CHAPTER FOUR

CALCULATIONS AND ANALYSIS

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Calculation and Analysis

4.1. Calculation of sprinkler system

4.1.1. Classification of Occupancies

The case of the design is a production workshop, included number of workshop machines, height of occupancies inside the workshop 1.8 m, and combustibility of contents is moderate to high, so the classification of occupancies is ordinary hazard (Gruop2).

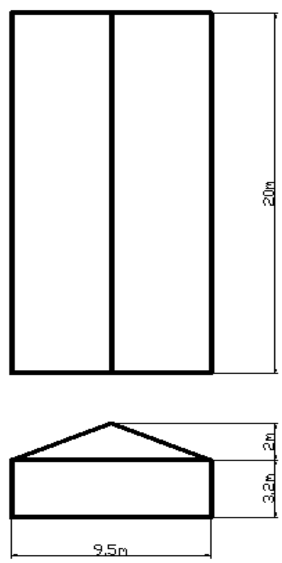


Figure 4-1: Geometric dimension of the workshop

4.1.2. Number of Sprinklers, and Spacing between Sprinklers

No. of Sprinkler = Area / Area coverage per Sprinkler

Area= 9.5*20 = 190 m^2

For ordinary hazard, maximum area coverage per Sprinkler = 12.1 m^2 from table (3-1).

Number of Sprinklers = 190/12.1 ≈ 16

Maximum spacing between sprinkler 15 ft (4.56 m), from table (3.2.a), and the distance from sprinklers to walls shall not exceed one-half of the allowable distance between sprinkler. For these considerations and for distribute the sprinklers to be consentient with the surface area let the number of sprinklers 20.

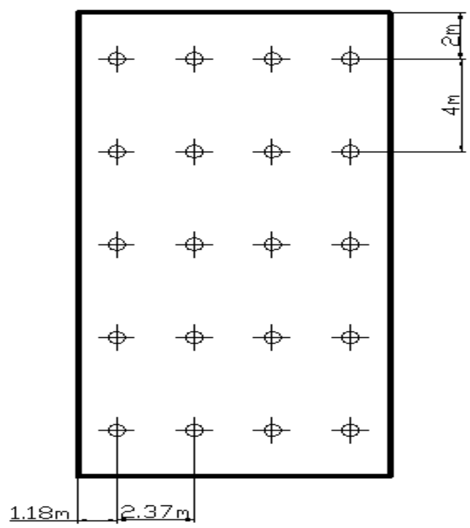


Figure 4-2: Selected Spacing Between Sprinklers

4.1.3. Area Coverage Per Sprinkler (Asp)

$A_{sp} = 4*2.37 = 9.48\ m^2$

Using table (3-2-a), this value is acceptable (Less than maximum spacing 130 ft^2).

4.1.4. Selection of the Sprinklers Network:

Tree network system can be used for this case, the design calculations using this way is not complex.

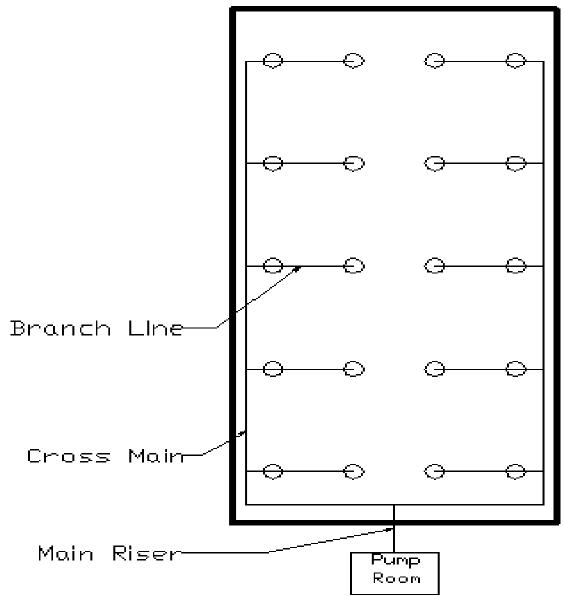


Figure 4-3. Sprinklers Network Using the Tree Network System

4.1.5. Selection of the Pipes Diameters

Ordinary hazard pipe schedule can be used to select the diameters of the pipes depend on the numbers of the sprinklers which the pipe feeds. Using steel pipe, the selected diameters of the pipes can be shown in the figure bellow in accordance with Table (3-5):

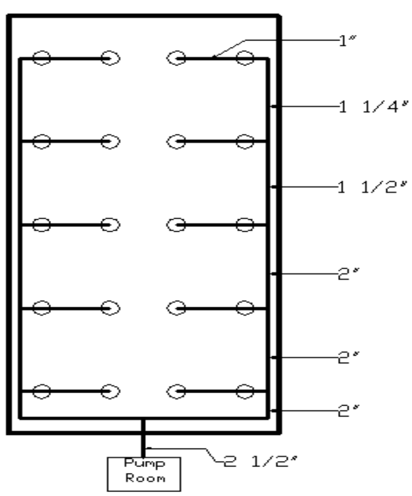


Figure 4-4: Selected Diameters of Pipes

4.1.6. Designing Area

Minimum designing area for ordinary hazard (group2) is 139 m^2 with 0.2 gpm/ft^2 density, as shown in the figure (3-1), these values can be used in this case .

Number of sprinkler in design area = Design area / Area Coverage Per Sprinkler

NO. of sprinklers in design area = 139 / 9.48 = 14.66

To create a rectangular Area, let the number of sprinkler is 16 sprinklers.

4.1.7. Calculation of GPM and Pressure

4.1.7.1. Calculation of discharge at the farther sprinkler head (Qst)

$$Q_{st} = A_{sp} * D_d \text{ ……………………….(4.1)}$$

Wher:

A_{sp} = Area coverage per sprinkler (ft^2).

D_d = Designing density (gpm / ft^2).

A_{sp} = 9.48 m^2 = (9.48 *3.28 *3.28) ft^2

D_d = 0.2 from the chart

Q_{st} = 9.48 * 3.28 * 3.28 *0.2 = 20.39 gpm

4.1.7.2. Calculation of Pressure at the Farther Sprinkler Head (Pst)

$$Q_{st} = k \sqrt{P_{st}} \text{ …………………………. (4.2)}$$

Where:

P_{st} = Pressure at the Farther Sprinkler Head (psi).

k = Nozzle Factor, For standard sprinkler heads the value of nozzle factor is 5.65

$P_{st} = (Q_{st}/k)^2$

$P_{st} = (20.39/5.65)^2 = 13.03$ psi

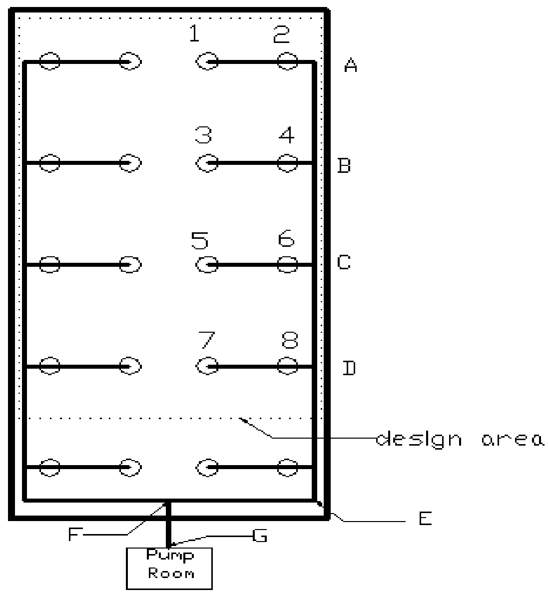


Figure 4-5. Positions of the Sprinklers inside the Design Area

4.1.7.3. Calculation of Pressure and (gpm) at the Sprinkler Head Number (2):

$P_2 = P_{st}$ + Pressure drop between point 1 and point 2 (P_{drop12})

$$P_{drop12} = P * L_{eq12} \text{ ………. } (4.3)$$

Where:

p = friction losses in the pipe (psi/ft), it can be calculated using equation (3.2):

$$p = 4.52\, Q^{1.85} / C^{1.85}\, D^{4.87}$$

Where:

Q = Volumetric flow rate (gpm)

D = Inside diameter of the pipe (inch)

C = The factor of friction losses, for equivalent schedule 40 steel pipe C = 120

$P = 4.52 * (20.39)^{1.85} / (120)1.85 * (1.049)^{4.87} = 0.134$ psi/ft

L_{eq12} = Equivalent length, this value includes the real length of the pipe and the equivalent length of the pieces and the joints throw the pipe, it can be found from the table (3-3).

In the pipe between point 1 and point 2 there are 90 standard elbow, diameter of pipe is 1", let the length between sprinkler and the branch line 1 ft.

L_{equ12} = (real length between 1 and 2) + (the length between sprinkler and the branch line) + (equivalent length of the elbow)

$L_{equ12} = 2.37*3.28 + 1 + 2 = 10.77$ ft

$P_{drop12} = p * L_{equ12} = 0.134 * 10.77 = 1.45$ psi

$P_2 = P_1 + P_{drop12} = 13.03 + 1.45 = 14.48$ psi

$Q_2 = 5.65 * \sqrt{P_2} = 5.65 * \sqrt{14.48} = 21.5$ gpm

4.1.7.4. Calculation of Pressure and (gpm) at point A

$Q_A = Q_1 + Q_2 = 20.39 + 21.5 = 41.89$ gpm

L_{eq2A} = (real length between 2 and A) + 2 (90^0 long turn elbow with 1 pipe diameter)

$L_{eq2A} = 1*3.28 + 2 = 5.28$ ft

$P_{2A} = (4.52*Q^{1.85})/(C^{1.85}*d^{4.87})$

$P_{2A} = (4.52*41.89^{1.85})/(120^{1.85} * 1.049^{4.87}) = 0.51$ psi

$P_{drop2A} = P_{2A} * Lequ_{2A} = 0.51 * 5.28 = 2.69$ psi

$P_A = P_{drop2A} + P_2 = 2.69 + 14.48 = 17.17$ psi

4.1.7.5. Calculation of Pressure and (gpm) at point B

$P_B = P_A + P_{dropAB}$

$P_{dropAB} = P_{AB} * L_{equAB}$

L_{equAB} = Length between A and B = 4*3.28 = 13.12 ft

$P_{AB} = (4.52*41.89^{1.85})/(120^{1.85} * 1.38^{4.87}) = 0.134$ psi/ft

$P_{dropAB} = P_{AB} * L_{equAB} = 0.134 * 13.12 = 1.76$ psi

$P_B = P_{dropAB} + P_A = 1.76 + 17.17 = 18.93$ psi

In the same way $Q_B = Q_C = Q_D = Q_A$ because branch lines are similar, but friction losses between these points must be consider, so gpm at these points can be calculate using following equation:

$$Q_{New} = Q * \sqrt{(P_{New} / P)} \quad \ldots\ldots\ldots\ldots (4.4)$$

$Q_B = 41.89 * \sqrt{(18.93 / 17.17)} = 43.98$ gpm

4.1.7.6. Calculation of Pressure and (gpm) at point C

$Q_{BC} = Q_B + Q_A = 43.98 + 41.89 = 85.87$ gpm

At Qc = 41.89 gpm and Pc = 17.17 psi

$P_{dropBC} = P_{BC} * L_{equBC}$

$P_{BC} = (4.52*85.87^{1.85})/(120^{1.85} * 1.61^{4.87}) = 0.24$ psi/ft

L_{equBC} = Length between C and B = 4*3.28 = 13.12 ft

P_{dropBC} = 0.24 * 13.12 = 3.14 psi

$P_C = P_B + P_{dropBC}$ = 18.93 + 3.14 = 22.07 psi

$Q_C = 41.89 * \sqrt{(22.07 / 17.17)} = 47.5$ gpm

4.1.7.7. Calculation of Pressure and (gpm) at point D

$Q_{CD} = Q_C + Q_{BC}$ = 47.5 + 85.87 = 133.36 gpm

$P_{dropCD} = P_{CD} * L_{equCD}$

$P_{CD} = (4.52*133.36^{1.85})/(120^{1.85} * 2.067^{4.87}) = 0.16$ psi/ft

L_{equCD} = Length between C and D = 4*3.28 = 13.12 ft

P_{dropCD} = 0.16 * 13.12 = 2.1 psi

$P_D = P_C + P_{dropCD}$ = 22.07 + 2.1 = 24.17 psi

$Q_D = 41.89 * \sqrt{(24.17 / 17.17)} = 49.7$ gpm

Total GPM at the right side of design area = $Q_D + Q_{CD}$

$Q_{total\ RIGHT} = Q_D + Q_{CD}$ = 49.7 + 133.36 = 183.06 gpm

Total GPM = $Q_{total\ RIGHT}$ * 2 = 183.06 * 2 = 366.12 gpm

4.1.7.8. Calculation of Pressure at point E

L_{eqDE} = 5*3.28 + 3 (from the table , 90^0 long turn elbow and 2" tube) = 19.4 ft

$P_{dropDE} = P_{DE} * L_{eqDE}$

$P_{DE} = (4.52*183.06^{1.85})/(120^{1.85} * 2.067^{4.87}) = 0.29$ psi/ft

P_{dropDE} = 0.29 * 19.4 = 5.63 psi

$P_E = P_D + P_{dropDE} = 24.17 + 5.63 = 29.8$ psi

4.1.7.9. Calculation of Pressure at point F

$P_F = P_E + P_{dropEF}$

$L_{eqEF} = 4.555 * 3.28 + 10$ (Tee flow turned 90^0 and 2" tube)

$L_{eqEF} = 24.94$ ft

$P_{EF} = (4.52*183.06^{1.85})/(120^{1.85} * 2.067^{4.87}) = 0.29$ psi/ft

$P_{dropEF} = 0.29 * 24.94 = 7.23$ psi

This value is not acceptable, P_{drop} must be less than 7 psi. So pipe diameter can be change to be 2.5".

$P_{EF} = (4.52*183.06^{1.85})/(120^{1.85} * 2.469^{4.87}) = 0.12$psi/ft

$L_{eqEF} = 4.555 * 3.28 + 12$ (Tee flow turned 90^0 and 2.5" tube)

$L_{eqEF} = 26.94$ ft

$P_{dropEF} = 0.12 * 26.94 = 3.26$ psi (acceptable value)

$P_F = P_E + P_{dropEF} = 29.8 + 3.26 = 33.06$ psi

4.1.7.10. Calculation of Pressure at point G

$P_G = P_F + P_{dropFG} + P_{elevation}$

Pressure Drop by Elevation = H / 10.28

Where: H is the head (meter)

$P_{elevation} = H / 10.28 = 3.2 / 10.28 = 0.31$ bar

$P_{elevation} = 0.31 * 14.5 = 4.5$ psi

$P_{FG} = (4.52*366.12^{1.85})/(120^{1.85} * 2.469^{4.87}) = 0.44$ psi/ft

The pipe from the out let of the pump (point G) to the point F include; one 90^0 standard elbow, and one butter fly valve, with 2.5" pipe diameter.

Real length between F and G = 3.2m + 2m (length of the main riser)

Real length between F and G = (3.2 + 2) * 3.28 = 17.06 ft

L_{eqFG} = 17.06 + 6 +7 = 30.06 ft

$P_{dropFG} = P_{FG} * L_{eqFG}$ = 0.44 * 30.06 = 13.23 psi (not acceptable)

Using 3" pipe diameter:

$P_{FG} = (4.52*366.12^{1.85})/ (120^{1.85} * 3.068^{4.87}) = 0.15$ psi/ft

L_{eqFG} = 17.06 + 7 + 10 = 34.06 ft

P_{dropFG} = 0.15 * 34.06 = 5.12 psi (acceptable value)

$P_G = P_F + P_{dropFG} + P_{elevation}$ = 33.06 + 5.12 + 4.5 = 42.67 psi

P_{pump} = 42.67 / 14.5 = 2.9 bar

Q_{pump} = 366.12 * 3.78 = 1383.9 L/min

New values of diameters after the design can be shown in the following figure:

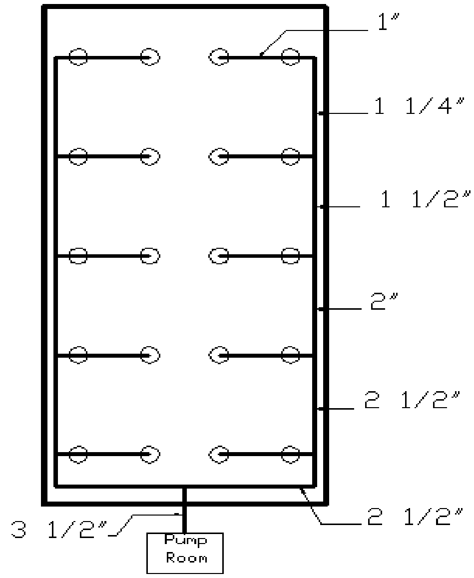


Figure 4-6. Designed Diameters of Pipes

4.1.8. Tank Capacity

For ordinary hazard time of flow is 60 min

Tank Capacity = Qpump * time of flow

Tank Capacity = 1383.9 * 60 = 83034 L

4.1.9. Simulation

Using the program of Elite for Firefighting Calculation; general project data, edit pipe data and edit pipe node data can be entered to the program as shown in figures below

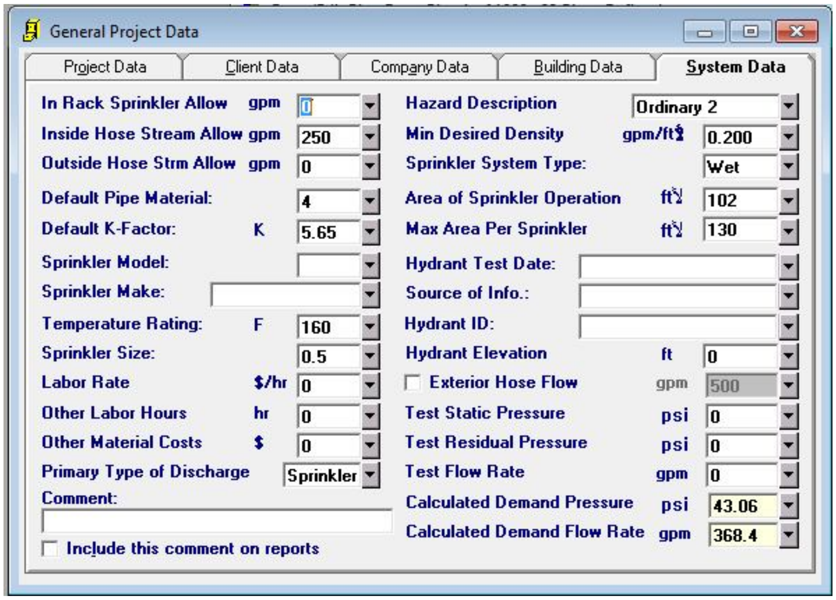


Figure 4-7: General Project Data

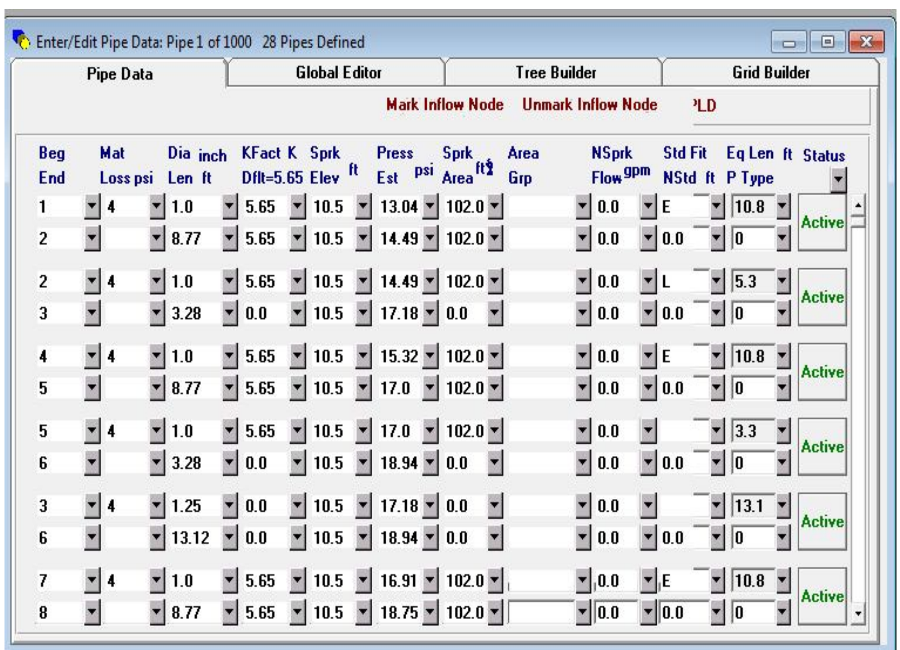
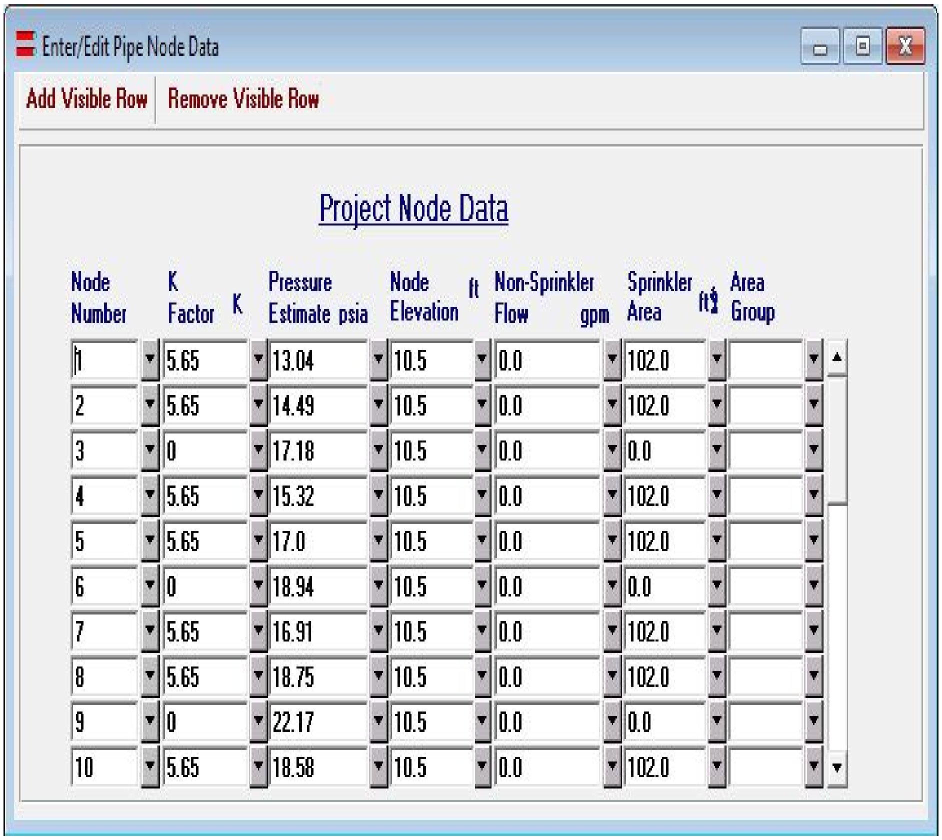


Figure 4-8. Edit Pipe Data


Enter/Edit Pipe Node Data

Add Visible Row | Remove Visible Row

Project Node Data

Node Number	K Factor K	Pressure Estimate psia	Node Elevation ft	Non-Sprinkler Flow gpm	Sprinkler Area ft²	Area Group
1	5.65	13.04	10.5	0.0	102.0	
2	5.65	14.49	10.5	0.0	102.0	
3	0	17.18	10.5	0.0	0.0	
4	5.65	15.32	10.5	0.0	102.0	
5	5.65	17.0	10.5	0.0	102.0	
6	0	18.94	10.5	0.0	0.0	
7	5.65	16.91	10.5	0.0	102.0	
8	5.65	18.75	10.5	0.0	102.0	
9	0	22.17	10.5	0.0	0.0	
10	5.65	18.58	10.5	0.0	102.0	

Figure 4-9: Edit Pipe Node Data

4.1.9.1 Simulation Results

Using Elite software application that demonstrates NFPA13 system design simulation, the software results is shown in figure (4-10).

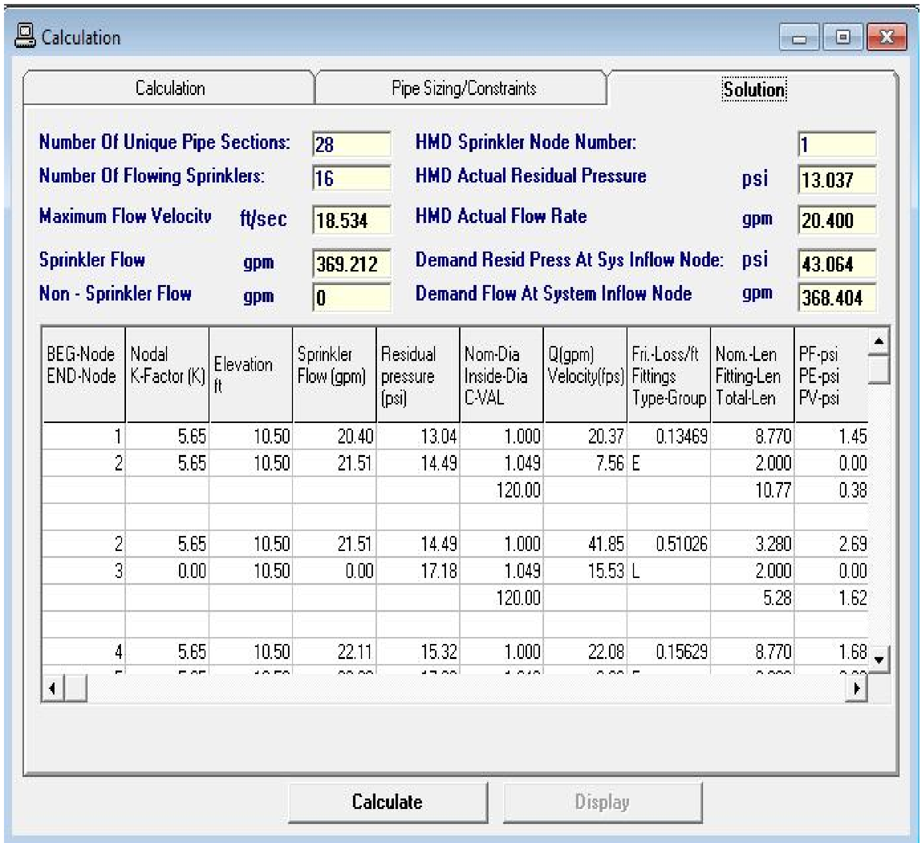


Figure 4-10: Simulation Results of Elite Program

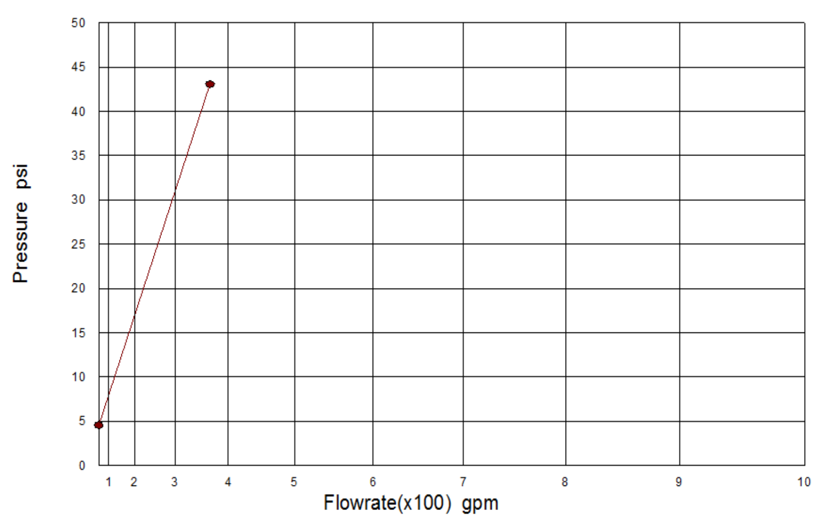


Figure 4-11. Demand Graph of the Hydraulic Supply

The results contains:

• Actual residual pressure at the farther sprinkler is 13.04 psi

• Actual flow rate at the farther sprinkler is 20.4 gpm

• Demand reside pressure at the pump is 43.06 psi

• Demand flow rate at the pump is 368.4 gpm

4.1.10. Discussion

From the analytical results and the simulation results table (4-1) shows that there are few different between the results in the two ways of calculation for differed fuzziness in each way.

Table 4-1 Comparing between Analytical Results and Simulation Results

The requirements	Analytical Results	Simulation Results
Number of Sprinklers	20 sprinklers	20 sprinklers
Distance between sprinklers	L = 4m & S = 2 37m	L = 4m & S= 2 37m
GPM	366.12 gpm	368.4 gpm
Pressure Required	42.67 psi	43.06 psi
Water Tank size	21967.2 g	22104 g

4.2. Calculations of FM-200 Agent System

4.2.1. Classification of Occupancies

The case of the design is an Electronic Lap, included number of educational electronic devices, class A hazard, room size is 4m wd x 8m lg x 4m high with one access door.

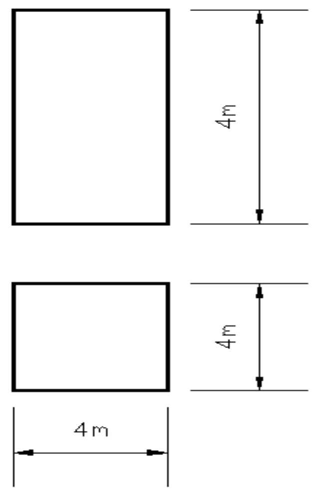


Figure 4-12: Geometric Dimension of the Lap

4.2.2. Simulation

For this case, using the simulation program of plumbing and firefighting calculations as shown in figure (4-13). The input requirements can be shown in Table (4-2).

Table 4-2 Input Parameter

Input Parameter	Value
surface area	32 m^2
height	4m
ambient temperature	22 ^0C

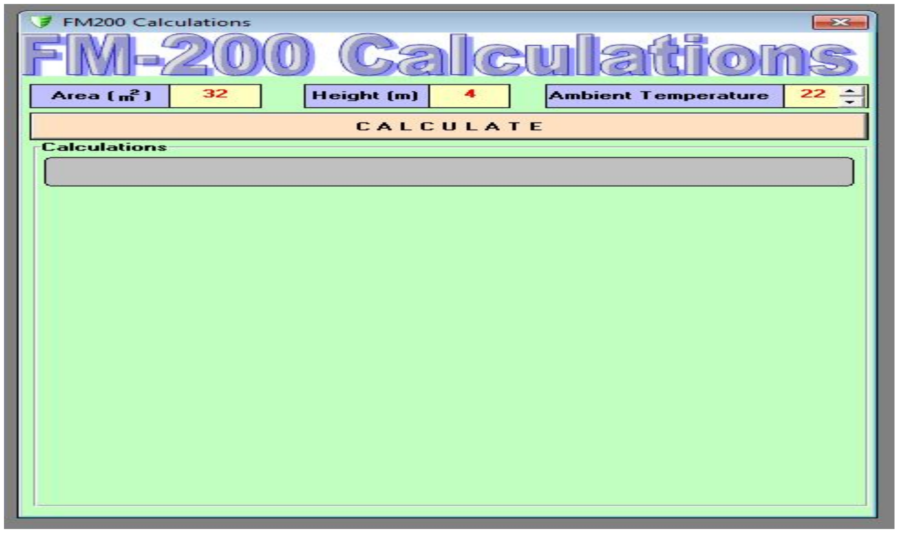


Figure 4-13: Calculation Program of Plumbing and Firefighting Calculations for Fm-200 Agent

4.2.3 Simulation Results

The results of the simulation is shown in figure (4-14), when the simulation program of plumbing and firefighting calculations used. Let the number of nozzles 4.

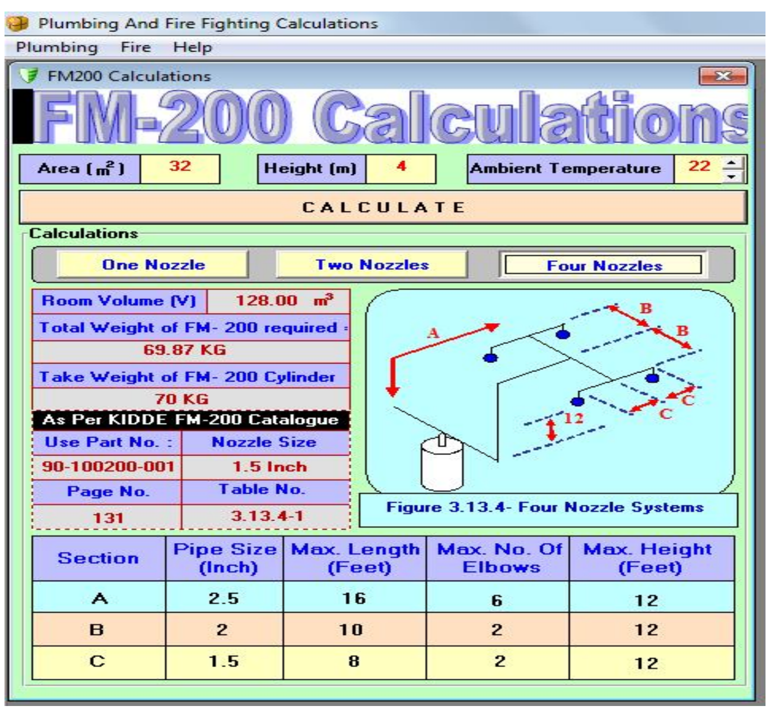


Fig 4-14: The Calculation Results for Fm-200 System

The program shows that

• Room volume is 128 m^2.

• Total weight of Fm-200 required is 69.87 kg.

• One Fm-200 cylinder of 70 kg weight can be used.

• Nozzle size is 1.5 inch.

4.2.4. Designed Dimensions of the Network

Using AutoCAD with the considerations of the figure (4-14), the designed dimensions of the Fm-200 Network for this case is shown in figure (4-15).

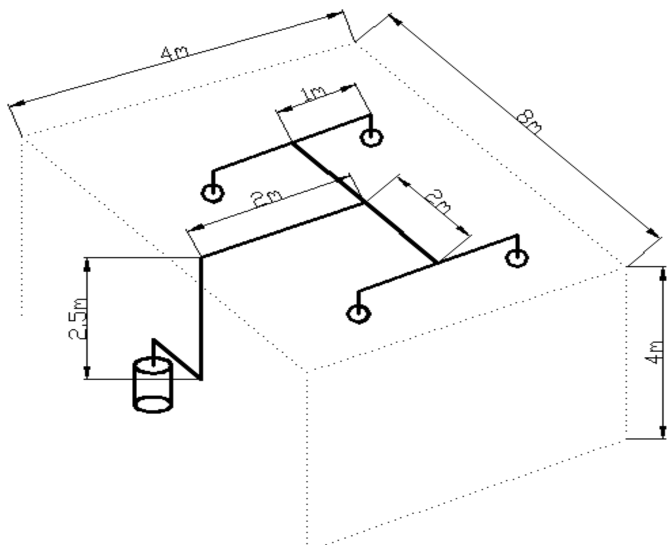


Figure 4-15: Designed Fm-200 Network of the Case

4.3. Calculations of CO_2 Agent System

4.3.1. Classification of Occupancies

The same case of the design that used for Fm-200 system can be used to compare between the two systems, an Electronic Lap, included number of educational electronic devices, room size is 4m wd x 8m lg x 4m high with one access door as shown in figure (4-12).

4.3.2. System Design

4.3.2.1. Simulation

For this case, the surface area is 32 m^2, height is 4m, ambient temperature is 22 ^0C, using the simulation program of plumbing and firefighting calculations as shown in figure (4-16).

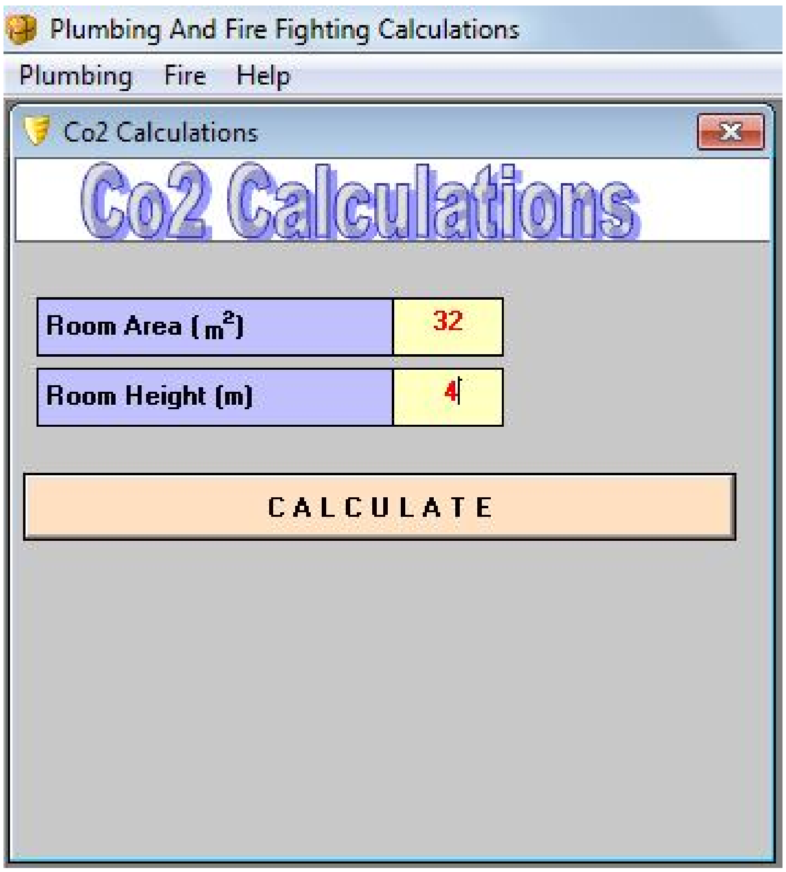


Figure 4-16: Calculation Program of Plumbing and Firefighting Calculations for CO2 Agent

4.3.2.2. Simulation Results

The results of the calculation is shown in figure (4-17), when the simulation program of plumbing and firefighting calculations used.

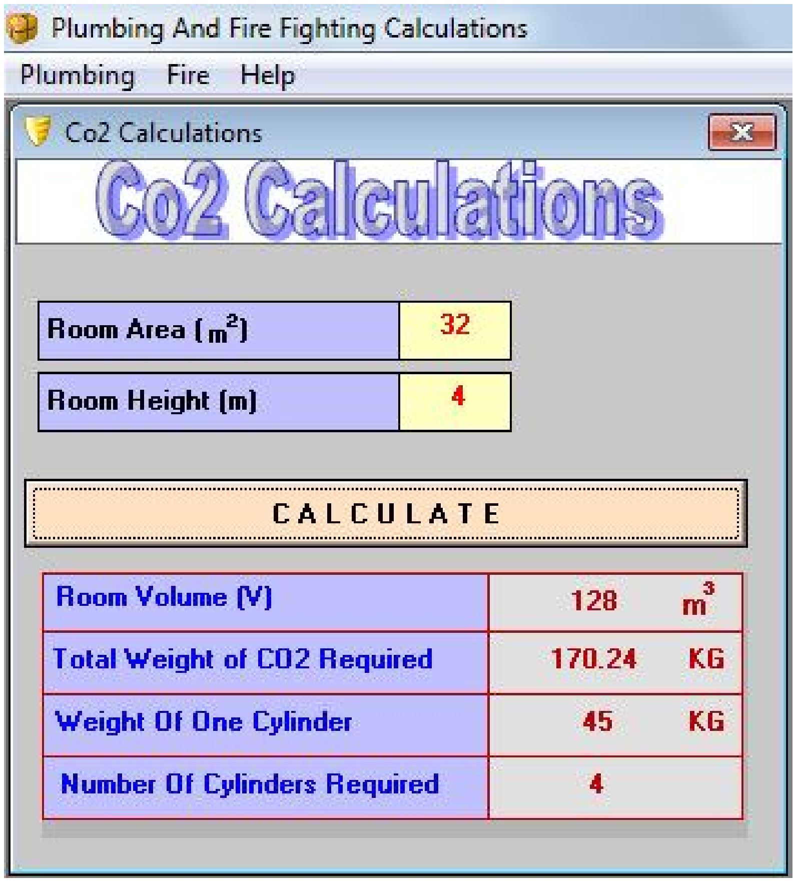


Fig 4-17: The Calculation Results for CO_2 System

The program shows that

- Room volume is 128 m^2.
- Total weight of CO_2 required is 170.24 kg.
- Weight of one cylinder is 45 kg.
- Number of cylinders required is 4 cylinders.

4.4. The results Analysis

The results of Fm-200 system and CO2 system shows that the similar case of 128m^3 room volume needs 69.87 kg of Fm-200 agent or 170.24 kg of CO2 agent. The average price of Fm-200 is 100 dollars per kg, and the average price of CO2 is 5 dollars per kg, that means for the same case of design, unit volume required of CO2 system is larger about two times more than Fm-200 system, and Fm-200 system is expensive about 20 times more than CO2 system.