7. ADDITIONAL STUDIES

7.1. Risk Assessment

Oil & Natural Gas Corporation (ONGC) Rajahmundry Asset, India, plans to establish an Early Production System (EPS) at BTSAD Bhimavaram. As part of the procedure for clearance by the MOEF&CC, ONGC need to submit a rapid risk assessment of the operations. ONGC has commissioned Bhagavathi Ana Labs Private Limited (BALPL) to conduct a rapid risk assessment of the proposed EPS and to establish the Risk Criteria and based on it provide recommendations and Mitigation measures to bring the level of risk to as low as reasonably practicable (ALARP). ONGC intends EPS with a capacity of 7LSCMD of Gas.

7.1.1.Rapid Risk Assessment Approach

Study Assumptions

The quantified risk assessment (QRA) approach used in this rapid risk assessment is necessarily generic in nature as the EPS is yet to be selected. However, a credible QRA can be achieved by the careful setting of assumptions and generally by taking a conservative view of the event frequency, equipment performance and consequence modelling. This will be the approach that has been followed in this study.

The principal study assumptions regarding: lifecycle, study scope, EPS data, legislative compliance, support services, operating practices are contained in **Table 72**. These assumptions have been applied to all generic QRA's. In addition, modelling assumptions specific to EPS are provided below.

ALARP Risk Principles

The ONGC definition of risk tolerability, against which all the QRA results have been assessed, below The definition of what level of risk is tolerable, difficult and necessarily subjective. For safety risks ONGC has adopted the ALARP principle (as low as reasonably practical) outlined in **Figure 35** below.

In general terms, the risk should be considered to be ALARP if the cost of reducing the risk further cannot be justified by the reduction in risk which would occur. For many risks these ALARP considerations may be addressed qualitatively. For high risk situations numerical risk tolerability performance standards are required.

If the risk is not considered to be ALARP even following the correct development and application of control measures, then alternative ways of achieving the operational objective shall be identified and considered. **Figure 36** shows the methodology adopted for the rapid risk assessment of the EPS operation.

Qualitative demonstration of ALARP

In relatively low risk situations when the ALARP justification is being made qualitatively some or all of the following can be applied where appropriate:

- demonstration of the application of best practice including technology and management techniques,
- reference to trends in accident and incident statistics, discussion /comparison of risk levels before and after possible change, i.e. identification of practicable options for reduction of risks following the preferred hierarchy as follows, elimination or minimisation of hazard, engineering design, suitable systems of working, and then personal protective equipment

FIGURE 35 : RAPID RISK ASSESSMENT METHODOLOGY

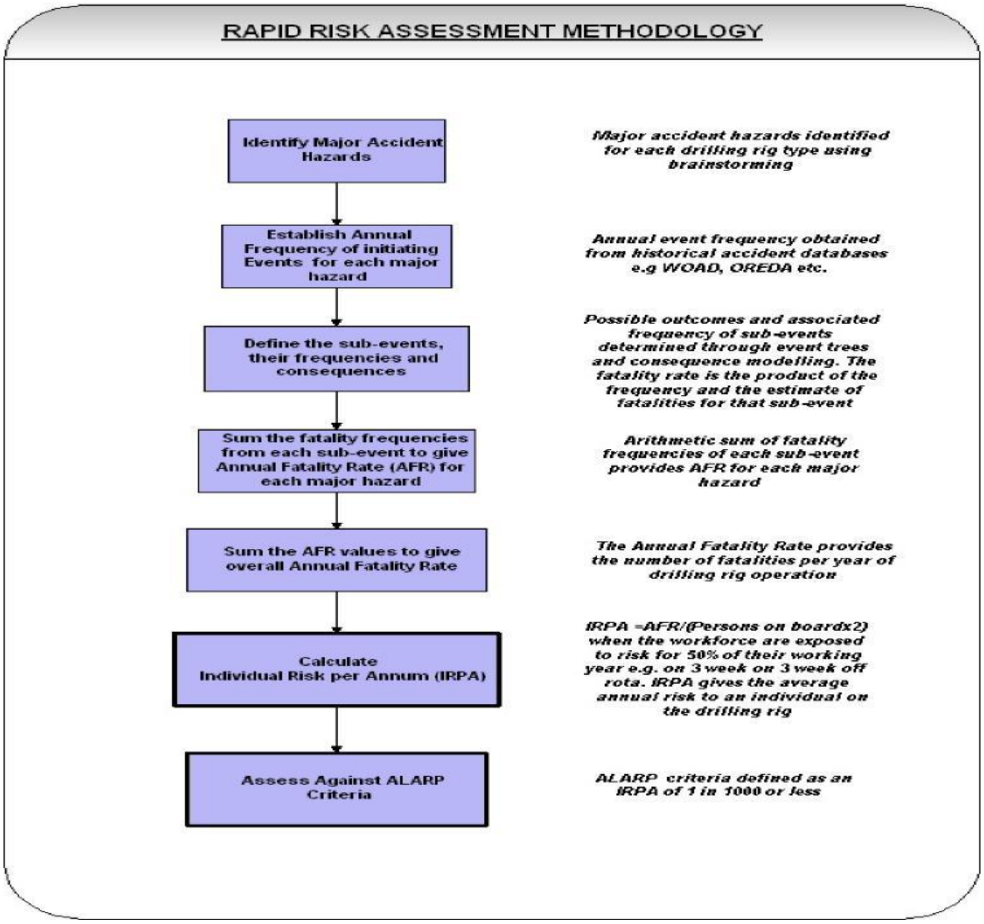
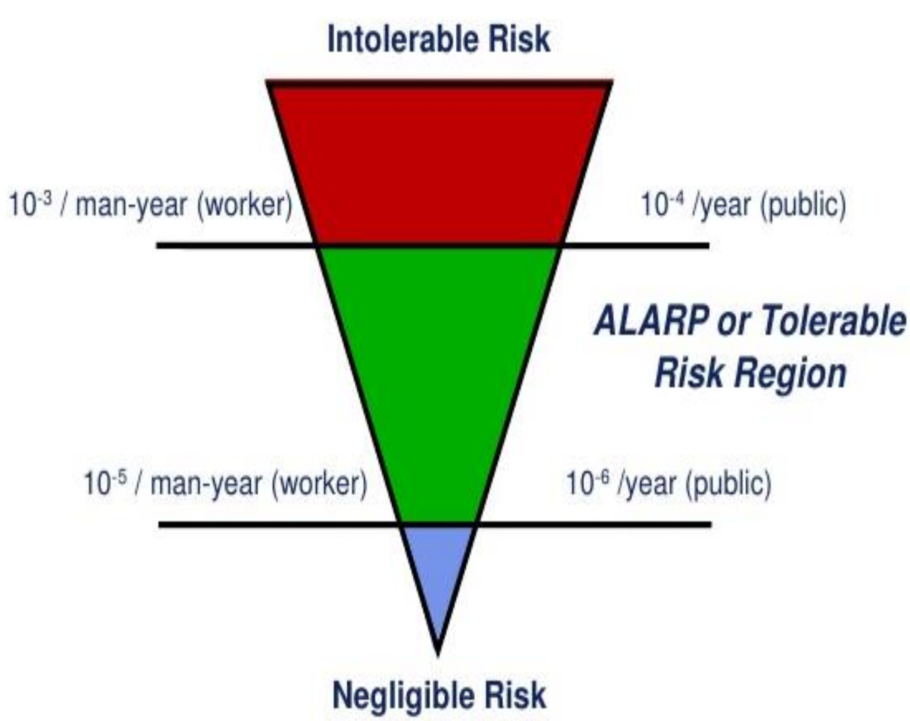


FIGURE 36 : ALARP CRITERIA



Quantitative demonstration of ALARP

Where the consequences of a hazard being realised are very high, i.e. where multiple fatalities, severe environmental damage or damage to installations, and/or major loss of production would result, then quantitative risk assessment (QRA) techniques must be used to demonstrate ALARP. It needs to be understood that QRA is not an exact science; it relies on the use of historical data which may be inaccurate or not directly relevant. Nevertheless, it is valuable in comparing risks to identify priorities and can be used with caution to establish absolute levels of risk. These absolute levels can then be compared with criteria which establish the way in which risks are to be treated.

ONGC has determined that, on the basis of generally accepted international risk acceptance criteria:

- No offshore installation shall pose an individual risk per annum (IRPA) of death to those involved in operating or maintaining the installation from major accidents greater than a 1 in 1,000 chance a year. If this risk can be shown to be less than 1 in 100,000 a year, then it will be accepted;
- Where the risk lies between these levels, then potential design improvements will be assessed to ensure that risks are reduced to an ALARP level.
- In other words: an IRPA greater than 1 in 1,000 a year cannot be accepted as ALARP; an IRPA less than 1 in 100,000 a year is automatically accepted; IRPA's between these levels may be accepted but additional safeguards should be examined to ensure that an ALARP level is reached.

Control Measures to Reduce Risks

Once it has been decided that a risk needs further control, the means of doing so should be evaluated in the following order of preference:

- Eliminate the hazard. Occasionally this may prove practicable, for example, by changing the material used, the process or the equipment. An example would be cleaning using a detergent instead of a flammable, toxic solvent;
- Technical solutions. Engineered control measures, for example enclosures, ventilation systems, alarms, trips and guards. These are relatively independent of the human factor, and generally can be made reliable;
- Procedural solutions. Doing things in a different way to improve safety relies on individuals complying with procedures. Training and communication are important to ensure that operators recognise the risks and know how to avoid them;
- Protective equipment (PPE). This is the least satisfactory form of control, and should only be considered after all others have been rejected.
- It should be noted that introducing controls can produce further risks which may need to be assessed in turn.

Risk cannot be justified save in extraordinary circumstances, Finally, each QRA requires:

- The identification of major hazards specific to the unit being assessed The construction of an event tree for each major hazard to derive a set of credible sub – events Numerical values for major hazard occurrence frequencies and event probabilities are derived from international accident databases of historical incidents and are combined in the event tree to derive occurrence frequencies for these sub events. BALPL have consistently adopted a conservative modelling approach in defining these frequencies and probabilities. All such modelling assumptions are listed;
- The modelling of the consequences in terms of potential fatalities from each credible sub event. As these are 'rapid', generic risk assessments, this modelling does not take the form of detailed physical modelling but rather reflects typical

outcomes based on historical data. BALPL have consistently adopted a conservative approach in deriving such outcomes and all such modelling assumptions are listed

It is ONGC intention to use the latest generation of EPS for this work. Hence the use of historical records which reflect the performance of potentially lower design and operational standards, may introduce an additional element of conservatism into the approach over and above that inherent in BALPL's selection and application of data.

TABLE 74 : PRINCIPAL STUDY ASSUMPTIONS

Assumption Number	Assumption Title	Description
1	Lifecycle	The risk analysis will assume that the EPS are securely on location and will cover a typical 'whole lifecycle' of the well operation including: • EPS Operation • Decommission of EPS
2	Study Scope	The QRA will address those hazards with the potential to cause a "major incident" (e.g. multiple fatalities) • The study is confined to events occurring on the EPS and the impact of any releases on the environment. • In the event of EPS removal
3	EPS Information	The EPS capacity is Gas processing of 7LSCMD
4	Site Information	BALPL identified all potential environmental sensitivities and an appropriate site survey for debris etc in earlier chapters.
5	Operator Information	Operator has and will apply modern Safety Management System
6	Acceptable Risk Levels	The individual risk per annum (IRPA) will be assessed against the ALARP risk level
7	Supporting Study Data	Industry acceptable data sources will be substantially utilised in the assessments. These include but are not limited to: • UK Health and Safety Executive (HSE) Hydrocarbon Ignition Database • Purple Book

7.1.1.1. Risk Analysis Results for EPS

Major Accident Hazards (MAH)

The major hazards identified for the EPS are shown in **Table 74.**

TABLE 75 : MAJOR ACCIDENT HAZARDS FOR EPS

Hazard	MAH	Including
1	Passing Vehicle Collision	Movement of material near EPS

Hazard	MAH	Including
2	Structural Failure	It is assumed that the unit has been chosen to be fit for purpose for its area of operation and that failure occurs as a result of extreme events such as earthquakes, extreme winds etc.
3	Non Process Fires	Cellulosic or electrical fires in accommodation: Storage tanks or pipe leaks leading to fires & explosions in machinery spaces: etc.
4	Hydrocarbon Leaks	Leaks, fires and explosions

Modelling Assumptions

The frequency to be assigned to the likelihood of occurrence of each major hazard is derived from industry reference sources and has been used to facilitate this frequency derivation and to support consequence modelling.

TABLE 76 : ASSUMPTIONS FOR PASSING VEHICLE COLLISION TO EPS

S.No	Assumption	Comments
1	Frequency of passing Vehicle collision is 0.0008 per year	As per above references
2	In 90% of such cases there is sufficient prior warning to allow for precautionary evacuation	No data has been found. This estimate is based on the assumed existence of the following controls to provide for early warning: EPS has radar which is regularly monitored, Control of Vehicle Movement
3	Of the remaining 10% of impacts, it is assumed that the following apply: • 75% do not impair the structural stability of the EPS; only 25% do • Of these 25%, one tenth also result in ignition leading to jet fires / explosion	Based on a conservative interpretation of data reference. Collision energy of 35 – 70 MJ is required for column collapse in rigs. Estimate taking account fires and explosions can occur when the EPS is in Operation (a small % - around 10% - of the time that the EPS is working) coupled with the fact that, when hydrocarbons are present controls exist to shut down flow (e.g. safety valves) these would have to be impaired
4	Ignore the possible impacts of pressure flow of gas same time as this incident occurs	Assume that the well is likely to be live (assuming that all 4 wells are operating) i.e. a probability of 0.11. Flow control with help of HP, LP Valves. Assume a typical reliability of 0.01 per demand for these 2 safety barriers.
5	When the vessels on EPS are toppled • 25% of the personnel near EPS are immediate fatalities • Remaining 75% escape. Probability of rescuing is 0.8	Estimate based on calculations using data from reference, assume moderate weather conditions

TABLE 77 : EVENT TREE FOR VEHICLE COLLISION TO EPS

	Men on rig	capsizes	Sub Event	
			Description	**Frequency per**
Probability	0.1	0.25		
Passing Vehicle impacts 8.E-04 per year	8.0E-05	2.0E-05	1 Capsizes	2.0E-05
		6.0E-05	2 Impact	6.0E-05
	7.2E-04		3 Collision when unoccupied	7.2E-04

TABLE 78 : CONSEQUENCE CALCULATIONS FOR VEHICLE COLLISION TO EPS

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalities	Men needing escape/ evacuati	Means of escape/ evacuati	Prob of fatality	Estm. Escape / evac fatalitie	Total fatalities	AFR
1 Capsizes	2.0E-05	114	0.25	29	86	R	2.E-01	17	46	9.1E-04
2 Impact	6.0E-05	114	0	0	114	H	1.3E-05	1.5E-03	0	8.9E-08
3 Collision when unoccupied	7.2E-04	114	0	0	114	H	1.3E-05	1.5E-03	0	1.1E-06

TOTAL AFR : 9.1E-04
IRPA : 4.0E-06

Evacuation methods

TR - muster in TR (no evacuation required) H - musters in TR and evacuation

TABLE 79 : ASSUMPTION FOR STRUCTURAL FAILURE OF EPS

S.No	Assumption	Comments
1	Probability of a structural failure in any year is assumed to be 0.0028	Structural failure includes: design error, fatigue failure, modification error, operating outside design parameters (e.g. extreme weather / earthquakes in excess of design conditions). It is assumed that the EPS has been correctly specified for the anticipated environmental conditions It is assumed that only the 2 most severe categories will contribute to major structural failure. These are: • total loss of the unit • severe damage to one or more modules of the unit / major damage to essential equipment These 2 categories comprise 12.8% and 22.8% of all structural failure contributions (35.6% in total) Hence the annual EPS failure rate is 0.0077*0.36 = 0.0028.
2	90% of failures are assumed to give some warning and hence allow time for precautionary evacuation	Estimate

S.No	Assumption	Comments
3	The remaining 10% of failures are split as follows: • 10% of them result in sudden collapse • The remaining 90% are the result of a progressive failure	Estimate
4	When escaping from the EPS sudden collapse scenario, personnel will have a 50 % survival probability	A potentially conservative interpretation which assumes that the collapse is so sudden that many escape routes become unusable
5	When escaping from the place progressive collapse scenario, personnel will have a 90 % survival probability	Based on a conservative interpretation of reference assuming that all such events will occur during severe weather. Reference gives a probability of failure to survive as 0.06.

TABLE 80 : EVENT TREE FOR STRUCTURAL FAILURE STRUCTURAL FAILURE OF EPS

			Sub Event	
	No precautionary	**Progressive failure**	**Description**	**Frequency per year**
Probability	0.1	0.1		
		2.8E-05	1 Loss of EPS, personnel have time to evacuate	2.8E-05
	2.8E-04			
Structural failure 2.8E-03 per year		2.5E-04	2 Catastrophic loss	2.5E-04
	2.5E-03		3 Loss of EPS with no personnel near	2.5E-03

TABLE 81 : CONSEQUENCE CALCULATIONS FOR STRUCTURAL FAILURE OF EPS

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalities	Men needing escape/ evacuati	Means of escape/ evacuation	Prob of fatality	Estm. Escape / evac fatalitie	Total fatalities	AFR
1 Loss of EPS, personnel have time to evacuate	2.8E-05	114	0	0	114	H	1.3E-05	1.5E-03	0	4.1E-08
2 Catastrophic loss	2.5E-04	114	0.5	57	114	L/R	1.E-01	11.4	68	1.7E-02
3 Loss of EPS with	2.5E-03	114	0	0	114	H	1.3E-05	1.5E-03	0	3.7E-06

TOTAL AFR 1.7E-02
IRPA 7.6E-05

<u>Evacuation methods</u> TR - muster in TR (no evacuation required) H - Muster in TR and evacuation

TABLE 82 : ASSUMPTIONS FOR NON PROCESS FIRES AT EPS

S.No	Assumption	Comments
1	Frequency of all fires is taken as 0.021 per annum	Possible sources are spills, electrical fires, accommodation fires.
2	All (100%) of these fires are assumed to be non-process related	Conservative approach reflecting the reality that most fires will be minor and arise from non-process related causes
3	Assume that 20 % of all fires result in significant damage	Reference states that 19% of all fires are considered significant or greater. This figure is rounded up to 20% to ensure conservatism.
4	Two fatalities will occur where there is significant damage. Otherwise, no fatality will occur	Conservative approach. As these fires are not process related the available inventory to feed the fire is assumed to be limited. Hence the fire will be contained and will not be capable of impacting many people near EPS. It is also assumed that EPS firefighting capability will always be able to extinguish the fire

TABLE 83 : EVENT TREE FOR NON PROCESS FIRES AT EPS

		Sub Event	
	Significant	**Description**	**Frequency per**
Probability	0.2		
Fire 2.1E-02 per year	4.2E-03	1 Fire causing no significant damages	4.2E-03
	1.7E-02	2 Fire resulting in no significant damages	1.7E-02

TABLE 84 : CONSEQUENCE CALCULATIONS FOR NON PROCESS FIRES OF EPS

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalities	Men needing escape/ evacuation	Means of escape/ evacuation	Prob of fatality	Estm. Escape / evac fatalities	Total fatalities	AFR
1 Fire causing no significant damages	4.2E-03	N/A	N/A	2	112	TR	0	0	2	8.4E-03
2 Fire resulting in no significant damages	1.7E-02	N/A	N/A	0	114	TR	0	0	0	0.0E+00

TOTAL AFR
8.4E-03
IRPA
3.7E-05

Evacuation methods TR - muster in TR (no evacuation required) H - muster in TR and evacuation

TABLE 85 : ASSUMPTIONS FOR HYDROCARBON LEAKS IN EPS

S.No	Assumption	Comments
1	Assume annual gas leakage frequency of 0.00027	Derived from reference assuming: • Gas Processing Facilities, High Pressure low pressure safety valves, Group Header, Test Header, Test Separator, Separation Units, Gas conditioning Units, Dew Point depression unit, N2 Removal Unit, Condensate stabilization, storage and evacuation, Off gas compressor, Gas Supply Unit, Produced water storage and evacuation, utilities for gas processing and associated pipework. This equates to pressure vessels, flanges, valves (assume inlet and outlet to isolate skid) and an assumed 40 metres of pipework • reference gives the following annual failure frequencies: pressure vessel (0.00015), valve (0.00023), flange (0.000088), piping (4" to 11" – 0.000036 per metre) • This produces an annual leak frequency of (4*0.00015)+(2*0.000088)+ (0.00023*2) +(40*0.000036) = 0.0027 • This happens throughout the year 365/365 = 1 • Thus annual leak frequency is 0.0027*1 =0.0027
2	Assume that 95% of leaks can be isolated	Typical value used in risk assessments. Detection can be by personnel or automatic equipment and relates to the probability of a single valve not closing. As isolation is possible via ESD valve this can be considered a conservative approach
3	If the gas release is not isolated all workers in the immediate vicinity will be assumed to be exposed	Conservative approach Assume 8 men in the immediate vicinity during EPS Operation
4	If the release is isolated no fatalities occur	If the release is isolated only a short lived jet fire or small flash fire is possible in the event of ignition or a small volume of potentially poisonous gas in the event that the gas contains H2S. In all these scenarios the threat is limited and contained and hence they do not result in any fatalities
5	Assume probability of ignition of 0.1	Reference suggests that the probability of ignition for small and large gas leaks is 0.005 and 0.3 respectively. Reference indicates that this upper value may be too conservative by recommending a probability of ignition for blowouts of 0.1. Most leaks from process equipment are small and hence a figure towards the lower end of the scale will be most appropriate. Although a lower figure may be justifiable the figure of 0.1 is considered suitably conservative
6	When ignition occurs: • 50% of the time it occurs immediately and results in a jet fire • 50% of the time it will be	In the event of ignition of hydrocarbons the following may occur • **pool fire**: a burning pool of liquid (oil) on the rig • **jet fire:** a burning jet of gas which if ignited soon after it occurs results in an intense stabilised jet which is

S.No	Assumption	Comments
	delayed and result in an explosion	very destructive to anything within it or close to it • **Flash fire:** delayed (say after 15 minutes) ignition of a gas release. In this time the release may have formed an extensive plume and the ensuing fire will kill everyone within it who is unprotected but not damage structures • **Confined explosion:** delayed ignition of a gas release within a confined space, the delay (usually in excess of 5 minutes) giving time for an explosive mixture to build up. It has the potential for considerable fatalities and damage. It is assumed that the necessary degree of confinement does not exist on a jack up • **Vapour cloud explosion:** an ignited gas plume which burns in such a way that it generates overpressures characteristic of an explosion. A simple but conservative approach has been taken that all immediate ignition events result in a jet fire while the results of all delayed ignition events (whether they are from a flash fire or a vapour cloud explosion) are equally severe
7	No allowance is made for the EPS firefighting capability	A very conservative approach which also reflects lack of knowledge of the rigs safety equipment
8	Probability of fatalities if the gas leak is not isolated are as follows: • 0% probability for un-ignited releases if low H_2S or CO_2 present. Otherwise see items 9 and 10 • 10% for jet fires • 50% for explosions	Generally reflective of a typical industry approach
9	For unignited gas releases assume a 5% probability that the reservoir contains volumes of H_2S or CO_2 at concentration levels high enough to cause fatalities	Estimate
10	Unignited releases if the gas contains high levels of H_2S or CO_2 • 10% probability of fatality for all personnel near EPS as a result of H_2S poisoning • 0% probability of fatality for all other personnel who are assumed to follow the pre-arranged H_2S drill and successfully evacuate the area • Personnel evacuating EPS	It is conservatively assumed that gas rather than oil is present in the feed. Assume that best practice H_2S protection measures are adopted and regular drills held. Assume personnel near the EPS are warned of impending danger by alarms, etc. Personnel at most risk assumed to be in open areas. All personnel follow procedures but, as a result of equipment failure or lack of training only 90% success is achieved

S.No	Assumption	Comments
	Area will have escape & evacuation probability of fatalities	

TABLE 86 : EVENT TREE FOR HYDROCARBON LEAKS IN EARLY PRODUCTION SYSTEM OPERATION

	Release is isolated	Ignition	Delayed ignition	High H_2S or CO_2 concentration	Sub Event	
					Description	Frequency per year
Probability	0.95	0.1	0.5	0.05		
Hydrocarbon leak 2.7E-03 per year	2.6E-03	2.6E-04	1.3E-04		1 Small flash fire	1.3E-04
			1.3E-04		2 Short-lived jet flame	1.3E-04
		2.3E-03		1.2E-04	3 Small gas cloud with high H_2S or CO_2 concentration	1.2E-04
				2.2E-03	4 Small gas cloud with low H_2S or CO_2 concentration	2.2E-03
	1.4E-04	1.4E-05	6.8E-06		5 Explosion	6.8E-06
			6.8E-06		6 Jet flame	6.8E-06
		1.2E-04		6.1E-06	7 Gas cloud with high H_2S or CO_2 concentration	6.1E-06
				1.2E-04	8 Gas cloud with low H_2S or CO_2 concentration	1.2E-04

TABLE 87 : CONSEQUENCE CALCULATIONS FOR HYDROCARBON LEAKS DURING WELL TESTING / EARLY PRODUCTION SYSTEM

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalities	Men needing escape/ evacuation	Means of escape/ evacuation	Prob of fatality	Estm. Escape/ evac	Total fatalities	AFR
1 Small flash fire	1.3E-04	10	0	0	114	TR	0	0	0	0.0E+00
2 Short-lived jet flame	1.3E-04	10	0	0	114	TR	0	0	0	0.0E+00
3 Small gas cloud with high H_2S or CO_2 concentration	1.2E-04	10	0	0	114	TR	0	0	0	0.0E+00
4 Small gas cloud	2.2E-03	10	0	0	114	TR	0	0	0	0.0E+00

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalitie	Men needing escape/ evacuati	Means of escape/ evacuati	Prob of fatality	Estm. Escape/ evac	Total fatalities	AFR
with low H_2S or CO_2 concentration										
5	6.8E-06	10	0.5	5	109	H	1.3E-	1.4E-	5	3.4E-
6 Jet flame	6.8E-06	10	0.1	1	113	H	1.3E-05	1.5E-03	1	6.8E-06
7 Gas cloud with high H_2S or CO_2	6.1E-067	10	0.1	1	113	H	1.3E-05	1.5E-03	1	6.1E-06
8 Gas cloud with low H_2S or CO_2 concentration	1.2E-04	10	0	0	114	H	1.3E-05	1.5E-03	0	1.7E-07

TOTAL AFR 4.7E-5
IRPA : 2.1E-07

Evacuation methods TR - muster in TR (no evacuation required)
H - muster in TR and evacuation

7.1.1.2. Calculation of Individual Risk Per Annum (IRPA)

- Event trees and consequence analysis will be used to evaluate the Annual Fatality Rate (AFR) for each major hazard
- By their method of calculation these AFR's provide a measure of the average risk to employees. They essentially weight each groups contribution to fatalities by exposure
- All major hazard AFR's will then be summed to derive a total AFR for EPS
- This figure is the average risk faced in one year by all personnel working in EPS and has been calculated assuming that the EPS always contains 8 personnel
- However, workforce of 8*2 = 16 to maintain a constant 16 man workforce near EPS for the whole year.
- Hence the IRPA can be simplistically assumed to be (Total AFR / 16)

7.1.1.3. Analysis Results

The results of the risk analysis for the EPS at BTSAD are shown in **Table 88.**

TABLE 88 : RISK RESULTS

Hazard No	Major Accident Hazard	Individual Risk Per Annum (IRPA)
1	Passing Vehicle collision	4.0E-06
2	Structural Failure	7.6E-05
3	Non Process Fires	3.7E-05

Hazard No	Major Accident Hazard	Individual Risk Per Annum (IRPA)
4	Hydrocarbon Leaks	2.1E-07
	TOTAL	**1.17E-04**

7.1.1.4. Comparison with ALARP Criteria

The total individual risk (IRPA) for the EPS operation at BTSAD has been estimated to be **1.17E-04** fatalities per annum. This is within the ALARP region of less than **1.00E-03** but greater than **1.00E-05**. The calculated fatality frequency for each individual hazard is also within the ALARP region with the exception of Vehicle Collision **(4.0E-06)** and Hydrocarbon Leaks **(2.1E-07).** Which are both in the 'broadly acceptable' region. IRPA's in the ALARP Region are tolerable but additional safeguards should be examined to ensure that an ALARP level is reached in practice and the risk further reduced using cost effective solutions.

7.1.1.5. Oil Spill Frequency

The event trees have identified a number of contributions to the release of hydrocarbons from the EPS. The safety impacts of these releases have been modelled in the consequence analyses; this section addresses their potential environmental impact taking account of the relative remoteness of Bantumilli South Field from the coastline.

Hydrocarbon releases may arise from the EPS Vessels, equipment / tanks, or from the feed pipeline. The releases are categorised as follows:

Tier 1 – spills <10 tonnes: These releases are assumed to have only a small, local to the unit, impact and to be capable of being managed solely by the unit. Most spills in this category are likely to be sufficiently small to be dispersed naturally; the remainder assumed to have a limited oil spill response capability. Such incidents can arise from: spills of oils /lubricants; diesel spillages etc. Events resulting in such minor spillages are not conducive to QRA and therefore have not been modelled as part of this QRA.

TABLE 89 : INITIATING EVENTS LEADING TO TIER 1 OIL SPILL

Initiating Event (Major Accident Hazard)	Hazard No	Annual Frequency
Passing Vehicle collision	1	4.0E-06

Tier 2 – spills >10 to 100 tonnes: These incidents may not be capable of being managed entirely by the EPS unit and may require some limited outside support.

TABLE 90 : INITIATING EVENTS LEADING TO TIER 2 OIL SPILL

Initiating Event (Major Accident Hazard)	Hazard No	Annual Frequency
Structural Failure	2	7.6E-05

Tier 3 – spills >100 tonnes These incidents, resulting from hydrocarbon releases from the feed line, have the potential to impact a wider area and, particularly at the upper end of the range, to impact the coast no matter how remote from the shore the unit may be.

TABLE 91 : INITIATING EVENTS LEADING TO TIER 3 OIL SPILL

Initiating Event (Major Accident Hazard)	Hazard No	Annual Frequency
Hydrocarbon Leaks	4	2.1E-07

NOTES:

1: Maximum volume = Open hole flow rate x Pump Capacity

2: Maximum volume assumes that ESD is not working

This gives a total spill frequency for Tier 2 and Tier 3 for a EPS operation of **8.0E-05.**

7.1.1.6. Recommendations

Recommendations are given in **Table 92** for each of the risks within the ALARP region. Implementing these recommendations will ensure that the assumptions in the risk assessment are valid and potentially provide cost effective risk reduction measures. These constitute 'best practice' for operational control and would form part of an effective Safety Management System.

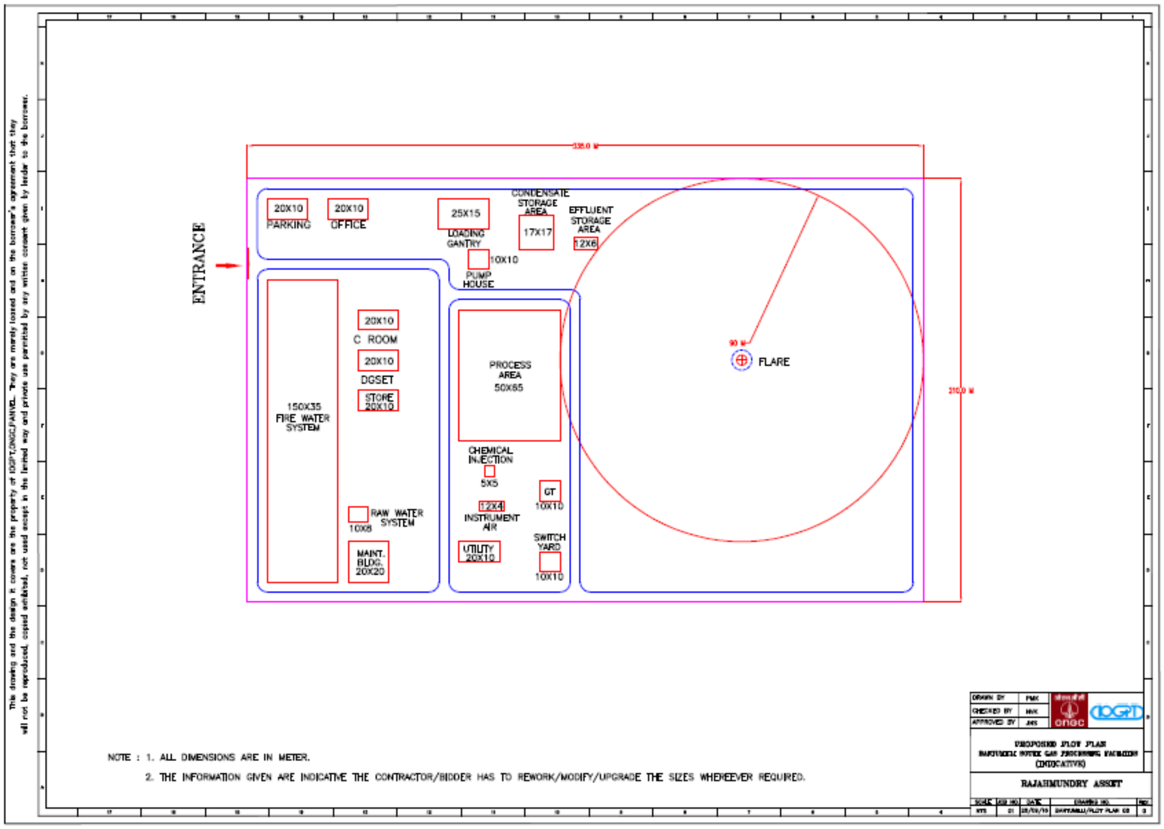
In addition recommendations have been made relating to preparedness for dealing with the risk of an oil spill during the EPS operation.

TABLE 92 : RECOMMENDATIONS FOR EPS

Hazard No	Hazard	Recommendation
1	Passing Vehicle Collision	Ensure that there is adequate monitoring by Transporting team. Emergency exercises to include dealing with errant Vehicles
2	Structural Failure	Establishment of Certified EPS as per National Standards, International Standards and Best Management Practices
3	Non-Process Fires	Maintain awareness of crew of fire risks within accommodation and engine spaces
4	All oil spills resulting from the major hazards	The oil spill planning requires: Response capability at EPS. Some pollution control capability back-up resources identified adequate training in Emergency Response Follow OISD RP 201

Proper zoning of the area is to be done to avoid cumulative fire scenarios. MSDS should be provided in the storage areas and clear demarcation of hazards is to be provided. If the tanks / Vessels near EPS are caught with fire the heat radiation will reach a distance of 300mts which will be well within the site premises. EPS Layout Plan is provided as **Figure 37.**

FIGURE 37 : EPS LAYOUT



7.2. Emergency Response Plan

7.2.1. Objectives And Scope

The key objective of this Emergency Response Plan (ERP) is to outline the management, organisational arrangements and available facilities that will be utilised by ONGC, in the event of an emergency situation arising during the proposed activity at BTSAD. The plan identifies the philosophy and approach for managing an emergency and provides an outline of the roles and responsibilities of key ONGC and contractor staff for potential emergency scenarios identified as part of the rapid risk assessment conducted for the proposed EPS activity.

The plan should not include specific action items for controlling emergencies but provides a basis on which specific detailed emergency response procedures may be developed.

This section outlines the key elements of an Emergency Response Plan to support the EPS activity.

7.2.1.1. Emergency Response Organisation And Communication

Initial response to any incident will be managed on site. The overall level of response will depend on the nature and scale of the emergency.

Emergency incidents have the potential to impact both ONGC (staff / reputation / schedule/ etc.). Hence there should be one ERP for the EPS operation that reflect the integration of both the ONGC Head Office and EPS Station. The initial response to all incidents should be managed by the EPS unit.

The specific structure and organisation of the ERP will be dependent on the location and capability of On Site Response Team .

7.2.1.2. Identified Emergency Scenarios

The Emergency Response Plan (ERP) must be capable of managing the response to the major hazards, identified and any associated environmental risks. In addition the ERP must also address "occupational" hazards including incidents such as Single and multiple accidents requiring medical evacuation).

7.2.1.3. Emergency Classification

The required response will depend on the scale of the incident. Emergency scenarios are categorised into three levels, typically:

Tier 1 Incident (Local Alert)
Tier 1 incidents require no external assistance and can be managed by the Emergency Co-ordinator using on site resources. Typical incidents may include:

- Single casualty (medevac);
- Oil spills <10 tonnes;
- ONGC equipment damage;

Tier 2 Incident (Site Alert)
Tier 2 incidents cannot be managed entirely on site. ONGC response is typically activated, Incidents may include:

- Substantial security incident;
- Multiple casualty (medevac);
- Oil spill 10-100 tonnes ;
- Substantial fire;
- Cyclone/flooding;
- Cultural conflict.

Tier 3 Incident (External Alert)
Tier 3 incidents are major emergencies beyond site resources with the potential to impact beyond the site limit. External assistance is required and there is immediate mobilisation of ONGC. Typical incidents may include:

- Major fire / explosion;
- Oil spill >100 tonnes;
- Fatality.

It should be noted that for any tier incident, when determining tiers for oil spills, the quantity of oil spilt is not the only factor. The environment potentially threatened by the oil is also considered in determining the tier of spill.

7.2.1.4. Emergency Response Activation

The level of callout to deal with an emergency needs to be defined and co-ordinated by ONGC. The Emergency Response Contact directory will be updated before the actual commencement of EPS activity.

7.2.2. Disaster Prevention Methods

Effective emergency management should include both detailed emergency response measures and appropriate prevention measures. It may be necessary for ONGC to maintain:

- Properly documented EHS Management System
- Competent personnel trained in disaster response duties
- Appropriate detection equipment (gas detection including H_2S, smoke detection, radar)
- Suitable firefighting equipment available and personnel properly trained in its use
- Operational emergency alarm and PA system
- Effective communication equipment including VHF Radio, V-SAT / INMARSAT, mobile VHF radios
- All equipment required for emergency response undergoes routine maintenance and is regularly tested / calibrated
- Detailed evacuation procedures including appropriate muster areas, escape routes including clear signs where appropriate. Personnel should be made aware of evacuation procedures through appropriate training.
- Regular drills/exercises to test ERP's
- Regular review of Emergency Response Plans with modifications as required.
- ONGC is also having Operational Risk Management Committee

Decommissioning Phase of EPS

At the completion of EPS Operation, an orderly withdrawal of all personnel and the removal of all Vessels, equipment, fixed and non-fixed items from the EPS site will be undertaken. All concrete or steel installations would be removed to at least 1 m below ground level, so as to ensure that there are no protruding surface structures. In the unlikely event if soil is found to be contaminated, measures would be taken to remove or treat appropriately all contaminated topsoil to promote its remediation.

has accorded top priority to safety and protection of environment in the operational areas. The activities are oriented towards prevention rather than cure and conducted in such a way as to ensure:

- Health and safety of its employees
- Protect the environment
- Optimal utilization of oil field equipment, instruments without leading to any health hazards.
- Health, safety and environment (HSE) matters have given equal status with all other primary business objectives.

7.3. Health and Safety

The field Development project proposes establishment of EPS at BTSAD with the required process facilities for producing gas from four existing well. A robust HSE Management Plan is proposed to be put in place so as to mitigate the negative impacts and the entire project is implemented in a sustainable way.

7.3.1. Occupational Health

An Occupational Health Management System is proposed to be kept in place aimed at promoting and maintaining physical, mental and social wellbeing to the highest degree among the personnel by monitoring their health and the state of the workplace. Occupational

Health monitoring shall be made applicable to all the workers at all installations and work centres.

Scope of activities
The scope of activities include the following –

- **Personnel Surveillance:**

Periodic Medical Examination, Pre-Employment Medical Examination and Pre- Placement Medical Examination. Investigations will be carried out at authorized laboratories.

- **Workplace Surveillance:**

Monitoring of all workplaces for Hazards Ergonomic Assessment of the Workplace
Sanitation Evaluation will be carried out including portability of Water

- **Educative Function:–**

By imparting training in:

- Occupational Health
- Preventive Medicine
- First Aid Training
- **Occupational Health Surveillance Program-**

Onshore operations comes under Mines Act, 1952 and as per Mines Act every person employed in a mine must undergo PME (Periodical Medical Examination) by an approved physician / Hospital at a reasonable periodic interval i.e.

- For age up to 45 yrs - Once in 5 years
- For age from 46 to 55 yrs - Once in 3 years
- For ages above 55 yrs - Once every year

The operator herewith ensures that he will adopt all measures to safeguard the health of the employees.

7.3.2.Safety

An effective Safety Management System will be put in place to prevent accidents, hazardous incidents and eliminate or minimise their consequences.

Enforcement of Safety
Safety shall be ensured through repeatedly highlighting its utility in preventing loss of life and property and providing training to employees on safe working. Following modes will be followed for this:

- Work Permit System
- Job safety analysis
- Training of employees and contractors
- Surprise checks
- Drills
- Operating manuals / Safety manuals

HSE Information & Corporate EHS Policy of ONGC is provided as Annexure III.

Monitoring of Systems
Following systems will be monitored regularly for effective implementation:

- Checking of safety interlocks
- Internal audits of facilities in line with OISD-STD-145
- Safety facilities as per OISD 189
- Management of change
- Testing / Inspection of equipment

- Checking of fire detection and protection system

Safety Promotion
Visuals play an important role in reminding personnel of safety information. Therefore, display of following information will be done in the premises:

- Safety precautions for critical operations at strategic locations
- Safety posters and slogans
- Safety records
- Do's and Don'ts at chemicals handling/storage/operation areas
- Need for Wearing helmet and other Personal Protective Equipment (PPEs)
- Labelling of chemicals
- Material Safety Data Sheet (MSDS)
- Safety manuals, Rules and Regulations
- Safety News Letters & bulletins
- Dissipation of incident information

Work Permit
In case, work is required to be performed in the plant / facility by any person other than the operating personnel of that area, a duly authorized written permit will be obtained by the person / agency executing the work before commencement of the work.

Based on the nature, the work would be undertaken under different types of permits. For example, following jobs will be undertaken with the duly issued hot work permit:

Cutting, Welding, Excavation, Road/Dyke cutting, Electrical lock out / Energising, Confined space entry, Boxing up of a vessel, Working on fragile roof structures, Radiography, Material Handling in operational areas, Crane operation etc. OISD-STD- 105 on Work Permit System will be adhered to regarding issuance of work permits.

Safe Work Practices
Safe Work Practices will be followed during EPS Construction and production operations as given below:

Safety during Dismantling Systems
Dismantling of the structures in old location, transportation and erection of the same at new location. The job involves handling of heavy loads up to 20-30 tons using various heavy material handling operations, transportation from location to location involves accidental risk and such transportation to be handled with extreme care. In EPS building the risks of accident are therefore involved in:

- Use of heavy material handling equipment.
- Transportation of heavy equipment from one location to another location. EPS operations involve risks associated with work at height, handling tools in awkward positions, danger of falling object on workers on the ground.

The recommendations listed below serve as a guide for minimizing hazards during rigging up and dismantling operations.

- All sheaves and shafts of the hoisting system will be checked (zin poles, hoisting sheaves, equalizer sheave, crown block sheaves, traveling block sheaves). All the sheaves, bearings and bushings to be greased.
- All the lifting ropes, casing lines and clamps fitted on lifting ropes will be checked. Lifting rope / bull line will be lubricated prior to lowering mast, draw works and sub-structure.
- Draw works brake, eddy current brake, hydrometric brake will be checked.

- Counter pre-loading tanks will be filled completely with water.
- Required power availability to draw works will be checked.
- Required normal working air pressure to hoisting clutch to be checked.
- Zin poles or Mole trucks for dragging tanks and heavy equipment in slushy areas will be used.
- All the threaded joints will be greased and the threaded ends will be covered by thread protectors to protect joints during transportation
- Lifting hooks will be checked for any cracks or damage during lifting and loading.

Production Operations
In the Production facilities, separators and pipelines under pressure, storage tanks and heater-treaters, are the basic facilities. Leakage from flow lines inside Early Production System (EPS) and also incoming and outgoing lines can result into oil spills/gas leakage. This can lead to fires. Therefore any oil spill/gas leakage is to be rectified on priority. The safety hazards common to installation are as follows:

Pressurized Vessels & Pipelines
The safety valves, pressure gauges and liquid level controls of separators need frequent checks. The separator and its safety valves unless tested and maintained properly can result in bursting of separator with serious consequences. The safety valve will be tested once in six months Back flow of fluids from separator to wellhead can also be hazardous. Hydrate formation in production systems and well heads needs special attention by taking suitable remedial measures.

Fire Hazards
Flammable matter like oil and gas are constantly present and unless sources of ignition like naked lights, frictional sparks, electrical sparks, static electric charges, lightning, Overheated surfaces, are carefully controlled, fire could be a major hazard. In some cases, even auto ignition takes place.

Accumulation of Oil Vapour
Oil vapour which is heavier than air tends to settle down and accumulate near loading and unloading point for road tankers, open pits containing accumulation of oil and around storage tanks, particularly during winter. The accumulated oil vapour can be easily ignited and may even explode. In a confined space, they tend to make the atmosphere leaner in oxygen content-confined to difficulty in normal breathing (asphyxiation) and/or adverse physiological effects (with more than 0.1% concentration of hydrocarbons).

Explosion Hazard
Large quantities of gas released from separators is generally piped away from the installation and flared, but in case the flare is extinguished, large quantities of unburnt gas is discharged into the atmosphere, which may lead to an explosion. Pyrophoric iron sulphide in lines and vessels can also cause an explosion when coming in contact with air.

Safe practices
Recommendations listed below will provide guidance for safety in the light of hazards mentioned above.

Separators and Pipelines

- Separators, connecting lines, valves, flow lines and collector lines will be hydraulically tested to one and half times the maximum working pressure and the installation will not be commissioned unless the test results are satisfactory.

- Separators, heater treater, bath heaters and other pressure vessels will be periodically hydraulically tested once in 3 years at 1.5 times the max permissible working pressure and a record will also be maintained thereof.
- Thickness measurements of all pressure vessels will be done at least once in 3 year.
- Every separator will be provided with a safety valve. The pressure leaving safety device shall be set to open at a pressure not exceeding 10% of the maximum allowable working pressure.
- The safety valve will be installed directly on the separator and no valves will be fitted between the vessel and the line connecting the safety valve. Every safety valve will be provided with an arrangement for testing its efficiency.
- Suitable working platforms with stair cases and hand rails will be provided for maintenance of separators and its safety valves. The discharge line of every safety valve will be connected to the flare line for safe disposal of gas released from it.
- Safety valves of the pressure vessels like separators, scrubbers, heater treaters etc. will be tested at least once in six months and record thereof.
- At the header manifold, a non-return valve will be provided in each flow line connected to well.
- In each flow line, an emergency shut-off valve will be installed on the upstream side of the non- return valve, which can be closed manually in case emergency.
- At the overhead crossing of a steam pipeline, a condensate trap will be provided just before such crossing, otherwise the condensate may cause severe hammer in the pipeline.
- A steam trap will also be provided in the pipeline immediately before it enters the storage tank.
- Thermal insulation with asbestos rope will be provided in the exhaust pipes of bath heater and heater treater at least up to a height of 1.8 meters from ground level.
- Process areas like separators platform, heater treater area, pump house, tank farm etc. will have free passage for safe working of operators. In case of interference by pipelines, in the free movement of operator, suitable walk ways will be made.
- Approach road for fire tenders inside EPS will be in good condition and there will not be any interference from any flow lines, overgrowth of grass etc.

Precautions against Fire

- The protected area surrounding the EPS will be enclosed by boundary walls or barbed wire fencing, not less than 1.8 meters in height, with gates which can be duly locked. Guards will be posted at the gates when so required, to prevent entry of unauthorized persons.
- Smoking is strictly prohibited inside the production installation. Prohibitory sign for these precautions will be displayed at the gate on the panel board. Anybody entering the EPS and if carrying any smoking apparatus like cigarettes, matches and lighters etc. must deposit the same at the gate.
- Emergency exit : In an enclosed area, before undertaking any operation, it will be ensured that there are at least two escape ways, unobstructed and easily accessible,
- Hand tools used for loosening or tightening etc. It will be of non-sparking type.
- The following precautions will be taken to prevent electrical spark:
- In every zone-1 hazardous area, only intrinsically safe flame-proof electrical apparatus and equipment(s) will be used, whereas in every zone-2 hazardous area, only flame-proof or increased safety or pressurized electrical apparatus and equipment will be used.
- EPS will be protected against lightning by suitable lightning arresters which will be installed as per I.S. standards. (IS: 4850-1968)
    - Lightning arresters will not be installed directly on storage tanks.

- While loading and unloading oil in road tankers, its engine will be stopped and battery isolated from the electric circuit. The engine will not be re-started and the battery will not be connected to the electric until all tanks and valves have been securely closed.
- At the loading arm, all oil pipelines, filling and delivery hoses, metallic loading arm, swivel joints, tank and chassis of tank vehicle will be electrically continuous and be efficiently earthed.
- Overheated surfaces can cause fire. The probable sources are, the discharge line of compressed air at high pressure, exhaust pipe of diesel and gas engines, chimneys of the emulsion heater treater, water bath heater and steam lines going to storage tanks.
  - The chimneys will be adequately insulated. The compressed air discharge lines will be connected to inter-coolers with automatic temperature recorder alarm, which will sound a warning if the temperature exceeds the prescribed limit.
  - In case of diesel engine, the exhaust gas will be conditioned so as to reduce its temperature.
- Hot work permit will be issued to the concerned persons by shift In-charge with approval from area In-charge, prior to commencement of any hot job inside the installations.
- Efficient earthing of all vessels and equipment's will be done to take care of static charges. Earthing connections will be checked every year and measured values will be recorded in a register. Earthing pits will be clearly marked for inspection.
- Spillage of flammable liquids will be minimized to mitigate risk of fire and will be immediately cleaned.
- All firefighting equipment's will be maintained in good condition.
- Electrical control room, switch gear room, computer room etc. will be maintained in good condition. There will be rubber mats in electrical control room and switch gear room and cables will be properly led in trenches. Lighting fixtures will be permanent and no hanging wires or naked bulbs are permitted. There will not be-any leakage of water from ceiling in electrical control room and switch gear room. Starter panels of all equipment's will be in good condition and rear doors will be closed when equipment's are in operation.
- Use of electrical equipment including lighting fitting is prohibited in zone-0 hazardous area. Flame proof and intrinsically safe lighting fitting/equipment's will be used in Zone- I and Zone- 2 hazardous area as per IS - 2148 - 1968 and IS - 8289 - 1976 and IS - 2206 - 1976.
- Vessel entry permit is to be issued by area in-charge with due approval of mines manager prior to taking up cleaning / maintenance jobs in any vessel.
- Fire hydrants, water sprinkler system, foam lines of storage tanks will be inspected regularly to ensure their smooth functioning.
- Regular inspection of well head fittings is to be carried out for any leakage of gas/oil. To prevent unauthorized entry to the EPS, periodical inspection of fencing is to be done.
- Flammable material will be kept away from source of heat and stored in suitable cans and at proper place.
- All electrical equipment's and fittings will be maintained properly.
- First aid items will be maintained properly.
- Regularly removal of accumulated waste material like dry vegetation is to be ensured.
- Routine maintenance of all machinery will be ensured.
- Close supervision of premises at all times is to be ensured.
- There will be proper drainage system in process areas. Necessary sumps will be available in all critical areas like pump house, storage tanks, separator platforms etc. to collect and recover spilled oil.
- Water supplies will be adequate.

- Prohibitory caution signs will be displayed at all critical places.

Precautions against Accumulation of Oil Vapour

Loading and unloading points and open pits into which oil is discharged are the possible locations where oil vapours may accumulate. It may also accumulate near the storage tank. Regular checks with explosive meter will be made for presence of flammable vapours, particularly in the night hours and in winter months. Whenever any dangerous accumulation of flammable vapours is observed, immediate steps will be taken to remove such accumulation by arranging adequate ventilation in the area. Suitable air blowers may be used for the purpose.

Disposal of Gas through Flare System

- A flare line shall be sited to a flare stack not less than 30 meters from any part of the EPS or petroleum storage tanks.
- As far as practicable, the flare line will be laid below ground. It will be provided with a bleeding valve and a knock-out drum to drain condensate from the line. In case of any overhead crossing, the bleeding valve will be located immediately before such crossing on the upstream side. Regular draining of the flare line is essential, as otherwise accumulation of liquid in the line may restrict passage and create a back pressure at the separators which may in turn lead to failure of the system.
- The flare line will terminate with a vertical riser pipe of not less than 9 meters in height.
- When the gas flow is intermittent, the flare line will be provided with a pilot burner with remote control electrical ignition device to ensure that the pilot burner is continuously lighted.
- At the flare stack, a water seal drum will be provided to prevent ingress of air into the flare line.
- Leakage of gas if any in flare line and in flare stack will be attended on priority.
- There will not be any seepage of effluent from effluent evaporation pit located in gas flare area.
- Effluent evaporation pit will be prepared with suitable masonry boundary wall and asbestos enclosure to prevent seepage and transmission of heat respectively.
- Passage to flare area will be kept accessible and free from dry vegetation.

Safe distances

- Smoking is strictly prohibited within 30 meters of EPS, separator, petroleum storage tank or other sources of flammable gases.
- No naked light or open flame or spark will be permitted within 30 meters of EPS or any place where petroleum is stored.
- No flame type, crude oil treater or other flame type equipment will be placed within 30 meters of any well, separator, petroleum storage tank except where such flame type equipment is fitted with a flame arrester.
- Flare will be sited not less than 30 meters from any part of EPS or petroleum storage tanks