LAYERS OF PROTECTION ANALYSIS AND FIRE SAFETY DESIGNING IN PIPELINE INSTALLATION , SMPL VIRAMGAM

By
(Sumit Alok)

UNIVERSITY OF PETROLEUM & ENERGY STUDIES

विद्यया शक्ति वशम्

College of Engineering
University of Petroleum & Energy Studies
Dehradun

May, 2009

A thesis submitted in partial fulfilment of the requirements for the Degree of
Master of Technology
(Health Safety and Environment)

By
(Sumit Alok)

Under the guidance of

Mr P.K Mishra
Operation Manager
WRPL, Viramgam

Approved

....

Dean

College of Engineering
University of Petroleum & Energy Studies
Dehradun
May, 2009

इंडियन ऑयल कॉर्पोरेशन लिमिटेड
पाइपलाइन्स प्रभाग : पश्चिमी क्षेत्र पाइपलाइन्स - विरमगाम / सिध्धपुर / आबूरोड
पो बॉक्स नं 4 विरमगाम, जिला अहमदाबाद, गुजरात 382 150
तावडिया रोड, सिध्धपुर, जिला पाटण, गुजरात 384 151
अम्बाजी रोड, आबू रोड, जिला सिरोही, राजस्थान 307 026

IndianOil

Indian Oil Corporation Limited
Pipelines Division - Western Region Pipelines - **Viramgam / Sidhpur / Abu Road**
Post Box No.4, Viramgam, Distt: Ahmedabad, Gujarat-382 150, Phone : (02715) 233510, 233327, Fax : (02715) 233412
Tavadia Road, Sidhpur, Distt: Patan, Gujarat-384 151, Phone : (02767) 220899, 221287, Fax : (02715) 233412
Ambaji Road, Abu Road, Distt: Sirohi, Rajasthan-307 026, Phone : (02974) 226251, 226276, Fax : (02715) 233412

(पाइपलाइन्स प्रभाग):
(Pipelines Division)

CERTIFICATE

This is to certify that the thesis work on **'LAYERS OF PROTECTION ANALYSIS AND FIRE SAFETY DESIGNING IN PIPELINE INSTALLATION, IOCL VIRAMGAM",** carried out by Mr. Sumit Alok, S&EPO in fulfillment of requirement for the award of degree of **Master of Technology in Health, Safety and Environment Engineering,** is a bonafide work carried out by him under my supervision and guidance.

This work has not been submitted anywhere else for any other degree. The original work has been carried out at **WRPL, Viramgam IndianOil**, India.

Date: 8th May, 2009

Prasun Kumar Mishra
Operations Manager,
WRPL, Viramgam
Indian Oil Corporation Ltd.

ACKNOWLEDGEMENT

This is to acknowledge with thanks the help, guidance and support that we have received during the thesis to the management of **INDIAN OIL, WRPL** for giving us an opportunity to carry out thesis work.

I have no words to express a deep sense of gratitude to our project mentor, **Mr. P.K Mishra**, Operation Manager, WRPL Viramgam, and INDIAN OIL for his able guidance throughout.

I express heartily thankful to **Shri Sanjay Kumar V**, CHRM, WRPL INDIAN OIL for the valuable support and opportunities given to us.

I would also like to thank **Mr. Ashish Gokhle** (Dy Manager,Safety & Environment protection), **Mr. Anish Kumar** (Operation Engineer), for their valuable support during the thesis duration right from the inception stage.

I thank Dean **UPES** and **Mr G.Sanjay Kumar** (Course Co-ordinator), **M-Tech HSE UPES** for the inputs and guidance provided by them.

Sumit Alok

ABSTRACT

Indian oil corporation Ltd , Pipeline division owns and operate Salaya Mathura Crude Oil pipeline for transporting crude oil from Vadinar in Gulf of Kutch to Koyali refinery , Mathura refiner and panipath refinery. SMPL have intermediate booster station at Vadinar , Jamnagar , Gauridad , Viramgam , Sidhpur , Aburoad, Kot , Sindra and Chaksu.This pipeline was commissened in 1978/81.SMPL comprises three tank farm at Vadinar , Viramgam & Chaksu to store crude oil of different category.

The project report examines layers of protection available at viramgam tank farm by the application of LOPA tool of Risk Assessment and design calculation of fire fighting of pumping station and tank farm. Oil industry Safety Directorate standard 116 & 11 , Tariff Advisory Committee (TAC) and NFPA standard has been consider for design calculation of fire fighting system .

Water flow requirement has been calculated with the consideration of single largest fire at a time. Water storage requirement is calculated with the consideration of capacity of fire fighting pumping to deliver water for four hour with the head of 7 kg/cm^2 at remotest point .Foam compound is also calculated for Layers of protection analysis have been carried out with the reference of available Safety manual and HAZOP studies.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

SMPL	Salaya Mathura Pipeline
WRPL	Western Region Pipeline
LOPA	Layers of protection Analysis
NFPA	National Fire Protection Agency
OISD	Oil Industry Safety Directorate
PID	Process & Instrumentation Diagram
PRV	Pressure Relief Valve
TAC	Tariff Advisory Committee
PSL	Pressure Switch Low
PSLL	Pressure Switch Low Low
NPL	Nitrogen pressure Low
LPM	Liters per Minute
UV	Ultra Violate
IR	Infrared
AFFF	Aqueous Film forming Foam
API	American Petroleum Institute
VK	Viramgam Koyali
VC	Viramgam Chaksu
RA	Risk Assessment
HAZOP	Hazard Operability
PHA	Preliminary Hazard Analysis
IPL	Independent Protection failure
PFD	Probability of failure on demand

CHAPTER 1

ABOUT SMPL , Viramgam

1. INTRODUCTION

The small town of Viramgam, the heart of Salaya Mathura c rude oil Pipeline (SMPL), is located about 60 Km away from India's second largest cotton producing town, Ahmedabad.. From the pipeline point of view, Viramgam is a "T" point bifurcating the pipeline into two lines, one goes to Koyali Refinery and another to Chaksu Booster cum Tank farm Station.

1.1 TECHNICAL SPECIFICATION

1.2 Main equipment

V-C- Section

- Mainline Engines
  No. of Mainline Engines: 2+1
  Make : APE Allen(U.K.)
  Engine BHP : 3136 x 3
  RPM (Max) : 750

- Mainline Pumps
  Make : BPCL
  Capacity : 2025 kl/hr.
  Head : 334 Meter

V-K Section

- Mainline Engines
  No. of Mainline Engines: 2+1
  Make : APE Allen (U.K.)
  Engine BHP : 1416 x 3
  RPM (Max) : 600

- Mainline Pumps
  Make : WEIR
  Capacity : 731 Kl/hr.
  Head : 336 Meter

1.1.2 Auxiliary facilities:

- Fuel bulk storage tanks of capacity 80 kl(HSD) and 250 Kl (Crude)
- Sump tank and re-injection facilities.
- Scrapper launching and receiving facilities.

- 2 Nos. Auto Centrifuges.
- 4 Nos. motor and 1 no. Engine driven compressors.
- 5 Nos. motor driven booster pumps.
- Effluent treatment plant.
- Turbine meters/Meter prover system.
- ❖ CC TV for monitoring the safety / security of tank farm & Pump station area.

1.1.3 Fire fighting system:

- Fire water pond - 2 nos. of 6250 kls each.
- Rim seal Foam/Holon Fire Fighting System /Semi fixed foam pourer system installed on the floating roof tanks.
- Water sprinkler system for cooling tanks.
- 3 Nos. Mobile, fire water foam tenders.
- Conventional equipment for fire fighting with foam.
- Fire Hydrant network throughout the installation.
- Engine driven FF pumps - 02 nos. (FF1, FF3) – Capacity 550 m3/Hr
01 nos (FF5) – Capacity 380 m3/Hr
- Motor driven FF pumps - 02 nos. FF2, FF4 (350 & 380 m3 / hr)
- Jockey Pump- - 02 Nos. (30 Cu. M. / hr.)

1.1.4 Tank farm

- 7 nos. of floating roof each of height 14.5 meters and diameter 79.5 meters and capacity 65,000 kls each.
- 2 nos. of floating roof tanks, each of height 14.0 meters and diameter 56.0 meters and capacity 30,000 kls each.

CHAPTER 2

LAYERS of PROTECTION ANALYSIS (LOPA)

2.1 Introduction

It is an analysis tool that typically on information developed by PHA. It uses order of magnitude for initial event frequency consequence severity likelihood failure of IPL (independent protection layers) it determines if there are sufficient layers of protection against an accident scenario.

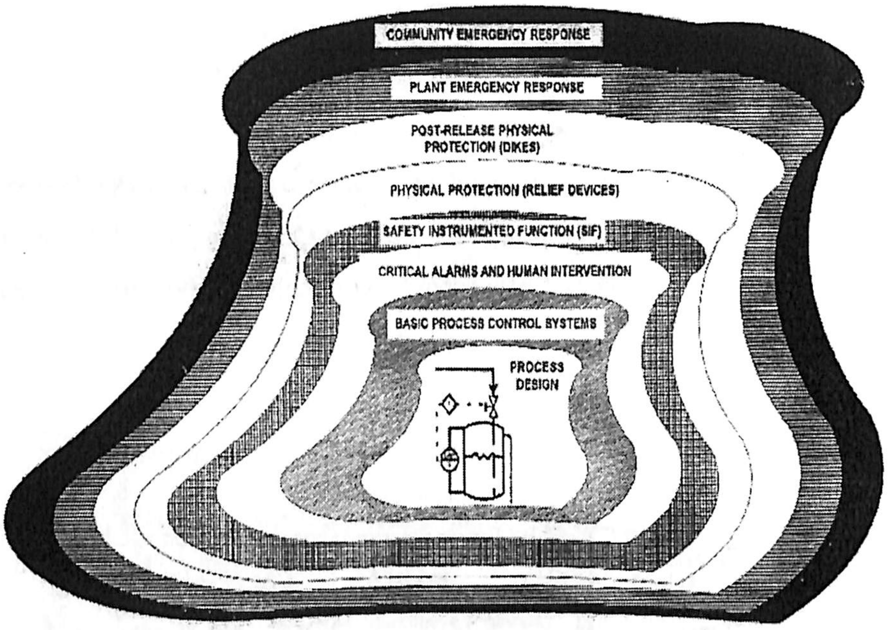


FIGURE 2.1. Layers of defense against a possible accident.

Features of LOPA

- Protection layers on process depend upon PROCESS COMPLEXITY and SEVERITY OF CONSEQUENCE.
- LOPA provides basis for the judgment either IPL is sufficient to control RISK
- LOPA never suggest which IPL or design should be selected but it assist in selecting alternates among IPL
- LOPA is not fully QUANTITATIVE RISK ASSESSMENT (QRA) approach.

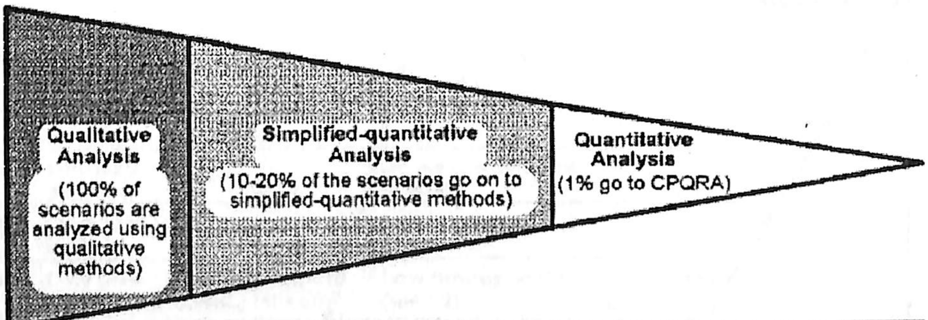
2.2 BENEFITS of LOPA

- It reproducibility evaluate the risk of selected ACCIDENT SCENARIO.
- ACCIDENT SCENARIO is identified by PHA or DESIGN review or HAZARD EVELUATION (HE), then LOPA is applied for UNACCEPTABLE ACCIDENT SCENARIO..

- LOPA is limited to evaluating a single cause consequence pair of scenario.
- Once cause- consequence is selected, LOPA is utilized to determine controls are meeting the definition of IPL and estimate RISK SCENARIO.
- Result of LOPA help analyst to decide how much additional risk reduction may be required.

APPLICATION METHODS OF LOPA

- After PHA (QRA), in which SCENARIO has been identified.
- When HE team believes SCENARIO is too complex for team to make judgment.
- When HE team recognizes consequence are too severe.
- When complexity of process increases, the level of hazard evaluation technique is also increased. LOPA utilized as screening tool prior to CPQRA.
- LOPA can scrutiny which scenario need more effective HE.



Techniques:	HAZOP What-if/Checklist FMEA	Quantified FMEA F&EI CEI	LOPA	Rough estimate with event tree	Event tree Fault tree HRA
Applicability to simple issues:	Good	Good	Good	Excessive	Excessive
Applicability to complex issues:	Poor	Poor	Fair	Fair	Good

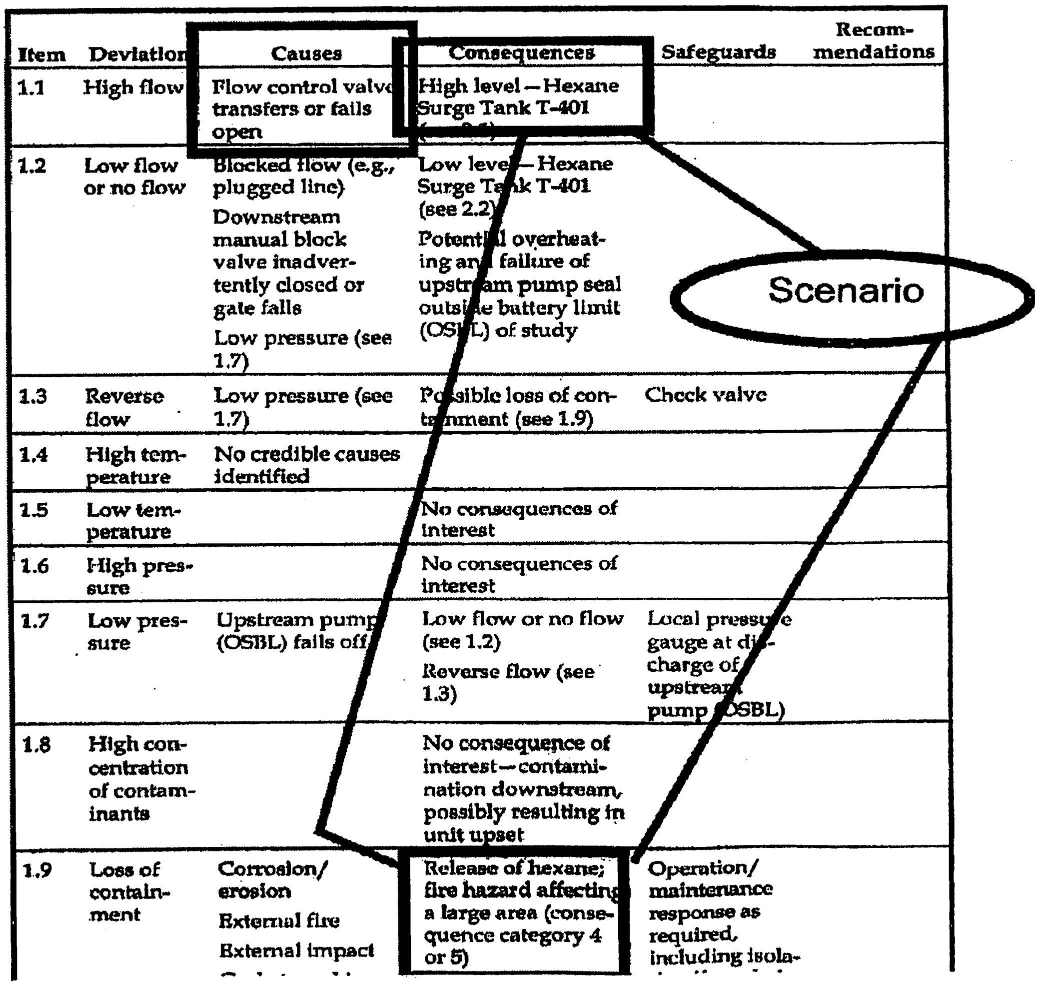
Legend
FMEA = Failure modes and effects analysis; can be quantified
F&EI = Dow Fire and Explosion Index
CEI = Dow Chemical Exposure Index
HRA = Human reliability analysis; uses human success/failure trees to model accident sequences
CPQRA= Quantitative risk analysis; includes statistical and probabilistic modeling of frequency and consequence of a single or multiple scenario

Figure 2:-LOPA feature

2.3STEPS in LOPA

1. Identify the consequence to screen the scenario.
- Consequence is typically identified during qualitative hazard review (HAZOP)
- Evaluate the consequence and estimate the magnitude
- Estimation of impact on HSE.

2. SELECT an accident scenario: - LOPA is applied to one scenario at one time. Scenario selected from other qualitative analysis. Scenario describes single CAUSE-CONSEQUENCE pair.



Item	Deviation	Causes	Consequences	Safeguards	Recom-mendations
1.1	High flow	Flow control valve transfers or fails open	High level — Hexane Surge Tank T-401		
1.2	Low flow or no flow	Blocked flow (e.g., plugged line) Downstream manual block valve inadvertently closed or gate fails Low pressure (see 1.7)	Low level — Hexane Surge Tank T-401 (see 2.2) Potential overheating and failure of upstream pump seal outside battery limit (OSBL) of study		
1.3	Reverse flow	Low pressure (see 1.7)	Possible loss of containment (see 1.9)	Check valve	
1.4	High temperature	No credible causes identified			
1.5	Low temperature		No consequences of interest		
1.6	High pressure		No consequences of interest		
1.7	Low pressure	Upstream pump (OSBL) fails off	Low flow or no flow (see 1.2) Reverse flow (see 1.3)	Local pressure gauge at discharge of upstream pump (OSBL)	
1.8	High concentration of contaminants		No consequence of interest — contamination downstream, possibly resulting in unit upset		
1.9	Loss of containment	Corrosion/ erosion External fire External impact	Release of hexane; fire hazard affecting a large area (consequence category 4 or 5)	Operation/ maintenance response as required, including isola-	

Figure 3:- CAUSE CONSEQUENCE.

3. Identify the initial event of the scenario and identify the initial event frequency :- The initial event which lead to failure is identified in this step and respected frequency for which scenario is valid

4. Identify the IPLs and estimate the probability of failure on demand of IPL:-In this step as per identified accident scenario and possible failure nos of IPL is estimated.
5. Estimate the risk of the scenario by mathematically combination of consequence, initiating event and IPL data: - factor adding to risk is also considered.
6. Evaluate the risk to reach a decision concerning the scenario.- This include comparing the risk of scenario to company's tolerable risk criteria or related target.

LIMITATION OF LOPA

- LOPA is simplified approach and should not be applied to all scenarios as in some case LOPA needs excessive effort while in some other case needed overly simplicity.
- LOPA is time consuming in comparison of HAZOP ,PHA
- LOPA is complement to HAZOP as it consider the scenario develop by it.
- LOPA results can't be comparing from one organization to another.

CHAPTER 3

LOPA application on

PIPELINE INSTALLATION

3.1 Identify the consequence to screen the scenario

S. No.	Activity	Hazards	Consequence	Exiting corrective action
1	Oil Storage in tanks	Inhalation of fumes	Risk of life/ Injury	Safety precautions during tank gauging is being followed. PPE to be used.
		Source of Ignition	Fire	All schedule maintenance are followed. Earthing system is checked as per schedule. Safety precautions are adhered for any job inside the station.
2	Oil water Separator	Inhalation of fumes	Risk of life/ Injury	All schedule maintenance are followed. Earthing system is checked as per schedule. Safety precautions are adhered for any job inside the station.
		Source of Ignition	Fire	All schedule maintenance are followed. Earthing system is checked as per schedule. Safety precautions are adhered for any job inside the station.
3	Operation of tanks	Source of Ignition	Fire	All schedule maintenance are followed. Earthing system is checked as per schedule. Safety precautions are adhered for any job inside the station.
4	Operation of mainline	Leakage	Third party damage	Routine maintenanve and monitoring of pipeline coating condition through cathodic protection.
		Source of Ignition	Fire	DMP is in existance and being practiced and awareness programme is conducted in villages.
5	Operation of station equipment	Noise	Hearing problem in long run	The PPE are being used. Statutory warning for entering to high noise is displayed at prominent locations as a caution.
		Loose electrical connection	Fire	All schedule maintenance are followed. Earthing system is checked as per schedule. Safety precautions are adhered for any job inside the station.
		Leakage	Propety Damage	Schedule maintenance of the pipeline in the station premicses, safety devices provided for the line protection is monitored.
6	Repair and Maintenance of tanks	Inhalation of dust during sand blasting	Breathing trouble	Use of PPE and safety precautions are followed.
		Welding	Effect on eyes	
		Sludge cleaning	Skin contact with sludge	
		Slippery surface	Injury	
		Working at higher	Injury	
7	Repair and Maintenance of station equipment.	Noise	Hearing problem in long run	To follow and adhereance of all written down safety precautions.
		Loose connection	Fire	
		Improper or no blinding.	Oil Spillage	
		Improper draining	Oil Spillage	
		Working on height	Injury/death	
8	Fire water pond/ tank cleaning	Slippery surface	Injury	To follow and adhereance of all written down safety precautions.
9	Unloading/ unloading of heavy materials	Lifting of weight more than specified limit	Injury	
			Property damage	
			Both	

Table 1 :- RA of pipeline installation

3.2 SELECTION OF AN ACCIDENT SCENARIO

As per Risk assessment two most critical scenarios has been selected

A)

Operation of tanks	Source of ignition	Fire

B)

Operation of mainline	Leakage	Third party damage

3.3 IDENTIFY THE INITIAL EVENT OF THE SCENARIO AND IDENTIFY THE INITIAL EVENT FREQUENCY

A) IDENTIFY THE INITIAL EVENT

Initiating events are grouped into three general types: external events, equipment failures, and human failures

- Initial event leading to fire scenario in tanks are :-
  - Failure of instrumentation system to indicate high level of crude in tank in control room.
  - Failure of inlet /outlet motor operated valve.
  - Thundering / lightning /sabotage /war /flood
  - Leakage from rim seal.
  - Leakage / bursting of tank shell.
  - Over-pressure inside tank.
  - Operator error.
- B) INITIAL EVENT FREQUENCY

Sl no	Initial event	Standard frequency(failure rate) per year	failure Rate
1	Failure of instrumentation system to indicate high level of crude in tank in control room.	1 to 1/100	0.01
2	Failure of inlet /outlet motor operated valve.	1/100 to 1/10000	0.00006849315
3	Thundering / lightning /sabotage /war /flood	1/100 to 1/10000	0.00000000951
4	Leakage from rim seal.	1/100 to 1/100000	0.00000000228
5	Over-pressure / Leakage / bursting of tank shell.	1/1000 to 1/100000	0.00000000019
6	Operator error.	1/10 to 1/1000	0.00000045662

Table :2 Initial event frequency of overflow of storage tank

- REFERENCE FREQUENCY RATE

Initiating Event	Frequency Range from Literature (per year)	Example of a Value Chosen by a Company for Use in LOPA (per year)
Pressure vessel residual failure	10^{-5} to 10^{-7}	1×10^{-6}
Piping residual failure — 100 m — Full Breach	10^{-5} to 10^{-6}	1×10^{-5}
Piping leak (10% section) — 100 m	10^{-3} to 10^{-4}	1×10^{-3}
Atmospheric tank failure	10^{-3} to 10^{-5}	1×10^{-3}
Gasket/packing blowout	10^{-2} to 10^{-6}	1×10^{-2}
Turbine/diesel engine overspeed with casing breach	10^{-3} to 10^{-4}	1×10^{-4}
Third party intervention (external impact by backhoe, vehicle, etc.)	10^{-2} to 10^{-4}	1×10^{-2}
Crane load drop	10^{-3} to 10^{-4} per lift	1×10^{-4} per lift
Lightning strike	10^{-3} to 10^{-4}	1×10^{-3}
Safety valve opens spuriously	10^{-2} to 10^{-4}	1×10^{-2}
Cooling water failure	1 to 10^{-2}	1×10^{-1}
Pump seal failure	10^{-1} to 10^{-2}	1×10^{-1}
Unloading/loading hose failure	1 to 10^{-2}	1×10^{-1}
BPCS instrument loop failure *Note:* IEC 61511 limit is more than 1×10^{-5}/hr or 8.76×10^{-2}/yr (IEC, 2001)	1 to 10^{-2}	1×10^{-1}
Regulator failure	1 to 10^{-1}	1×10^{-1}
Small external fire (aggregate causes)	10^{-1} to 10^{-2}	1×10^{-1}
Large external fire (aggregate causes)	10^{-2} to 10^{-3}	1×10^{-2}
LOTO (lock-out tag-out) procedure* failure *overall failure of a multiple-element process	10^{-3} to 10^{-4} per opportunity	1×10^{-3} per opportunity
Operator failure (to execute routine procedure, assuming well trained, unstressed, not fatigued)	10^{-1} to 10^{-3} per opportunity	1×10^{-2} per opportunity

Table 3 :- Standard Frequency Rate

3.4 IDENTIFY THE IPLS AND ESTIMATE THE PROBABILITY OF FAILURE

An IPL is a device, system, or action that is capable of preventing a scenario from proceeding to its undesired consequence independent of the initiating event or the action of any other layer of protection associated with the scenario.

IPL	Comments *Assuming an adequate design basis and adequate inspection and maintenance procedures*	PFD from Literature and Industry	PFD Used in This Book (For screening)
Dike	Will reduce the frequency of large consequences (widespread spill) of a tank overfill/rupture/spill/ etc.	$1 \times 10^{-2} - 1 \times 10^{-3}$	1×10^{-2}
Underground Drainage System	Will reduce the frequency of large consequences (widespread spill) of a tank overfill/rupture/spill/ etc.	$1 \times 10^{-2} - 1 \times 10^{-3}$	1×10^{-2}
Open Vent (no valve)	Will prevent over pressure	$1 \times 10^{-2} - 1 \times 10^{-3}$	1×10^{-2}
Fireproofing	Will reduce rate of heat input and provide additional time for depressurizing/firefighting/etc.	$1 \times 10^{-2} - 1 \times 10^{-3}$	1×10^{-2}
Blast-wall/ Bunker	Will reduce the frequency of large consequences of an explosion by confining blast and protecting equipment/buildings/etc.	$1 \times 10^{-2} - 1 \times 10^{-3}$	1×10^{-3}
"Inherently Safe" Design	If properly implemented can significantly reduce the frequency of consequences associated with a scenario. Note: the LOPA rules for some companies allow inherently safe design features to eliminate certain scenarios (e.g., vessel design pressure exceeds all possible high pressure challenges).	$1 \times 10^{-1} - 1 \times 10^{-6}$	1×10^{-2}
Flame/Detonation Arrestors	If properly designed, installed and maintained these should eliminate the potential for flashback through a piping system or into a vessel or tank.	$1 \times 10^{-1} - 1 \times 10^{-3}$	1×10^{-2}

Table 4 :-PFD of IPL

In order to be considered an IPL, a device, system, or action must be

- **effective** in preventing the consequence when it functions as designed,
- **independent** of the initiating event and the components of any other IPL already claimed for the same scenario,
- **auditable;** the assumed effectiveness in terms of consequence prevention

The effectiveness of an IPL is quantified in terms of its **probability of failure on demand** (PFD) which is defined as the probability that a system (in case the IPL) will fail to perform a specified function on demand. The PFD is a dimensionless number between 0 and 1. The smaller the value of the PFD, the larger the reduction in frequency of the consequence for a given initiating event frequency. The "reduction in frequency" achieved by an IPL is sometimes termed the "risk reduction factor."

- **Active IPL**

IPL	Comments *Assuming an adequate design basis and inspection/maintenance procedures*	PFD from Literature and Industry	PFD Used in This Book (For screening)
Relief valve	Prevents system exceeding specified overpressure. Effectiveness of this device is sensitive to service and experience.	$1 \times 10^{-1} - 1 \times 10^{-5}$	1×10^{-2}
Rupture disc	Prevents system exceeding specified overpressure. Effectiveness can be very sensitive to service and experience	$1 \times 10^{-1} - 1 \times 10^{-5}$	1×10^{-2}
Basic Process Control System	Can be credited as an IPL if not associated with the initiating event being considered (see also Chapter 11). (See IEC 61508 (IEC, 1998) and IEC 61511 (IEC, 2001) for additional discussion.)	$1 \times 10^{-1} - 1 \times 10^{-2}$ ($>1 \times 10^{-1}$ allowed by IEC)	1×10^{-1}
Safety Instrumented Functions (Interlocks)	See IEC 61508 (IEC, 1998) and IEC 61511 (IEC, 2001) for life cycle requirements and additional discussion		
SIL 1	Typically consists of: Single sensor (redundant for fault tolerance) Single logic processor (redundant for fault tolerance) Single final element (redundant for fault tolerance)	$\geq 1 \times 10^{-2} - < 1 \times 10^{-1}$	
SIL 2	Typically consists of: "Multiple" sensors (for fault tolerance) "Multiple" channel logic processor (for fault tolerance) "Multiple" final elements (for fault tolerance)	$\geq 1 \times 10^{-3} - < 1 \times 10^{-2}$	This book does not specify a specific SIL level. Continuing examples calculate a required PFD for a SIF
SIL 3	Typically consists of: Multiple sensors Multiple channel logic processor Multiple final elements	$\geq 1 \times 10^{-4} - < 1 \times 10^{-3}$	

Table 5 :-PFD of Active IPL

Examples of Human Action IPLs*

IPL	Comments *Assuming adequate documentation, training and testing procedures*	PFD from Literature and Industry	PFD Used in This Book (For screening)
Human action with 10 minutes response time.	Simple well-documented action with clear and reliable indications that the action is required	$1.0 - 1 \times 10^{-1}$	1×10^{-1}
Human response to BPCS indication or alarm with 40 minutes response time	Simple well-documented action with clear and reliable indications that the action is required. (The PFD is limited by IEC 61511; IEC 2001.)	1×10^{-1} ($>1 \times 10^{-1}$ allowed by IEC)	1×10^{-1}
Human action with 40 minutes response time	Simple well-documented action with clear and reliable indications that the action is required	$1 \times 10^{-1} - 1 \times 10^{-2}$	1×10^{-1}

Table 6:- PFD of Human action

Based on above mention data PFD of IPL can be calculated as:-

scenario number -01	equipment no:-VT 01 to 09	scenarion title:- Fire, third party loss
date	**description**	**probability**
Consequence Description / category	Overflow of Crude Oil from any of tank can lead to pool fire , flash fire with probable ignition , injury fatility , stoppage of operation and third party loss.	N/A
Initial Event	Failure of instrumentation system to indicate high level of crude in tank in control room.	1/10
Conditional modifier (if Applicable)		
	Probability of ignition	Yes
	Probability of personnel in affect	Yes
	probability of fatal injury	Yes
	others	
INDIPENDENT PROTECTION OF LAYER		
	1 High Alarm in control room (PFD)	1/10
	2 log book entry of tank level on every hour & manual level measurement of crude level (PFD)	1/100
	3 Interlock of inlet valve of tank on HIGH- HIGH level (PFD)	1/10
	4 Automatic closing of pumping inlet valve and diverting main line flow to SURG relief Tank (PFD)	1/10
	5 Dyke wall (PFD)	1/100
Safeguard (Non IPL)	Rim Seal protection, High Tower Camera for feal time view of tank	
Total PFD of all IPL		1/10000000
Risk Tolerence criteria met? (y/n)		
Remarks	Probablity of failure of IPL is very less than initial event probablity, So it is safe.	

CHAPTER 4

Codes and Standard for Designing aspect of Fire safety

4.1 TAC RULES FOR WATER SPRAY SYSTEM

The purpose of these rules is to provide minimum requirement for fixed water spray system based on good engineering practice. Here water spray system refers to use of water at a particular pressure, velocity and density discharge from specially designed nozzle. This system should be independent of or supplementary to other form of protection

Based upon criticality and requirement two types of spray system have been envisaged , they are

1) Medium velocity water spray system
2) High velocity water spray system

4.1.1 MEDIUM VELOCITY WATER SPRAY SYSTEM

This type of system are installed to control the burning and to provide cooling of exposure protection to such risk where extinguishment is always not possible or even desirable i.e fire involving flammable fluids having flash point below 65^0

Medium velocity water protection system covers following areas

A. General area protection ex flammable gas storage area
B. Horizontal storage vessel ex LPG bullet
C. Vertical storage vessel ex. Toluene tank
D. Spherical storage vessel
E. Spot protection

A) GENERAL AREA PROTECTION:-

Definition: -

A process plant where flammable liquid are contained in vessel and or pipes forming a large small complex of the plant either in a room or outdoors or under a roof with open sides

Or

A plant where more than 1000 liters of flammable liquid / solvent are stored in small container

General information:-

The density of water application depends upon type of flammable liquid handled in plants and upon the object of protection and site condition. Some of examples are control burning of spilt liquid exposure protection of plant, ceiling height, area of fire involved.

General requirement:-

- Sprayers installed in area at ceiling level for spill fire protection up to 3M from ceiling sprayer.
- Where ceiling height is more than 13M from floor, conventional open type sprinkler should be used.
- At lower level, vessel, pump, drum, manifold etc. inside the plant need to be protected by sprayers.
- If obstruction is extended up more than 1M in width, underneath of them local sprinkler should be installed.
- Sprayers installed at lower level should be provided with baffle plates.
- Following detail drawing should be submitted along with proposal
  a) Plan and sectional view
  b) Column, beam and trusses of supporting structure.
  c) Working detail of sprayer, detector, piping, spacing, zone division etc.
  d) Location of deluge valve, piping, size etc.
  e) Drawing of nodes for hydraulics calculation etc
  f) Detail of liquid handle , quantity etc
  g) Site-plan
  h) Protrubences
  i) Sprayer character

Design density:-

- The density of water application depends upon flash point of chemical and ceiling height of risk as per figure no 01

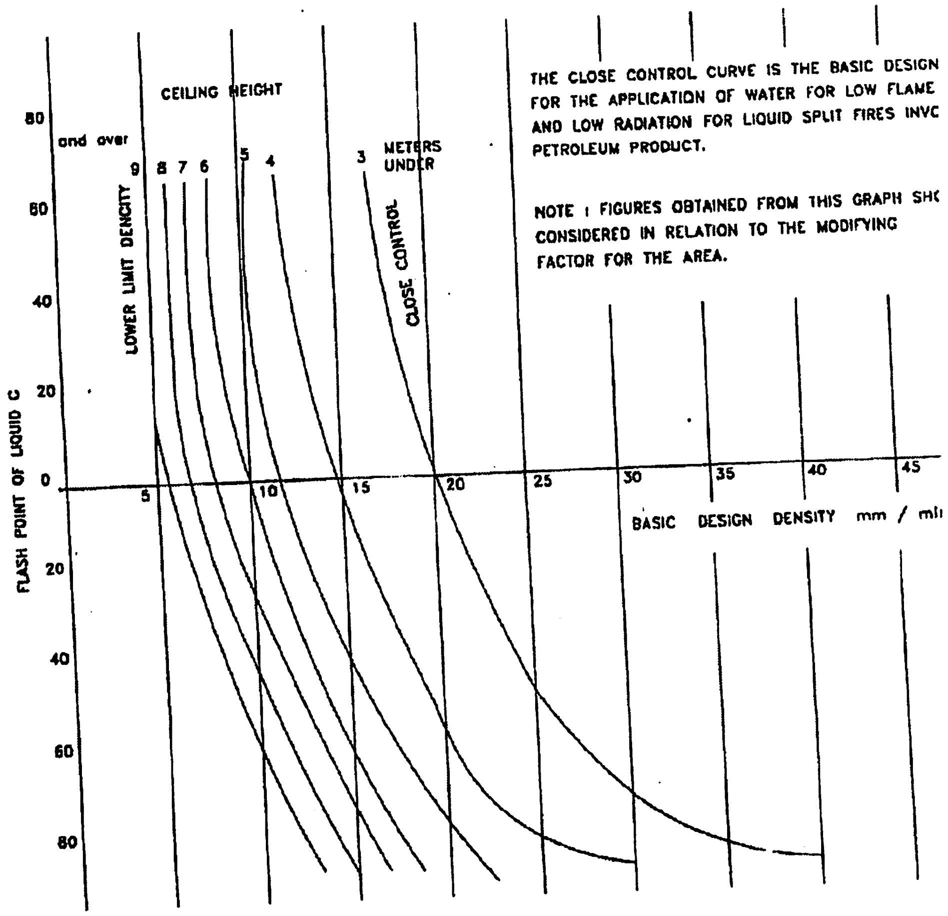


Figure no 04: Density of water Application

- The density obtained should be added by fire load factor.

Fire load factor = (b*(a+b)/900) + 0.33

Where

a = longer side in meters

b = shorter side in meter

Layout of protection network:-

- The discharge cone angle of the sprayers shall be selected by figure no. 2 .If height is more than 13M, only open type sprinkler should be used and for height less than 1M, sprayer with cone angle 1000 should be install.

- There shall be at least 1 sprayer for each 9 M^2 floor area
- Distance adjoining sprayer shall not exceed 3M anywhere.
- Distance between last sprayer and external wall < 1.5M
- Sprayer piping should be installed along the slope.

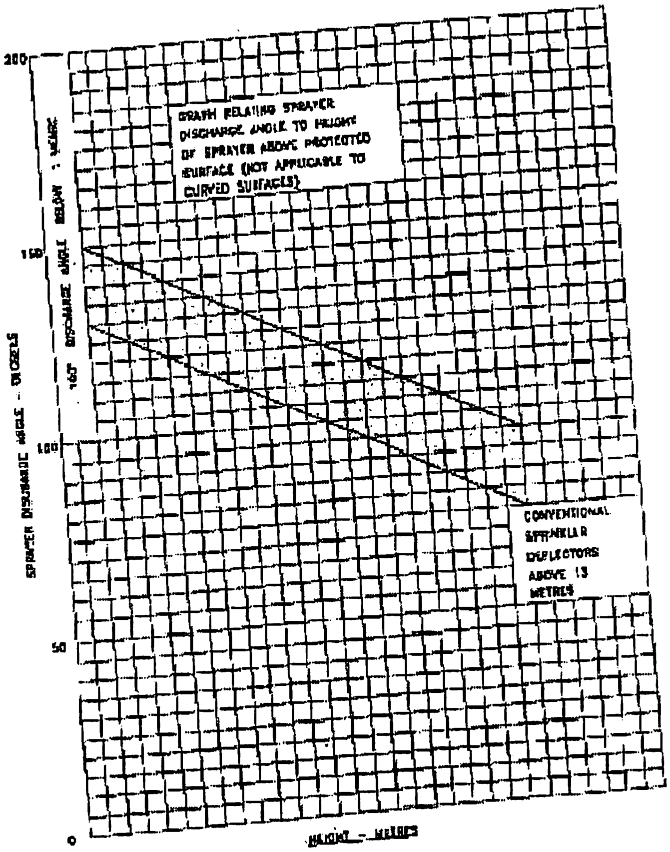


Figure no 05: Discharge Cone Angle

Equipment protection:-

- If top of vessel are more than 15M below the ceiling, local protection should be provided by sprayer with density not less than 10.2 lpm/m^2
- If obstruction is extended up more than 1M in width, underneath of them local sprinkler should be installed.
- Pump Manifold etc should be totally wetted by individual sprayer at same time

Piping and Support:-

- Sprayer and sprinkler shall be supported from the building structure, capable of supporting water filled pipe.
- Thickness of support pipe should not be less than 3 mm.
- The first support on a nominally horizontal distribution pipe shall not be less than 2M.
- The last support on nominally horizontal distribution pipe shall not be more than 450 mm from end.
- At least one support shall be provided for each range pipe connecting sprayers and pipe connecting distribution pipe and first sprayer on range pipe.
- The last support on range pipe shall not be more than 1.5M range pipe end or horizontal arm pipe of 450 mm.
- Welded joint shall not be permitted for pipes and fitting of less than 50mm diameter.
- Outgoing main pipe from deluge valve of the system shall be supported at every 3.5M

Hydraulics:-

- For the protection of large areas risk should be divided in several zones of not less than 6M in width and all zones in plan view of the risk falling within 6M from any point within zones shall operate simultaneously.
- Each zones should be controlled by individual deluge valve and flow through valve shall not be more than following

Table No 07:- Discharge flow through Deluge valve

Deluge valve size in mm	Discharge flow in lpm
150	13500
100	5000
80	1150

- 1.4 bar < designed pressure in each zone < 3.5 bar
- Velocity in distribution pipe < 5 m/s
- Aggregate pumping capacity shall be determined by largest demand arising out of combination of deluge valve when zones operate simultaneously.

Detection System:-

- Detection network should be similar to sprayer network
- As far as possible detection piping should be independently supported.

B) PROTECTION OF HORIZONTAL CYLINDRICAL VESSEL

The horizontal cylindrical vessel is the type of horizontal vessel whose example is LPG bullets are considered.

General Requirement: -

- The complete exposed area needs to be protected at uniform density of water application.
- Supporting legs and product pipes within bund needs protection-
  a) No protection required if supporting steel members are 300 mm or shorter.
  b) If no bund wall is there in tank area then sprayer protects product pipe within 15 m of tank shell.
  c) Sprayers protect occupancies like pump house, loading shed within 15 m.
- Sprayer shall be installed normal to the exposed area of vessel.
- The sprayer characteristics are 'K' factor, cone angle and discharge.
- The sprayers orifice size > 6mm.
- The cone angle lies between 600 to1250 whereas for local protections like supporting
- The legs, it can be less than 600.
- Minimum and maximum pressures in network shall be 1.4 bars to 3.5 bars.
- The vessels should be spaced at more than 15m from each other. The pumping & water
- The requirement is determined by water demand for largest vessel.
- Proposal for protection should be accompanied by full detail dimensional working drawing having following:
  a) Plan elevation

  b) Site-plan

c) Protuberances like valves, drains, manholes, flanges, ladders, supporting legs etc.

d) Protection and detection piping in different colors

e) Sprayer characteristics

f) Run Down shall not be considered for horizontal vessels.

g) The protection network can be fabricated in form of horizontal rows of sprayers connected by piping or ring, with distances 0.65m, 0.55m, 0.45m from tank surface and can be calculated as per following graphs:

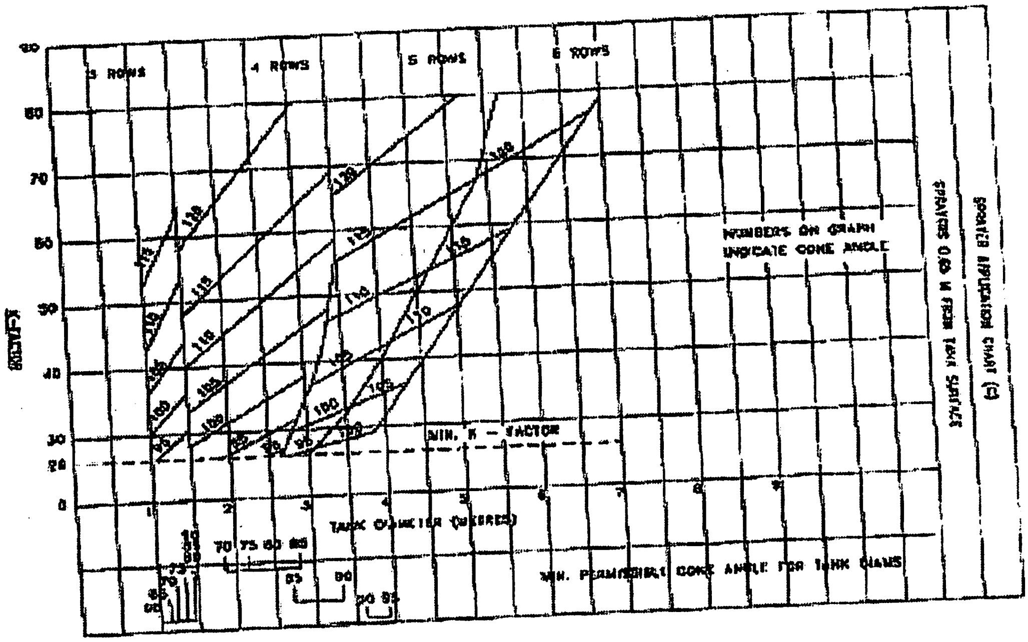


Figure no 06: Graph for calculation of number of rows of sprayer for 0.65m distances from tank

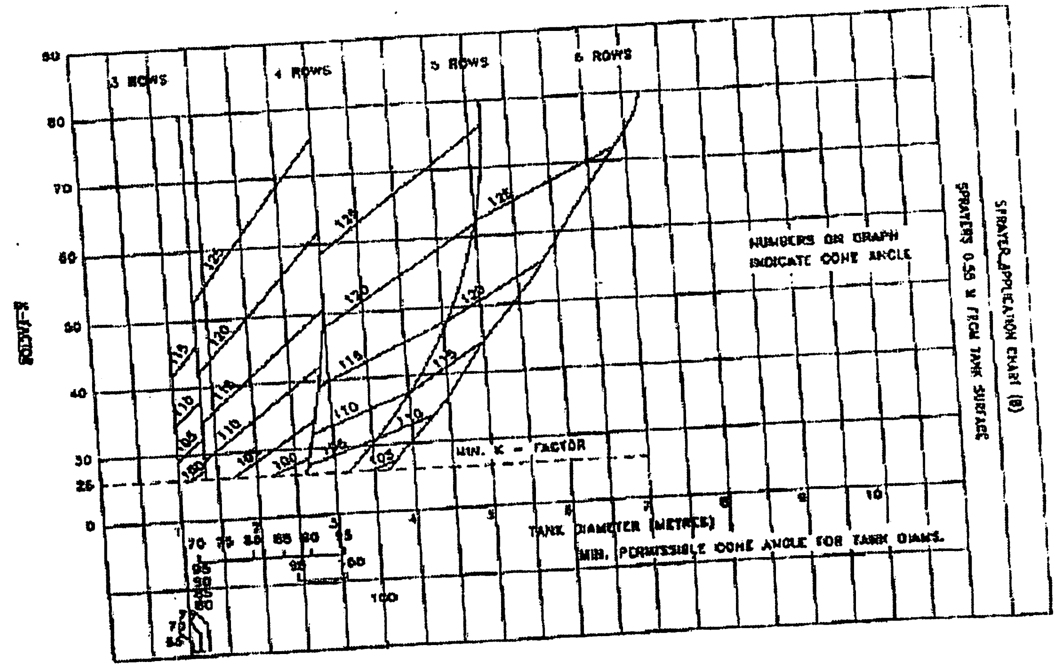


Figure no 07: Calculation of number of rows of sprayer for 0.55m distances from tank

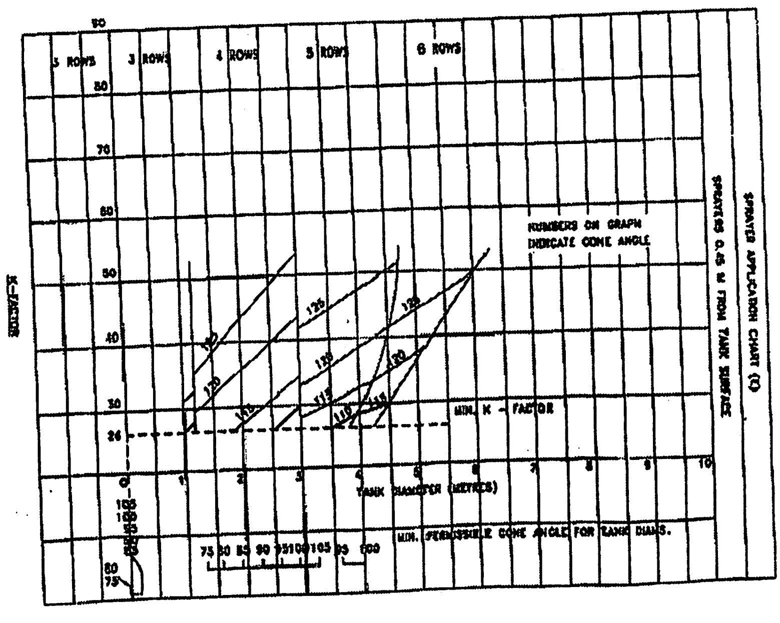


Figure no 08: Calculation of number of rows of sprayer for 0.45m distances from tank

Density of discharge:

- Water is applied at 10.2 lpm/m^2 of exposed area of the vessel, legs and products pipe.
- In case of high wind velocity (near sea coast), sprayer-protecting tankage is installed at 0.45m from the surface.

Distribution of Sprayers:

- The sprayer horizontal rows and spacing of network from tank is calculated as earlier.
- Spacing of sprayers for product pipes shall not exceed 3m and sprayer and sprayer shall be at a distance of not more than 800 mm from the pipes.

Piping layout and supports:

- Main feed pipe from deluge valve of the system shall be supported at every 3.5m
- Vertical feed pipe to establish flow from bottom to top rings at intervals < 3.5m
- The sprayer in bottom ring shall point 450 upwards.

Pipe-work hydraulics:-

- For different flow rates in top and bottom rings, size of the pipes can be obtained through following data (considering discharge from all sprayers between adjacent pipes does not exceed given rate):

Table No 08:- Pipe Size based on flow rate For Top Ring

Nominal flow to largest number of sprayers between adjacent vertical pipes (lpm)	25	32	40
Nominal diameter of pipe (mm)	0-100	100-160	160-250

Table No 09:- Pipe Size based on flow rate for bottom ring

Average flow (lpm)	260	440	680	1040	1800	2700
Nominal diameter of pipe (mm)	25	32	40	50	65	80

- Running pressure at points of feed from deluge valve to bottom ring should be between 1.4bar to 3.5 bar
- Losses apart from the static loss should be less than 0.35 bar.
- Velocity in horizontal pipe across bottom ring and vertical feed pipes connecting bottom and top rings should not exceed 10m/s.

DECTECTION SYSTEM

- Spacing of detectors on rows < 2.5m
- Detectors shall be located at distance <1m from the shell.
- Separate detectors should be there for manholes and flanges.
- 1 central row of detectors shall be allowed for two vessels. Vessels concerned shall be wetted simultaneously.

C) PROTECTION OF VERTICAL CYLINDRICAL VESSEL

General Requirement: -

- The complete exposed area needs to be protected at uniform density of water application.
- Product pipes within bund needs protection-
  a) If no bund wall is there in tank area then sprayer protects product pipe within 15 m of tank shell.
  b) Sprayers protect occupancies like pump house, loading shed within 15 m.
- The protection-piping network should be in the form by horizontal rings at regular interval and vertical feeder mains.
- Conical/flat roof shall be protected by water spray system. Sprayer should be connected through explosion relief valve assembly.
- The sprayer characteristics are 'K' factor, cone angle and discharge.
- The sprayers orifice size > 6mm.
- The cone angle lies between 600 to1250 whereas for local protections like supporting legs, it can be less than 600.
- Minimum and maximum pressures in network shall be 1.4 bars to 3.5 bars.
- The vessels should be located in individual dyke and spaced 15m apart. The pumping & water requirement is determined by water demand for largest vessel.

- Proposal for protection should be accompanied by full detail dimensional working drawing having following:
  a) Plan elevation
  b) Site-plan
  c) Protruberances like valves, drains, manholes, flanges, ladders, supporting legs
  d) Protection and detection piping in different colors
  e) Sprayer characteristics
- Run Down shall be considered provided there are no obstructions on the sides.

Density of discharge:

- Water is applied at 10.2 lpm/m^2 of exposed area of the tank shell and roof.
- Supporting legs if any shall also receive water at same density.

Distribution of Sprayers:

- The sprayer shall be spaced < 2.5m in the rings
- There shall be a ring at every 3.5m height.
- Spacing of sprayers for product pipes shall not exceed 3m and sprayer and sprayer shall be at a distance of not more than 800 mm from the pipes.

Piping layout and supports:

- Main feed pipe from deluge valve of the system shall be supported at every 3.5m
- Minimum 2 vertical feeders shall be provided.
- The top ring shall be just below top of vessel and bottom ring at not more than 2m from ground level.
- The sprayer in bottom ring shall be slightly upwards.

Hydraulics:

- Running pressure at points of feed from deluge valve to bottom ring should be between 1.4bar to 3.5 bar
- Velocity in feeder pipes should not exceed 5m/s.

Detection System:-

- Spacing of detectors in rings < 3m
- Detectors shall be located at distance <1m from the shell.
- For conical roof the detector shall be installed on $9m^2$ area basis.
- Separate detectors should be there for manholes and flanges.

D) PROTECTION OF SPHERICAL VESSEL

General: -

- Complete exposed area of sphere shall be protected by uniform density of water application.
- Water spray for supporting leg and product pipeline in bund area within 15 m should be available.
- Protection network around vessel shall be fabricated in form of vertical or horizontal ring.
- Sprayer orifice size < 6mm.
- 600 < cone angle < 1250
- 1.4 bar < pressure < 3.5 bar.
- Run down should not be consider.
- 550 mm < distance between sprayer and exposed area < 650 mm
- If spheres are installed at a distance of 15M, largest sphere will determine pumping and storage requirement.
- If spheres distance less than 15 m aggregate water demand for all sphere will determine pumping and storage requirement.
- Detail dimensional drawing should show following
  a) Plan elevation
  b) Site-plan
  c) Protrubences
  d) Protection and detection piping
  e) Sprayer character

System design

- Water density on exposed surface > 10.2 lpm/m^2
- Distribution of sprayer and layout of piping
  a) Sprayer should not be placed more than "S" distance, which is distance between sprayers measured along arc between the points of impingement of sprayers.
  b) "S" distance varies as per diameter of vessel and cone angle, which is found out from chart.
  c) Obstruction or roof portion of sphere shall be protected with separate sprayer with water density 10.2 lpm/m^2
  d) No of ring should be governed by spacing of sprayer.
  e) 1.4 < system pressure < 3.5 bar.
  f) For product pipeline, spacing of sprayer shall not exceed 3m and shall not more than 800 mm from pipeline.

Pipe support

- Pipe work on top of hemisphere rest on surface.
- Pipe work below hemisphere support separately from ground.

Detection System:-

- It is not necessary to provide detector sprinkler for whole surface. Detectors at minimum three level shall be follows as
  a) Minimum three detectors under lower pole adjacent to product pipeline.
  b) Ring of detector at equator
  c) Minimum three detector at upper crown
- Detector should be suitable supported on sprayer piping.
- Detector position from surface < 300mm

4.1.2 HIGH VELOCITY WATER SPRAY SYSTEM

High velocity water spray systems are installed to extinguish fire involving liquid with flash point of 650^{0}C or higher. Principles of extinguishment are

- Emulsification
- Cooling
- Smothering

Important application areas of high velocity water spray system are:-

1. Transformer, oil filled equipment
2. Turbo alternator and other
3. Oil fired boiler room, oil quenching

4.1.2.1 Transformer Protection

A) Guideline

- Transformer protection shall contemplate on all exterior surfaces except underwater.
- Due to irregulars shape, there is much more water interaction on surface than their top.
- Detail information shall made on proposal like dimension, location, specification, fitting etc.
- Electrical clearance should be maintained by electrical code.

B) Water Supply: - The effective capacity of reservoir shall not be less than 40 minutes run for aggregate pumping capacity.

C) General layout and design: -

- Transformer should be protected using ring of nozzle for every 3 meter interval from
- top to bottom.
- If transformer is at more than 300 mm above ground level, projector shall employ to spray horizontally.
- Projector: -
- It should be less than 6 mm in orifice.
- Projector should aim at angle so that all water impinges upon transformer.

- Projector should cover oil pipe, joints, flanges and spaces between transformers.

D) Fire barrier wall: - In between transformer / equipment fire barrier wall to be constructed of following dimension

- Brick wall thickness – 355 mm
- RCC wall thickness – 200 mm
- Minimum height of wall – 600 mm

Permissible space for which wall is not required.

Table No 10:- Oil tank Spacing

Oil tank capacity of transformer (liters)	Spacing (meters)
Up to 5000	6
5001 to 10000	8
10001 to 20000	10
20001 to 30000	12.5
Over 30000	15.0

E) System Design

- Density of discharge > 10.2 lpm/m^2
- Projector on ring should be installed in between 500 mm to 800mm
- Vertical distance should be maintained so that spray pattern should intersect each other.
- For Out-door transformer pressure should be designed in between 3.5 to 5 bar.
- For In-door transformer pressure should designed in between 2.8 to 5 bar

F) Detection system for transformer:- Automatic detection system should be located based on nature of hazard , air velocity , temperature variation , structure.

For Outdoor Transformer:-

- Ring of detector around the top and 2nd ring around the base of transformer.
- Detectors shall be placed at max gap of 2.0 meters.
- Distance between transformer and detectors < 300mm
- Flange of pipe shall be in between 300 mm from detector.
- For Indoor transformer:-
- When transformer is less than 6 m in height, maximum coverage for area < 12 m^2

- When transformer is more than 6 m in height detector should close to top of transformer.

4.2 OIL INDUSTRY SAFETY DIRECTORATE

In Indian scenario OISD codes plays vital role in designing fire protection facility for hydrocarbon industries. OISD is a self-regulatory body staffed with personnel drawn from various oil companies

Major functions of OISD are to:

- Oversee the implementation of all the decisions of the Safety Council
- Keep abreast of the latest design and operating practices in the area of safety and fire fighting in the hydrocarbon industry
- Prepare Standards
- Carryout periodic safety audits, review, suggest procedures for improvements and report on the implementation of the recommendations to Safety Council
- Collect relevant information and exchange it with the members of the Oil Industry including information regarding near miss accidents, accidents and disasters occurring in the Oil Industry
- Ensure implementation of all approved codes of practices for Safety, Health and Environment
- Review disaster control procedures and company preparedness

EXTRACT OF OISD CODES USED DURING TRAINING WORK

FIRE PROTECTION PHILOSOPHY

The Fire Protection Philosophy is based on Loss Prevention and Control. It considers that a hydrocarbon processing plant carries inherent potential hazard. A fire in one part/section of the plant can endanger other sections of plant as well. If fire breaks out, it must be controlled / extinguished as quickly as possible to minimize the loss to life and property and to prevent further spread of fire.

A).***General Considerations***

The size of process plant, pressure and temperature conditions, size of storage, plant location and terrain determine the basic fire protection need. Material of construction for infrastructure facilities shall conform to National Building Code(NBC) / statutory regulations.

The following fire protection facilities shall be provided depending upon the nature of the installation and risk involved.

- Fire Water System
- Foam System
- Clean Agent Fire Protection system
- Carbon Dioxide System
- Dry Chemical Extinguishing System
- Detection and Alarm system
- Communication System
- Portable fire fighting equipment
- Mobile fire fighting equipment

B).*Design Criteria*

The following shall be the basic design criteria for a fire protection system.

- Facilities should be designed on the basis that city firewater supply is not available close to the installation.
- Fire protection facilities shall be designed to fight two major fires simultaneously anywhere in the installation.
- Fire water requirements will be decided as per calculation

All the tank farms and other areas of installation where hydrocarbons are handled shall be fully covered by hydrant System.

B.1 Fixed Water Spray on storage Tanks

- Class 'A' Petroleum storage in above ground tanks shall have fixed water spray system, whether floating roof or fixed roof.

- Class 'B' Petroleum storage tanks of following dimensions shall be provided with fixed water spray.
- Floating roof tanks of diameter larger than 30 M.
- Fixed roof tanks of diameter larger than 20 M.

B.2 Semi-fixed Foam system for Storage

Semi-fixed Foam system shall be provided for the following tanks:

- Floating roof tanks storing Class 'A' and Class 'B' petroleum products.
- Fixed roof tanks storing Class 'A' and class 'B' petroleum products.
- Fixed roof tanks storing class 'C' petroleum products, of diameter larger than 40 M.

B.3 Automatic Actuated Rim seal Protection System for Floating Roof tanks:

Automatic Actuated rim seal fire extinguishing system should be considered for floating roof tank diameter of 60 meters and above for class "A" products. However, in lightning prone area, for floating roof tank of diameter 60 meters and above, Automatic rim seal fire-extinguishing system shall be provided. The Automatic Actuated rim seal fire extinguishing system may be based on Foam Flooding or Clean Agent Flooding mechanism. This is in addition to the water spray and semi-fixed foam system on all the floating roof tanks storing class A & B products.

B.4 Automatic Water Spray for Pressurized storages including LPG / Hydrogen

- LPG and hydrogen Pressure storage vessels shall be provided with automatic water spray system.
- Automatic water spray system shall be provided in LPG bottling stations, LPG loading/unloading gantries and LPG pump and compressor areas in all new

refineries and for existing refineries this conversion to automatic shall be done in phased manner.

B.5 Water Spray System in Process Unit

Water spray system shall be provided for hazardous locations and equipment in process unit areas. Some of these areas are:

- Un-insulated vessels having capacity larger than 50 m3 and containing class A or B flammable liquid.
- Vessels inaccessible to fire tender/ mobile equipment, fire hydrants
- Pumps handling petroleum products class 'A' under pipe racks.
- Pumps handling products above auto-ignition temperature under pipe racks
- Air fin coolers in hydrocarbon service located above pipe racks / elevated location.
- Water spray rings for columns of height more than 45 M should be provided

B.6 Water Spray for Electrical Installation

The water to be used should be clear and non saline.

B.7 Clean Agent (Holon substitute) for Control rooms

Selection of Clean Agent and design of Fire protection system for process control rooms, computer rooms and pressurized rooms should follow the Standard on "Clean Agent Extinguishing systems NFPA Standard 2001

B.8 Loading / unloading Gantry

Oil loading/unloading Tank Truck & Tank Wagon Gantries shall be provided with water spray and/or foam system.

C.0 *Fire Water System*

Based on the site requirement, water is used for fire extinguishment, fire control, cooling of equipment and protection of equipment as well as personnel from heat radiation. For these purposes water in appropriate form should be used such as straight jet, water fog, water curtain, water spray, deluge/ sprinkler, for foam making etc.

Fire water system shall comprise of firewater storage, firewater pumps and distribution piping network along with hydrants and monitors, as the main components.

C.1 Basis

The fire water system in an installation shall be designed to meet the fire water flow requirement for fighting two fires simultaneously or single fire for largest floating roof tank roof sinking case, whichever requiring largest water demand.

C.2 Firewater Flow Rate

Two of the largest flow rates calculated for different sections as shown below shall be added and that shall be taken as design flow rate.

C.2.1 Fire Water flow rate for tank farm shall be aggregate of the following:

- Water flow calculated for cooling a tank-on-fire at a rate of 3 lpm/m^2 of tank shell area.
- Water flow calculated for all other tanks falling within a radius of (R+30) M from centre of the tank on fire and situated in the same dyke area, at a rate of 3 lpm/m^2 of tank shell area.
- Water flow calculated for all other tanks falling outside a radius of (R+30) M from centre of the tank on fire and situated in the same dyke area at a rate of 1 lpm/m^2 of tank shell area.
- Water flow required for applying foam into a single largest cone roof or floating roof tank (after the roof has sunk) burning surface area of oil, by way of fixed foam system, where provided or by use of water/foam monitors. (Refer section 6.8 for foam rates).
- Firewater flow rate for supplementary stream shall be based on using 4 single hydrant outlets and 1 monitor simultaneously. Capacity of each hydrant outlet as 36 m3/hr and of each monitor as 144 m3/hr may be considered at a pressure of 7 kg/cm^2g.

C.2.2 Fire water flow rate for LPG sphere storage area shall be aggregate of the following:

- Water flow calculated for cooling LPG sphere on fire at a rate of 10.2 lpm/m2 of sphere surface area.
- Water flow calculated for all other spheres falling within a radius of (R+30) meter from centre of the sphere on fire at the rate of 10.2 Ipm/m2 of surface area.
- If the water rate as calculated above works out to be more than 2000 m3/hr the layout of the spheres should be reviewed.
- Water flow for supplementary stream shall be considered as 288 m3/hr as indicated under item
- The spheres should be laid in two separate groups with each group limited to a maximum of 6 vessels The groups shall preferably be separated by a distance of (R+30) meter.

C.2.3 Water flow rate requirements for fire fighting in other major areas shall be calculated based on criteria in terms of lpm/m^2 given in table no. 5

Table No 05:- Water application Rate

Application Area	Water application rate
Atmospheric storage	3 Ipm/m^2 of tank shell tanks area for tank on fire
	3 Ipm/m^2 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 Ipm/m^2 of tank shell area for exposure protection for tanks located outside (R+30) metre from centre of tank-on-fire within the same dyke area.
Pressure Storage Vessels	10.2 Ipm/m^2 of shell area
Process Unit Area	

• Pumps • Columns, other extremely hazardous area	20.4Ipm/m² 10.2 Ipm/m²
LPG pump house	20.4 Ipm/m²
LPG Tank Truck & Tank Wagon loading/ unloading gantries	10.2 Ipm/m²
LPG Bottling plants: • Carousel machine • Filled cylinder storage • Empty cylinder storage • LPG cylinder cold repair shed	 10.2 Ipm/m² 10.2 Ipm/m² 10.2 Ipm/m² 10.2 Ipm/m²
Oil Tank Truck & Tank Wagon loading/ unloading gantries	10.2 Ipm/m²
Cable Trays	10.2 Ipm/m²
Transformers	10.2 Ipm/m²

D.0 ***Header Pressure***

The fire water system shall be designed for a minimum residual pressure of 7.0 kg/cm2g at the hydraulically remotest point of application at the designed flow rate at that point. The fire water network shall be kept pressurized at minimum 7.0 kg/cm^{2}g at all the time.

E.0 ***Storage & Make-Up Water***

E.1 Firewater Storage

- Water for the hydrant service shall be stored in any easily accessible surface or underground lined reservoir or above ground tanks of steel, concrete or masonry.
- The storage should be located as far away as possible not less than 60 M from hazardous areas to avoid any damage in case of fire/explosion.
- The effective capacity of the reservoir above the level of suction point shall be minimum 4 hours aggregate working capacity of main pumps (excluding standby pumps). Where rate of make up water supply is 50% or more, this storage capacity may be reduced to 3 hours aggregate working capacity of main pumps.

- Storage reservoir shall be in two equal interconnected compartments to facilitate cleaning and repairs.
- Large natural reservoirs having water capacity exceeding 10 times the aggregate water requirement of fire pumps may be left unlined.

- Fire water supply shall be preferably from fresh water source such as river, tubewell or lake. Where fresh water source is not easily available, fire water supply may be sea water or other acceptable source like treated effluent water.

E.2 Make Up Water

- Suitable provisions shall be kept for make up firewater during fire fighting time. Provision to be made to divert water from various sources like ETP, Process Cooling Water, river, ponds etc. to the fire water system.
- F.0 Firewater Pumps
- Firewater pumps shall be used exclusively for fire fighting purposes.

F.1 Type of Pumps

- Firewater pumps shall be of the following type:
- Electric motor driven centrifugal pumps
- Diesel engine driven centrifugal pumps
- The pumps shall be horizontal centrifugal type or vertical turbine submersible pumps. Each pump shall be capable of discharging 150% of its rated capacity at a minimum of 65% of the rated head. The shut-off head shall not exceed 120% of rated head, for horizontal pumps and 140% in case of vertical turbine type pumps.
- Number of diesel driven pumps shall be minimum 50% of the total number of pumps. Minimum 50% of total flow requirement should be available through diesel driven pumps all the time. Power supply to the electric driven pumps should be from two separate feeders.

F.2 Capacity of main Pumps

The capacity and number of main firewater pumps shall be fixed based on design fire water rate. The capacity of each pump shall not be less than 400 m3/hr or more than 1000 m^3/hr. All pumps should be identical with respect to capacity and head characteristics.

F.3 Standby Pumps

- When total number of working pumps work out to be one or two, 100% standby pumps shall be provided.
- When total numbers of working pumps are more than two, 50% standby pumps shall be provided.
- In cases where two sets of firewater storage and pumps are provided, the number of pumps at each location shall be according to hydraulic analysis of piping network.

F.4 Jockey Pumps

The firewater network shall be kept pressurized at minimum 7.0 kg/cm^2 by jockey pumps. 2 Jockey pumps (1 working plus 1 standby) shall be provided. The capacity of the pump shall be sufficient to maintain system pressure in the event of leakages from valves etc. The capacity of jockey pumps shall be 5% minimum and maximum 10% of the design fire water rate. Its head shall be higher than the main fire water pumps. Auto cut-in / cut-off facility should be provided for jockey pumps

F.5 Location of pumps

Firewater pumps shall be located as far away as possible not less than 60 M from hazardous areas to avoid any damage in case of fire/explosion.

G.0 ***Distribution Network***

G.1 Looping & Maintainability

The fire water network shall be laid in closed loops as far as possible to ensure multi-directional flow in the system. Isolation valves shall be provided in the network to enable isolation of any section of the network without affecting the flow in the rest. The isolation valves shall be normally located near the loop junctions. Additional valves shall be provided in the segments where the length of the segment exceeds 300 M.

G.2 Criteria for Above / Underground Network

The firewater network piping should normally be laid above ground at a height of atleast 300 mm above finished ground level

G.3 Protection for underground pipelines

Where the pipes are laid underground the following protections shall be provided:

- The main shall have at least one-meter earth cushion in open ground and 1.5 meter earth cushion under the roads. In case of crane movement areas, pipes may be protected with concrete/steel encasement.
- The mains shall be provided with protection against soil corrosion by suitable coating/wrapping.
- Pipe supports under the pipe line shall be suitable for soil conditions.

G.4 Protection for above ground pipelines

Where the pipes are laid above ground, the following protection shall be provided:

- The firewater mains shall be laid on independent sleepers by the side of road. These shall not be laid along with process piping on common sleepers.
- The mains shall be supported at regular intervals not exceeding 6 meter. It should be supported at every 3 M for pipes less than 150 mm diameter.
- The system for above ground portion shall be analyzed for flexibility against thermal expansion and necessary expansion loops shall be provided wherever called for.

G.5 Fire hydrants

Fire hydrants shall be provided in the network to ensure protection to all the facilities. The location of the hydrants shall be carefully decided keeping in view the easy accessibility. The maximum distance between two hydrants, however, shall not exceed 30 metre around hydrocarbon storage and hazardous areas and 45 metre in other areas. Each hydrant shall have two outlets inclined towards the ground. The outlets shall be of female instantaneous type having a standard size of 63 mm conforming to Indian Standards.

H.0 *Hydrants & Monitors - Details*

H.1 Hydrants

- .At least one hydrant post shall be provided for every 30 M of external wall measurement or perimeter of unit battery limit in case of high hazard areas.
- Hydrants protecting utilities and miscellaneous buildings in high hazard areas may be spaced at 45 M intervals.
- The hydrants shall be located at a minimum distance of 15 M from the periphery of storage tank or hazardous equipment under protection. For process plants location of hydrants shall be decided based on coverage of all areas.
- In the case of buildings, this distance shall not be less than 5 M and more than 15 M from the face of building..
- Double headed hydrants with two separate landing valves on 4" stand post shall be used. All hydrant outlets shall be situated at a workable height of about 1.2 metre above ground level.

H.2 Monitors

- A minimum of 2 monitors shall be provided for the protection of each such area. Water monitors for protection of heaters shall be installed so that the heater can be isolated from the remainder of the plant in an emergency.
- The monitors should not be installed less than 15 M from hazardous equipment.
- Variable flow monitors may be installed at critical locations.
- The requirement of monitors shall be established based on hazard involved and layout considerations. The location of water monitors shall not exceed 45 M from the hazard to be protected.

J.0 *Fixed Water Sprinkler System*

- Fixed water sprinkler system is a fixed pipe tailor made system to which sprinklers with fusible bulbs are attached. Each sprinkler riser/system includes a controlling valve and a device for actuating an alarm for the operation of the system. The system is usually activated by heat from a fire and discharges water over the fire area automatically.

- The water for sprinkler system shall be tapped from plant fire hydrant system, the design of which should include the flow requirement of the largest sprinkler installation.
- The design flow for sprinkler installation would depend on the type of hazard and height of piled storage. The water flow rate for automatic sprinkler system for car parking area shall be taken as 5.1 Ipm/m^2 of the area protected by sprinkler installation. The design water flow shall be restricted to a minimum 100 m3/hr and to a maximum 200 m^3/hr. The design flow rate for other areas shall be taken as 10.2 Ipm/m^2 of the area protected by sprinkler installation, subject to a minimum of 150 m3/hr. and a maximum of 400 m^3/ hr

4.3 COMPARISON OF WATER APPLICATION RATES

Application Area	**As per OISD**, Minimum water application rate (in lpm/m^2)	**As per NFPA** Minimum water application rate (in lpm/m^2)	**As per TAC** Minimum water application rate (in lpm/m^2)	**API 2030** Minimum water application rate (in lpm/m^2)
Atmospheric storage	3 of tank shell tanks area for tank on fire	10.2 for vessel	• 10.2 horizontal • 10.2 vertical • 10.2 sphere	4.1
	3 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 of tank shell area for exposure protection for tanks located outside (R+30) metre from centre of tank-on-fire within the same dyke area.			

Pressure Storage Vessels	10.2 of shell area			10.2
Process Unit Area • Pumps • Compressor	 20.4 10.2	 20.4 20.4		 20.4 10.2
LPG Tank Truck & Tank Wagon loading/ unloading gantries	• 10.2		• 10.2horizontal • 10.2 vertical	• 10.2
LPG Bottling plants: • Carousel machine • Filled cylinder storage • Empty cylinder storage • LPG cylinder cold repair shed	• 10.2 • 10.2 • 10.2 • 10.2			• 10.2
Cable Trays	10.2	6.2	12.2	12.1-20.4
Transformers	10.2	• 10.2on projected area • 6.1on nonabsorbent ground area	• 10.2	• 10.2
Conveyer		10.2		

CHAPTER 5

Fire Design Calculation

5.1 FLOW RATE CALCULATION

Fire Water Flow rate calculation for storage tank			
Sl no	Data		
			unit
1	Total storage capacity in one dyke area	65000	m3
2	Diameter of each tank	79	m
3	No of tank in each dyke	1	no
4	Total No. of tanks	9	no
5	Height of each tank	14.47	m
Section-1 FIRE WATER FLOW RATE FOR FLOATING ROOF TANK			
A)	**Cooling water flow rate**		
1	Cooling water rate(tank area)	3	lpm/m2
4	Cooling water requirement	10768.28	lpm
		646.0971	m3/hr
B)	**Foam water flow rate**		
1	Foam solution application rate (rim seal)	12	lpm/m2
2	Foam solution required	2381.376	lpm.
3	Foam water required (97%)	2309.935	Lpm
		138.5961	m3/hr
	Total water flow rate (A +B)		
	Tank cooling	646.0971	m3/hr
	Foam water requirement	138.5961	m3/hr
	Total	784.6932	
Section-2 FIRE WATER FLOW RATE FOR SUPPLEMENTARY HOSE STREAMS			
	Water for 4 single hydrant streams	144	m3/hr
	Water for 1 monitor stream	144	m3/hr
	Total water requirement	288	m3/hr
Design fire water flow rate (highest among section 1 &2)		784.6932	m3/hr
	say	800	m3/hr

Note :- Existing combined low rate capacity of available pumps is 2210 m^3/Hr .

5.2 FIRE WATER CALCULATION

5.2.1 Basic for designing

As per standard "The fire water system in an installation should be designed to meet the fire water flow required for fighting one largest risk at a time"

5.2.2 Criteria for designing

As per standard

"Water for the hydrant service shall be stored in any easily accessible surface or underground lined reservoir or above ground tanks of steel concrete or masonry. The effective capacity of the reservoir / tank above the level of suction point shall be minimum 4 hours aggregate working capacity of pumps. Where make up water supply source is 50% or more of design flow rate, the storage capacity may be reduced to 3 hours.

The installation shall have facilities for receiving and diverting all the water coming to the installation to fire water storage tanks in case of an emergency. "

5.2.3 Water Storage calculation

Total no of fire fighting pump = 05

i. FF1 capacity(engine driven) :- 550 m^3/Hr
ii. FF2 capacity(motor driven) :- 350 m^3Hr
iii. FF3 capacity(engine driven) :- 550 m^3/Hr
iv. FF4 capacity(motor driven) :- 380 m^3/Hr
v. FF5 capacity(engine driven) :- 380 m^3/Hr

Total capacity = 2210 m^3/Hr

Water storage requirement for 4 hours aggregate working capacity of pumps = 2210 *4

= 8840 m^3

Note :- Available fire water storage capacity is 12500

5.3 FOAM REQUIREMENT CALCULATION

5.3.1 FIRE FIGHTING FOAM:

Fire fighting foam is a homogeneous mass of tiny air or gas filled bubble of low specific gravity, which when applied in correct manner and in sufficient quantity, forms a compact fluid and stable blanket which is capable of floating on the surface of flammable liquids and preventing atmospheric air from reaching the liquid.

5.3.2 Types of Foam Compound

Two Types of foams are used for fighting liquid fires:

5.3.2.1 Chemical foam:

When two or more chemicals are added the foam generates due to chemical reaction. The most common ingredients used for chemical foam are sodium bicarbonate and aluminimum sulphate with stabilizer. The chemical foam is generally used in Fire extinguishers.

5.3.2.2 Mechanical foam :

It is produced by mechanically mixing a gas or air to a solution of foam compound (concentrate) in water. Various types of foam concentrates are used for generating foam, depending on the requirement and suitability. Each concentrate has its own advantage and limitations. The brief description of foam concentrates is given below.

5.3.3 Mechanical foam Compound:

Mechanical foam compound may be classified in to 3 categories based on it's expansion ratio.

5.3.3.1 Low expansion foam :

Foam expansion ratio may be up to 50 to 1, but usually between 5:1 to 15:1 as typically produced by self aspirating foam branch pipes.

The low expansion foam contains more water and has better resistant to fire. It is suitable for hydrocarbon liquid fires and is widely used in oil refinery, oil platforms, petrochemical and other chemical industries

5.3.3.2 Medium Expansion Foam

Foam expansion ratio vary from 51:1 to 500:1 as typically produced by self aspirating foam branch pipes with nets. This foam has limited use in controlling hydrocarbon liquid fire because of it's limitations w.r.t. poor cooling, poor resistant to hot surface/radiant heat etc.

5.3.3.2 High Expansion Foam:

Foam expansion ratio vary from 501:1 to 1500:1, usually between 750:1 to 1000:1 as typically produced by foam generators with air fans. This foam has also very limited use in controlling hydrocarbon liquid fire because of its limitations w.r.t. poor cooling, poor resistant to hot surface/radiant heat etc. It is used for protection of hydrocarbon gases stored under cryogenic conditions and for warehouse protection.

5.3.4 TYPES OF LOW EXPANSION FOAM:

- **PROTEIN BASE FOAM:**

  The foam concentrate is prepared from hydrolyzed protein either from animals or Vegetable source. The suitable stabilizer and preservatives are also added.

  The concentrate forms a thick foam blanket and is suitable for hydrocarbon liquid fires, but not on water miscible liquids. The effectiveness of foam is not very good on deep pools or low flash point fuels which have had lengthy preborn time unless applied very gently to the surface.

  The concentrate is available for induction rate of 3 to 6%. The shelf life of concentrate is 2 years.

- **FLUORO PROTEIN FOAM:**

  This is similar to protein base foam with fluro-chemical which makes it more effective than protein base foam.

  The concentrate forms a thick foam blanket and is suitable for hydrocarbon liquid fires, but not on water miscible liquids. The foam is very effective on deep pools of low flash point fuels which have had lengthy pre burn time.

  The concentrate is available for induction rate of 3 to 6% and the shelf life is similar to that of protein base foam.

- **AQUEOUS FILM FORMING FOAM (AFFF):**

  The foam concentrate mainly consists of fluoro carbon surfactants, foaming agent and stabilizer.

  This can be used with fresh water as well as with sea water.

  It produces very fluid foam, which flows freely on liquid surface. The aqueous film produced suppresses the liquid vapor quickly. The foam has quick fire knock down property and is suitable for liquid hydrocarbon fires. As the foam has poor drainage rate, the effectiveness is limited on deep pool fires of low flash point fuels which have lengthy pre burn time.

The concentrate is available for induction rate of 3 to 6% and the shelf life is more than 10 years.

- **MULTIPURPOSE AFFF:**

Multipurpose AFFF concentrate is synthetic, foaming liquid designed especially for fire protection of water soluble solvents and water insoluble hydrocarbon liquids. This can be used either with fresh water of sea water.

When applied it forms foam with a cohesive polymeric layer on liquid surface, which suppresses the vapor and extinguishes the fire. The foam is also suitable for deep pool fires because of superior drainage rate and more resistive to hot fuels/radiant heat.

The 3% induction rate is suitable for liquid hydrocarbon fires and 5% for water miscible solvents.

The shelf life of concentrate is not less than 10 years. This can also be used with non aspirating type nozzles.

- **FILM FORMING FLOURO PROTEIN (FFFP)**

FFFP combines the rapid fire knock down quality of conventional film forming AFFF with the high level of post fire security and burn back resistance of flouro protein foam. The concentrate can either be used with fresh water or sea water.

The foam is suitable for hydrocarbon liquid fires including deep pool fires of low flash point fuels which have had lengthy pre burn time.

The concentrate is available for induction rate of 3 to 6% and the shelf life is not less than 5 years. This can also be used with non aspirating type nozzles.

5.3.5 FOAM COMPOUND REQUIREMENT FOR A DEPOT/TERMINAL

Sl no	Data Required		unit
1	Capacity of each tank	65000	m3
2	No. of tanks in one dyke	1	no
3	Total storage capacity in one dyke area	65000	m3
4	Diameter of each tank	79	m
5	Height of each tank	14.47	m
6	width of rim seal area	0.8	m
Section A :- Foam compound requirement for floating roof tank			
1	Foam solution application rate	12	lpm/m2
3	seal area	[redacted]	
4	Foam solution required	[redacted]	lpm
5	Foam solution required for 65 min	[redacted]	ltrs
6	Foam compound required for 65 minutes	[redacted]	ltrs
Section B :- Foam compound requirement for one portable foam monitor			
1	Capacity of Portable monitor	2400	lpm
2	Foam solution required for 65 min	[redacted]	ltrs
3	Foam compound required (3%)	[redacted]	lpm
Section C :- Foam compound requirement for 2 hose stream			
1	Capacity of hose stream	1140	lpm
2	Foam solution required for 65 min	[redacted]	ltrs
3	Foam compound required (3%)	[redacted]	lpm
Total Foam Compound requirement			
1	for floating roof tank	4643.683	ltrs
2	one portable foam monitor	4680	ltrs
3	2 hose stream	4446	ltrs
	Total	13769.68	ltrs
	Say	**14000**	**ltrs**

Existing storage amount of foam compound = 28000 ltrs

5.4 FOAM FLOODING SYSTEM DESIGNING FOR PUMPING SHED

5.4.1 Introduction of Foam flooding system

It consist of two parts

A. Automatic heat detection

B. Foam flooding system.

A) DETECTION SYSTEM:

It comprises of rate of rise cum fixed temperature heat detectors & UV IR detectors.

- Rate of rise cum fixed temperature type heat detectors:

The signal sensed by the detector is directed to the control panel provided in the control room. The panel in-turn gives the command for actuation of foam flooding system.

The detector will activate if the rate of rise in temperature is in the tune of 2 degree/minute with fixed temperature limit of 75 to 80 degrees & response time of 75 to 90 seconds.

- UV-IR flame detectors:

In addition to the rate of rise heat detectors UV IR flame detectors has been provided for fire detection. These UV IR detectors detect the UV & IR rays coming out from the hydrocarbon flame & send the signal to the control panel for actuation of foam system. The UV IR flame detectors have a range of 90-degree solid cone of vision (vertically & horizontally) with response time of approximately 3 seconds.

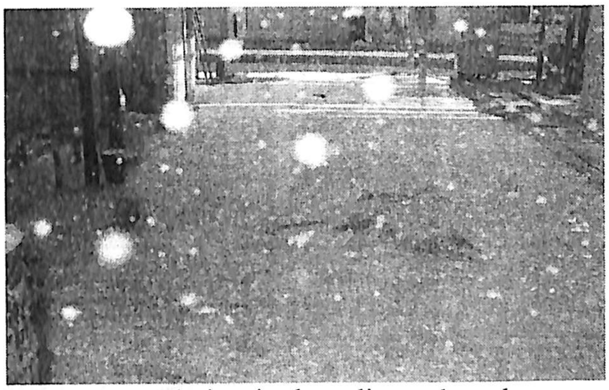
UV IR detectors will actuate only in case of presence of both UV & IR radiations from flame matrix. These detectors are solar blind & will not response to the UV radiation sources like arc welding, nuclear radiations, lightning etc. & IR sources like interrupted hot body radiations.

B) FOAM FLOODING SYSTEM:

It consists of a foam bladder of capacity 2500 Liters located near the pump shed. After receiving the signal from heat / UV-IR detector 24V DC supply is sent from panel to the solenoid valve mounted on the deluge valve near the foam tank, due to which solenoid valve operates & in turn opens the deluge valve by draining the water from top chamber.

Fig 09:- Foam Flooding System

5.4.2 OPERATION OF SYSTEM



After receipt of signal from any of the detector/ manual call point provided in the engine shed a 24 DC supply is sent to the solenoid valve which in turn actuates & drain the top chamber of the deluge valve. After opening the deluge valve water enters the foam tank & pressurise the foam bladder due to which the foam compound is inducted in the main stream. Foam water solution is then directed to the foam sprinkler nozzles through the piping network. In case the main deluge valve fails to operate butter fly valve provided in the bypass line can be opened to actuate the foam flooding.

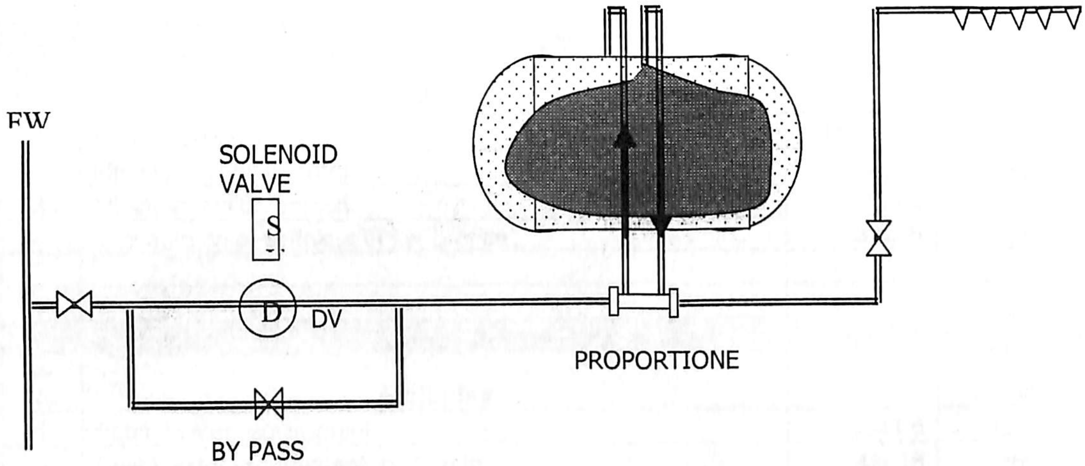


Fig 10 :-SCHEMATIC DIAGRAM OF AUTOMATIC FOAM FLOODING SYSTEM

5.4.3 DESIGN CALCULATION

5.4.3.1 Design Basis

- As per OISD and NFPA standard minimum design discharge of water of foam water application = 6.7 lpm /m^2
- TAC/ OISD / NFPA standard for spacing between sprinklers on a branch line or between branch line = 3.7 m
- TAC/ OISD / NFPA standard for minimum spacing shall not exceed 9.3 m^2

5.4.3.2 Calculation For Designing Foam flooding System

"Considering area to be protected with foam flooding system have length and width is 36 and 18 respectively."

Data required			
Sl No	Attributes		Unit
1	Length	36	m
2	Width	18	m
3	Area covered per Sprinkler	9.3	m2
4	Spacing between sprinkler	3.7	m
5	Water Density requirement	6.7	lpm /m^2
Calculation for sprinkler nos requirement			
Sl No	Attributes		Unit
1	Area of protected area	648	m2
2	Min No of sprinkler required	69.67742	no
3	Minimum No of branch	9.72973	no
4	minimum no of sprinkler in per branch	4.864865	no
Hydraulic Calculation			
Sl No	Attributes		Unit
1	Area of protected area	45150.97	m2
2	Min No of sprinkler required	4640.516	no
3	Minimum No of branch	133.2	no
4	minimum no of sprinkler in per branch	14.32258	no
Foam Storage Requirement			
Sl No	Attributes		Unit
1	Foam Water requirement	4341.6	lpm
2	Foam water requirement for 10 min	43416	ltrs
3	Foam compound requirement	1302.48	ltrs
4	Foam requirement during stabilisation time (30 sec)	651.24	ltrs
5	**Total foam requirement**	**1953.72**	ltrs
	Say	2000	ltrs

Note Actual availability of foam compound with Foam flooding system :-2500 ltrs

5.5 RIM SEAL PROTECTION SYSTEM

5.5.0 Introduction

The automatic actuated foam flooding system is a system designed to automatically detect and extinguish the floating roof tank rim seal fire at its incipient stage. The system is mounted on the roof of the tank.

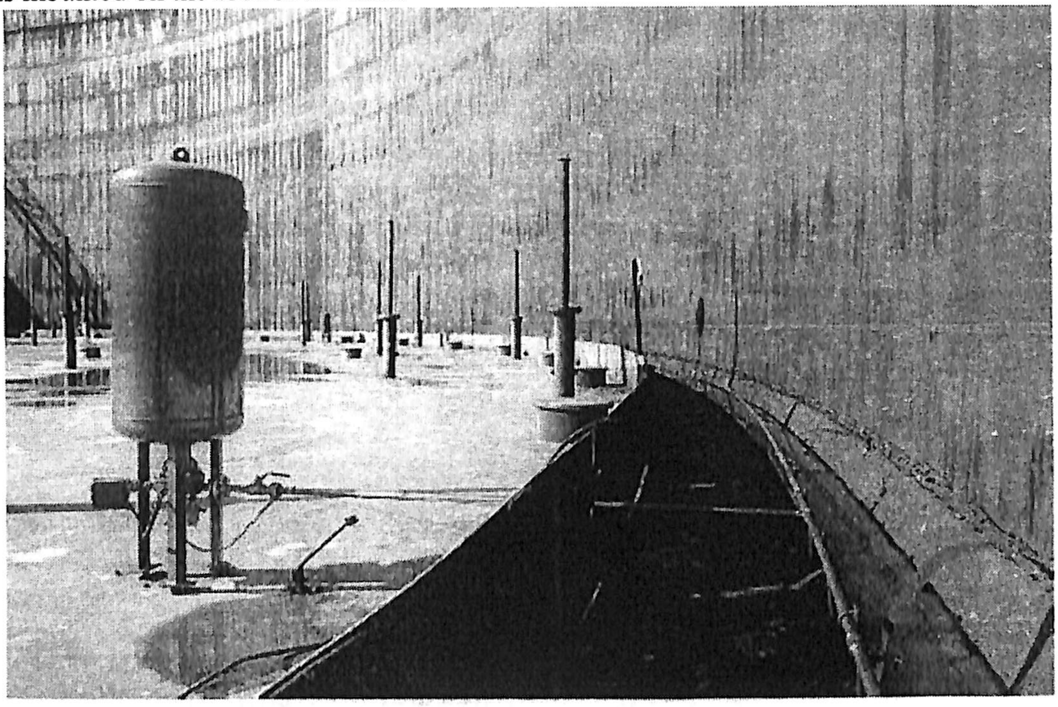


Figure 11 :- Rim Seal Protection

5.5.1 Guideline for designing.

The system consists of a long foam line (typically available in 40 Mts. length) laid along the tank perimeter. The foam aspirating nozzles are mounted on the line at an interval of 2.5 mts. The premix foam is contained in a vessel which is kept charged with nitrogen through a nitrogen cylinder. The System is designed for minimum foam application rate of 18 lpm/m2 of rimseal area. For effective control, foam is applied for a period of 40 seconds.

The system consists of a detector network normally thermoplastic tubing type, which is kept charged with nitrogen. In case of fire, tube ruptures and the pressure drop triggers the foam discharge.

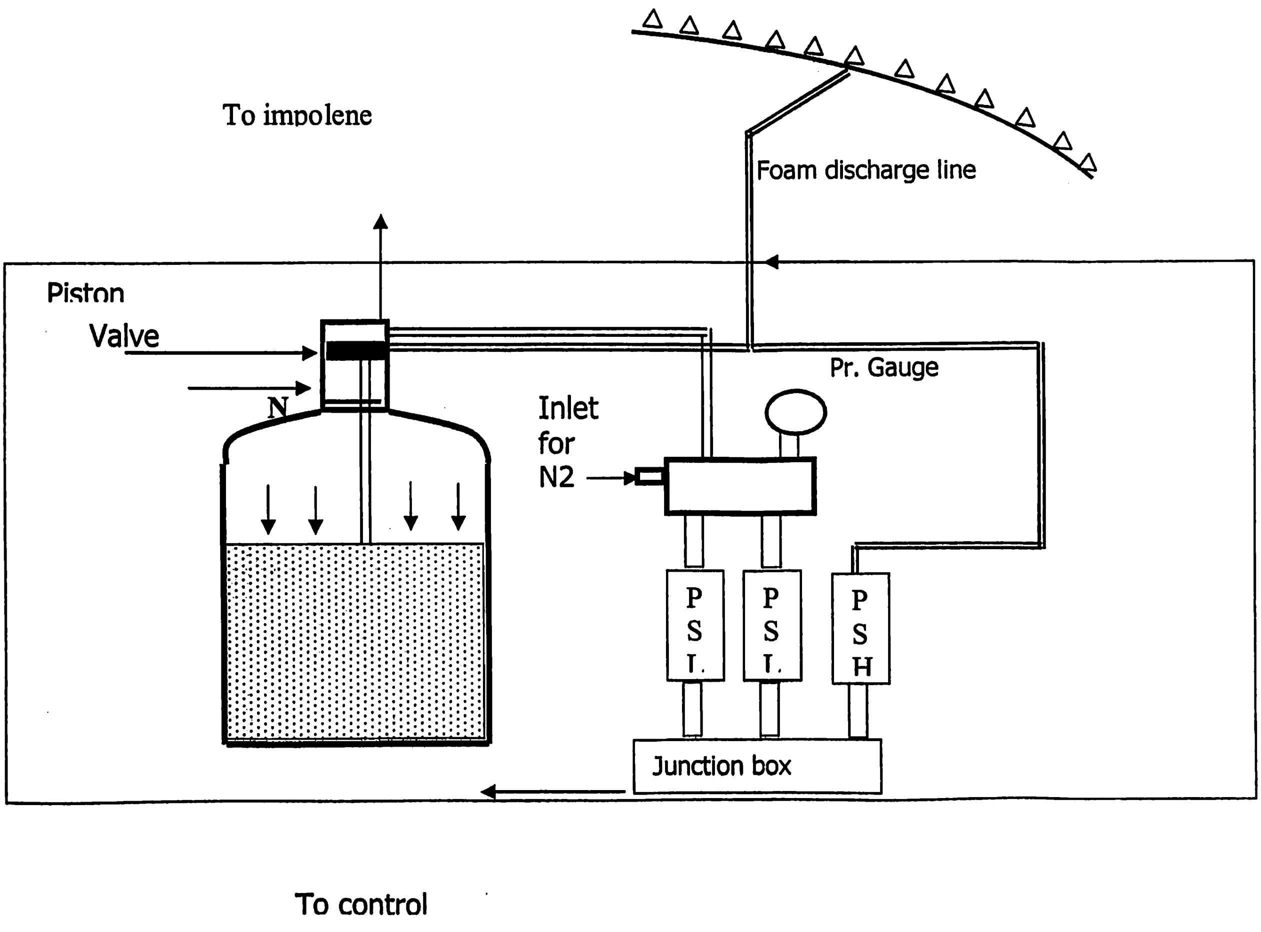
The provision of audio-visual alarms for different operating parameters can also be coupled with the system.

The detection tube (impolene tube pressurised with nitrogen) is mounted in between the primary & secondary seal. The foam discharge nozzle is positioned between primary seal & weather shield.

This system comprises 3 pressure switches –

- (PSL)- connected to the valve head of detection tube system. This switch is set to operate at falling 11 bar pressure. This pressure switch indicates the pressure in the system below 11 bar.
- (PSLL)- connected to impolene tubing. This switch is set to operate if pressure drops to 9 bar falling.
- (PSLL) – connected to foam discharge line (outlet) of differential pressure valve on cylinder. This switch will operate when at rising 3 bar pressure which indicates that the AFFF solution discharge has started.

Figure 12 :-SCHEMATIC DIAGRAM OF AUTOMATIC RIM SEAL FOAM SYSTEM



5.5.3 Design Calculation For Rim Seal Protection System

Diameter of Floating roof tank	= 79 m
Rimseal area of Tank :	=3.14 X 79 X 0.3
	= 74.5 M2
Rate of Foam application @ 18 LPM/M2	= 1341 LPM

Total Foam soln. required in 40 sec. = 894 lts.

Total nos. of Modular unit required for the tank = 3.14 *79/40

= 6.2 ~ 7

Foam Solution required in each module = 894 /7

= 127 ~ 130 ltrs

5.6 JOCKEY PUMP SPECIFICATION CALCULATION

As per Standard

"The fire water network shall be kept pressurized at minimum 7.0 kg/cm2 g by jockey pumps. 2 Jockey pumps (1 working plus 1 stand by) shall be provided. The capacity of the pump shall be sufficient to maintain system pressure in the event of leakages from valves etc. The capacity of jockey pumps shall be 3% (minimum) and 10% (maximum) of the design fire water rate and its head higher than the main fire water pumps.

Sl no	Parameter		Unit
1	Design fire water Flow rate	800	Kl/hr
2	Minimum Flow rate of jockey pump	24	Kl/hr
3	Maximum Flow rate of jockey pump	80	Kl/hr
4	Head of Jockey pump	>123.45	m

Note: - Flow rate of available jockey pump is 30 kl/hr and head is 120 m. So it is not complying standard.

CHAPTER 6

CONCLUSION

Based on NFPA, OISD & TAC codes following fire safety designing parameters have been calculated:

- Fire water flow rate
- Fire water storage
- Foam compound storage
- Foam quantity for foam flooding system in Mainline pumping Unit
- Foam based Rim seal module capacity.
- Jockey pumps specification.

All calculated values of above parameters are found below the existing available specification. Only jockey pump's head should be increased.

By LOPA analysis, various independent analysis have been recognized for storage tank. The probability of failure on demand value of independent protection layer found less that probability of occurrence of initial event. So storage tank is safe against overflow

REFERENCES

1. API Standard 521, "Pressure relieving and Depressurizing System", 5th edition, January 2007.
2. Lees, F.P. "Loss Prevention in Process Industries", 2nd edition, 1995
3. NFPA-11, "Foam extinguishing system" February 2004.
4. NFPA-15, "Water spray fixed system" February 2004.
5. OISD-116, "Fire Protection Facilities for Petroleum Refineries and Oil/Gas Processing Plants" 2nd edition, August 2007.
6. OISD-117, "Fire protection facilities for petroleum depots, terminals, pipeline installations and lube oil installations" 2nd edition, August 2007.
7. TAC," Rules for Water Spray System".
8. Layers of protection analysis :- CCPS