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FIRE LOAD OCCUPANCY OF VARIOUS ZONES IN AN PHARMACEUTICAL INDUSTRY

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Abstract – Considering the highly flammable and toxic substances, which are stored and used in the various processes for the manufacturing of the finished good in the pharmaceutical industry, it is necessary to know the quantity of flammable/combustible materials stored in the chemical factory. In order to ascertain the fire load, we have found the calorific value for each of the flammable/combustible substance. The quantification is based on the lowest and highest quantity of flammable/combustible material found in the factory premises. By using the combination method, we have calculated the fire load, so that we can know the lowest and highest fire load during the study period. Further in order to know the criticality, we have classified in to various hazardous occupancy zones in the factory. These zones, which represents various criticality levels of the fire load. The occupancy of the fire load has been categorized in to low/medium and high hazardous occupancy zones.

Key words. Flammable/combustible substance, Fire load, Low/medium/high level hazardous occupancy zones and critical hazardous zones

1. Introduction

The scientific calculations with the available tools, which includes both computer-based approach and the various experiments, which are used to demonstrate the performance-based fire load calculation. The various formulas, which are used in the calculations, which play a vital role in knowing the potential of the fire load for the various flammable/combustible substances, which are stored and used in the various zones of the chemical factory. All the fire load, which have been calculated, shall represent fires that may occur in the various zones considering the amount flammable/combatable materials stored during the study, which mainly depends on the area and quantity of the flammable/combustible materials stored in the chemical factory in their allocated zones. Although it varies in the day today activities, which are carried out based on the market demand received though a global network. Care has been taken to know its quantification, distribution of flammable/hazardous substances in each zone of the space, where the flammable/combustible materials are used for the production and other activities. It is necessary to identify the calorific values of the flammable/combustible substances, which are stored in the various occupancy of the building/factory premises, so that the criticality for catching the fire can be identified [1-3].

The quantity of flammable/combustible materials, which are used in the chemical factory are quantified into various zones. These zones are further calculated based on the calorific value of substance. Finally, which are expressed in the form of fire load Kcal / m^2. Both the movable and fixed flammable/combustible substances have been considered, while calculating the fire load [4]. Kumar and Rao [5] reported that fire load of the residential building in the Kanpur, India have calculated for the fixed and transient loads, where floor areas of the rooms have been taken into considering where the fire loads varied from 278 to 852 MJ/m^2. Mahdinia et al. [6] have identified that the risk levels of the fire load are high in the 12 sections of the Qom hospital, which is located at Iran. Similarly, fire load in the hydrogen manufacturing plant, it was found that the risk of all sections of the units are in the unacceptable level [7]. The flammable/combustible material types, quantity will be different in the different zones. It is depending upon the occupancy type or the activity, which has been carried out in their respective zones. The types of fire and their intensity of heat will depend on the flammable/ combustible substance storage capacity in the various zones of the hazardous occupancy area. The components of the fire such as fuel, oxygen and heat will interact with each other in equal proportion to catch fire. The fire flame will burn all the substances, which are kept inside of the building/factory in their respective zones. The fire flame depends up on the few factors, which are in their respective zones [8]. These factors, which are responsible for the severity of the fire load (low/medium/high occupancy) [5,9]. The duration of fire occurrence mainly depends on the flammable material and number of zones or the enclosures, which are present in premises of the chemical factory [10]. It will result in the energeias of heat and contributing to increase of toxic gas, which may cause death to the people who are living in the respective zone. Also, the fire may spread from one zone to another zone based on the intensity of the heat and the amount of flammable/combustible substances present in the factory.

Technically we can say that the chemical flammable/combustible substance will catch fire easily depends on the flash point of the substance. The lower the flash point, the easier the fire will catch in a spontaneous way, so it is very much necessary that the flammable/combustible substances to be categorized as low/medium/high hazardous occupancy of the substances in the factory based on the fire load. Fire load with respect to the residential building were caried out by many of the researchers [3, 5, 11, 12], office building [13, 14], commercial building [15, 16], high rise building [17, 18], green building [19], educational building [20], various shopping complex [21, 22], car parking area [23] and Canadian nuclear reactor [24]. Very less information is available in the international level with respect to the fire load calculation in the pharmaceutical industry, although no articles have been published in the national level. The study gives a broader idea for calculating the fire loads for the pharmaceutical industry and categorizing it in the form of low/medium/High hazardous occupancy have been presented.

2. Methodology

The various methods, which are used for calculating the fire load, which are as follows

2.1. The Survey Method - The National Fire Protection Association Standard (NFPA) 557 [25] have recommended that the fire load can be calculated by using weighing method. Weighing all the flammable/combustible materials, which are kept in their allocated zones in the factory by using a surveyor. However, in other case the fire load survey can also be carried out by using the various inventory, which are made. Survey method can be carried by combination of weighing and the inventory method [26]. Many of the research have used survey method [27, 9] Such type of methodology will help in identifying the ways of reducing the fire hazard, frequency of its occurrence and its consequence [8].

2.2. Weighing method – The method is carried out by a person entering the various zones by identify the flammable/combustible substances and quantifying it by using appropriate calibrated weighing machine, which is considered as a direct method. It is different from the inventory method. In this method the actual quantification flammable/combustible in the allocated zones are considered, the use

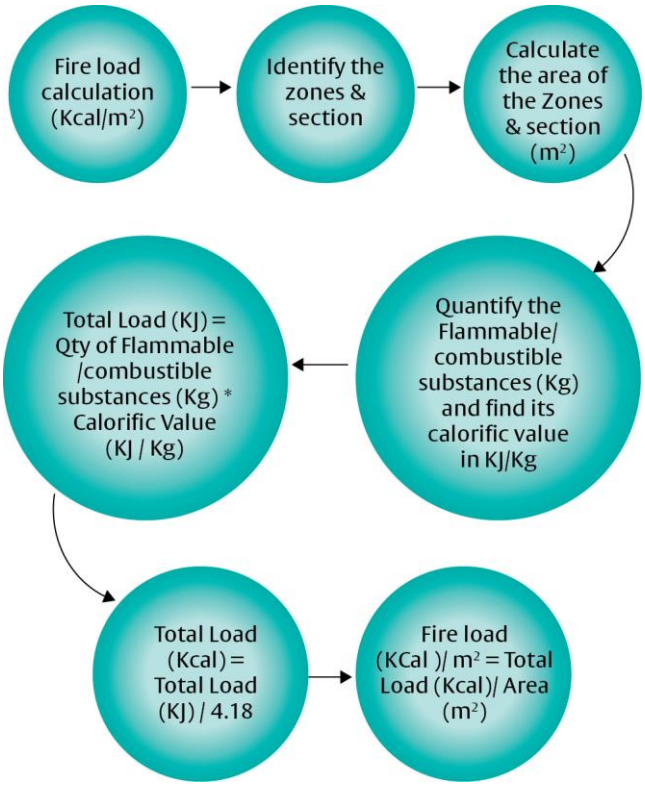
of the weighing method is not common method, as it takes both manpower, and it is time consuming job.

2.3. Inventory method –This method is used by identifying the masses of the flammable/combustible substances, which are kept in the measurable volume with respect to their density. The method, which has taken into consideration the physical quantity of the flammable/combustible chemicals/substances, which are kept in the various zones – Quantification will be documented in the form of an inventory. This inventory of the flammable/combustible materials in the allocated zones plays a vital role in knowing the stock of the flammable/combustible substances present in the factory. By having the inventory, it helps in calculating the fire load [28, 29]. However, the inventory method, which considers both the fixed or movable flammable/combustible substances, which are kept in the allocated zones ((NFPA) 557) [25].

2.4. Combination method – It is a Combination of the weighing method and the inventory method. The quantification by weighing of the flammable/combustible substances we can know its mass content (in a measurable volume). Here we also consider the pre weighed mass quantity, which has an inventory of flammable/combustible substances present in the factory, which have considered to be direct cum visualizing and quantifying the flammable/combustible substances have been considered as a more powerful method to obtain the fire load. Although certain international authors have reported that using the combination of weighing and inventory method may obstruct or delay in the progress in getting the quantification of the data, so it has resulted in more time for calculating the fire load [27, 30, 31].

In this paper we have followed the combination method, which has resulted in getting the results by calculating the values of the total load (KJ), followed by the total load (Kcal), and the fire load ((KCal)/ m^2 has been derived during the study. The various formulas, which are used for calculating the fire load, which are shown in the Figure. 1.

Figure. 1, Diagrammatic flow representation of the fire load calculation



Zone	Sections	Total floor area m^2	Flammable/ Combustible substance	Quantity of Flammable/ combustible substance (Kg)	Calorific Value (KJ / Kg)	Total Load (KJ)	Total Load (Kcal)	Fire load (Kcal/m^2)	Type of Occupancy AS per NFPA 557
1	Guard room	9	Wooden Furniture	100	21000	2100000	502392	**55,821**	**Low Hazard Occupancy**
2	Transformer Area	32.3	Transformer oil	900	42000	37800000	9043062	**2,79,971**	**Medium Hazard Occupancy**
3	Office building	24.6	Wooden Furniture	350	21000	7350000	1758373	**1,10,306**	**Low Hazard Occupancy**
			Paper	150	18000	2700000	645933		
			Cloth	25	20000	500000	119617		
			Plastic	25	31700	792500	189593		
			Total Load			**11342500**	**2713517**		
4	Stairs	12.3	Paper	500	18000	9000000	2153110	**1,75,050**	**Low Hazard Occupancy**
5	Store room GF	22.6	Paper	100	18000	1800000	430622	**19,054**	**Low Hazard Occupancy**
6	Lab 1 GF	20.8	Plastic	50	31700	1585000	379187	**66,537**	**Low Hazard Occupancy**
			Wooden Furniture	200	21000	4200000	1004785		
			Total Load			**5785000**	**1383971**		
7	Lab 2 GF	20.8	Plastic	50	31700	1585000	379187	**72,604**	**Low Hazard Occupancy**
			Wooden Furniture	200	21000	4200000	1004785		
			Paper	20	18000	360000	86124		
			Methanol	2.5	22800	57000	13636		
			Toluene	2.5	40550	101375	24252		
			Total Load			**6303375**	**1507984**		
8	Electrical MCC room	45.5	Rubber mat	15	23000	345000	82536	**18,482**	**Low Hazard Occupancy**
			Plastic	100	31700	3170000	758373		
			Total Load			**3515000**	**840909**		

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Zone	Sections	Total floor area m^2	Flammable/ Combustible substance	Quantity of Flammable/ combustible substance (Kg)	Calorific Value (KJ / Kg)	Total Load (KJ)	Total Load (Kcal)	Fire load (Kcal/m^2)	Type of Occupancy AS per NFPA 557
9	Toilet	7.4	NA	NIL	NIL	NIL	NIL	NA	**Low Hazard Occupancy**
10	Thermic Fluid heater	11.2	Diesel	200	44000	8800000	2105263	**1,87,970**	**Low Hazard Occupancy**
11	Boiler	13	Diesel	200	44000	8800000	2105263	**1,61,943**	**Low Hazard Occupancy**
12	Chimney	7.6	NA	NIL	NIL	NIL	NIL	NA	**Low Hazard Occupancy**
13	Cooling tower CT2	16	NA	NIL	NIL	NIL	NIL	NA	**Low Hazard Occupancy**
14	DG Sets	45.5	Diesel	400	44000	17600000	4210526	**92,539**	**Low Hazard Occupancy**
15	DM water plant and utility	10.1	NA	NIL	NIL	NIL	NIL	NA	**Low Hazard Occupancy**
16	I Floor office area	17.2	NA	NIL	NIL	NIL	NIL	NA	**Low Hazard Occupancy**
17	Document store 1st floor	8.2	Paper	10	18000	180000	43062	**1,27,786**	**Low Hazard Occupancy**
			Wooden Furniture	200	21000	4200000	1004785		
			Total Load			**4380000**	**1047847**		
18	First floor office (conference room)	24.6	Wooden Furniture	200	21000	4200000	1004785	**77,396**	**Low Hazard Occupancy**
			Paper	200	18000	3600000	861244		
			Plastic	5	31700	158500	37919		
			Total Load			**7958500**	**1903947**		
19	First floor lab	23	Wooden Furniture	100	21000	2100000	502392	**3,35,656**	**Medium Hazard Occupancy**
			Paper	1500	18000	27000000	6459330		
			Plastic	100	31700	3170000	758373		

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Zone	Sections	Total floor area m^2	Flammable/ Combustible substance	Quantity of Flammable/ combustible substance (Kg)	Calorific Value (KJ / Kg)	Total Load (KJ)	Total Load (Kcal)	Fire load (Kcal/m^2)	Type of Occupancy AS per NFPA 557
			Total Load			32270000	7720096		
20	First floor guest room	19.8	Wooden Furniture	200	21000	4200000	1004785	**60,582**	**Low Hazard Occupancy**
			Paper	10	18000	180000	43062		
			Plastic	20	31700	634000	151675		
			Total Load			**5014000**	**1199522**		
21	First floor Barcode room	21.4	Paper	100	18000	1800000	430622	**25,438**	**Low Hazard Occupancy**
			Plastic	15	31700	475500	113756		
			Total Load			**2275500**	**544378**		
22	First floor Engg stores	6.2	Paper	10	18000	180000	43062	**24,888**	**Low Hazard Occupancy**
			Paint	15	31000	465000	111244		
			Total Load			**645000**	**154306**		
23	Hazardous Waste Room	9	Paper	50	18000	900000	215311	**66,055**	**Low Hazard Occupancy**
			Plastic	50	31700	1585000	379187		
			Total Load			**2485000**	**594497.6**		
24	Metering room	15	Plastic	20	31700	634000	151675	**10,112**	**Low Hazard Occupancy**
25	Old transformer	7.5	Transformer oil	350	42000	14700000	3516746	**4,68,900**	**Medium Hazard Occupancy**
26	Fire Pump House	33.9	Diesel	100	44000	4400000	1052632	**31,051**	**Low Hazard Occupancy**
27	RM & PM stores (G+1)	245	Poly Vinyl Alcohol	25000	21310	532750000	127452153	**9,69,741**	**High Hazard Occupancy**
			Other Liquid RM	6000	35000	210000000	50239234		
			Formaldehyde	400	16830	6732000	1610526		
			N Octanol	1000	37530	37530000	8978469		

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Zone	Sections	Total floor area m^2	Flammable/ Combustible substance	Quantity of Flammable/ combustible substance (Kg)	Calorific Value (KJ / Kg)	Total Load (KJ)	Total Load (Kcal)	Fire load (Kcal/m^2)	Type of Occupancy AS per NFPA 557
			Other Liq	1000	35000	35000000	8373206		
			HDPE Carboy	5000	31700	158500000	37918660		
			Wooden Furniture	600	21000	12600000	3014354		
			Total Load			**993112000**	**237586603**		
28	Compressor room	10.9	NA	NIL	NIL	NIL	NIL	NA	**Low Hazard Occupancy**
29	Packing area (G+1)	728	HDPE Carboy	13500	31700	427950000	102380383	**1,51,674**	**Low Hazard Occupancy**
			Wooden Furniture	1600	21000	33600000	8038278		
			Total Load			**461550000**	**110418660**		
30	Manufacturing Plants (G+1)	802	Vinyl Acetate Monomer	7000	22688	158816000	37994258	**58,549**	**Low Hazard Occupancy**
			Poly Vinyl Alcohol	1600	21310	34096000	8156938		
			Formaldehyde	200	16830	3366000	805263		
			Total Load			**196278000**	**46956459**		

3. Results and Discussion

3.1. Based on the lowest and highest quantity of the combustible/flammable hazardous substances stored in the factory

We have classified in to thirty zones during the study (Tabel.1). During the study it was observed that the quantity of the flammable/combustible materials varied from 2.5 to 25,000 kg. The lowest, which are in the form of solvents like toluene and methanol stored in the zone 7 whose area is 20.8 $m^{2.}$. Both are highly flammable and irritant in nature. Although exposure to the toluene, which leads to cancer, whereas exposure to methanol leads to increase in the toxicity in the body. High safety precautions to be taken by wearing the suitable PPE, while handling the hazardous flammable chemicals like toluene and methanol. The flammable/combustible material, which are highest in the form of Poly Vinyl Alcohol, which is stored in the Zone 27 whose area is 245 m^2 (Tabel.1), which is irritant and carcinogenic in nature. Categorizing in various zones playing a vital role in identifying the risk of the criticality in the performance-based fire safety [32]. While we consider the calorific value of the lowest and the highest quantity of the flammable substances stored, it was found that the calorific value of toluene was highest, followed by methanol and lowest was poly vinyl alcohol (Table. 1). It is reported by the many of the authors that the fire load mainly depends on occupancy of the hazardous and flammable/combustible materials, which are stored in the various zones of the building [33, 34, 35, 36, 37]. The materials such as some of the structural element, furniture, paper and lining material will release heat when they catch fire. The burning depends up on the calorific value of the substance, which plays an important role in calculating the fire load [26], where the calorific value of the flammable solvents like toluene and methanol were higher but in case of the poly vinyl alcohol the calorific value is similar to that of the wooden furniture.

3.2. Based on the fire load - lowest and highest hazardous occupancy in the factory

By calculating the fire load, we have obtained the lowest and highest fire load for the hazardous occupancy zones, which were 18, 482 and 9,69, 741 kcal/m^2. The lowest fire load is in the zone 8, where rubber mat and plastic mats are stored in area of 45.5 m^2. Whereas in case of highest fire load it has been found in the zone 27, where highly flammable/combustible materials such as Poly vinyl alcohol, Formaldehyde, N-Octano, Other liquid chemicals, HDPE carboy and wooden furniture are stored in an area of 245 m^2. In the lowest hazardous occupancy zone, the rubber mat and plastic mats calorific value are 23,000 and 31,700 KJ/Kg. In case of highest hazard occupancy zone, the highest calorific value is N Octanol, followed by HDPE carboy, other liquid RM, poly vinyl alcohol, wooden furniture and formaldehyde is the lowest (Tabel. 1). Care should be taken, while handling the chemicals in the Zone 27, as all the substances are highly flammable in nature. N Octanol is highly combustible in nature, irritant and it is having long-lasting hazardous impact to the aquatic life, in case it is let into the water bodies, while HDPE materials does not affect the environment nor the health of the Individuals who are handling the substance. Other liquid raw materials, which includes flammable substance, irritant, toxic and carcinogenic in nature, wood and formaldehyde is combustible substance. Further the formaldehyde is considered to be an irritant, carcinogenic and hazard to the environment. Many of the zones in the industries and the high-rise building have the fire protection but in the past many people reported the concern over safety systems, like fire that has happened in the Shanghai fire in the year of 2010 [12], in some of the buildings, where the combustible/flammable materials are stored in the smaller area in the residential building [12]. The total fire load, which varied from 2143.7 to 4515.6 MJ/m^2 and its calorific value varied from 16.3 to 17.5 MJ/kg in the warehouse located in Tamil Nadu, India [38], which is very less compared to the present study.

3.3. Based on the fire load - Low/Medium/High hazardous occupancy area in the factory

Among the thirty zones identified the study, the low / medium / high hazard occupancy zone were 26, 3 and 1. In the low hazard occupancy zone, the lowest and the highest fire load are 10, 112 and 1,87,970 kcal/ m^2, which are located in the hazardous occupancy zone of 24 and 10 (Tabel. 1). In this zone, the fire load is very minimum, even though the quantity of the material stored in the zones were high, the highest was 13, 500 Kg (Zone 29) in the form of HDPE carboy. There are three medium hazard occupancy zones. In the medium hazard occupancy zone, where the lowest and the highest fire load were 2,79,971 and 4,68,900 kcal/ m^2, which are located in the zones of 2 and 25, which were 27 and 2 times higher when it is compared with the low hazard occupancy zones of the lowest and highest fire load values. Only single zone is the highest hazard occupancy zone, where the highest flammable and hazardous chemicals are stored, its fire load were 9,69,741kcal/ m^2, which is zone 27. Chow et al. [35] has studied the fire load for the eight floors of the high raised building in the Hong Kong for the movable combustible substances by inspecting it in the visualization way, he has concluded that the average

living area was small, but their half of the area has exceeded the upper limit of the fire load of 1135 MJ/m^2, which has been prescribed in the local code [39]. [40] reported that fire load densities were 1400 MJ/m^2 for fifty residency occupancy building. Although very less information is published with respect to the fire loads in the chemical/pharmaceutical industry. Sushant Gadilohar and Ratnesh Kumar [41] have reported that the fire load varied from 110.54 to 269 MJ/m^2 in the various occupancies of the rooms one to eight, which is very much low compared to the lowest and highest fire load in the low hazard occupancy zones during the study. Although we have observed vast difference in the calorific values in all the three zones irrespective of the low/medium/high level occupancies. It is recommended to build fire resistance walls in case of medium and high-level fire hazardous occupancy zone, so that we can minimize the severity of the fire [42].

4. Conclusion

Based on the study we have identified the lowest and highest quantity of flammable/combustible material, which are stored in the factory. We have concluded that the lowest and highest fire load occupancy are in the form of Zone 8 and 27. There are 26, 3 and 1 number of zones, which are categorized as low, medium and high-level fire load occupancy area. The single high-level hazard occupancy zone, where all the flammable/combustible substances, which are stored in the zone 27 are highly flammable in nature, so it is recommended to follow the proper safety instructions, while handling the flammable/combustible materials in the raw material. Only trained people are recommended in handling the flammable/combustible substances.

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