“REVIEW OF THE DESIGN AND CONSTRUCTION REQUIREMENT OF WATER SPRAY SYSTEM AND FOAM SYSTEM IN PETROLEUM INDUSTRY”

Major Project

Submitted in partial fulfillment of the requirement for the award of Degree of Bachelor of Engineering in Fire Technology & Safety Engineering

Submitted to

RAJIV GANDHI PROUDYOGIKI VISHWAVIDYALAYA
BHOPAL (M.P.)

Submitted By:

Student Name	Enrollment Number
1. Mitan Vyas	(0808FT161063)
2. Mohit Pawar	(0808FT161065)
3. Moin Khan	(0808FT161066)
4. Rajveer Thakur	(0808FT161085)
5. Shivani Shah	(0808FT161100)
6. Virendra Singh	(0808FT161118)

UNDER THE SUPERVISION OF:-

MR. GAURAV ANTHONY
ASSISTANT PROFESSOR

IPS ACADEMY INDORE

INSTITUTE OF ENGINEERING & SCIENCE

FIRE TECHNOLOGY & SAFETY ENGINEERINGDEPARTMENT

SESSION: 2019-20

IPS ACADEMY INDORE

INSTITUTE OF ENGINEERING & SCIENCE

FIRE TECHNOLOGY & SAFETY ENGINEERINGDEPARTMENT

CERTIFICATE

We are pleased to certify that the major project entitled "Review of the Design and Construction Requirement of Water Spray System and Foam System in Petroleum Industry" Submitted by

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1. Mitan Vyas	(0808FT161063)
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4. Rajveer Thakur	(0808FT161085)
5. Shivani Shah	(0808FT161100)
6. Virendra Singh	(0808FT161118)

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

Date: Date:

IPS ACADEMY INDORE
INSTITUTE OF ENGINEERING & SCIENCE
FIRE TECHNOLOGY & SAFETY ENGINEERINGDEPARTMENT

RECOMMENDATION

It is recommended that the major project entitled **“Review of the Design and Construction Requirement of Water Spray System and Foam System in Petroleum Industry”**Submitted by

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SUPERVISOR

Dr. Praveen Patel
Head
Fire Technology & Safety Engineering Department
IPS Academy
Institute of Engineering & Science

Dr. Archana Keerti Chowdhary
Principal
IPS Academy
Institute of Engineering & Science, Indore

IPS ACADEMY INDORE

INSTITUTE OF ENGINEERING & SCIENCE

FIRE TECHNOLOGY & SAFETY ENGINEERINGDEPARTMENT

ACKNOWLEDGEMENT

It is great pleasure to express profound gratitude to our esteemed guideMr. N.K. Jain, Assistant Professor, Fire Technology & Safety Engg. Department, for their whole hearted support and guidance to us.

We express our sincere thanks to Dr. Praveen Patel, Head of the Department, Fire Technology & Safety Engg. Department for his valuable inspiration, able guidance and untiring help, which enabled us to carry out and complete this work.

We also express our sincere gratitude to Dr. Archana Keerti Chowdhary, Principal, Institute of Engineering & Science, IPS Academy, Indore for extending all the facilities during the course of study.

We also take this opportunity to express our deep gratitude to all the Faculty members and Staff of Fire Technology & Safety Engineering Department, for their appreciation and moral support.

We are also thankful to all the persons who helped us directly or indirectly to bring the project work to its present shape.

ABSTRACT

We have to make our project on Petroleum and Oil/Gas Refinery in order to known various activities, their layout & relevant hazards and requirements of fire fighting systems with their arrangements.

Petroleum and Oil/Gas Refinery is one of the important unit for producing, Storing, Dispatching the petroleum products. Being one of the most important industry, these also contains a lot of hazards which can lead to accidents whether to the industry itself or to the general public. Petroleum or rock oil probably originated from underground organic matter or due to chemical reaction in the sky thousands of million years ago. It consists mainly of mixture of gases, liquid and solid hydrocarbons which are broken into various products by fractional distillation during refining. From the medieval times, petroleum has been a source of energy and recently pre-dominated the synthesis of organic compounds. Petroleum exploration and use have some environmental challenges.

Petroleum industry largely depends upon the import and export of crude oil. It plays a major role in the economy of the Country. Petroleum industries play a major in role in generation of employment in various parts of world.

Due to presence of number of hazards, petroleum industry needs to employ various fire protection systems. Medium velocity water spray system and foam system are the two major and most important systems which shall be installed where petroleum products are stored or processed. As the fire needs to be controlled at the earliest stage possible, the systems must be fast in response and must be reliable so that the extinguishment of fire can be achieved without damage to the plant or to the general public.

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LIST OF SYMBOLS, ABBREVIATION & NOMENCLATURE

MVWS – Medium Velocity Water Spray System

HVWS – High Velocity Water Spray System

**AFFF - ** Aqueous Film Forming Foam

AR - Alcohol Resistant

ILBP - Inline Balance Pressure

NFPA – National Fire Protection Association

OISD – Oil Industry Safety Directorate

CHAPTER- 1

INTRODUCTION

1.1 INTRODUCTION

Water spray System is designed to direct the water at the required density, from nozzles having predetermined patterns to completely impinge water into the hazard surface being protected. They are designed to use effectively in a variety of special hazards applications including flammable and combustible liquid hazards as well as transformers and turbines.

It is a special fixed pipe system connected to a reliable source of fire protection water supply and equipped with water spray nozzles for specific water discharge and distribution over the surface or area to be protected. The piping system is connected to the water supply through an automatically actuated deluge valve which initiates flow of water. Automatic actuation is achieved by operation of automatic detecting equipment installed along with water spray nozzles. There are two types of systems namely high velocity and medium velocity systems.

Advantages of Water Spray Systems

- Extinguishes fires quickly and prevents fires from spreading over a large area.
- Minimizes the damage caused by fire and reduces downtimes, protects the future of your business.
- High flexibility in design and implementation
- Reduces fumes and binds contaminants.
- Allows large open areas and thus a more flexible use of the premises.
- Uses water, a natural fire extinguishing agent that is available in unlimited quantities at a very low price.

Water Spray System are considered effective for any one or a combination of the following:-

i. Extinguishment – Water spray extinguishes a fire by cooling it, smothering it with the steam produced, emulsifying or diluting some flammable liquids, or by combining these factors.

ii. Control of burning – With its consequent limitations of fire spread, controlled burning may be applied if the burning combustible cannot be extinguished by water spray or if extinguishment is not desirable.

iii. Exposure protection – Exposures are protected by applying water spray directly to the exposed structures or equipment to remote or reduce the heat transferred to them from exposing fire. Water spray curtains mounted at a distance from the exposed surface are less effective than direct application.

iv. Prevention of fire – It is sometimes possible to use water spray to dissolve, dilute, disperse, or cool flammable or combustible materials before they are ignited by an exposing ignition source.

Medium Velocity Water Spray System (MVWS):

Fires on Hydrocarbon are more frequent due to the volatility of the hydrocarbon and its property to not dissolve with water and lighter than water the fire extinguishing of hydrocarbon fire with water is not possible. In case of fire on Hydrocarbon if the water is sprayed, due to the light weight of the hydrocarbon it will float on the water and reignite them to fire and due to the speed of water the fire will travel from one place to other place. However for this plant water spray system can be provided as exposure protection. That means if any plant is under fire the plants nearby shall be kept cool with the water spray system, while plant under fire shall be applied foam.

This system is mostly used for the protection of the following

- Hydrocarbon Storage tank
- Expander & Sale Gas Compressors
- Off Gas Compressors

Fig 1.1:- MVWS on Storage Tank.

Advantages of M.V. Water Spray System

- Entire area is flooded with foam, hence very useful for fire fighting in hazardous area, plant, storage tanks, etc. where manual approach is difficult.
- Very quick in response.
- The fire losses is kept low as the area under fire get foam blanket and also cooling due to water contain and so chances of spreading fire is negligible.

Applications of MVWS System

i. For fire-risks involving the lighter oils, Liquefied Petroleum gases, and other flammable liquids, where it may not be possible or desirable to extinguish the fire completely.

ii. For the protection of vessels, plant, and structures exposed to heat from adjacent and surrounding fires.

iii. Cable galley and cable spreader room.

iv. Switch yard and control room building.

v. Ash handling and coal handling plant area.

vi. Pump area.

vii. Crusher house.

Fig 1.2: - MVWS piping arrangement on LPG Bullets

Spray Nozzle — A normally open water discharging device which, when supplied with water under pressure will distribute the water in a special, directional pattern peculiar to the particular device.

The nozzles are effectively designed to exposed vertical, horizontal, curved and irregular shaped surface to allow cooling and to allow absorption of excessive heat from external fire and avoid damage to structure or spread of fire.

The minimum desirable pressure to achieve a reasonable spray pattern is 1.4 bars and maximum desirable pressure is 3.5 bars.

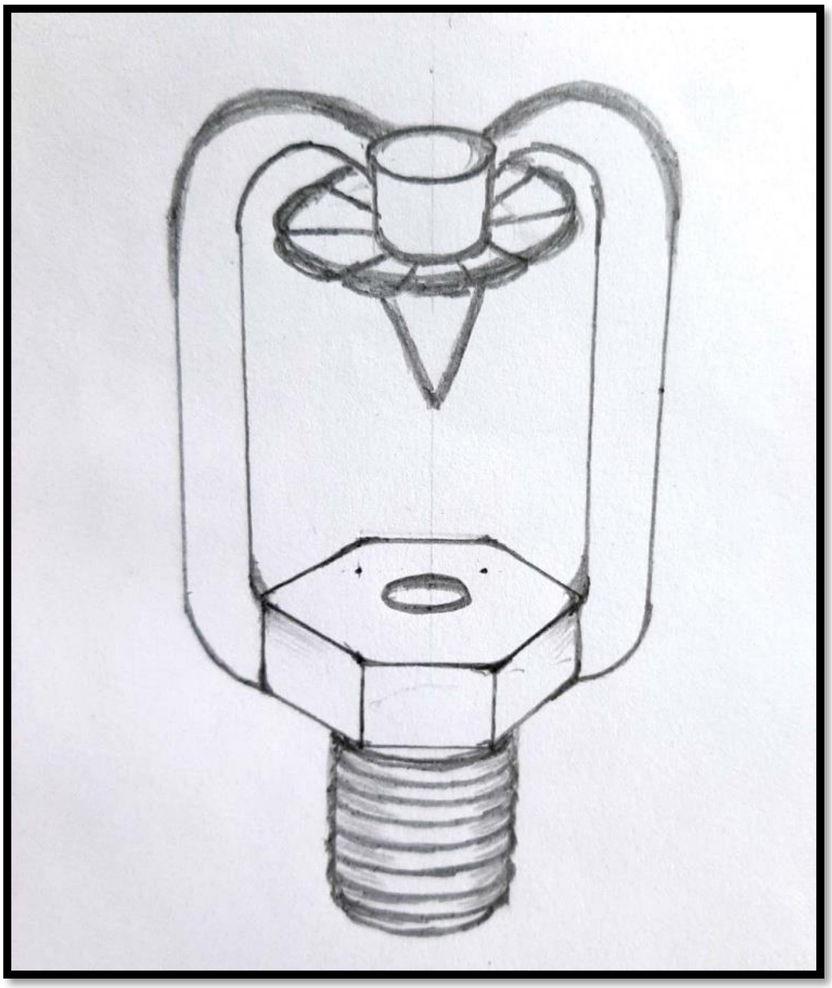


Fig 1.3: - Spray Nozzle

HEAT DETECTORS:-

Quartzite Bulb Detector:-quartzite bulb is filled with highly expandable liquid with small amount of gas inside. As the temperature increases, the liquid expands and the pressure of liquid causes the bulb to burst, leading to the activation.

Quartzoid Bulb Sprinklers (Q. B. S.) Detection is used to for detection of fire which will be connected to deluge valve for auto operation of the system. QBD shall be of 68 Deg or 79 Deg C or any other temperature depending upon the ambient temperature of the location of the plant.

Nominal Operating Temperature (Celsius)	Bulb Color
57	Orange
68	Red
79	Yellow
93	Green
141	Blue
182	Mauve
227	Black

Table 1.1: - Classification of Heat Detector

FOAM SYSTEM

INTRODUCTION

As defined in National Fire Protection Association (NFPA) 11, foam is:

"An aggregate of air-filled bubbles formed from aqueous solutions which is lower in density than flammable liquids. It is used principally to form a cohesive floating blanket on flammable and combustible liquids, and prevents or extinguishes fire by excluding air and cooling the fuel. It also prevents re-ignition by suppressing formation of flammable vapors. It has the property of adhering to surfaces, which provides a degree of exposure protection from adjacent fires."

A semi-fixed foam pourer system is one of the fire protection systems provided for tanks fires. It consists of a foam solution feed line which is permanently or temporarily installed through which a foam 1concentrate feed is connected to foam tenders. It operates as per the design considerations and will control the fire in the tanks.

The semi-fixed foam pourer system is installed on the following criteria:

- Floating roof and fixed roof (conical roof and dome roof) storage tank containing petroleum class A hydrocarbon products.
- Floating roof and fixed roof (conical roof and dome roof) storage tank containing petroleum class B hydrocarbon products.
- Storage tanks of diameter 40 meters and above containing class C hydrocarbon product.

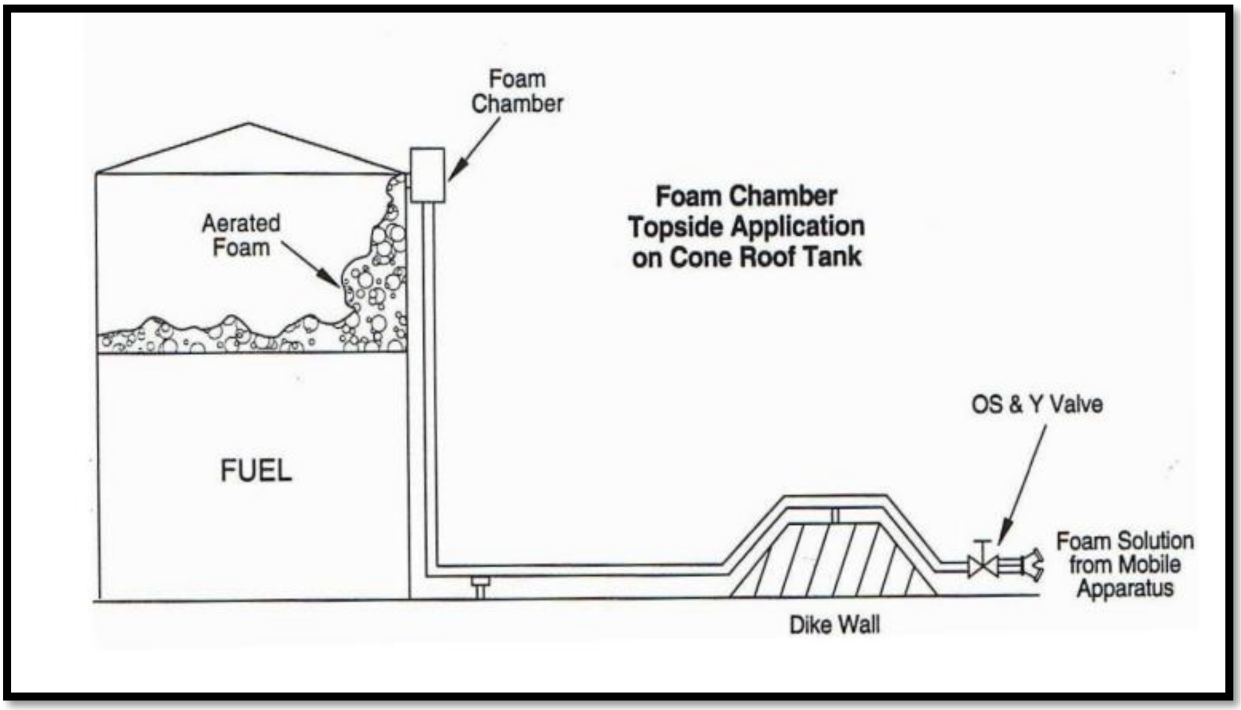


Fig 1.4: - Semi-Fixed Foam Pourer System

Design Criteria:

The foam pourer system is designed to supply foam for floating roof storage tanks at the rate of 12 LPM/m^2 of rim seal area. The spacing of foam pourer system at the top of the outer shell around the tank perimeter is provided at every 24 meters intervals to cover the entire rim-seal area. In case of fixed roof storage tanks the foam pourer system is designed to supply foam at the rate of 5 LPM/m^2 to cover the entire liquid surface area.

The storage tanks having demand rate more than 3000 LPM, a balanced proportioner is fitted with the foam inlet piping which is connected to the firewater network with an isolation valve. The foam proportioner consists of various inlet points through which the foam transport vehicle supply the foam concentrate.

The storage tanks having foam demand rate less than 3000 LPM, a male instantaneous coupling is present outside the dyke through which foam tender supply foam solution.

Aqueous Film Forming Foam (AFFF) concentrate is used for all systems at 3% induction rate to make foam.

For protection of alcohol based product fires such as Methanol and other similar storage tanks, AFFF Alcohol Resistant (AR) foam concentrate is used at 6% induction rate.

The Semi-Fixed foam pourer system consists of equally spaced foam pourers at the top shell or over rim seal. A foam maker is provided at the inlet side of foam pourer. The foam maker receives foam solution through fixed pipe network.

The system consists of foam landing valve on the wind girder of floating roof tank for spill on roof scenario or manual fire fighting for rim seal fire. The landing valve is provided near to the access ladder landing on wind girder which is connected to one of the foam pourer or its foam ring main.

The foam landing valve is kept closed in normal condition which can be operated manually after connecting delivery hose for fire fighting.

Fig 1.5: - Fire fighting through foam landing valve

WORKING OF BALANCED FOAM PROPORTIONER

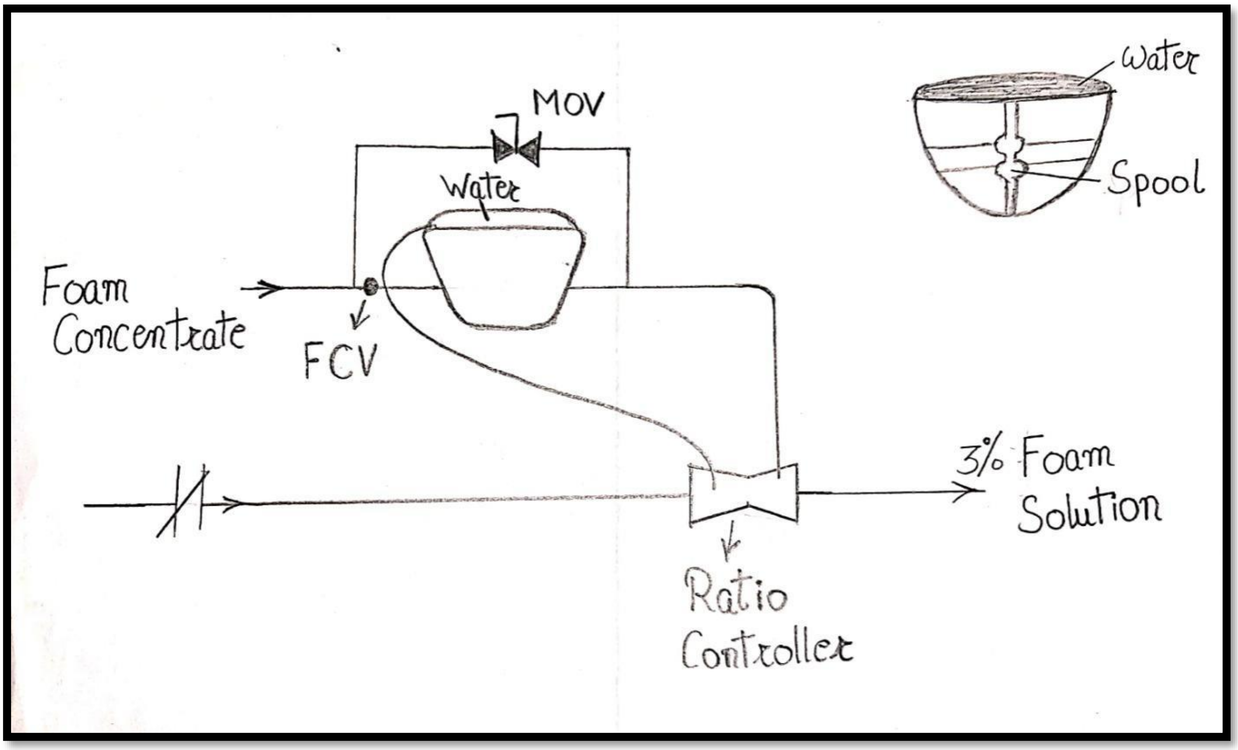


Fig 1.6: - Foam Balanced Proportioner

Inline Balance Pressure Foam Proportioner (ILBP) is used with positive displacement foam concentrate supply pump. The system controls accurate flow of foam concentrate into the water stream over a wide range of flow rate and pressure.

Inline balance pressure proportioning system utilizes a single, positive displacement foam concentrate supply pump, an atmospheric foam concentrate storage tank, inline balance proportioner, and a foam concentrate regulating valve. The pressure regulating valve is mounted on foam concentrate return line to the foam concentrate storage tank. The valve regulates the foam concentrate supply pressure.

The Inline balance pressure proportioner consists of a ratio controller, diaphragm operated pressure balancing valve, water and foam gauges, and pressure sensing hose of Teflon tube with stainless steel braided cover, interconnecting trim fittings with various control and flush valves. The water inlet pressure and foam concentrate pressure at metering orifice is sensed by a diaphragm valve and it automatically balances the concentrate supply to provide accurately proportioned water foam solution over a wide range of flow conditions. A foam concentrate supply valve is also provided as an optional item. The system requires foam concentrate supply pressure of 1.5- 2.0 bar. Higher than the water supply pressure. The Inline balance pressure proportioner is also provided with a manual balancing valve.

1.2 BACKGROUND & MOTIVATION

The spray system and foam system is designed for the protection tank or other facilities to fulfill the purpose of early detection and control of fire at the earliest state.

The risk of catastrophic fire with a proper firefighting system is less. Proper installation and maintenance of firefighting equipment shall be done for reduction of fire hazard.

The need for and use of tank fire protection systems have been discussed for many years and a variety of practices have evolved. Some facilities have been constructed with fire suppression systems while others have no fire suppression systems installed. In light of current industry practices, designs of some existing systems may be adequate while others need to be rehabilitated. A few existing fire suppression systems have been abandoned or may need improvements in their maintenance and testing practices. In some cases, plant staff may not understand fully what the system was intended to do when implemented or how it currently works. And finally, plants originally designed for full-time operators may now be unattended, thus changing the way fire suppression systems must be monitored and operated.

1.3 OBJECTIVE OF THE PROJECT

There are many tanks and processing units in the refinery which are used to store, process or transfer the flammable liquids. These facilities have a high risk to hazards like explosion, BLEVE; boil over, catastrophic fire, etc. So various fire protection system are needed to be installed which may be either fixed and/or portable in order to avoid the mentioned risks.

The need for and use of fire protection systems have been discussed for many years and a variety of practices have evolved. A few existing fire suppression systems have been abandoned or may need improvements in their maintenance and testing practices. In some cases, plant staff may not understand fully what the system was intended to do when implemented or how it currently works.

In light of current industry practices, designs of some existing systems may be adequate while others need to be rehabilitated. Also, since most plants were built, environmental laws have become much more stringent. Oil and water containment systems related to tank fire protection systems may have become obsolete and the new emphasis on protecting the environment must be taken into account.

Use of active fire suppression systems for large, flammable oil filled tanks where structures and other equipment are at risk from a fire. Such systems must be evaluated carefully to ensure they meet all current codes and standards including environmental laws and regulation. Fire suppression should be considered for smaller, mineral-oil-filled transformers where the risk and/or consequences of fire are unacceptable.

Tank fires are rare but the impact is great the fire's effect on adjacent equipment and structures can be mitigated and therefore must be considered. An uncontained fire can do a significant amount of damage and result in a prolonged, unscheduled outage. Water spray systems can be effective in minimizing damage caused by a tank fire but only if properly designed, constructed, operated, maintained, and tested.

1.4 SCOPE OF PROJECT

The scope of the project is to identify the hazards related with refinery and process units and to design the protection system for their protection in case of fire. The aim of this project is to promote "Good Fire Safety Practices". This specifies the requirements for firefighting facilities employed for fire extinguishment by

i. Proper designing of water spray and foam systems.
ii. Presenting typical tank fire scene.
iii. Local Application systems.
iv. Calculation of Water and Foam quantity required.
v. Total Foam flooding system.

CHAPTER – 2

LITERATURE REVIEW

2.1 INTRODUCTION

There are many researches done on water spray system and its operations which also include the failure hazards associated with it which presents number of problems in its safe working.

There are some research papers which help in resolving the problems which obstruct the operation of water spray system which are following:-

i Effects of water content on evaporation and combustion characteristics of water emulsified diesel spray by Zhaowen Wang .

ii Experimental investigation on heat transfer of spray cooling with the mixture of ethanol and water by HongLiu

iii Experimental investigation on the performance of a water spray cooling system by Lzhou.

iv Numerical method for determining water droplets size distributions of spray nozzles using a two-zone model by W.Plumecocq.

v Numerical investigation on propagation behavior of gaseous detonation in water spray by HiroakiWatanabe.

vi Mitigation of industrial hazards by water spray curtains by Jean-MarieBuchlin.

vii A study of water cooling using different water application technique. Protect storage tank walls against thermal radiation.

viii Experimental study on interaction of water mist spray with high-velocity gas jet by P.Zhu.

ix Spray breakup and structure of spray flames for low-volatility wet fuels by José E.Madero.

x Develop an unmanned aerial vehicle based automatic aerialspraying system by lXinyuXue.

xi Research on heat transfer characteristic for hot oil spraying heating processing crude oil tank by JianZhao.

xii Characteristics of spray angle for effervescent-swirl atomizers by M.Ochowiak.

xiii Experimental investigation of spray characteristics of alternative aviation fuels by Kumaran Kannaiyan.

2.2 Literature Contribution to the Project Work

Zhaowen Wang et al. (2018) provides a research paper on Effects of water content on evaporation and combustion characteristics of water emulsified diesel spray. This paper show that water content plays a significant role in affecting spray and combustion characteristics of water emulsified diesel. Due to its potential of reducing NOX and soot emissions simultaneously while improving thermal efficiency, water emulsified diesel is considered as one of the most promising fuels for compression ignition engines. In this study, spray and combustion characteristics of neat diesel and water emulsified diesel with various water contents (10%, 20% and 30% by mass) were investigated. The influence of micro-explosion on high pressure spray characteristics of water emulsified diesel was optically observed and discussed. Experiments were conducted in a constant volume combustion chamber with a high-speed schlieren system to capture the spray and combustion processes. The results show that water content plays a significant role in affecting spray and combustion characteristics of water emulsified diesel. Under non-evaporating condition, the spray tip penetration increases with the water content but the corresponding spray angle decreases with the water content. Such an effect was found diminishing under evaporating condition. The spray volume of test fuels increases from non-evaporating to evaporating condition, and the relative volume increase of water emulsified diesel is at least 5 times higher than that of neat diesel. Both the ignition delay and flame lift-off length increase with water content. Consequently, the integrated natural flame luminosity decreases with the increase of water content. In addition, indirect evidences have proven that the occurrence of micro-explosion can enhance the breakup and evaporation processes of water emulsified diesel spray, and the use of water emulsified diesel can effectively reduce soot emission.

HongLiuet al. (2018) have provides a research paper on Experimental investigation on heat transfer of spray cooling with the mixture of ethanol and water. In this paper Experiments were conducted to investigate the performance of the spray cooling heat transfer. Pure water and the mixture of water and ethanol (the volume fraction of ethanol ranges from 0.05% to 10%) were used as working fluids. The performance of pure water and the mixture were compared using the identical heater and solid-cone spray nozzle. The maximum heat flux in the experiment was up to 170 W/cm2. The experimental results indicated that adding ethanol to water is one of the most effective methods to enhance the heat dissipation and to control the device temperature simultaneously. The volume fraction of ethanol in water is the main factor affecting the spray cooling performance. The optimal volume fraction of ethanol for the improvement of the heat transfer performance is4%.

Zhou et al. (2018) provides a research paper on Experimental investigation on the performance of a water spray cooling system. In this paper, the performance of a water spray cooling system is investigated experimentally. The influence factors including the nozzle atomization effect, spray height, heat flux, and inlet pressure and gravity angle are discussed. Results show that under the same operating conditions, the main influencing factor is the spray mass flow rate involved in heat transfer. Heat transfer performance becomes better with the increases of mass flow rate. For the same nozzle, the best heat transfer performance appears under the critical height. The performance of spray cooling is improved with the growth of inlet pressure and evaporation intensity under the same inlet temperature. Furthermore, the heat transfer performance is closely related with the gravity angle. The best heat transfer performance appears when the gravity angle is between 30° and 120°. Heat transfer performs the worst when the gravity angle reaches 180°. Besides, experimental dimensionless correlations of Nussle number are given in non-boiling area with water coolant

W.Plumecocq et al. (2018) provides a research paper on Numerical method for determining water droplets size distributions of spray nozzles using a two-zone model. This paper show that The water spray systems are widely used for fire safety area and is a well-established technique for providing safety and protection of nuclear installations and also industrial facilities. One major challenge is to be able to properly determine the technical features of the water spray system that is required for predictive simulations. For that, a Phase Doppler Interferometer (PDI) device, that is a complex and challenging laser technique, is often used to measure the water droplets size distributions and the water droplets velocities. However, some usual water spray models can require as input parameters only an overall water droplets size distribution and water droplets initial velocity and some statistical methods are needed to determine them from local accurate measurements. In this paper, it is addressed a new calibration approach for assessing the input parameters of this modeling by using large-scale and well-controlled fire tests. Then, by introducing some correlations to take into account different operating conditions of the pressure at the spray nozzle head, this technique is validated on other large-scale fire tests. After discussing thoroughly the results, this new method shows that it can be a valuable and efficient tool for determining the overall features of water spray systems linked with the modeling of water spray system used in this study.

HirokiWatanabe et al. (2018) provides a research paper on Numerical investigation on propagation behavior of gaseous detonation in water spray. In this paper, a two-dimensional (2D) numerical simulation is conducted to clarify the propagation behavior of gaseous detonation in a water spray and its structure. The computational target refers to the experiment conducted by G. Jarsalé et al., and C_2H_4–air gaseous detonation propagates where the water droplets (WDs) are sprayed. The parameters used are the C_2H_4–air equivalence ratio and WD mass fraction. The flow field, Favre-averaged one-dimensional profile, and cellular structure are revealed in 2D simulations. Stable propagation of gaseous detonation is observed in the water spray, and the decrease in velocity relative to the Chapman–Jouguet velocity without WDs is as much as 3.2%. Adding WDs changes the cellular pattern, especially for leaner mixtures. The weak triple point decays, and the cell width increases because of the longer induction length due to decreased velocity. The WD presence changes the detonation flow field substantially, and evaporation occurs primarily at 10 mm behind the shock wave. The high-evaporation region propagates at the detonation speed, and the compression wave formed when the detonation reflects from the two-phase medium propagates backward. Furthermore, WD evaporation suppresses the velocity and temperature fluctuations. Rapid evaporation with WDs leads to lower hydrodynamic thickness than that without WDs or in the Zel'dovich–von Neumann–Döringmodel.

Jean-Marie al. (2017) provides a research paper on Mitigation of industrial hazards by water spray curtains, this paper show that Nowadays, the water spray curtain is recognized as a useful technique to mitigate major industrial hazards. It combines attractive features such as simplicity of use, efficiency and adaptability to different types of risks. In case of accidental toxic gas releases, the spray curtain may be used as a direct-contact reactor exchanging momentum, heat and mass with the gas phase. The cloud is diluted, warmed, and if toxic, some of its toxic content can be absorbed by the droplets to which chemical reactants can be added. In case of fire, water sprays can provide thermal shielding to maintain the integrity of storage tanks. The curtain behaves as a filter and can produce significant attenuation of the incident radiation that impinges on crucial structures such as petro- chemical storage tanks.

The paper gives an overview of the main features of the modeling and on practical industrial applications with a special focus on the adequate water curtain operating conditions and the influence of environmental factors.

NiallRamsden et al. (2017) provides a research paper on a study of water cooling using different water application techniques to protect storage tank walls against thermal radiation. This paper shows that amongst the hazards associated with storage tanks is the effect of the thermal radiation that results from an adjacent tank fire and its consequences for the mechanical strength of the metal and the tank contents at elevated temperatures, which may lead ultimately to the failure of the tank. A series of tests were undertaken to study the generation of dry spots and the effectiveness of the use of water cooling reducing the hazards of fire for adjacent tanks. The research involved an extensive programme of experiments studying the effectiveness of different water cooling techniques on mitigating tank and pool fires. The work was conducted at Asturias, Spain, by the LASTFIRE Project. This report gives a description and the findings of the work performed, which involved evaluating the effectiveness of water cooling in reducing the heat loading on an adjacent tank impacted by a pool fire. The results demonstrate that water cooling and the liquid in the adjacent tank can significantly reduce heat loading, as the wall temperature is maintained below that at which catastrophic failure might occur, or such that the rate of temperature rise is reduced to a level that provides time for emergency response teams to control the fire incident.

P Zhu et al. (2017) provides a research paper on Experimental study on interaction of water mist spray with high-velocity gas jet. This paper shows that Water mist spray is considered a potential and effective method for controlling or mitigating the risk of natural gas (NG) leakage. In order to address the lack of understanding of the dynamical behaviors and interacting mechanisms between water mist spray and high-velocity leakage gas jets, a series of small-scale experiments were conducted by means of a 2D particle image velocimetry technique. For safety reasons, nitrogen was tested instead of NG. The results demonstrate that the two-phase flow field could be divided into gas- or spray-dominant flow for different gas- spray momentum ratios. The exponential correlation model based on the effective gas-spray momentum ratio ΦEff could predict the vertical gas-spray interaction interface position more effectively. The gas-spray momentum ratio and relative gas-spray opening angle values are important factors affecting the gas-spray interaction. An effective gas-spray momentum ratio of ΦEff<1 is necessary for practical applications. A counter-rotating vortex pair is formed due to the entrainment effect of the high-velocity gas flow, which may enhance the mitigation efficiency by means of effective gas-droplet mixing. The comparison of Nozzle A with Nozzle B indicates that the water mist spray with larger coverage relative to the gas plume should exhibit superior performance in terms of controlling or mitigation effects.

Jose E Madero et al. (2017) provides a research paper on Spray breakup and structure of spray flames for low-volatility wet fuels. In this paper Studies of high-water-content fuels (a.k.a., wet fuels) have demonstrated that, under proper conditions, stable combustion can be achieved at very high water concentrations. Stable spray flames of wet fuels have been attained with fuel/water mixtures having stoichiometric adiabatic flame temperatures as low as 251 °C. In this study, we investigate low-volatility wet fuels, using glycerol as the fuel and ethanol as a stabilization additive. This study expands on previous work by determining the minimum amount of ethanol that needs to be added to a glycerol/water mixture to produce a stable flame and by investigating the spray dynamics and structure for these fuels, to delineate the mechanism of ignition and to understand how ethanol alters the vaporization behavior, droplet breakup, and spray dynamics. Detailed 2-D velocity, Sauter mean diameter (SMD), 2-D flux, and number concentration measurements were performed with a Phase Doppler Particle Analyzer (PDPA) in sprays of three fuel/water mixtures: (a) 30% glycerol/70% water, (b) 30% glycerol/10% ethanol/60% water, and (c) the same mixtures but in a combusting spray. All percentages are by weight. Results show that the addition of ethanol to the glycerol/water mixture turns the hollow-cone spray pattern into a narrow full-cone pattern, leading to recirculation of fine droplets in the region just downstream of the nozzle, which is essential to ignition. The high concentration of fine droplets, along with the high vapor pressure and high activity coefficient of ethanol, lead to extremely rapid vaporization of ethanol in the inner recirculation zone. The combustion of the ethanol raises the temperature in this region, while the swirling flow brings heat upstream towards the nozzle, further enhancing stability. These results explain why the addition of 10% ethanol can lead to robust flames of glycerol/water mixtures that might not be expected to yield stable combustion.

XinyuXue et al. (2016) provides a research paper on Develop an unmanned aerial vehicle based automatic aerial spraying system. This paper tells about developing of an aerial vehicle based automatic aerial spraying system. The system used a highly integrated and ultra-low power MSP430 single-chip micro-computer with an independent functional module. This allowed route planning software to direct the UAV to the desired spray area. The test results of route precision showed that in a 3–4 m/s crosswind, route deviations were around 0.2 m. The result of multiple-spraying swath uniformity tests showed a minimum coefficient of variation of 25% when flying at a height of 5 m with a spraying swath of 7 m and a wind speed of 0–2 m/s. When the spraying swath was 9 m or 5 m, the coefficients were 34% and 41%, respectively. Spray uniformity for these UAV tests were superior to the Standard Requirement for ultra-low volume spraying variation coefficient, 60%.

Andrew K. Kim and Bogdan Z. Dlugogorski (2005) provide research paper on a newly developed compressed air foam (CAM) system based on an overhead pipe installed and presents result following its free suppression performance.

Kumaran Kannaiyan et al. (2014) provide research paper on Experimental investigation of spray characteristics of alternative aviation fuels. These paper shows that Synthetic fuels derived from non-oil feedstock are gaining importance due to their cleaner combustion characteristics. This work investigates spray characteristics of two Gas-to-Liquids (GTL) synthetic jet fuels from a pilot-scale pressure swirl nozzle and compares them with those of the conventional Jet A-1 fuel. The microscopic spray parameters are measured at 0.3 and 0.9 MPa injection pressures at several points in the spray using phase Doppler anemometry. The results show that the effect of fuel physical properties on the spray characteristics is predominantly evident in the regions close to the nozzle exit at the higher injection pressure. The lower viscosity and surface tension of GTL fuel seems to lead to faster disintegration and dispersion of the droplets when compared to those of Jet A-1 fuel under atmospheric conditions. Although the global characteristics of the fuels are similar, the effects of fuel properties are evident on the local spray characteristics at the higher injection pressure.

CHAPTER – 3

AREA OF STUDY

3.1 OCCUPANCY/ INDUSTRY INTRODUCTION

The area of study of the project is based on an occupancy/ industry which are an oil and gas processing plant.

Oil and gas processing plant: Oil and gas wells produce a mixture of hydrocarbon gas, condensate or oil; water with dissolved minerals, usually including a large amount of salt; other gases, including nitrogen, carbon dioxide (CO_2), and possibly hydrogen sulphide (H_2S); and solids, including sand from the reservoir, dirt, scale, and corrosion products from the tubing. The purpose of oil and gas processing is to separate, remove, or transform these various components to make the hydrocarbons ready for sale.

The refinery consists of various units which together process the basic feedstock, crude oil, to obtain finished products deploying the following major refining processes:

- Crude oil distillation
- Catalytic cracking
- Catalytic reforming
- Delayed coking

Special features of the refinery complex:

- High proportion of high value products such as propylene and LPG (Adding to over 10% on crude processed as compared to 2-3% for most other refineries)
- Nil production of low value ‘black oils’- fuel oils (compared to 12-20% on crude processed for most other refineries) under normal circumstances.

Process Technologies:

All process units of the Jamnagar Manufacturing Division are based on state of the art technologies. Some of the major technologies are:

- Hydrodesulphurization
- Catalytic Reforming unit
- Fluid Catalytic Cracking unit
- Delayed Coker Unit
- Sulphur Recovery

All facilities require safety systems, including:

i. Fire and gas detection
ii. Fire-fighting equipment
iii. A means of evacuation, such as life rafts and escape capsules for offshore
iv. Other equipment, depending on the location and complexity of the facility and whether it Is manned

3.2 DESCRIPTION ON MATERIAL, PROCESS AND OPERATION

Material:

Medium Velocity Water Spray System: -

COMPONENT	MODEL MV-A & MV-AS	MODEL MV-B & MV-BS	MODEL MV-E
Housing	Brass, IS:291 GR.-1 (Equivalent to ASTM B21)	Stainless Steel, A351-CF8M	Aluminium Bronze IS:305-AB1 (Equivalent to ASTM-A148)
PIN	Brass, IS:291 GR.-1 (Equivalent to ASTM B21)	Stainless Steel	Bronze IS:7811 (Equivalent to B139 / BS2874-PB102)
Deflector	Brass, IS:291 GR.-1 (Equivalent to ASTM B21)	Stainless Steel	Bronze IS:7814- GR-II (Equivalent to BS2870-PB102)
Strainer	Copper	Stainless Steel	---

Table 3.1: - Material Specification of Water Spray System

Foam System: -

COMPONENT	MATERIAL
Body	Cast Iron to BS 2789
Internal Fitting	Stainless Steel
Deflector	Carbon Steel
Internal Mesh	Stainless Steel
Pipe	Steel tube to BS 1387

Table 3.2: - Material Specification of Foam System

Process:

i. Crude oil distillation: - This process is based on the principle that different substances boil at different temperatures. For example, crude oil contains kerosene and naphtha, which are useful fractions (naphtha is made into petrol for cars, and kerosene is made into jet fuel). When you evaporate the mixture of kerosene and naphtha, and then cool it, the kerosene condenses at a higher temperature than the naphtha. As the mixture cools, the kerosene condenses first, and the naphtha condenses later.

ii. Catalytic cracking: - Fluid catalytic cracking (FCC) is one of the most important conversion processes used in petroleum refineries. It is widely used to convert the high-boiling, high-molecular weight hydrocarbon fractions of petroleumcrude oils into more valuable gasoline, ole fine gases, and other products. Cracking of petroleum hydrocarbons was originally done by thermal cracking, which has been almost completely replaced by catalytic cracking because it produces more gasoline with a higher octane rating. It also produces byproduct gases that have more carbon-carbon double bonds (i.e. more olefins), and hence more economic value, than those produced by thermal cracking.

iii. Catalytic reforming:- Catalytic reforming is a chemical process used to convert petroleum refinery naphtha distilled from crude oil (typically having low octane ratings) into high-octane liquid products called reformates, which are premium blending stocks for high-octane gasoline. The process converts low-octane linear hydrocarbons (paraffin's) into branched alkenes (isoparaffins) and cyclic naphthenes, which are then partially dehydrogenated to produce high-octane aromatic hydrocarbons. The dehydrogenation also produces significant amounts of byproduct hydrogen gas, which is fed into other refinery processes such as hydro cracking. A side reaction is hydrogenolysis, which produces light hydrocarbons of lower value, such as methane, ethane, propane and butanes.

Operation:

The Medium Velocity Water Spray System can be operated by two ways:

- Manual Operation
- Deluge Valve

Manual Operation

The manually operated medium velocity water spray system is installed at Hot Flare Liquid Rundown Cooler, Fin-fan cooler etc. It can be operated by a manual hand lever. Manual system is generally used for cooling purpose.

Deluge valve

The Deluge Valve with Pneumatic Actuation Trim is specifically designed for fire protection systems actuated by a fire detection and release system of dry pilot line and/or pneumatic remote control. The Automatic Water Control Valve used in this deluge system is a pressure operated, sleeve actuated, axial valve designed for use in fire protection systems. The Pneumatically actuated Deluge Valve is used for automatic or manual operation. The dry pilot line, which is pressurized with compressed air, functions as a thermal detector equipped with a fixed temperature QBD. When one or more of the QBD heads located on the pilot line fuses, or when a manual release station is operated locally or remotely, the Deluge Valve opens and water flows from all open nozzles on the system. The control trim includes all the pilot valves, actuators, accessories, fittings, and gauges to provide for proper operation in either vertical or horizontal installation. The standard material Deluge Valve is rated to 300 psi (21 bars) and is available in sizes 1½" (40 mm) to 12" (300 mm). The only moving part in the Deluge Valve, when it operates, is the reinforced sleeve, which forms a drip-tight seal with the corrosion resistant core. It has a smooth opening to prevent any water hammer in the piping system. The unique design and variety of materials and coatings make the Deluge Valve ideally suitable for use with sea water.

Deluge Valve system components:

- Main valve assembly
- 3 way pilot valve
- Water supply
- Control panel
- Pressure switch (PSH AND PSL)
- Detection line (QBD)
- Water Sprayer
- Pressure gauge
- Riser
- Spray rings

Pressure rating – 1.5 bar (minimum) to 21 bar (maximum)

Material of construction:

a. Valve Housing – Carbon steel
b. Valve ends – Ductile iron
c. Sleeve – Elastomeric rubber reinforced with polymer
d. Coating – epoxy powder (0.1mm)

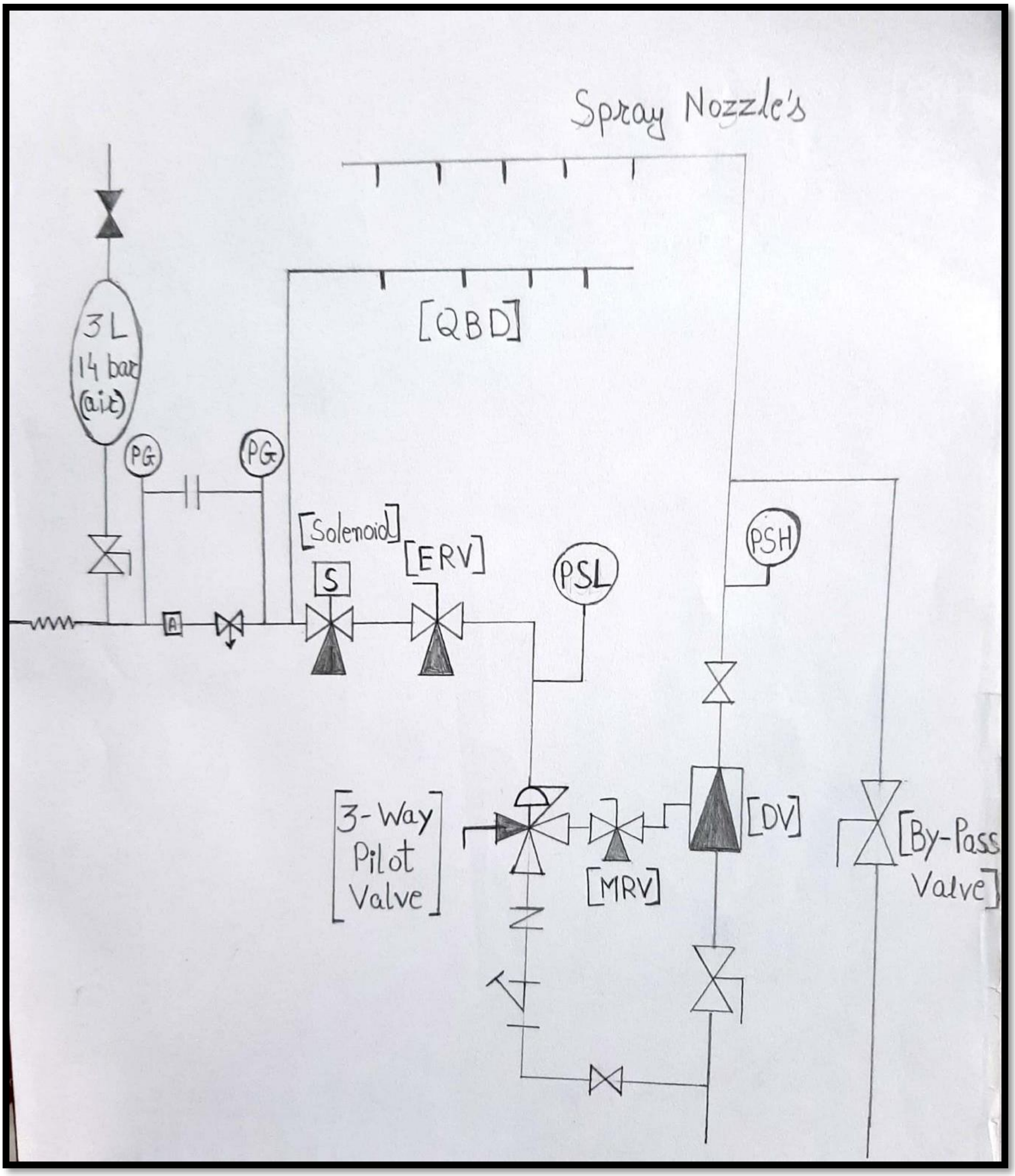


Fig 3.1: - Deluge Valve

Operation of Deluge Valve:

The INBAL deluge valve consists of an annular space which is known as control chamber present between the housing and the sleeve. This control chamber is held in closed position as long as the inlet pressure is introduced into it. The system consists of a 3-way pilot valve which serves a dual purpose of thermal detection and release system. In set position the up-stream water supply applies pressure on the control chamber. The pneumatic actuator is kept closed position by the help of air pilot line. Also the energized solenoid valve keeps the line closed because of which the deluge valve remains in closed position.

There are various ways through which a Deluge valve can be actuated:-

i. Depressurization of detection line through Quartzite Bulb.
ii. Manual operation of solenoid valve through F&G system i.e. through control room.
iii. Operation of manual release valve of deluge pilot line.
iv. Manual operation of Emergency release valve of dry pilot line.
v. By-pass line.

Once the pressure gets released because of functioning of the above mentioned ways the deluge valve opens wide allowing the flow of water to the system and alarm device. The water then flows to the nozzles on the system.

The pneumatic actuator latch in an open position due to release of air through dry pilot line which will restrict the closing of the valve even air releasing device is closed.

Resetting of Deluge valve:

i. Close the isolation valve.
ii. Open the low point drain valve.
iii. Inspect and replace the quartzite bulb/ solenoid.
iv. Open the air supply to build up the air pressure inside the control chamber.
v. Open the isolation valve.

3.3 DESCRIPTION ON PROJECT AREA (Atmospheric Storage Tanks)

The first step in the project is to gain knowledge about the process in which the project is to be carried out. The detailed study includes individual activity carried out in the industry. A detailed study is made on the individual equipment or process that is studied. This study includes the working of the equipment, the working condition and the standards to be followed, the safety precautions to be taken, etc.

Flammable and combustible liquid storage tanks are found in refineries, petrochemical plants, bulk storage of petroleum products and marine terminals. Airports, local fuel companies, power plants and large manufacturing facilities such as automobiles and steel plants may also have bulk storage of flammable and combustible liquids

Storage tanks store flammable and combustible liquids in various ways, depending on the facilities. These tanks can vary from 5 meters to 150 meters in diameter and can have an average height of 15 meters. These flammable liquids such as heavy oil, petrol, diesel, kerosene, ATF, etc. are stored in tanks at atmospheric temperature or under low pressure of 0.5 bar. If they found sufficient amount of energy, they may get ignite and can lead to fire or explosion. If an explosion occurs it may have a devastating effect with waves or overpressure created during explosion, which affects nearby tank also and can be a catastrophic situation. Such tanks can store huge volume of crude and other petroleum products of flammable and combustible liquids. Larger industrial facilities may own more than 300 Tanks of varying sizes which contain various products. These tanks may be placed very near to each other and have various other thanks within a common dyke.

The storage tank is covered by the peripheral boundary called dykes which acts as barriers to prevent the spilled liquid due to overflow or structural failure of the tank. Every tank is separated and segregated according to their classification. They are usually made of compacted dirt or concrete similar type materials. The dyke of height is considered 2 m. It can be extended on the special recommendation to prevent overflow of flammable liquids. Dykes are made consideration of the total capacity of the tank and additional certain percentage above this as a safety margin. If there is more than one tank in one dyke, the dyke capacity should be at least the volume of the largest tank in consideration a safety margin.

Types of Tanks

• Fixed roof tanks

• Internal floating roof

• Open top floating roof tanks

Fixed Roof Tanks

Tanks with fixed roofs include cone roof tanks, dome roof tanks, and column supported roof tanks, all of which are of either welded, riveted (other types), or bolted (other types) construction. Fixed roof tanks are typically used to store a range of refined products, from volatile materials to heavy fuel oils.

Fixed roof tanks are welded to the curb at the top of the shell and covered from top section and shell is formed in such a way that the forces are resisting downwards, such as dome roof and conical shape. The tanks have one or more structural section called wind girders which are placed around the tank from the top for resisting bulking and wind loads. The minimum thickness of the roof plating is 5 mm on the new tank. The minimum thickness of the roof plating is 5 mm of a new tank. To support the roof plating in tanks up to about 30 meters diameter

Roof trusses often extend downwards below the curb and therefore may lead to a reduction in storage capacity if, at a later stage. The fixed roof tank is made to hold an internal floating roof cover. The roof plating is attached to the curb, by welding, and if specified the weld may be minimal to make the joint frangible as a protection against accidental overpressure.

All fixed roof should be vented by open vents or through pressure/vacuum valves. For liquids to get in, air and vapor must be pushed out. The pressure in the tank must be slightly above atmospheric.

For a liquid to get out, air and vapor must be sucked in for this the pressure in the tank must be slightly below atmospheric

Dome roof tanks are similar to internal floating roof tanks are designed as a cover over the external floating roof tank. The main purpose of dome rook is to provide protection from fugitive emission to the environment.

Internal Floating Roof Tank

Internal floating roof tank consists of a permanently fixed roof with a floating roof inside the tank. The internal roof floats on pontoons or has a double deck for floatation over the liquid surface. These tanks will generally be found in service conditions where high volatility (Low Flash Point) or toxic liquids are stored. In a fixed roof tank without a floating cover, the liquid surface is in direct contact with the airspace above it.

The presence of an internal floating cover reduces these vapor losses by at least 95%, a very important feature where high cost, toxic or flammable materials are concerned. The tank will normally be fitted with open vents around the fixed roof (as Specified in BS 2654 and API 650), but PV vents are often used in practice.

External Floating Roof Tank

External floating roof tank consists of a roof which floats on the surface of the liquid, but the roof is exposed to the atmosphere. The roof goes up and down with the change in liquid level. The external floating roof consists of rim seal which prevents the vapors from escaping. Typically, such tanks are used for the storage of crude oil and all volatile (low flash point) products. Crude oil tends to be self-protective where the open tank shell is concerned, while white oils lack this property and the exposed shells become roughened by exposure to the weather.

Pattern of Spray angles

1. **65º**

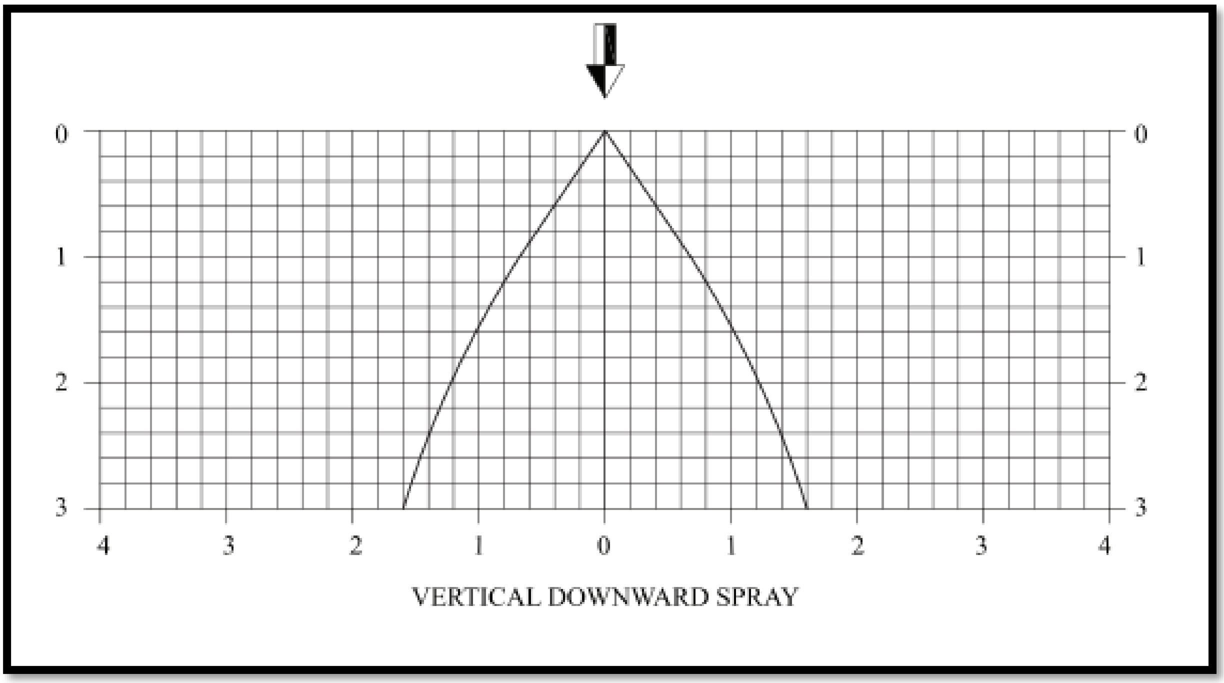


Fig 3.2: - 65º Spray Angle

2. **90º**

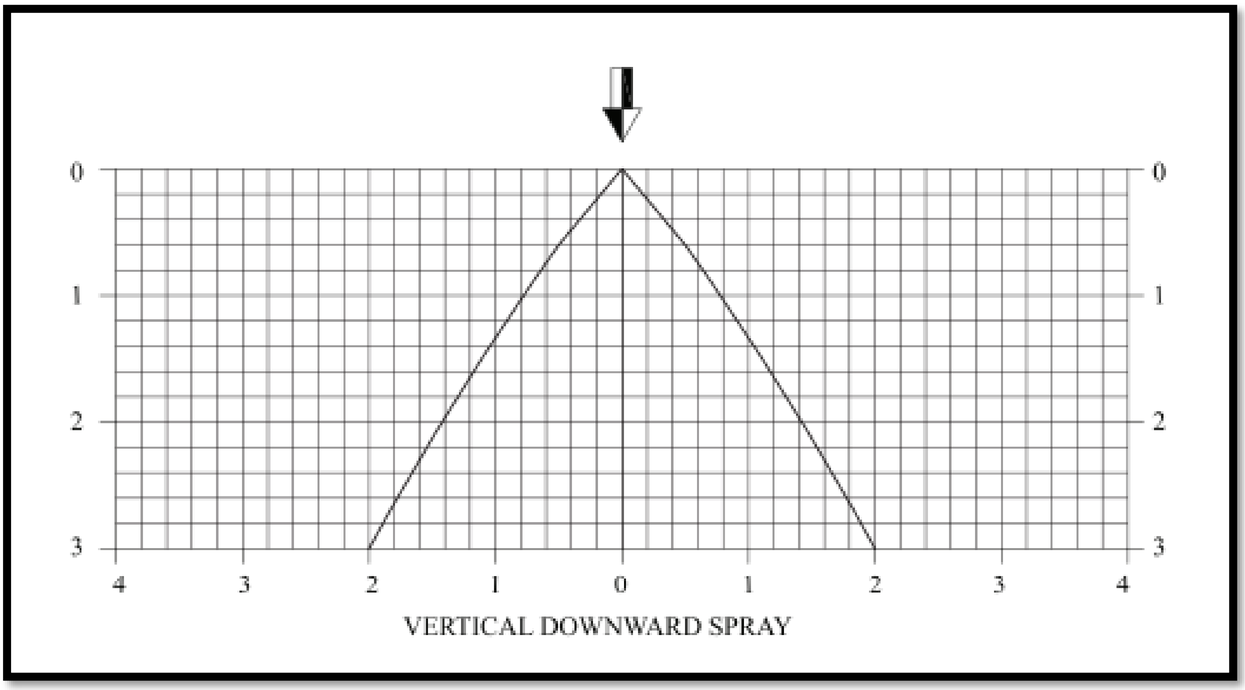


Fig 3.3: - 90º Spray Angle

3. 120º

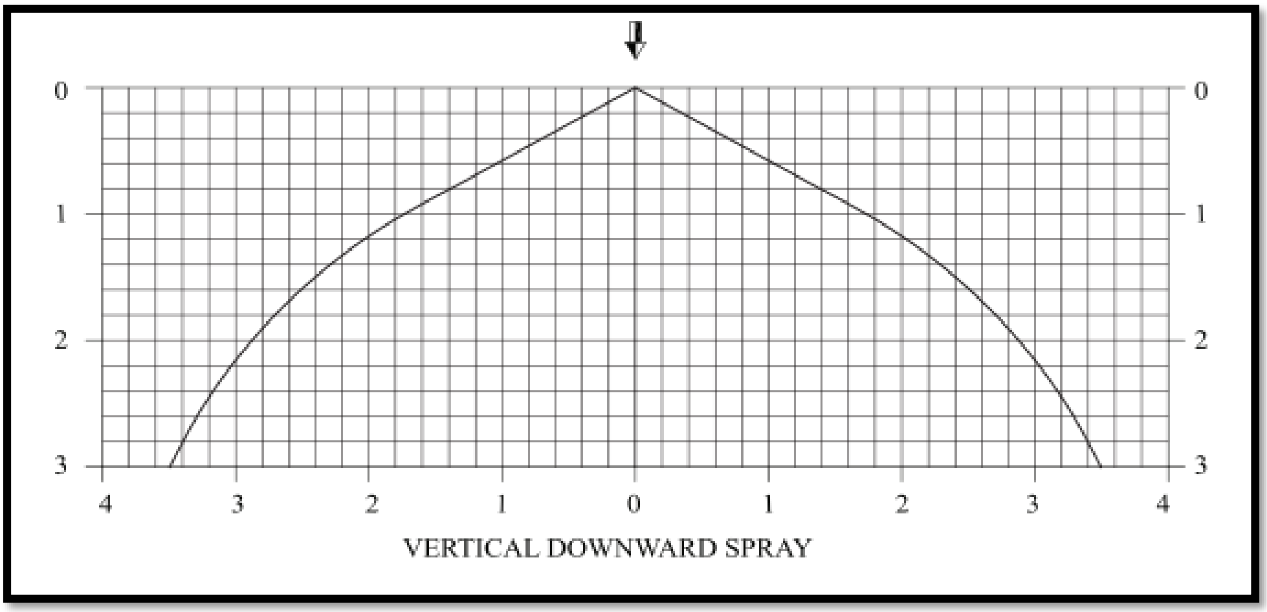


Fig 3.4: - 120º Spray Angle

Foam Pourer on a Floating Roof Tank

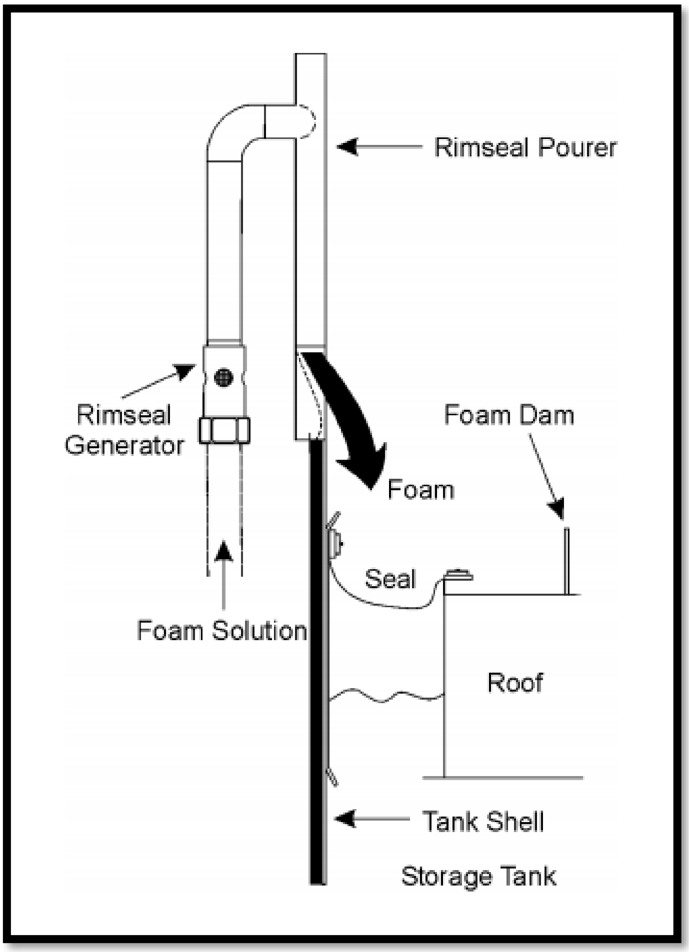


Fig 3.5: - Foam Pourer

CHAPTER – 4

PROBLEM FORMULATION

4.1 LEGAL PARAMETER

The works covered by the specification shall be designed, engineered, manufactured, built, tested and commissioned in accordance with the Acts, Rules, Laws and Regulations of India. The equipment to be furnished under this specification shall conform to latest issue (with all amendments) of specified standards.

In addition to meeting the specific requirement called for technical Specification, the equipment shall also conform to the general requirement of the applicable standards, which shall form an integral part of the specification.

i. IS 15325 - This Code deals with the provisions of automatic water spray systems and installations in premises. It also covers the essential water supplies and their maintenance. IS Code was adopted by the Bureau of Indian Standards, after the draft finalized by the Fire Fighting Sectional ('Committee had been approved by the Civil Engineering Division Council.

ii. IS 12835 – Design and installation of fixed foam fire extinguishing system. This standard lays down the requirements for design, installation, selection, inspection, operation and maintenance for both fixed and portable type of low expansion foam system.

iii. NFPA 15- This edition of NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection, was prepared by the Technical Committee on Water Spray Fixed Systems and acted on by NFPA at its May Association Technical Meeting held May 13–17, 2001, in Anaheim, CA. It was issued by the Standards Council on July 13, 2001, with an effective date of August 2, 2001, and supersedes all previous editions.

The Standard for Water Spray Fixed Systems for Fire Protection, formerly Water Spray Nozzles and Extinguishing Systems, first prepared by the Committee on Manufacturing Hazards, was tentatively adopted in 1939, with final adoption in 1940. Subsequently, this standard was placed under the jurisdiction of the Committee on Special extinguishing Systems, and a new edition was adopted in 1947. In 1959 the committee organization was further changed to place primary responsibility in the hands of the

Committee on Water Spray, under the general supervision of the General Committee on Special Extinguishing Methods. In 1966 the General Committee on Special Extinguishing Methods was discontinued, and the Committee on Water Spray was constituted as an independent committee. Revised editions were presented in 1969, 1973, 1977, 1979, and1982. This standard provides the minimum requirements for the design, installation, and system acceptance testing of water spray fixed systems for fire protection service and the minimum requirements for the periodic testing and maintenance of ultra high- speed water spray fixed systems.

i. NFPA 72- which provides the specifications for automatic detection system to actuate the water spray system
ii. NFPA 11- Standard for Low, Medium and High expansion Foam. It covers all aspects of the design, installation, operation, testing, and maintenance of low-, medium-, and high-expansion foam systems for fire protection. Criteria apply to fixed, semi-fixed, or portable systems for interior and exterior hazards.

4.2 STATEMENT OF PROBLEM FOR WHICH PROJECT IS PROPOSED

The safety of flammable fuel tanks is a matter of serious concern. Fire hazards lead into serious consequences such as EXPLOSION, spillage, BLEVE etc. Protection devices are not always accurate and fast due to possible malfunctions or other technical matters so the need for multiple devices and functions is required as backup. The installation of spray system is a reliable method of preventing and extinguishing fires on tanks containing flammable liquids for early detection and controlled burning in comparison with older equipment.

4.3 INDUSTRIAL HAZARDS

Petroleum and petrochemical industry may lead to hazard condition by means of fire, explosion, explosive chemical noise, electrical shock and etc. which result in health, environment and economic loss. These hazards can be a result of the presence of cleaning chemicals, hazardous gases, improper or insufficient lockout-tag out, vapors, fumes, dusts, or excessive heat or cold. Atmospheric storage tank fire very common in industrial facilities. In this work various accidents of storage tanks that taken place in Industrial facilities in Asia over last 40 years. Prevention and mitigation measures are also provided to help operating engineers handling similar types of situations in the future. The results show that 70% of accidents occurred in oil terminals or storage, petroleum refineries and Fire and explosion account for 90% of the accidents. There were accidents caused by lightning, by human errors, including poor operations and maintenance. Other causes were equipment failure, static electricity, sabotage, crack and rupture, leak and line rupture, open flames, etc. Most of these accidents would have been avoided if proper safety management programs, good engineering practices implemented.

4.3.1 Causes of Accidents

- **Lightning**

Lightning is one of the most common sources of ignition that may lead to a fire on atmospheric floating roof tanks. In a survey 95% of fire events taken place with the lightning-ignited rim seal fires. It is not necessary that lightning should directly strike on a tank for ignition to occur, a strike in the immediate nearby can generate that certain amount of static charge between the tank shell and floating roof tank that may lead to a fire. The Recent fire which took place on Diesel tank, due to thunder stormed noticed on Butcher Island off Mumbai in Oct 2017 since no fatality was noticed but it took four hours for fuel to completely burn off. This incident costs a nearly financial loss of at least 60-70 crore. Another fire which took place on crude oil tank at HPCL in July 2017 due to the lightning strike at Vishakhapatnam.

- **Maintenance Error**

Welding, Grinding during maintenance work is responsible for some catastrophic failures of storage tank vapor explode. Electric sparks and shocks can ignite flammable liquids or vapors lead to fire or explosion also. An incident caused at Lanjou, china refinery due to electric shock generated from electric motors and an incident in 1984 at Kaohsiung, Taiwan has resulted in the same cause. A chemical plant at Chaiyi, an accident caused by sparks generated from the electric soldering machine. To minimize electric hazards, each section, rooms, and areas must be taken into account in determining its classification defined in NFPA 70, National Electrical Code, Article 500, and Hazards (Classified) Locations.

- **Operational Error**

Overfilling of tanks is about the frequent cause of this category. Products came out releasing large volumes of vapors into the atmosphere and finding some ignition source lead to fire or explosion. If the tank is filled with flammable liquid and if it overfills, fire or explosion is almost non avoidable. In 2001, Wuyi, Zhejiang, China, 50 Kg of Benzene leaked due to overfilling of tank leads to 46 Children and 2 villagers hospitalized.

Eight out of Ten accidents take place in leakage due to Operational Error. In 2009, Jaipur fire at Indian Oil Corporation, Terminal, is caused due non availability of Standard procedure and Absence of Leakage stop device from a remote location i.e., remote operated valve.

- **Sabotage**

Sabotage is the fourth cause which can have an impact on any incident on the storage tank. Any terrorist activity or theft operation can lead to major emergencies. The various tank farms were put on fire during the Iraqi occupation of Kuwait in 1991. Few burnt tanks were fought for Extinguishment; the rest was left for complete burnout due to the war situation.

- **Equipment Failure**

An external floating roof tank of the tank consists of roof drain, breather Valve, and emergency roof drain. There were cases where roof drain found chocked and water gets accumulated on the surface of roof resulting in rook sunken case. Sometimes the excess pressure develops inside the, to relive breather valve is provided; it is found that valve failure leads to buckling of the tank. There is a seal, which is provided on the perimeter of the tank which slides up and down with the tank roof and protects the vapor from escaping out. Failure of seal or material integrity loss leads to various incidents of vapor escape.

- **Static Electricity**

Taking samples of storage tanks containing flammable liquids in open area results in static electricity. An accident in Japan in 1992 used metal devices or container for taking sample connected with conductive threads. To minimize the hazard, avoid taking a sample in open access. If the open access sample is unavoidable, better use nonconductive materials sampling gauges. Avoid using any device made of metal. The maximum static charge is developed during transferring of material. Bonding of containers should be done to make potential equal.

- **Leak and Line Rupture**

The incident took place in 1977, there is LPG leaked at Vishakhapatnam for without detected for various hours and after tanker ship pumped at the shore of Vishakhapatnam, resulting in a thick blanket of smokes which overwhelming the entire port city resulting in 37 deaths and 100 injuries.

- **Open Flames**

Open Flames resulting from cigarette smoking, ground fires, and hot particles also ignite flammable vapors around storage tanks.

- **Natural Disasters**

Due to Impact of seismic motions in earthquake phenomenon on the structure of storage tank leads to cracking of its structure which leads to leakage of flammable liquid due to a disturbance in equilibrium. As Asia comes in an earthquake-prone area, there is always a fear of some catastrophic failure of a tank. Fortunately, there are only a few cases which result from an earthquake. The fire involved in Japan Refinery in 1964 in Niigata, resulted from sparks ignited hydrocarbon vapors released due to an earthquake.

- **Runaway Reactions**

Runaway reaction may take place when impurities mixed with material stored in tanks resulting in an exothermic reaction. One of biggest disaster that took place in India, Bhopal gas Tragedy, 1984, caused due to water got mixed with methyl isocyanate stored in underground storage tank releasing huge volume of toxic gas killing hundreds of people

4.3.2 Types of Incident Scenarios

- **Boil Over**

Boil over is a phenomenon which occurs in storage tank fire consist of heavy hydrocarbon or a blend of hydrocarbon liquids e.g. Crude is released in explosive form when burning oil comes in contact with water, which settled at bottom of the tank. The heat is dissipated downwards and converts water into steam which expands 1500 times and carries burning crude with it. A boil over in tank covers an area of approximately 10D of the tank in downwind direction and 5D of the tank in crosswind directions.

- **Slopover**

Slopover is a phenomenon which occurs when water is applied to full surface fire tank and the water gets accumulated downwards results in overfill of product from the tank.

- **Vent Fire**

Vent fire takes place in the fixed roof tank when one or more of vents get ignited due to vapor flammable vapor released. The presence of flammable vapors has been always there either due to tank filling operation or tank's daily breathing cycle. More of vent fire found due to lightning strikes or found some ignition source nearby.

- **Full Surface Fire (Fixed Roof Tank)**

A full surface of the fixed roof can occur due to vent fire escalation. A vapor cloud explosion can occur is flammable vapor is found within flammable range during the flame flashback, mainly if flame arrestors/PV is not in working condition. If a tank is constructed as per API 650, it should separate from weal seam. Depending on the vapor space explosion force, the roof may remove partially ("Fish's mouth" opening) or fully removed.

- **Full Surface Fire (Open Floating Roof Tank)**

Full surface fire is one where the tank roof has lost its buoyancy and some or the entire liquid surface has been exposed and involved in fire.

- **Rim Seal Fire**

A rim seal fire takes place where the seal between the tank shell and roof has lost its integrity and released vapors exposed to an ignition source and involved in fire.

- **Bund Fire**

A fire in the band is a type that occurs outside the tank shell within the containment area. These types of fire involved small spillage fill up to fire covering whole bund area.

CHAPTER - 5

ANALYSIS AND METHODOLOGIES

5.1 Introduction

Water spray systems should only be designed by specialists. All system designs should include working drawings, specifications and hydraulic calculations which should be forwarded to the manufacturer of the installation components for approval.

Consideration should be given to drainage facilities to handle water discharged from the system and to the likelihood of spilt combustible or flammable liquids which may be present within the protected area.

The discussion in this report show the design criteria selected for water spray system selection for tanks it also show the installation philosophy carried out refinery and petrochemical plant according to OISD, TACAND NFPA standards to ensure the water spray system should be in good working condition.

5.2 Data obtained from Occupancy/Industry

Oil and gas processing plant: Oil and gas wells produce a mixture of hydrocarbon gas, condensate or oil; water with dissolved minerals, usually including a large amount of salt; other gases, including nitrogen, carbon dioxide (CO_2), and possibly hydrogen sulphide (H_2S); and solids, including sand from the reservoir, dirt, scale, and corrosion products from the tubing. The purpose of oil and gas processing is to separate, remove, or transform these various components to make the hydrocarbons ready for sale.

For the hydrocarbons (gas or liquid) to be sold, they must be:

i. Separated from the water &solids.
ii. Measured.
iii. Sold.
iv. Transported by pipeline, truck, rail, or ocean tanker to the user.

The goal is to produce oil that meets the purchaser's specifications that define the maximum allowable amounts of the following:

i. Water.
ii. Salt.
iii. Other impurities.

Similarly, the gas must be processed to meet purchaser's water vapour and hydrocarbon dew point specifications to limit condensation during transportation.

The equipment between the wells and the pipeline, or other transportation system, is called an oilfield facility. An oilfield facility is different from a refinery or chemical plant in a number of ways. The process is simpler in a facility, consisting not of chemical reactions to make new molecules, but of:

i. Phase separation.
ii. Temperature changes.
iii. Pressure changes.

In a refinery, the feed-stream flow rate and composition are defined before the equipment is designed. For a facility, the composition is usually estimated based on drill stem tests of exploration wells or from existing wells in similar fields. The design flow rates are estimated from well logs and reservoir simulations. Even if the estimates are good, the following change over the life of the field as wells mature and new wells are drilled.

The fire protection systems are based on heat detection through thermal fuses/ quartz bulbs. These sensors shall be installed at all critical places described below:

In storage area these detectors shall be provided encircling each vessel equi-spaced with a maximum spacing of 3 meter and not more than 2 meter from the ground.
The detector shall be designed to blow at 79 deg C temperature (max). The air will start leaking thus resulting in disturbing the three way pilot valve.

5.3 Data Analysis/Assessment

Table 5.1:-Water flow rate of spray system as per OISD standard

Application Area	Water application rate
Atmospheric storage tank	3 LPM/M2 of tank shell tanks area for tank on fire 3 LPM/M2 of tank shell area for exposure protection for tanks located within (R+30) M from centre of tank-on fire within the same dyke area. 1 LPM/M2 of tank shell area for exposure protection for tanks located outside (R+30)m from centre of tank-on-fire within the same dyke area.
Pressure Storage	10.2 LPM/M2 of Vessels shell area
Pumps(Volatile product service located under Pipe rack)	20.4 LPM/M2
Columns	10.2 LPM/M2
LPG pump house	20.4 LPM/M2
LPG Tank Truck	10.2 LPM/M2
Carousel machine	10.2 LPM/M2
Filled cylinder storage	10.2 LPM/M2
Empty cylinder storage	10.2 LPM/M2

CHAPTER 6
SOLUTION DOMAIN

6.1 Observation

Steps to be followed:-

- Calculate the total surface area of vessels to be protected.
- Decide the water requirement density.
- Calculate water requirement by multiplying total surface area vessels to be protected and water requirement density.
- Calculate number of sprayers ring required.
- Calculate number of water spray nozzles in each sprayer ring.
- Assume discharge percentage on each sprayer ring based considering parameters like rundown (in case of vertical storage tanks), number of sprayer nozzles needed in each rings etc.
- Calculate discharge in each ring according to discharge percentage assumed.
- Calculate discharge in each sprayer of ring.
- Calculate K factor of each sprayer.
- Go for next standard K factor from table.
- Calculate actual discharge from this standard k factor.
- Calculate total actual discharge.
- Calculate diameter of sprayer ring and feed pipe.
- Decide deluge valve based on discharge required.
- Calculate number of detection ring required for storage vessels.
- Then find out number of detectors needed in each ring.

FIGURE6.1:-design of Water spray system

6.2 Result obtained and its interpretation

Design considerations:

- Water application rate- 10.2 LPM/m^2
- Position of sprayer from surface- 450mm to 600mm
- Maximum distance between two sprayer- 2.5m
- Maximum height between two sprayer rings- 3.5m
- Minimum and Maximum pressure in spray network- 1.4 bar to 3..5 bar
- Maximum distance between two detectors- 3m
- Position from surface- 1m (max.)

Diameter of tank- 36 m

Height of tank- 20m

Steps:

1. Calculation of curved surface area to be protected

Curve surface area = π*D*H

= 3.14*36*20

= 2260.8 m^2

2. Water requirement

Water requirement = curved surface area*water application rate

= 2260.8*10.2 LPM

= 23060.16 LPM

3. Number of sprayer rings required

- Bottom ring should not be greater than 2 m from ground
- Top ring should be just below the top of vessel
- Distance between two consecutive rings should not be greater than 3.5m.
- Position of top most ring from top of vessel is 0.8 m

Number if sprayers = (H-h-2)/3.5+1

Where, H = height of tank in meter

h = distance from top of tank to topmost ring in meter

2m is the maximum distance of bottom ring from ground.

3.5 3 is the maximum distance between 2 sprayer rings.

No. of sprayer = (H-h-2)/3.5+1

= (20-0.8-2)/3.5+1

= 17.2/3.5+1

= 4.91+1

= 5.91

= 6

Taking it as 6 sprayer rings

4. Number of water spray nozzle in each ring:

- To calculate this we have to divide the circumference of ring by coverage length of each sprayer.
- Distance between two sprayer = 2.5 m

$$= \frac{\text{circumference of sprayer ring}}{\text{Maximum coverage of each sprayer}}$$

$$= \frac{\pi*(D+2b)}{2.5}$$

Here, D = diameter of tank in m

b = distance between sprayer ring and tank shell in m

$$= \frac{\pi*(36+2*0.6)}{2.5}$$

= 46

Thus number of sprayers in one ring is 46 approx

Total number of sprayers in 6 rings of shell = 46*6 = 276

5. Discharge on each sprayer ring:

- Let the total discharge be 100%. Therefore discharge on each sprayer ring will be divided equally.

  $$= \frac{\text{Discharge (\%)}}{\text{Total no. of rings}}$$

  $$= \frac{100}{6}$$

  = 16.66% in each ring

- Now,

  16.66% of total water required we get,

  $$= \frac{23060.16*16.66}{100}$$

  = 3841.82 LPM in each ring

- So discharge through one nozzle,

  $$= \frac{3841.82}{46}$$

  = 83.51 LPM

6. Calculation of K factor:

- Discharge from spray nozzle is calculated by formula, $Q=K\sqrt{P}$

  Where, Q is discharge in LPM

  K is nozzle constant

  P in pressure in bars

  Here, we take pressure equals to 2 bars for calculating actual discharge from nozzle.

- Q = 83.51
- P = 2

  Putting the value in formula,

- $Q=K\sqrt{P}$
- $83.51 = K\sqrt{2}$
- K = 59.05
- Taking standard value of K we get, K = 63.

- Putting value of K in Q = K$\sqrt{P}$

  $= 63\sqrt{2}$

  = 89.09
- Total discharge in one ring = 89.09*46

  = 4098.14 LPM
- Total water requirement = 4098.14*6

  = 24588.84 LPM

7. Calculation of diameter of each sprayer ring pipe:

- It can be calculated by formula, Q = A*V
- Where, Q = discharge in LPM

  A = area in square meter

  V = velocity in m/sec
- Taking maximum velocity in sprayer pipe as 5m/sec
- Q = 4098.14
- A = $(\pi/4)*D^2$

  Q = A*V

  $4098.14 = (\pi/4)*D^2*5$

  $$D^2 = \frac{4098.14*4}{1000*60*5*\pi}$$

  $D = \sqrt{0.0174}$

  D = 0.131 m = 5 inch approx

  The diameter of sprayer ring pipe is 5 inch

10. Detection system

- Spacing between detectors is 3 m.
- Distance of detection ring from tank shell is 300 mm.
- Number of detector in a ring = $\frac{\text{circumference of the detector ring}}{3}$

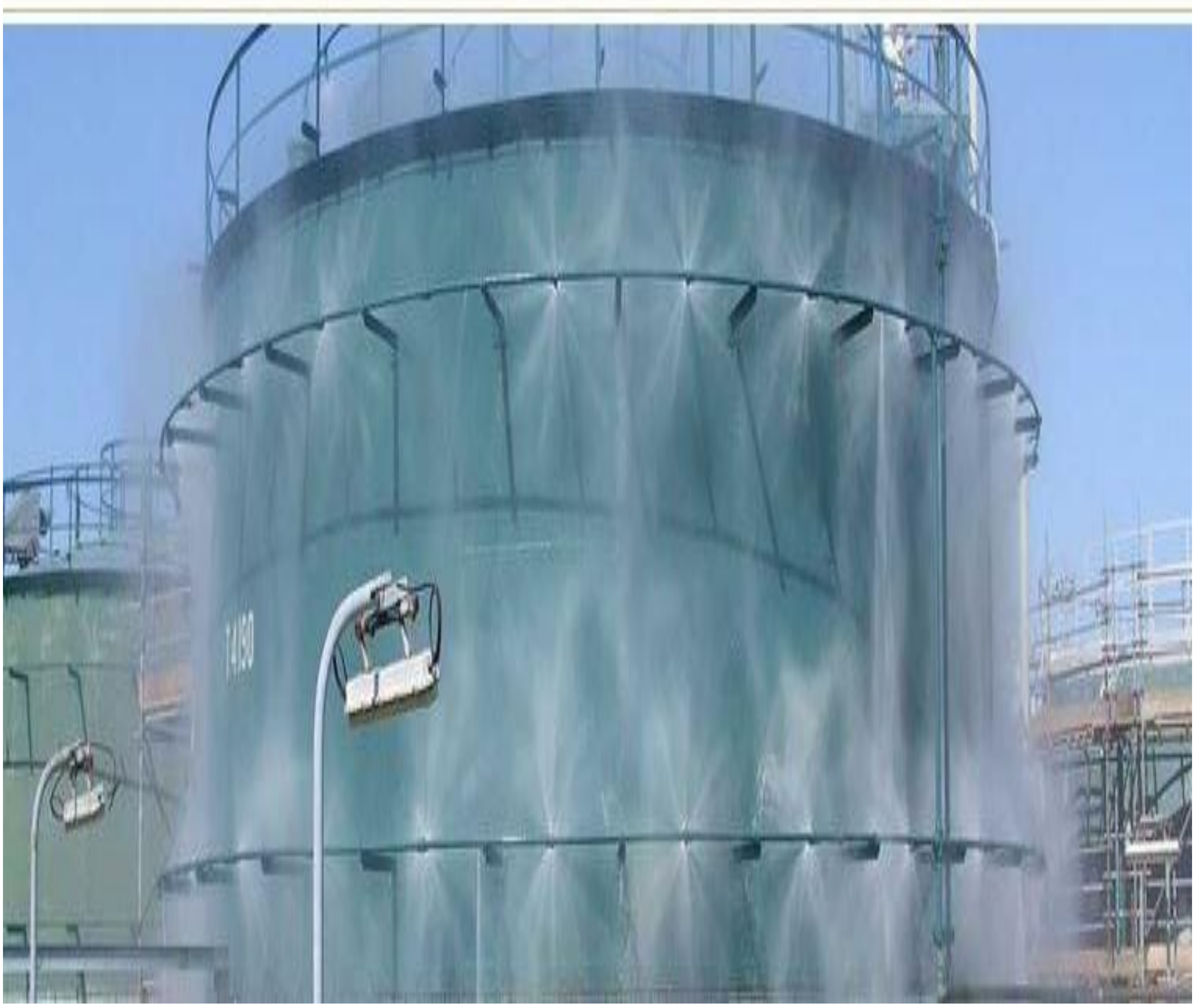
$$= \frac{3.14*(36+2*0.3)}{3}$$

= 38.936

Therefore we take as 39 detectors in a ring.

- As there are 2 detector rings, one at top and other at the bottom
- So, Total number of detectors = 39*2

- Total number of detectors = 78



6.3 Important finding and conclusion

BLOW OFF CAP:-

It is an outer cover for nozzle having a closed end portion and wall portion that together form an open ended cavity shaped to receive the discharge end of the nozzle and cover the orifice the closed end portion includes a closed end that is located in close proximity to the orifice of the nozzle when the blow off cap is mounted on the discharge end of the nozzle such that the orifice direct the fire water spray directly onto the closed end portion

The blow off cap wherein the o-ring provides a seal to prevent grease from entering the nozzle.

The blow off cap the interior groove having a depth and height based on at least one of an o-ring size and a discharge pressure The blow off cap cover is formed of metal or plastic.

Divide water sprayer ring into segment:-

We can divide water sprayer ring into three segments to maintain 1LPM/M2 discharge of spray outlet at tank present outside of (R+30) M of the fire tank

Also solve problem of water wastage during cooling of storage tank which is outside of (R+30)M from centre of fire tank.

CHAPTER 7
RECOMMENDATION AND FUTURE SCOPE

Recommendations and Future Scope

Water spray systems should only be designed by specialists. All system designs should include working drawings, specifications and hydraulic calculations which should be forwarded to the manufacturer of the installation components for approval.

Consideration should be given to drainage facilities to handle water discharged from the system and to the likelihood of spilt combustible or flammable liquids which may be present within the protected area. The discussion in this report show the design criteria selected for water spray system selection for tanks it also show the installation philosophy carried out refinery and petrochemical plant according to OISD and NFPA standards to ensure the water spray system should be in good working condition.

DESIGN OF SPRAYER AND BLOW OFF CAP:-

The sprayer can be designed having much more efficiency which will cover more larger area also the particle size of the water droplet can be reduced so that the absorption of heat can be attained in least possible time.

Blow off cap is an outer cover for nozzle having a closed end portion and wall portion that together form an open ended cavity shaped to receive the discharge end of the nozzle and cover the orifice the closed end portion includes a closed end that is located in close proximity to the orifice of the nozzle when the blow off cap is mounted on the discharge end of the nozzle such that the orifice direct the fire water spray directly onto the closed end portion

The blow off cap wherein the o-ring provides a seal to prevent grease from entering the nozzle. Its cover is formed of metal or plastic.

Divide water sprayer ring into segment:-

We can divide water sprayer ring into three segments to maintain 1LPM/M2 discharge of spray outlet at tank present outside of (R+30) M of the fire tank

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