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A Fire Intensity of Different Type of Material in Process Industry

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Abstract: *This paper is focused on different type of combustible material`s internal energy called calorific value, and their fire intensity when the material burn. Fire hazard is play major role for increase the accident, loss of life and property in the processing industry as well as storage area of the industry. The reason for high amount of fire in industry dwellings is due to the reasons that such buildings were not subjected to fire prevention legislation or continuing managerial supervision, till construction of multi-storeyed buildings had started. The total amount of fuel present in a building is never constant as everyday same or the other additions are being made and waste materials are being thrown away. But a reasonable accurate fire load of the building can always be calculated or is otherwise known from experience. The first load in building depends upon the size of the building but fire load density i.e. the total fire load per square metre of the floor area of building as a whole is dependent on the occupancy type of building if optimally equipped. In this paper included the fire load of combustible materials available in industry. The fire load of combustible materials is the amount of heat in kilo-calorie which is liberated per square meter of floor area of a compartment by the combustion of the contents of the building and any combustible parts of the building itself. The amount of heat is used as the basis for grading of occupancies. The fire load is determined by multiplying the weight of all combustible materials by their calorific values and dividing the figure by the floor area under consideration.*

Keywords: Combustible Material, Calorific Value, Fire Intensity, Fire Prevention, Fire Load.

I. Introduction

Fire can be useful, but it can be deadly. It has always fascinated and frightened; and as the proverb states; "fire is a good servant and a bad master". Without fire, civilisation would be radically different, it might not even exist. However, the cost of fires which get out of control is high, and an average of seven to eight people die in fires in the India every week.

There is a risk of fire in every building that is designed, and it is accepted that complete safety fire is an impossible goal. The fire risks inherent in different building types are normally only highlighted when a particularly serious and fatal fire attracts public attention. Such major fires underline the importance of building design and remind architects of their responsibility to minimise the risks of fire in buildings. Fire and outbursts in Industries, Generating Stations, Substations and other plants are not uncommon. Large scale destruction to life and property is caused by fires due to various reasons and explosions of Oil filled / Gas Cooled Electrical Equipment. Fires kill several hundred persons and destroy property worth several crores of rupes every year. More than 85% of fires in various types of plants/buildings/hotels/shops/godowns etc. are caused by electrical sparks or short circuits, poor housekeeping, poor fire prevention & protection system. Fires cause deaths of persons due to flames and poisonous gases. Fires result in extensive damage to property, plant and equipment, control cabling. Smoke and gases due to fire may travel through ventilating ducts and enter in various rooms of the building. Fire and Combustion, whenever a substance undergoes a chemical change (oxidation) by combining with oxygen, it usually liberates certain amount of heat. The process of oxidation accompanied by evolution of heat is called combustion.

Fire is rapid combustion resulting in release of heat and light of flame. Fire is an active, burning, (combustion, fast oxidation, process accompanied by heat, light and poisonous gases/smoke/carbon dioxide gas due to combustion. Flame is luminous, hot zone of the fire. Fire is started /ignited/begun at a hot spot and spreads along the combustible material to neighbouring area, subject to availability of (1) Combustible material (2) Air and (3) Heat and local temperature rise as per figure 1.

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Role of combustible materials in burning: Most of the materials have a temperature (flash point) at which they give off flammable vapours. Burning takes place when these vapours mixed with air (oxygen) in the presence of ignition temperature. Practically all fuel must vaporize before it burns. When these vapours reach the auto ignition temperature, the fuel vapour gets ignited automatically and burns.

Role of Oxygen in burning: When correct amount of oxygen combines with flammable vapours at the flash point, the burning takes place. For practical purpose, when sufficient oxygen is not present a fire cannot burn. When oxygen supply is limited, hydrogen has a greater affinity for oxygen to form water vapours, leaving insufficient oxygen to produce carbon dioxide. Some of the carbon will remain unburned in the form of dense black smoke. Some of the carbon will find sufficient oxygen to form carbon monoxide.

Role of Heat in burning: The combination of oxygen with fuel vapours, in burning release heat energy. This heat then goes on to vaporize more and more fuel, when in burning releases more heat in a rapidly accelerating process. The experiments have in fact revealed that the oxidation process is complicated and takes place in various stages in the form of chain reaction. It is continuous branched chain reaction, in which free radicals are continuously generated and are multiplied to propagate or spread the fire. So apart from above mentioned three elements fourth elements i.e. continuous branched chain reaction is also very essential to start and propagate a fire.

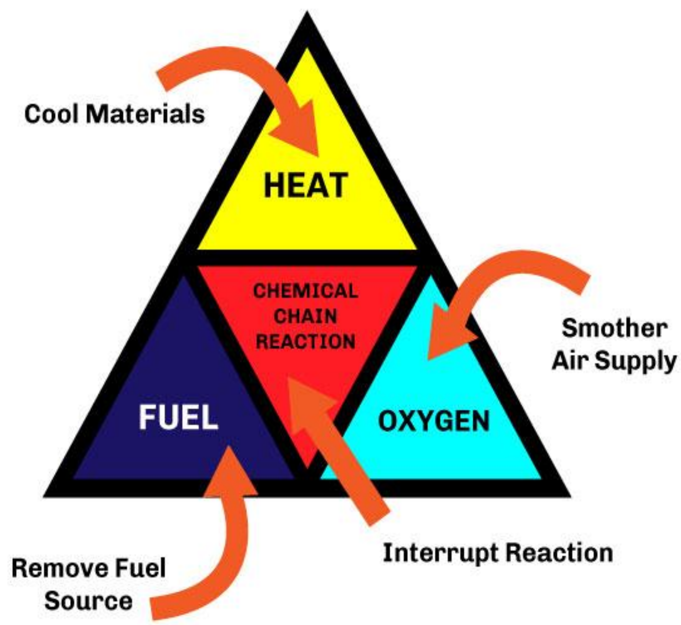

Figure 1: Responsible Elements for Fire

Various materials differ in their ignition temperature and fire characteristics. Combustion is a continuous process requiring continuous supply of new fuel and new oxidizer in the flame zone. In addition, the new fuel and new oxidizer must be brought up to ignition temperature before they well react, by high speed collision of their molecules, to start the branding chain reaction between their free radicals which bring about the release of available energy mainly in form of heat. This heat is fed back from the flame zone and the hot products of the combustion to the new supplies. Rate of combustion varies from substance to substance and is described as slow, rapid, or spontaneous. (1) Slow Combustion. A chemical reaction accompanied by slow evolution of heat but not by light, is slow combustion, e.g., cotton waste burning in ill ventilated place. (2) Rapid Combustion. A chemical reaction accompanied by a rapid evolution of heat and in many cases by an appreciable amount of light is called rapid combustion, e.g., petroleum products. (3) Spontaneous Combustion. It is a combustion occurring as a result of heat by the absorption of atmospheric oxygen at ordinary temperature, without the application of external heat provided supporter of combustion is present e.g. , Lignite dust, paint scraps etc. Sometimes spontaneous combustion is also due to chemical reaction, e.g., phosphorous in contact with wood and saw dust when exposed to steam pipe.

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II. Fire HAZARD PROPERTIES OF FLAMMABLE LIQUIDS, GASES AND SOLIDS AND VOLATILE SOLIDS IN API INDUSTRY

The use of single fire hazard property such as flash point, ignition temperature etc., should not be used to describe or appraise the hazard or fire risk of a material, product, assembly or system under fire conditions. The subject fire hazard properties have been determined under controlled laboratory conditions and may properly be employed to measure or describe the response of materials products, assemblies or systems under these conditions. Properties measures under such conditions may be used as elements of a fire risk assessment only when such assessment takes into account all of the factors which are pertinent to the evaluation of the fire hazard of a given situation. Any solid material like charcoal or wood when heated continuously results in a process chemical decomposition process which increases in its intensity as the temperature is raised until a stage is reached at which the decomposition process is giving off more heat than is required to maintain steady temperature. At this stage the temperature of the body will increase without any further external heating i.e. self-heating has started and within an elapse of few seconds obvious signs of ignition will appear, such as active smouldering or flaming. In many cases the ignition temperature would be regarded as the temperature at which smouldering or flaming is first observed.

According to NFPA-325M “Fire hazard properties of flammable liquids, gases, solids and volatile solids” ignition temperature of a substance, whether solid , liquid, or gaseous, is the minimum temperature required to initiate or cause self-sustained combustion independently of the heating of heating element or in the absence of any source of ignition. Some of the variables known to affect ignition temperature area:

1. Percentage composition of the vapour or gas-air mixture.
2. Shape and size of the space where the ignition occurs.
3. Rate and duration of heating.
4. Kind and temperature of the ignition source.
5. Catalytic or other effect of materials that may be present.
6. Oxygen concentration.

As there are many differences in ignition temperature test method, such as size and shape of containers, method of heating and ignition source, it is not surprising that ignition temperatures are affected by the test method. The ignition temperature of liquid will depend on the proportion of vapour and air present at the liquid surface. When the temperature of the liquid is such that enough vapour is given off and a combustible mixture (i.e. of the correct proportion, vapour to oxygen) can from at the liquid surface then the flash-point of the liquid is said to have been reached.

Table 1: Ignition Temperature of Some Common Solid Materials

Sr. No	Material	Ignition ^oC	Temperature ^oF
1	Coal	130	266
2	Hay	175	347
3	Newspaper	185	365
4	Sawdust	195-220	383-428
5	Jute	195	383
6	Cotton	230	446
7	Rayon	235	455
8	Wood	200-220	392-428
9	Magnesium	510	950

2.1 Flash-Over

In any given phase of fire, a fire can extinguish itself or if not discovered and extinguished, develop further and auto-propagate. It has been repeated observed in room fire of a certain stage that the fire suddenly fills the entire space. The oxygen concentration reduces and the carob monoxide and carbon dioxide concertation increases by the same amount. This phenomenon is known “flash-over”. The flash-over can be defined as the point at which the fire changes from a two dimensional to a three dimensional manifestation.

2.2 Flammable (Explosive) Range

The range of flammable vapour or gas-air mixture between the upper and lower flammable limits is known as the "flammable range" also often referred as "explosive range" for example, the lower limit of flammability of acrylonitrile at ordinary ambient temperature is approximately 3 percentage vapour in air by volume, while the upper limit of flammability is about 17 percent. All concentrations by volume of acrylonitrile vapour in air falling between 3 percent and 17 percent are in the flammable or explosive range.

2.3 Fire Severity and Controlling Factors

Fire severity can be defined as "the condition of the fire which is related to its potential to create maximum temperature duration of burning". The damage caused to material is proportional to fire severity. In case of buildings the intensity of fire severity is dependent on:

- Nature of fuel.
- Amount of fuel.
- Arrangement of fuel.
- Size and shape of room or compartment containing the fire.
- Area and disposition of windows.
- Thermal insulation of walls and ceilings.
- State of the atmosphere inside and outside the building i.e. availability of oxygen.

In building construction a large variety of materials are used which is differ widely in their fire property. Some materials are compulsory for building construction like sand, cement, bricks, steel but some other are optional like finishing decorating and furnishing materials in which building designer has wide choice. Although wood is essential it can be coated with fire retardant or fire resistant material to the advantage of building. The nature of material with respect to fire can be divided in two board headings; total heat content and rate of burning. The second property of any material is not the unique property of depends upon the last six factors given above. The first property of fuel is known as calorific value of material. Calorific value of fuel is defined is the total quantity of heat released by it after complete combustion of its some specified quantity. The sum of the calorific values of all combustible contents in a building including its structure are known as total fire load of the building.

III. METHODOLOGY

Fire load is the amount of heat in kilo-calorie which is liberated per square meter of floor area of a compartment by the combustion of the contents of the building and any combustible parts of the building itself. The amount of heat is used as the basis for grading of occupancies. The fire load is determined by multiplying the weight of all combustible materials by their calorific values and dividing the figure by the floor area under consideration. Fire load shall be graded into three classes, low fire load is not exceeding 27500 kcal/m^2 and as applying generally to domestic buildings, hotel and offices and similar buildings, moderate fire load is exceeding 275000 kcal/m^2 but not exceeding 550000 kcal/m^2 generally to trading establishment and factories, high fire load is the value exceeds 550000 kcal/m^2 but does not exceed 1,100,000 kcal/m^2 applying to fire load grading to godowns and similar structure.

The contents of a building are rarely disposed uniformly over the whole floor area. From the fire protection standpoint it would be undesirable to have all combustible material concentrated on a fraction of the floor area, as the average taken over the whole area would not give a true representation of the actual conditions, and the resulting effects on the structure immediately surrounding would be out of all proportion to these expected on the basis of average fire load. Several methods are used in fire load surveys in buildings, warehouses, as well as in industries. These are weighing, inventory, the combination of weighing and inventory. The NFPA Standard 557 also proposes that a fire load survey can be conducted by either the weighing or the inventory technique or a combination of them.

3.1 Weighing Method

In this method, fire load calculation is based on measured weights of combustibles and the corresponding calorific value of the materials. The necessary approximations are to be made in situations where items within the compartment did not

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match pre-weighed values. The fire load is calculated using the calorific value (hc) of different materials to convert measured weights into energy units (MJ).

3.2 Inventory Method

The inventory method calculates fire load based on the measured volume of items. Weights of items were obtained by multiplying the measured volume of combustibles by its density. This method did not use pre-weighed items and no direct measurement of mass is done. Similar to the direct weighing method, items are classified under different homogeneous material groups. Fire loads are calculated from the masses of the items and their corresponding calorific value.

3.3 Combination Method

This method uses data from the direct weighing method and inventory method. Weights of items are obtained from: directly weighing items, pre-weighed items, measured dimensions with subsequent conversion into weights through the use of the item's material densities. Fire load is calculated by the product of item weights and their corresponding calorific values.

IV. Calculation

The fire load should consist of all combustible building contents and the relevant combustible parts of the construction, including linings and finishing. Combustible parts of the combustion which do not char during the fire need not to be taken into account.

The characteristic fire load is defined as:

$$Q_{fi,k} = \sum M_{k,i} \cdot H_{u,i} \{kcal/kg * kg\}$$

Where, $M_{k,i}$ is the amount of combustible material [kg]

$H_{u,i}$ is the net calorific value [MJ/kg]

The characteristic fire load density $Q_{f,k}$ per unit area is defined as:

$$Q_{f,k} = Q_{fi,k} / A \quad \{kcal/m^2\}$$

Where, A is the floor area (A_f) of the fire compartment or reference space, or inner surface area (A_t) of the fire compartment

Table 2: Plant Area and Calorific Value of Material In Area

Sr. No	Plant/Division	Area in Sq. Meter	Calorific value in kcal/kg	Mass of Combustible Material in kg
1	Spinning Unit	36065	4700	300000
2	Weaving Unit	28425	4700	400000

The scope of the Fire Load Calculation covers the following:-

- To undertake identify hazards associated with industries.
- To undertake a calculation for fire load using calorific value, quantity of material and floor of each and every hazard associated with given building dimension.
- To undertake the total of the all fire load and calculate the final Fire Load for plant.
- To undertake a calculation for fire load of each and every hazard associated with given building dimension.
- To provide final total fire load calculation.

4.1 Spinning Unit

The characteristic fire load $Q_{fi,k} = \sum M_{k,i} \cdot H_{u,i}$ {kcal/kg * kg}

$= 300000 * 4700$ {kcal/kg * kg}

$= 1{,}410{,}000{,}000$ {kcal}

The characteristic fire load density $Q_{f,k}$ per unit area $Q_{f,k} = Q_{fi,k} / A$ {kcal/m²}

$= 1{,}410{,}000{,}000 / 36065$ {kcal/m²}

$= 39{,}096.0765$ {kcal/m²}

4.2 Weaving Unit:

The characteristic fire load $Q_{fi,k} = \sum M_{k,i} \cdot H_{u,i}$ {kcal/kg * kg}

= 400000 * 4700 {kcal/kg * kg}

= 1,880,000,000 {kcal}

The characteristic fire load density Qf,k per unit area Qf,k = Qfi,k/ A {kcal/m2}

= 1,880,000,000/ 28425 {kcal/m2}

= 66,138.962 {kcal/m2}

V. Conclusion

On the basis of research, we have identified fire load calculation by combination methodology of a process industry. Fire load calculation has been calculated spinning unit and weaving unit of the industry, which have 36065 sq. meter of area (spinning unit) and 28425 sq. meter of area (weaving unit). The total fire load calculation of the spinning unit and weaving unit area are 39,096.0765 {kcal/m2}, 66,138.962 {kcal/m2}. Following first aid firefighting arrangement should be recommended for both area of the industry.

5.1 For Spinning Unit

Installation of fire extinguishers:

Type of hazard: - Class 'A' fire due to normal combustibles.

As per IS 2190 this is Ordinary Hazard so one 9 liters water expelling extinguisher for every 600 sq.mtr of floor area with minimum 4 extinguishers per compartment /floor should be installed. Extinguisher should be available within 25 meter radius.

No. of Fire Extinguishers = 36065/600 = 60.1, so that number of fire extinguishers required is 60.

5.2 For Weaving Unit

Installation of fire extinguishers:

Type of hazard: - Class 'A' fire due to normal combustibles.

As per IS 2190 this is Ordinary Hazard so one 9 liters water expelling extinguisher for every 600 sq. mtr of floor area with minimum 4 extinguishers per compartment /floor should be installed. Extinguisher should be available within 25 meter radius.

No. of Fire Extinguishers = 28425/600 = 47, so that number of fire extinguishers required is 47.

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