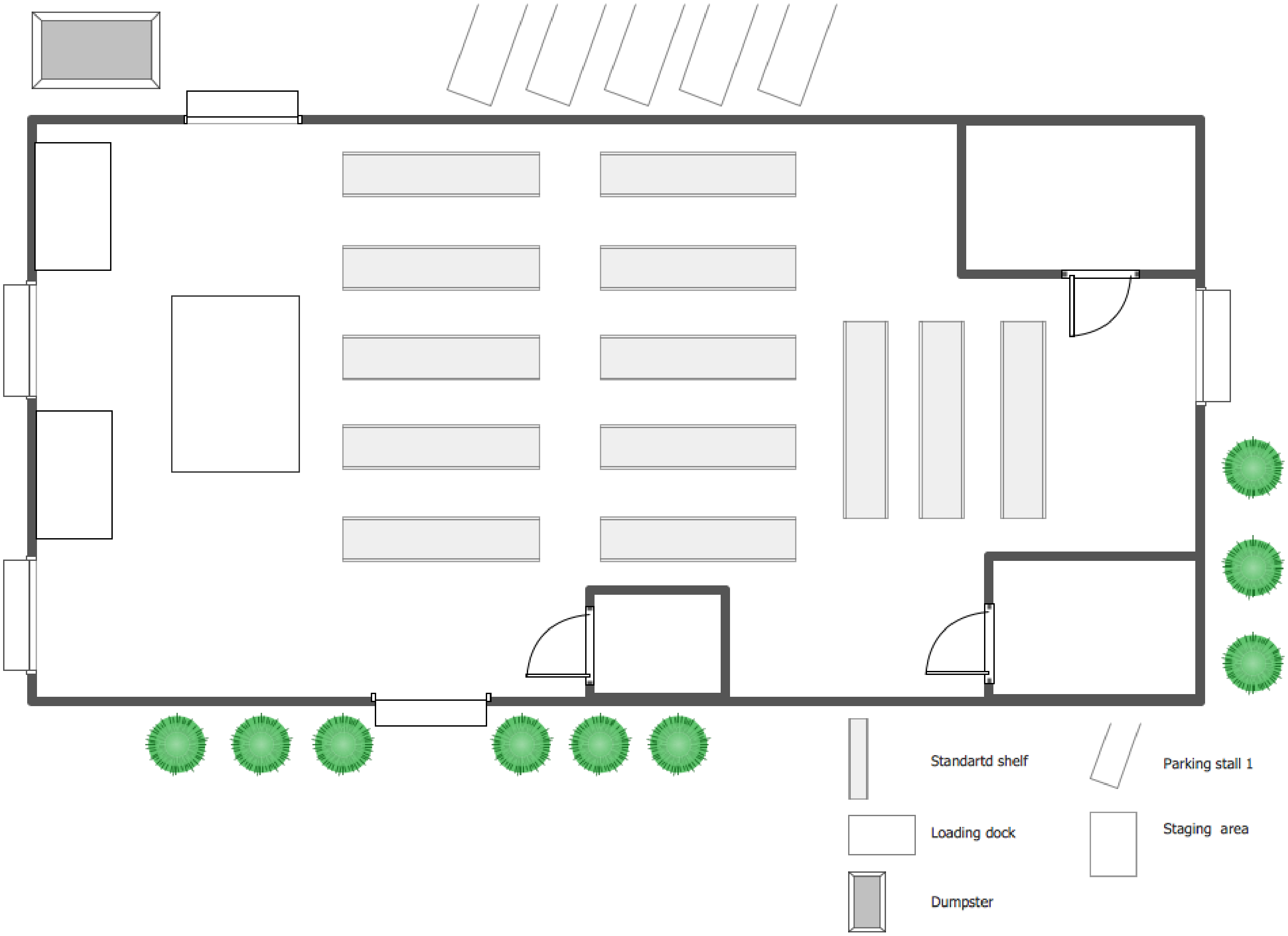
6b. Uncloseable Openings

6c. Ventilation System

6d. Temprature Extereme

7. Determine Final Design Quantity.

Example Project-1(Total Flooding Type)



Volume of Space : 500 Cubic Meter

Type of Combustible : Ethyl Alcohol

Determine Design quantity and Rate of Discharge …?

Step -1 : Define Hazard

Surface Flame Spread

Step -2 :Determine Min. Extinguishing Concentration(MEC)

Step -3 :Determine Design Concentration(DC)

Table 45.14 Minimum extinguishing and design concentrations for selected flammable liquids

Material	MEC, vol.%	DC, vol.%
Acetone	27[a]	34
Acetylene	55	66
Carbon disulfide	60	72
Ethyl alcohol	36	43
Hexane	29	35
Methyl alcohol	33	40
Propane	30	36

Step -4 :Determine Net Hazard Volume (Vnet)

Vnet = 500 Cubic Mtr.

Step -5 :Determine Base Design Quantity(mBD)

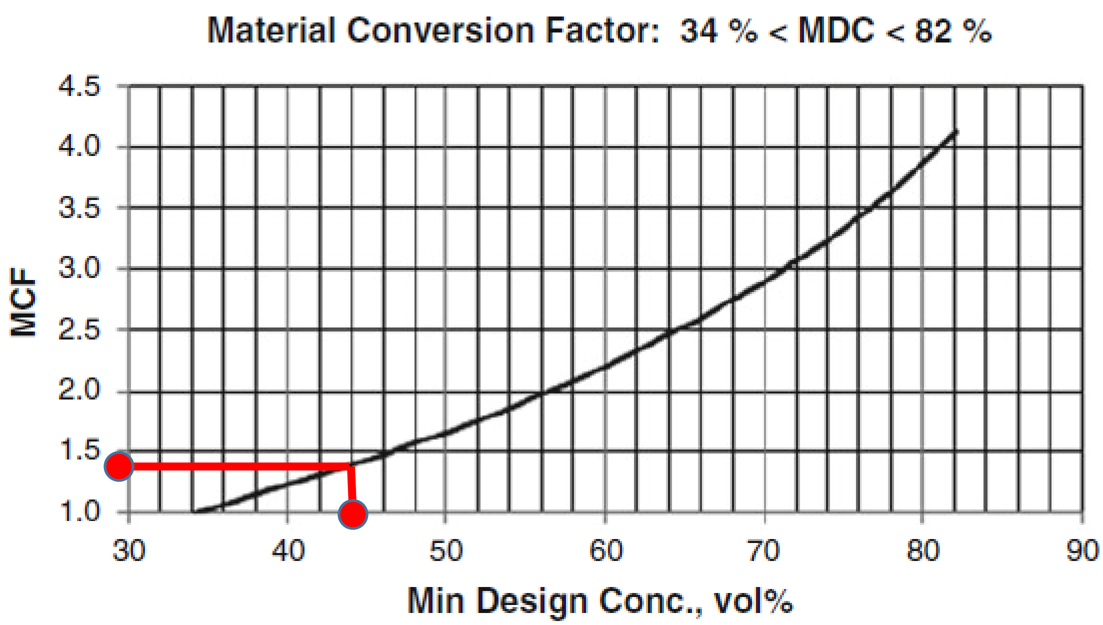
Base Design Quantity (mBD) = Vnet x FF

mBD = 500 x 0.8 = 400 kg

Table 45.15 Flooding factors vs. hazard volume

Protected volume (V_P), m3	Flooding factor, kg/m^3	Minimum quantity, kg
≤3.96	1.15	–
3.97–14.15	1.07	4.5
14.16–45.28	1.01	15.1
45.29–127.35	0.9	45.4
127.35–1415	0.8	113.5
>1415	0.74	1135

Step -6 :Determine additional Quantity



Material Conversion Factor = 1.4

Modified Quantity = mBD x MCF

= 400 x 1.4

mD = 560 kg

Adjustment for leakage in system(mlo) = 0 kg

Adjustment for ventilation(mlv) = 0 kg

Adjustment for Temprature Extreme(mT) = 0 kg

Final Design Quanity (mFD) = mD+mlo+mlv+mT

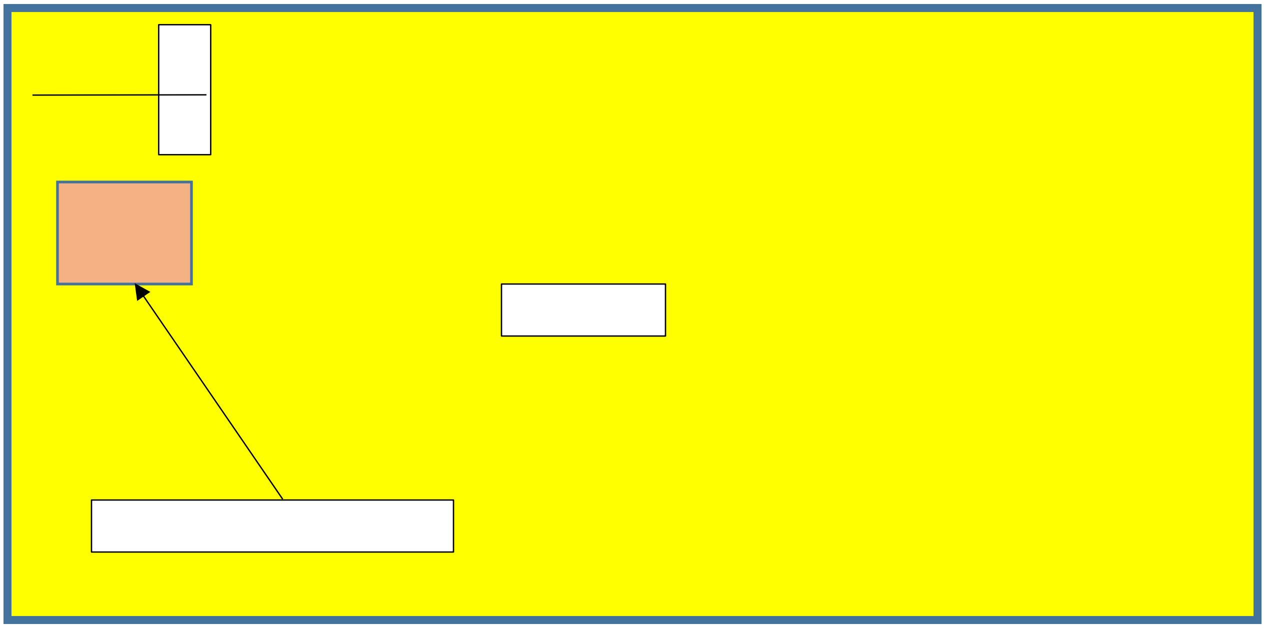
= 560+0+0+0

$\boxed{\text{mFD = 560 kg}}$

Discharge Time (t) = 1 Min.

$\boxed{\text{Discharge Rate (w) = 560 kg/Min.}}$

Example Project-2(Total Flooding Type)

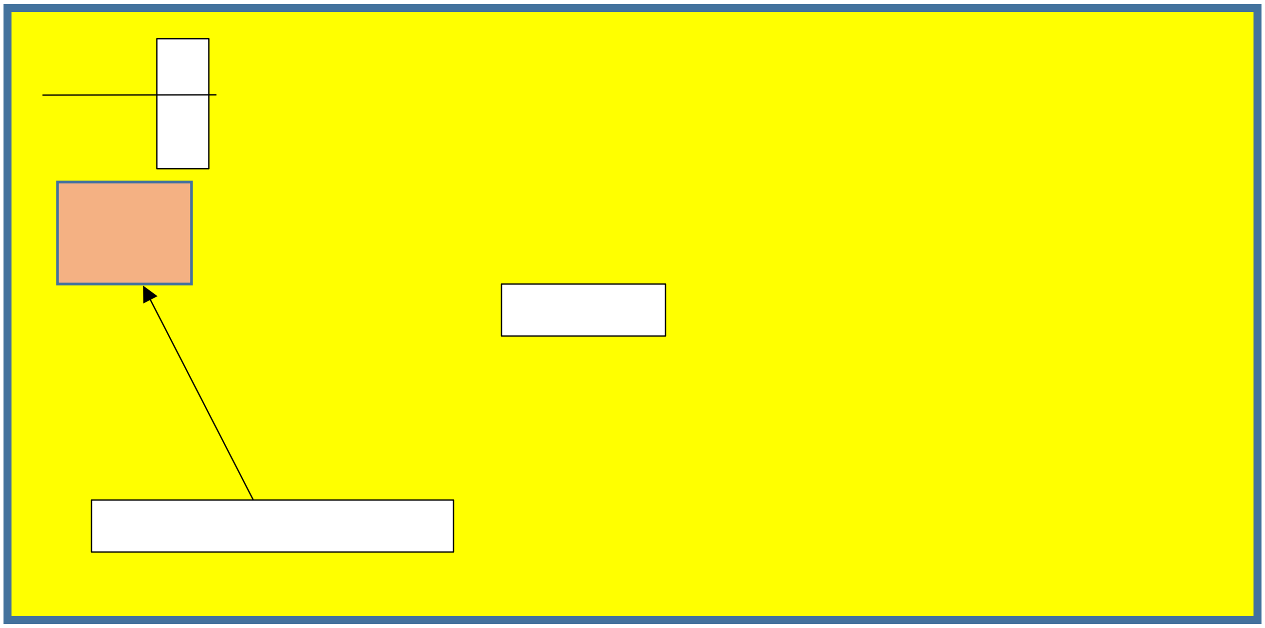


Volume of Space : 60 Cubic Meter

Type of Combustible : Petroleum spirit

Determine Design quantity and Rate of Discharge …?

Example Project-3(Total Flooding Type)

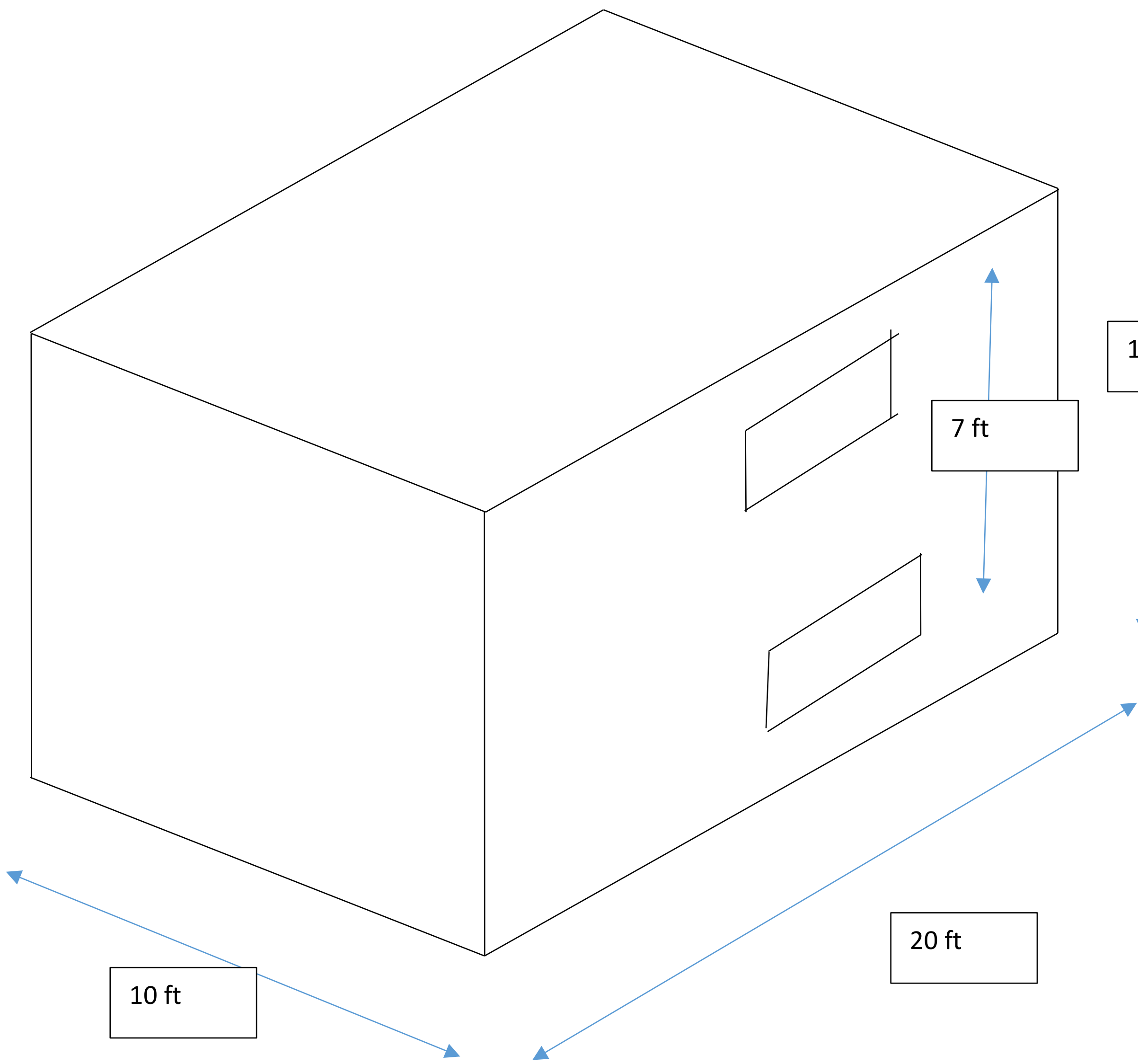


Volume of Space : 300 Cubic Meter

Type of Combustible : Ethylene Oxide

Determine Design quantity and Rate of Discharge …?

Example Project-4(Total Flooding Type)



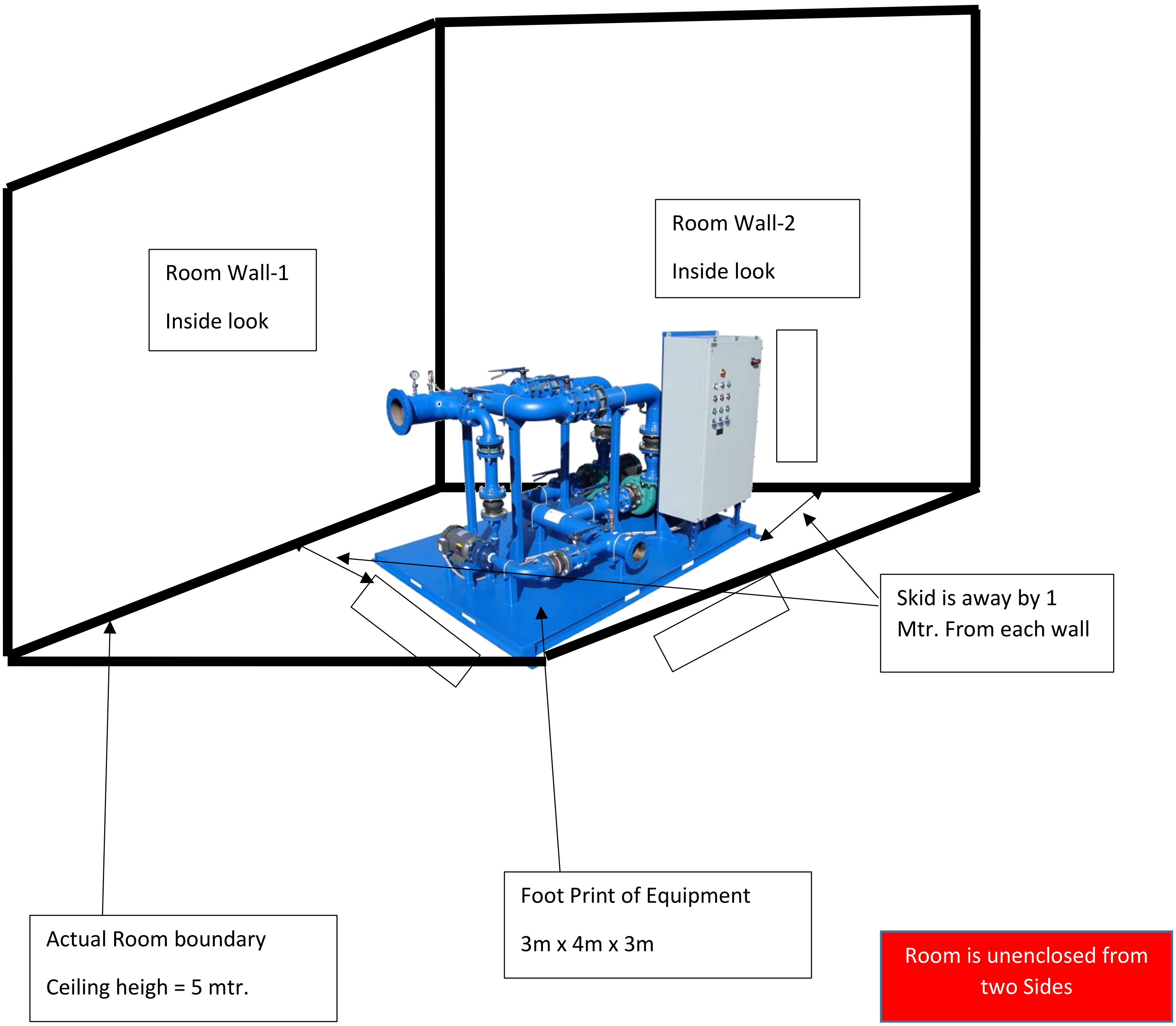
Type of Combustible : Gasoline

Area of Openings : 5 Sq. Ft. Each

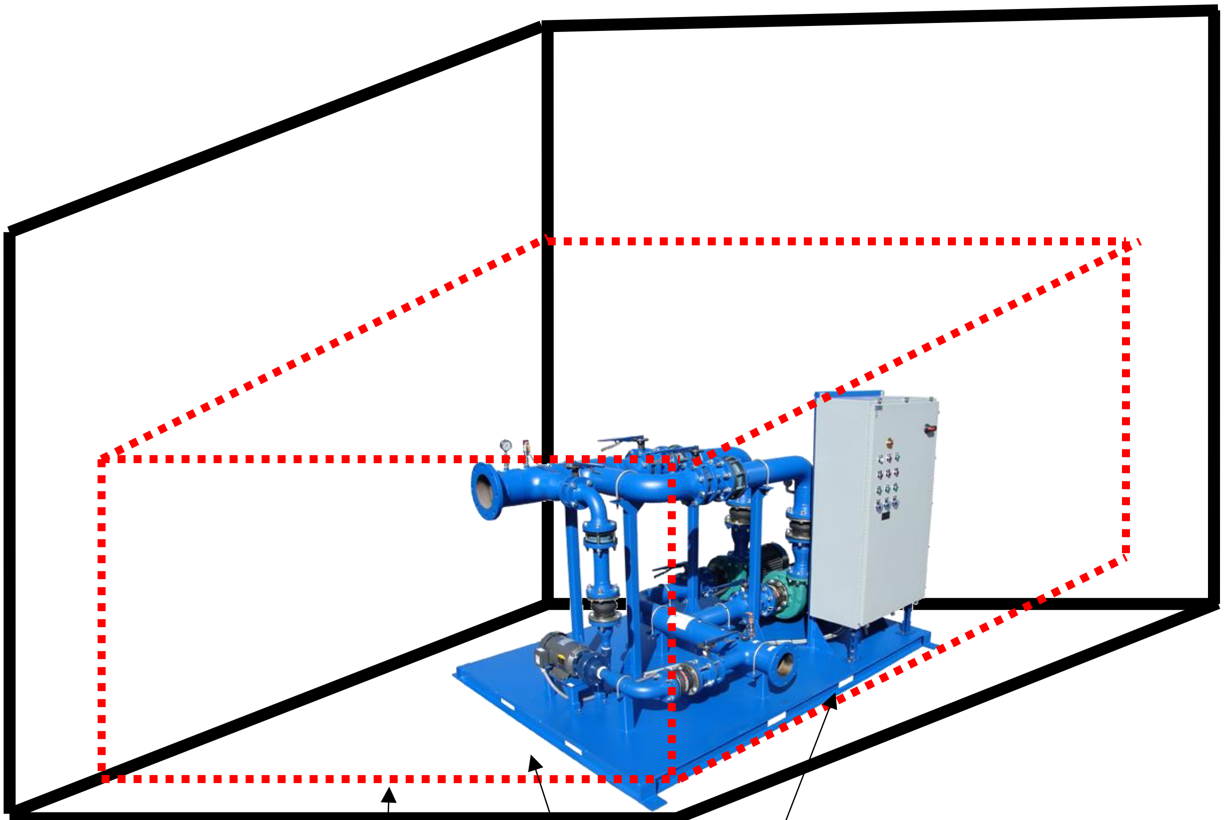
Example Project-1 – Local Application System

Diesel Fuel Pumping Skid

Rate by Volume Method(Placement of Skid)



Rate by Volume Method(Virtual Design boundary)



Virtual Design Volume boudary

0.6 Mtr from equipment

Length of Pump Skid

Length of Virtual boundry (L) = 1+4+0.6 = 5.6 mtr.

Distance of equipment from wall

Distance from equipment to virtual boundary

Width of Virtual boundry (W) = 1+3+0.6 =4.6 Mtr.

Height of Virtual boundry (H) = 3+0.6 = 3.6 Mtr.

Size of Protected Volume (V) = L x Wx H

= 5.6 x 4.6 x 3.6

$$\boxed{V = 92.73 \text{ Cubic Mtr.}}$$

Perimeter of Protected Space = Sum of all Sides

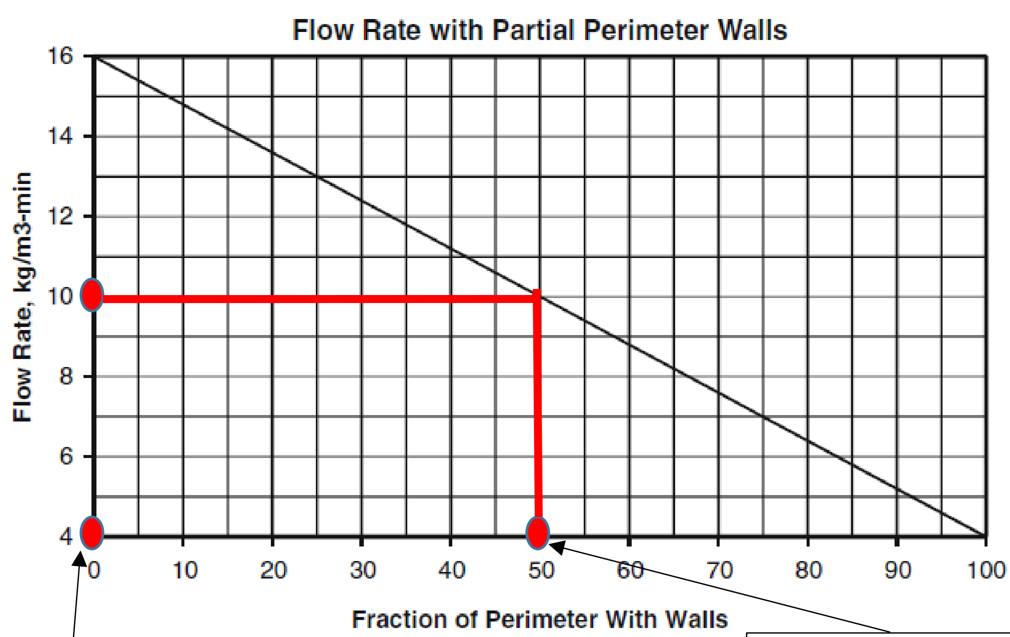
= 2(L Side) + 2(W Side)

= 2((L Side) + W Side))

= 2((1+4+0.6)+ (1+3+0.6))

= 2(10.2)

= 14.8 Mtr.



Should never be less than this value.

Two wall of room are not enclosed

Total discharge rate of a basic System = 16 kg/min. Cubic mtr.

The discharge rate may be reduced by as much as 12 kg/min · m3 in proportion to the fraction of the perimeter of the virtual volume that consists of permanent and continuous walls that extend at least 0.6 m above the hazard, and provided that the walls are not actually part of the protected hazard.

Therefore, Design Rate of CO_2 = Protected Volume x Flow rate (from above graph)
= 97.5 cubic Mtr x 10 kg/ Cubic Mtr x Min.

$\boxed{\text{Design flow rate = 970 Kg/ Min.}}$

Duration of Liquid Discharge = 30 Sec

Therefore,

Design Quantity of CO_2 = Rate of Discharge x Discharge Time x High pressure efficiency factor(*For high pressure systems increase gas quantity by 40% as only 70% of cylinder is effective)*

= 927 x 0.5 x 1.4

$\boxed{\text{Design Quantity of CO2 = 649 kg}}$

The number of 45.4 kg high pressure CO_2 Cylinder = 649/45.4 = 14.3 say 15

$\boxed{\text{Number of Cylinder = 15}}$

Example Project-2 – Local Application System

Paint Spray Booth

Dimensions
Length = 2.13 m
Width = 2.44 m (open Front)
Height = 1.83 m

Determine the Design Quantity of CO_2 and Discharge Rate…?

Example Project-3 – Local Application System

Printer

Four Sides are opened(no continuous solid walls)
Dimensions

L = 1.52 m
W = 1.22 m
H = 1.22

Determine the Design Quantity of CO_2 and Discharge Rate…?

Pipe Size & Orifice Size Determination

1. Determine the Terminal Pressure for a low Pressure System Consisting of single 2 inch. Sch. 80 pipeline with an equivalent length of 500 ft. and flow rate of 1000 lb/min.

Solution:

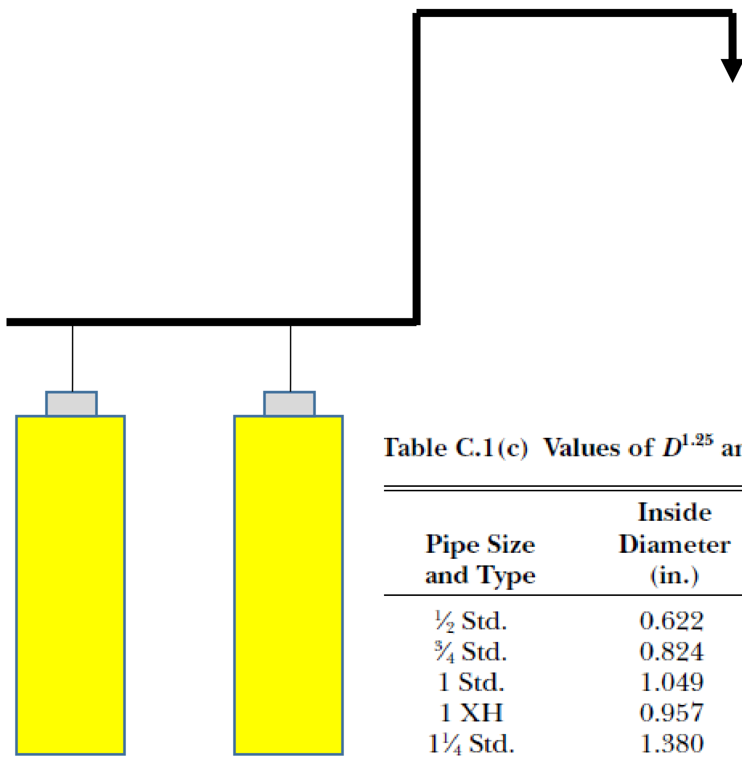


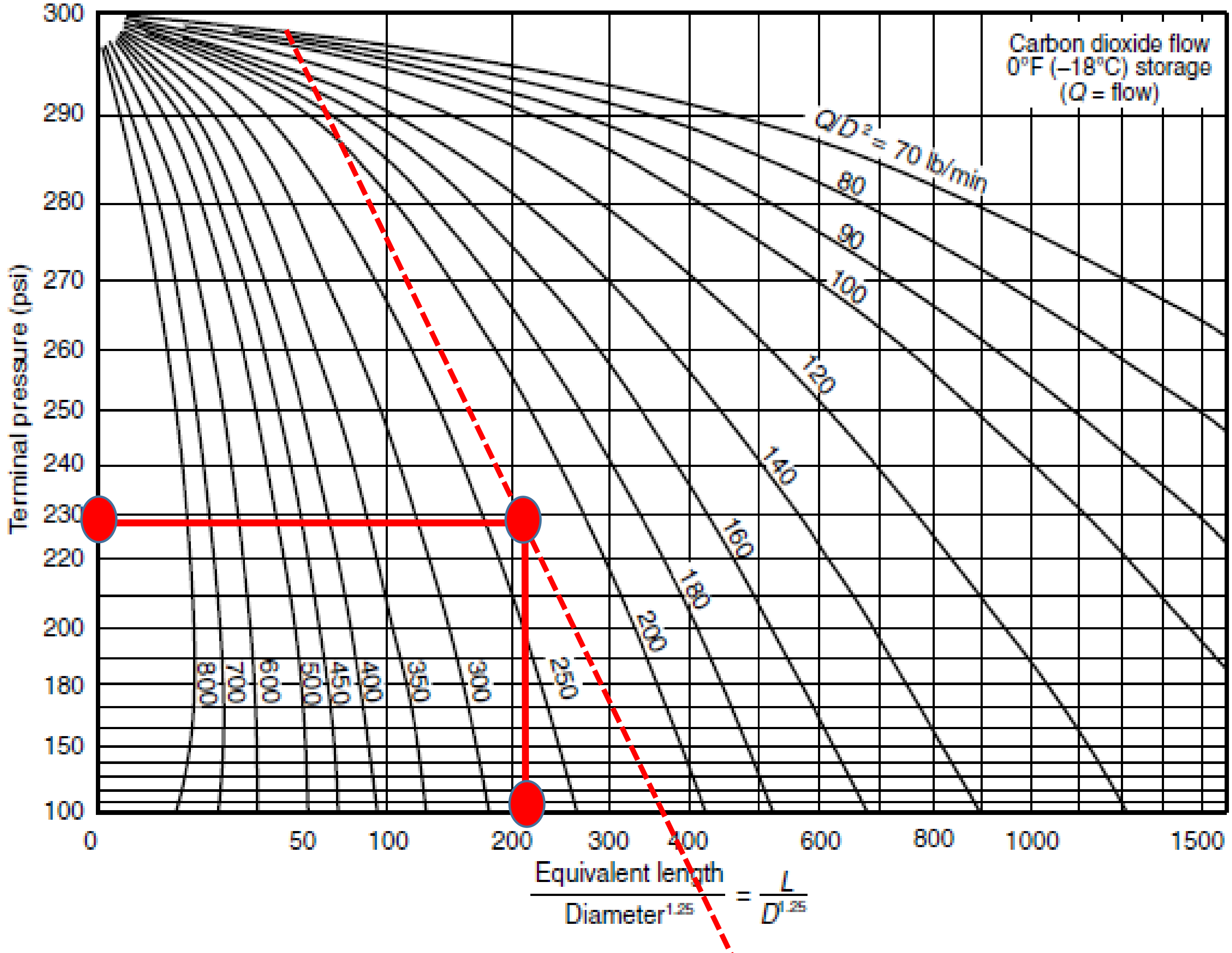
Table C.1(c) Values of $D^{1.25}$ and D^2 for Various Pipe Sizes

Pipe Size and Type	Inside Diameter (in.)	$D^{1.25}$	D^2
½ Std.	0.622	0.5521	0.3869
¾ Std.	0.824	0.785	0.679
1 Std.	1.049	1.0615	1.100
1 XH	0.957	0.9465	0.9158
1¼ Std.	1.380	1.496	1.904
1¼ XH	1.278	1.359	1.633
1½ Std.	1.610	1.813	2.592
1½ XH	1.500	1.660	2.250
2 Std.	2.067	2.475	4.272
2 XH	1.939	2.288	3.760
2½ Std.	2.469	3.09	6.096
2½ XH	2.323	2.865	5.396
3 Std.	3.068	4.06	9.413
3 XH	2.900	3.79	8.410
4 Std.	4.026	5.71	16.21
4 XH	3.826	5.34	14.64
5 Std.	5.047	7.54	25.47
5 XH	4.813	7.14	23.16
6 Std.	6.065	9.50	36.78
6 XH	5.761	8.92	33.19

Take following ratios,

$\frac{Q}{D^2} \frac{1000}{4.28}$ = 234 lb/min.in2

$\frac{L}{D^{1.25}} \frac{500}{2.48}$ = 201 lb/min.in2



Considering single nozzle termination.

And refering to table 4.7.5.2.1 of NFPA 12

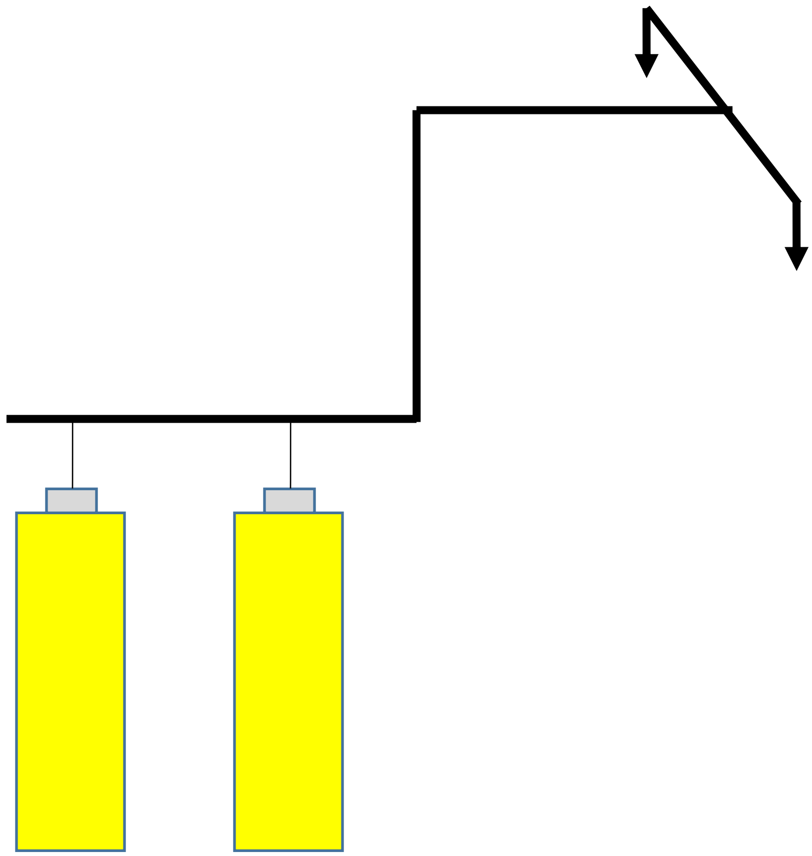
Table 4.7.5.2.1 Discharge Rate per Square Inch of Equivalent Orifice Area for Low-Pressure Storage [300 psi (2068 kPa)]

Orifice Pressure		Discharge Rate	
psi	kPa	lb/min·in.^{2}	kg/min·mm^2
300	2068	4220	2.970
290	1999	2900	2.041
280	1931	2375	1.671
270	1862	2050	1.443
260	1793	1825	1.284
250	1724	1655	1.165
240	1655	1525	1.073
230	1586	1410	0.992
220	1517	1305	0.918
210	1448	1210	0.851
200	1379	1125	0.792
190	1310	1048	0.737
180	1241	977	0.688
170	1172	912	0.642
160	1103	852	0.600
150	1034	795	0.559

Equivalent Orifice area $= \frac{1000}{1410}$ = 0.709 Sq. Inch(Diameter will be 0.95 inch.)

Nozzle Diameter = 0.95 Inch.

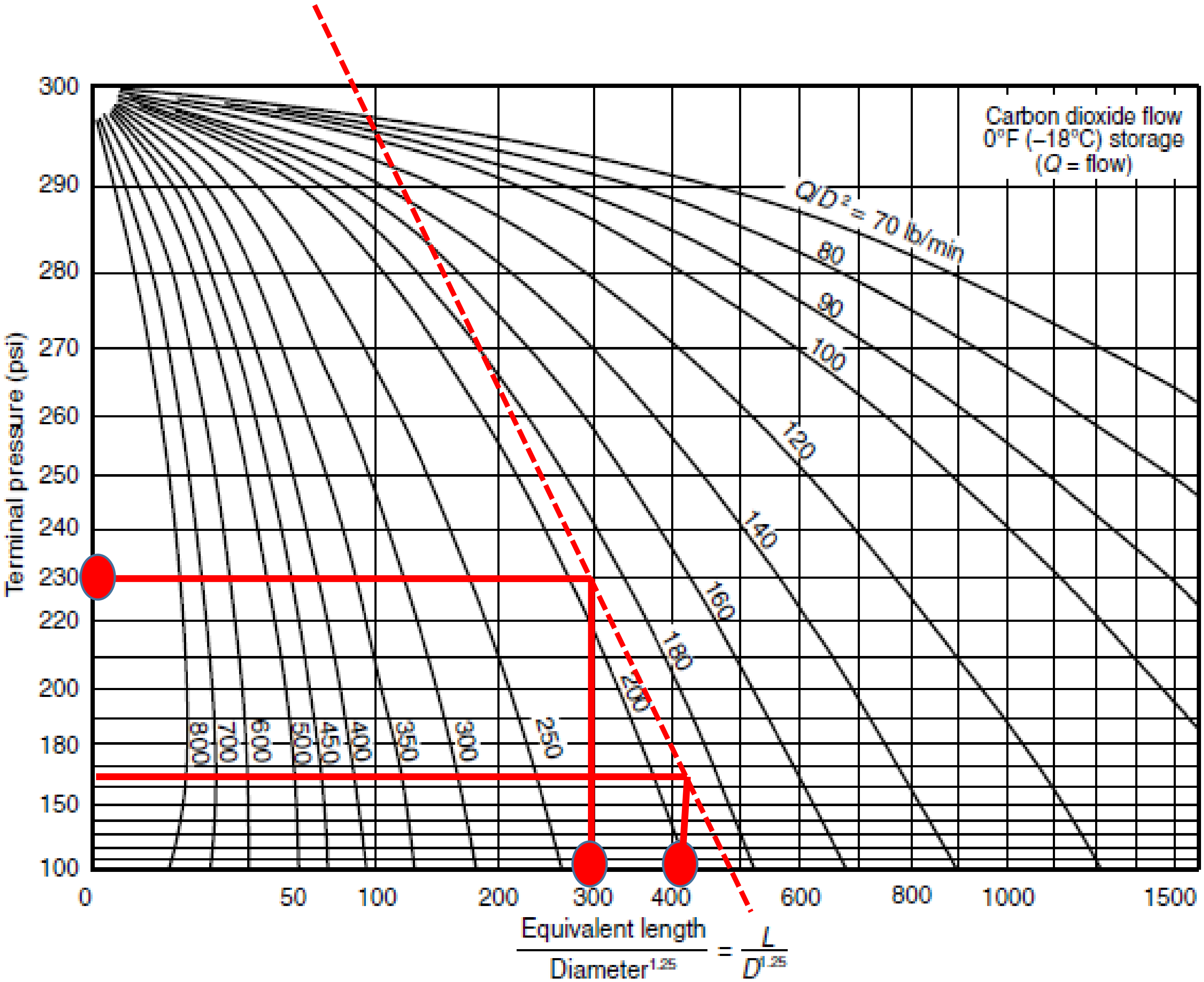
2. Modifying previous example, Determine the Terminal Pressure for a low Pressure System Consisting of the pipeline branched into two smaller pipelines the branch lines are equal and consist of 1-1⁄2 in. Schedule 40 pipe with equivalent lengths of 200 ft (61 m) and that the flow in each branch line is to be 500 lb/min (227 kg/min).



Take following ratios,

$\frac{Q}{D^2} \frac{500}{2.592}$ = 193 lb/min.in2

$\frac{L}{D^{1.25}} \frac{200}{1.813}$ = 110 lb/min.in2



New $\frac{L}{D^{1.25}}$ = 110+300 = 410 ft/Sq. inch.

Terminal Pressure with new equivalent length = 165 psi

Equivalent Orifice area = $\frac{500}{912}$ = 0.5482 Sq. Inch(Diameter will be 0.83 inch.)

Nozzle Diameter = 0.83 inch.