Fire Load Density and Fire Adequacy – An Important Tool for Firefighting

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Abstract: *In recent years, occurrences of industrial fire have become a more common incident which attracts highpoints the need of fire adequacy of the company for mitigation of fire. The present study investigates the Fire Load, Fire Load Density of "XYZ Industry Private Limited", Sanand (Gujarat) to check the Fire adequacy as per Gujarat Factories Rules 1963. As per the GFR 1963, Rule 66-A (2), in every factory adequate provision of water-supply for firefighting shall be made and where the amount of water required in Liters per minute is 550 Liters/min. In present study, the total combustible materials with their calorific values were considered to calculate the total fire load. Fire load density, then calculated by using the floor area in m^2. The fire hydrant data was considered for the fire adequacy. The total fire load density was 1190.25 MJ/m^3 (284354.24 kcal/m^2). As per standards, the calculated fire load density is more than 275000kcal/ m^2, hence it is concluded that the mentioned industries having "Moderate Fire Load". The use of wooden and plastic pallets, polythene bags, and carton material can be reduced to reduce the fire load density of the plant. Regarding the fire adequacy, the water requirement for firefighting was 646 KL (approximately) and the industry having the dedicate water storage of 700 KL used for firefighting. It concluded that the industry having sufficient amount of water for firefighting as per Gujarat Factories Rules, 1963.*

Key Words: *Fire load, Fire density, Fire adequacy, Moderate fire, firefighting.*

1. INTRODUCTION

A procedure in which materials combine chemically with oxygen from the air and typically give out bright light, heat, and smoke is known as fire. Fire is the major hazard which may occur in chemical, textile, automobile and oil industry. Due to fire hazard, such industries loss the productivity in terms of property damage, damage to materials and sometime loss of human life also. Oxygen, heat, and fuel are frequently referred to as the "fire triangle", while when chain reaction of chemical is added, it is "fire tetrahedron." To extinguish the fire just take any one thing away and fire will extinguish automatically.

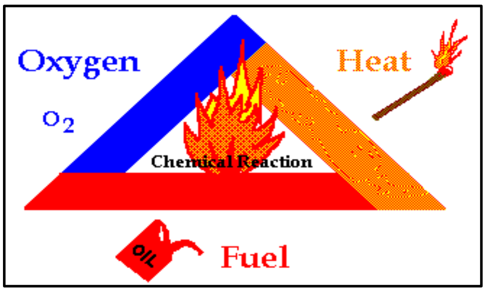

Image1: Ideal Image of Fire Triangle

The measurement of fire load of a building, section or any specific area is a method of establishing the potential severity of an imaginary future fire. It is the heat output per unit floor area, often in KJ /m2, calculated from the calorific value of the materials present. Fire load and fire load density is used for assessing industrial risk of fire safety. An empty room with cement floor and ceiling, cinderblock walls, and no flammable materials would have approximately zero fire loading; any fire entering such a room from elsewhere will find nothing to feed on. Though, nearly anything that makes a room convenient (such as wooden furniture, electrical appliances, or computer equipment etc.), or attractive (such as wood panelling, acoustic tile, carpeting, curtains, or wall decorations), will increase the fire load of that area. Some usages inherently carry high fire loading as a side effect (an art gallery and studio, for example, is likely to contain large amounts of canvas, paints, solvents, and wooden framing). The area or buildings under construction or renovation tend to carry high fire loads as they have combustible and flammable materials like construction materials, solvents, and fuel for generators. It is customary to divide the fire load into two categories: moveable fire load (also termed as content fire load) and fixed fire load (also termed as non-movable fire load or permanent fire load). Fire load density is defined as the fire load be an average by characteristic area of the section or compartment.

1.1. STUDY AREA:

The present study conducted at "XYZ Industry Private Limited", Sanand (Gujarat). To maintained the confidentiality, author used "XYZ" instead of real name. The investigated industry falls in "Moderate Hazard" as per Gujarat State Factories Rule, 1963. As per information given by the industry, they having the Fire Hydrant System with Fire Pump House. Three pumps namely, Electrical driven pump (Capacity - 171 m3/hr), Diesel operated pump (Capacity - 137 m3/hr), and Jockey pump (Capacity – 10.8 m3/hr) are maintained in working condition to tackle the fire emergency.

2. METHODOLOGY:

Estimation of combustible material of a building can be determined by three methods.

- Direct measurement of mass, with conversion based on the net heat of combustion
- Direct measurement of volume (with conversion based on a combination of density and net heat of combustion)
- Energy release measurement by calorimetry of an item sufficiently

The amount of heat liberated from a combustible material per square meter in floor area is known as Fire Load Density. The mass of the material is calculated in kg. The calculated mass is multiplied by its calorific value in MJ/kg to get fire load. The calculated value is then divided by area of the floor to give fire load density. The formulae of Fire Load are given below:

$$qc = \sum Hv\ mv / Af$$

Where,
qc = Fire Load density in MJ/m^2
mv = Total mass of the combustible material in kg
Hv = Calorific value of the combustible material in MJ/kg [3]
Af = Area of floor in m^2

The common combustible material used in the all areas with their calorific value is shown by Table – 1.

Sr. No.	Combustible Materials	Calorific value in MJ/kg
1	Chair (wood)	17.5
2	Chair (Plastic)	25.0
3	Table (wood)	18.6
4	Polythene Bags (Big)	17.5
5	Cardboard box (Carton)	16.9
6	Paper (average)	16.3
7	Cushion foam	40
8	Rubber	27.5
9	Pallets (Wood)	18.6
10	Pallets (Plastic)	25.0

Table – 1: Calorific Values of Combustible Material

3. RESULT & DISCUSSION:

3.1. FIRE LOAD CALCULATION:

Based upon the collected data regarding the combustible material available in different sections of the industry, their calorific value, dimension of each section, fire load was calculated using the standard formula. The details are mention in Table – 2.

Sr. No.	Combustible Materials	Calorific Value (MJ/Kg)	Mass (M-Kg)	Energy Contained (E-MJ)	Floor Area Af2 (m2)	Fire Load Density (MJ/ m^3)
1	Chair (wood)	17.5	4150	72625	560.39	129.60
2	Chair (Plastic)	25.0	3490	87250	560.39	155.70
3	Table/Cupboards (wood)	18.6	6485	120621	560.39	215.24
4	Polythene Bags (Big)	17.5	980	17150	560.39	30.60
5	Cardboard box (Carton)	16.9	3500	59150	560.39	105.55

6	Paper (average)	16.3	1750	28525	560.39	50.90
7	Cushion foam	40	850	34000	560.39	60.67
8	Rubber Items	27.5	550	15125	560.39	26.99
9	Pallets (Wood)	18.6	5850	108810	560.39	194.17
10	Pallets (Hard Plastic)	25.0	4950	123750	560.39	220.83
Total Fire Load Density (MJ/ m3)						**1190.25**

Table – 2: Calculation of Fire Load Density

As per Fire load calculated in Table – 2, highest fire load was contributed by Pallets (Hard Plastic) (220.83 MJ/m^3) followed by Tables (Wood) (215.24 MJ/m^3) and the lower fire load was recorded for Rubber Items (26.99 MJ/m^3) followed by Polythene Bags (Big) (30.60 MJ/m^3). The bags of raw material were placed on wooden pallets showing 194.17 MJ/m^3 fire load density. Cartoon boxes were used for packing the products which contributes the 105.55 MJ/m^3 fire load density. The fire load density shown by Plastic and wooden Chairs was 155.70 MJ/m^{3}and 129.60 MJ/m^3 respectively. The total fire load density was 1190.25 MJ/m^3 (284354.24 kcal/m^2).

3.2. Fire Adequacy:

As per Gujarat Factories Rules 1963, Rule 66-A (2), in every factory adequate provision of water-supply for firefighting shall be made and where the amount of water required in Ltrs per minute is 550 Liters/min or more as calculated from the formula mentioned below, power-driven trailer pumps of adequate capacity shall be provided and maintained:

Water required in Liters per minute = (A + B + C + D)/ 20

In the above formula –

A = the total area in square meters of all floors including galleries in all buildings of the factory;

B = the total area in square meters of all floors and galleries including open spaces in which combustible materials are handled or stored;

C = the total area in square meters of all floors over 15 meters above ground level and

D = the total area in square meters of all floors of buildings other than those of fire resisting construction provided fire-resisting constructions of various floors is so certified by any Fire Association or Fire Insurance Company

As per rule 66 (A) (11) Water-supply shall be provided to give flow of water as required under sub-rule (e) for at least 100 minutes. At least 50 percent of this water-supply or 4,50,000 Ltrs whichever is less shall be in the form of static tanks of adequate capacities (not less than 45,000 Ltrs each) distributed round the factory with due regard to the potential fire risks in the factory. (Where piped supply is provided, the size of the Hydrant main shall not be less than 15 cm. diameter and it shall be capable of supplying minimum of 4,500 Ltrs per minute at a pressure of not less than 7 kg/sq.cm.

Provided also that where the factory is situated at not more than 3 kilometers from an established city or town fire service, the pumping capacity based on the amount of water arrived at by the formula above may be reduced by 25% but no account shall be taken of this reduction in calculating water supply required under clause(a).

The section wise dimension of the plant is tabulated in Table – 3.

Sr. No.	Name of the Area	A (m^2)	B (m^2)	C (m^2)	D (m^2)
1	RM Section	50.80	0.00	50.80	50.80
2	Store	47.11	0.00	47.11	47.11
3	Office Staff Area	181.74	0.00	181.74	181.74
4	Pantry	4.22	0.00	0.00	4.22
5	Manager Cabin	12.47	0.00	12.47	12.47
6	Meeting Room	12.47	0.00	12.47	12.47
7	Directors Cabin	20.82	0.00	20.82	20.82
8	FG Section	50.80	0.00	50.80	50.80
9	QC Cabin	12.47	0.00	12.47	12.47
10	Security Section	13.08	0.00	0.00	13.08

11	Molding Section	13.08	0.00	13.08	13.08
12	Manufacture Area - I	47.11	0.00	47.11	47.11
13	Manufacture Area - I	47.11	0.00	47.11	47.11
14	Manufacture Area - I	47.11	0.00	47.11	47.11
15	Production Area	1591.49	0.00	1591.49	1591.49
Total		**2151.88**	**0.00**	**2147.66**	**2151.88**

Table – 3: Area in m^2 to check the fire adequacy

Water Required for firefighting in Litre/min= (A+B+C+D)/20
= (2151.88 + 0.00 + 2147.66 + 2151.88)/20
= 6451.42 Litre/min

Water requirement is more than 550 LPM, therefore power-driven trailer pump is required and Fire Water Storage is required for 100 min firefighting.

Fire water required for 100-minute firefighting = 6451.42 X100 Litres = 6,45,142 Litres (646 KL Approx.)

The XYZ Industry having two water storage tanks dedicated for fire. The capacity of the tank is 400 KL and 300 KL respectively. Existing fire water capacity is more than the requirement 400 KL + 300 KL= 700 KL.

Fire Water Flow rate required = (6451.42 X 60) Litres/Hr. = 387085.2 s2 Litres/Hr.= 39 m3/hr. (Approx.)

171 and 137 m3/hr electrically Operated Pump shall be considered for fire pump house which will be capable to give the desired water flow rate as per above calculation. Existing fire pump capacity is enough to give required flow of water.

4. CONCLUSION:

Fire load density and Fire Adequacy is analyzed in a XYZ Industries Private Limited, Sanand and the study gives following conclusion:

The total fire load density was 1190.25 MJ/m^3 (284354.24 kcal/m^2). As per standards, the calculated fire load density is more than 275000kcal/ m^2, hence it is concluded that the mentioned industries having "Moderate Fire Load". The use of wooden and plastic pallets, polythene bags, and carton material can be reduced to reduce the fire load density of the plant. Regarding the fire adequacy, the water requirement for firefighting was 646 KL (approximately) and the industry having the dedicate water storage of 700 KL used for firefighting. It concluded that the industry having sufficient amount of water for firefighting. According to Gujarat Factories Rules, 1963, the present industry adequate for 100-minute firefighting as per the fire load calculation. The study also suggested that, incorporate the sprinkler in manufacturing unit area as per NBC guidelines to tackle the fire emergency. The substantial barrier (either Irons or bricks) must be provided to each section to avoid the spread of fire.

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