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Design & Development of Automatic Fire- Sprinkler System in Indian Railways

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Abstract- As population is increasing day by day very rapidly, the number of people in trains is also increasing, who travel from one station to another. There were many incidents of fire, which happened in Indian Railways in the past, due to short circuit of wires, smoking, spark from brakes because of wear & cooking by vendors in the pantry carts. The main objective of the paper is to provide protection to human beings without creating any stampede, jostling, and protect the property of government by using Automatic Fire Sprinkler System.

Index Terms- *Sprinkler System; Train Compartment; Fire Suppression System; Hydraulic Calculation; Design Layout of Train Coach.*

1. INTRODUCTION

The Indian Railways is the world's third largest railway network, after US and China. In India, most people travel by train, as it is the cheapest transportation covering long as well as short distances in comparison with any other transportation services. Railways are used to take people & transport goods from one station to another. It is one of the world's largest commercial employers with more than 1.8 million employees. According to the survey, around 18000 trains run every day.

As there are many people who travel by train every day, it is necessary to provide them safe & sound travel, keeping risks like "fire incidents" to a minimum. In the past, many train accidents happened due to fire in coaches of Indian Railways [2]. For instance: In the year 2001- 2002, three people died due to fire and later in year 2009, nine people died because of the fire in coaches. In the year 2012- 2013, 32 people died as fire occurred in the coaches and this number was increased in the year of 2013-2014, in which approximately 36 people died. Hence it is imperative to provide the security to the people, who travel in their day to day life[iv], [5], [ii], [11].

The main purpose of the paper is to provide the design and development of automatic fire sprinkler system, which will work automatically, when fire occurs in the coach of a train.

1.1 Causes of Fire

- Due to lighted cigarettes, matchsticks, or lighters thrown around carelessly.
- From pantry cart of the train, due to heedlessness in switching off the burner or other means.
- Accumulation of empty card board boxes and other waste materials in the train compartments may aggravate the risk of fire.
- The fire may arise, due to the short circuit in the electrical wires.
- Due to non- working exhaust fan in the non-ac pantry cars, tapping of power from light and fan through open wires to connect mobile phones and other electronic appliances, food waste dumped near toilets, non-maintenance of boilers may cause fire in the train compartments[iii], [3].

1.2 Recommendations Given by RDSO & their Implementation

- During fire, stop the train
- Provision of fire alarm detector.
- Providing ladder to escape.
- Cooking is prohibited in AC pantry cars.
- There would be one extinguisher in each vehicle with seated places and two extinguishers in each sleeper coach, required to be provided.

During an audit, it was found that:

- The automatic fire detection alarm system in the running train was not implemented.
- The loading in parcel vans, was not perfectly supervised to ensure the booking of vehicles, without petrol or diesel & avoidance of the restricted materials.
- With the present design of emergency windows, it is not possible for the passengers to evacuate themselves eventually in the case of emergency [4], [6], & [8].

Therefore, it is pivotal to provide proper safety to all human beings against fire and to make them aware about the tactics to deal with fire without panic. The

aim of the paper is to design and develop the proper fire protection system to all human beings using Fire Suppression Systems.

2. Fire Fighting System

Fire is basically a chemical reaction which involves the continuous rapid oxidation of millions of fuel molecules and reaction occurs at a rapid rate.

There are three main components which are required for combustion to occur:

- **Fuel** – to vaporize and burn.
- **Oxygen** – to combine with fuel vapour.
- **Heat** – to raise the temperature of the fuel vapour to its ignition temperature.

Fire Fighting System can be classified into two main groups:

2.1 Fire Detection System:

Fire detection system is the system in which there are devices such as, heat detector (detects the heat at certain temperature), smoke detector (detects the smoke in the occupancy), beam detectors (used to detect any fire in double height area occupancy by using transmitters and receivers), control panels, and many more used to detect the smoke and fire.

2.2 Fire Suppression System:

Fire Suppression Systems are used to repress the fire by cutting off the oxygen from the environment, by reducing the heat and by controlling the dissemination of fuel.

Fire Suppression System can be broadly classified as following:

1) **Water Based System**- Use to control the fire by reducing the heat.
2) **Foam Based System**- Use to control the fire by controlling the spreading of fuel
3) **Gas Based System**- Use to control the fire by cutting off the oxygen from the environment [1].

Water Based System can be divided into the following parts:

- **Wet Pipe System**- It is a system in which the piping contains water, so that water can be discharged immediately from sprinklers opened by heat or fire.
- **Dry Pipe System**- It is a system, in which the piping contains air or nitrogen under pressure and the release of which from the opening of sprinklers, permits the water pressure to open the dry pipe valve and water comes to control the fire. It is used, where the wet pipe systems may be inappropriate.
- **Pre- Action System**- It is a system in which an automatic sprinklers and dry pipe is used. The activation of detector activates the pre-action valve and water comes into the pipe and after the bursting of sprinklers, the water shed down to control the fire.
- **Deluge System**- It is a system in which open sprinklers are attached to the piping system that is connected to the water supply through the valve that is opened by the operation of a detection system that is installed in the same areas as the sprinklers.
- **Combined System**- Automatic Sprinklers, dry pipe valves, and air exhaust systems are used for actuation in combined systems. Detection system opens the dry pipe valve, also opens the air exhaust valve at the end of the feed main, which usually precedes the opening of sprinklers, water flows in system towards opened sprinklers [12].

3. METHODOLOGY

In the proposed design system, the train coaches are implemented with Pre-Action Sprinkler pipe system in which detectors, first detect the heat, then open the pre- action valve and allowing water, to enter the system piping which is primarily filled with air or nitrogen gas. The water will not flow from the automatic sprinklers, until heat activates the operating element in sprinklers [7], [10].

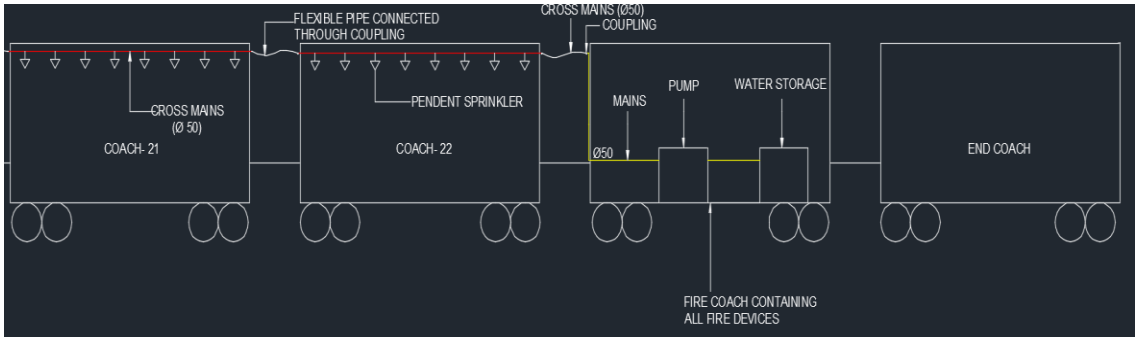

Figure- 1: Side View of Train Coaches with Sprinkler Systems

3.1 Construction

According to the proposed design (Figure- 1), the fire coach (containing all fire equipment for instance: pump, water storage and many more) is placed at the opposite end of the train engine. The header which emanates from the pump, in the fire coach, is approximately of 50 mm size diameter and made up of Schedule 40- Black-Steel Pipe- ASTM A 135. The header supplies water to the compartment cross mains, which are made up of Schedule 40- Black-Steel Pipe- ASTM A 135. The cross mains that are used between the coaches, connected through couplings, are flexible and made up of Stainless Steel, and of 50 mm size diameter which will transfer water from that coach(compartment) to another, on an emergency. The cross mains are made up of mild steel. The sprinklers flow water through 25 mm of diameter. The header is connected to the cross mains through couplings. Furthermore, the cross mains of one coach is connected to the other's cross mains through coupling and so on.

3.2 Pipe Material

- Pipe material for Header- Schedule 40- Black-Steel Pipe- ASTM A 135.
- Pipe Material for cross mains, in between two coaches, connected through coupling and transfers water from one coach to another- Stainless Steel Flexible Pipe.
- Pipe Material for cross mains in the compartment- Schedule 40- Black-Steel Pipe- ASTM A 135.

As per the figure- 2, the fire coach supplies water to all the train coaches including pantry. Each train coach has eight sprinklers, to control the fire in the compartment of train.

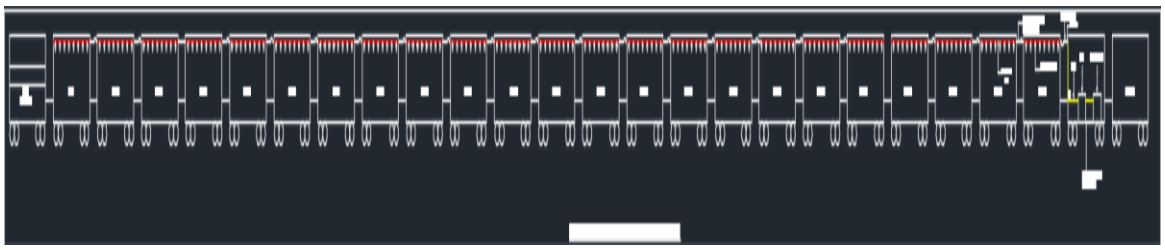

Figure- 2: Side View of Train Layout

3.3 Calculation

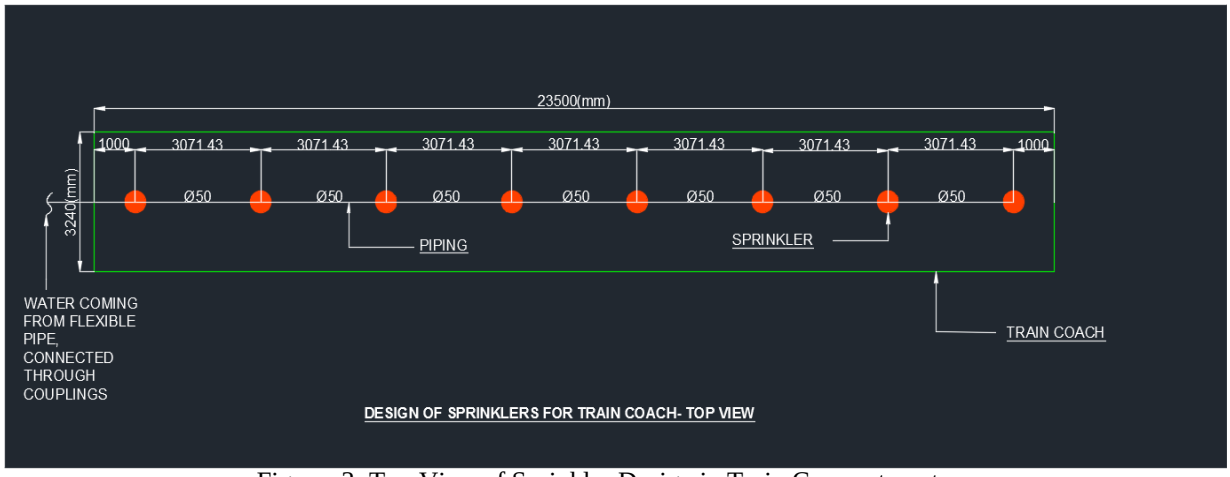

Figure- 3: Top View of Sprinkler Design in Train Compartment

The length of one train coach in India is approximately 23.5 metre and width is 3.24 metre (Refer Figure- 3).

To implement the sprinkler system in a coach, there are certain formulae and steps in NFPA- 13 that can be used.

Area to be protected = 75m^2;

Hazard = Light;

Per Sprinkler's Protection Area = 12m^2;

In figure-3, there is the design of sprinklers for the train coach which has a length of approximately 23.5 metre and width of 3.24 metre[i]. As per NFPA-13 rules, the distance between sprinklers is 3071.43 millimetre and the distance between wall and sprinkler is 1000 millimetre. There are eight sprinklers, designed in the coach of the train, to protect the human beings from fire.

According to NFPA-13, following formula is used to calculate the water storage;

Pump Capacity & Water Storage (Theoretical):

Design Density for light hazard = .10gpm/ft^2; (As per NFPA-13)

Area to be protected = 75m^2; (A= L*W= 23.5*3.24); where L- Length of the train compartment; and W- Width of the train compartment;

According to the formula, mentioned in NFPA-13, the flow shall be needed,

Q= d*a; Q= (.10*75)/.09= 83.33 GPM= 315 LPM= 18900 L (Litres); where, d- design density; a- area of protection; Q- Flow in GPM;

Now, per sprinkler discharge will be**,**

Method

Q= Amax*design density;

Amax= S*L; Amax= 3.071*3.240;

Q= (9.95004*.10)/.09; Q= 11.0556 GPM= 41.79 LPM;

Now, the discharge factor, as per the formula mentioned in NFPA- 13,

Q= K*P$^{.5}$; where k- orifice discharge factor of sprinkler; P- pressure in bar;

41.79= K*(.5)$^{0.5}$; K=59.1089 LPM/bar$^{0.5}$;

As per NFPA- 13(2016) [Referred Table 6.2.3.1], the K-factor can be taken as 60 LPM/bar$^{0.5}$;

Now, per sprinkler discharge will be, **Q= K*P$^{0.5}$= 60*.707= 42.42 LPM;**

According to the new sprinkler discharge, the actual water storage capacity will be,

As there are eight sprinklers in the train compartment as per design criteria, hence the flow from the eight sprinklers will be

approximately 339.36 LPM and for one hour of water operation, the actual water demand will be 20361.6 Litres [9], [13].

3.4 Working

In the pre-action system, when fire starts, the detection system detects the smoke, and operates the pre-action valve to open, through control panel. After the opening of the pre-action valve, water comes inside the pipe of the sprinkler system from fire water reservoir. As the pre-action system uses an automatic sprinkler, that operates after the activation of its operating element from heat. The sprinkler has a threaded body to connect to the pipe work with a valve sealed to hold the water back, which is retained by glass bulb that contains liquid having co-efficient of expansion. In the bulb, there is the small quantity of vapor which is entrapped and due to the increase in the temperature, the liquid expands and increases the pressure until vapor is compressed. Further increase in pressure, shatters the bulb and water shed down.

As the pre-action system provides the double detection, therefore it is suitable to use in those areas, which are highly sensitive to the effects of the accidental sprinkler water discharge. In train, if there is the false discharge of water, it will create panic among people, that's why the pre-action system is suitable and appropriate to use in train.

4. CONCLUSION

- With the installation of fire extinguisher system, there will be the implementation of pre- action system, which will make the journey hazardous free, because sometimes, when the fire occurs, due to panic or due to lack of knowledge, people are not able to use the extinguishers properly, which cause accidents. Hence, proper safety system is to be provided to give complete protection.
- The fire coach will supply water up to maximum of 3 to 4 coaches.
- Fire resistant materials should be used to avoid fire in trains and evacuation from the emergency window should be refurbished.
- The sprinklers will be connected through flexible pipes which are made up of Cu tubes, which will be heat resistant.

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