CHAPTER 6

RISK ASSESSMENT AND CONSEQUENCE ANALYSIS
CHAPTER 6

RISK ASSESSMENT AND CONSEQUENCE ANALYSIS

6.1 RISK ASSESSMENT, CONSEQUENCE ANALYSIS AND OCCUPATIONAL SAFETY DURING DRILLING AND PRODUCTION TESTING

6.1.1 INTRODUCTION

Hydrocarbon operations are generally hazardous in nature by virtue of intrinsic chemical properties of hydrocarbons or their temperature or pressure of operation or a combination of these. Fire, explosion, hazardous release or a combination of these are the hazards associated with hydrocarbon operations. These have resulted in the development of more comprehensive, systematic and sophisticated methods of Safety Engineering, such as, Hazard Analysis and Risk Assessment to improve upon the integrity, reliability and safety of hydrocarbon operations.

The primary emphasis in safety engineering is to reduce risk to human life and environment. The broad tools attempt to minimize the chances of accidents occurring. Yet, there always exists, no matter how remote, that small probability of a major accident occurring. If the accident involves hydrocarbons in sufficient large quantities, the consequences may be serious to the project, to surrounding area and the population therein.

Derrick floor is the center stage of all the drilling operations and it is most susceptible to accidents. Safety precautions with utmost care are required to be taken during drilling as per the prevailing regulations and practices so that accidents can be avoided. Due to advancement in technology, number of equipments have been developed over a period of time to cater the need of smooth operation on derrick floor. Various standards are required to be referred to cover the variety of equipments used for safe operation in drilling and it is desirable to use a properly prepared manual for occupational safety while working or drilling over a rig. Safety systems for drilling rigs and safe working conditions and practices to be adopted during exploratory drilling operations and well testing are discussed in this section.

6.1.2 IDENTIFICATION OF HAZARDS IN DRILLING AND PRODUCTION TESTING OPERATIONS

Various hazards associated with drilling and testing operations of hydrocarbons are briefly described in following sub-sections.

6.1.2.1 Minor Oil Spill

A minor oil spill is confined within the well site area. The conditions which can result in minor oil spill are as follows:

- **Diesel Fuel Storage System**: Oil spillage from tanker unloading, leaking valves, lines and storage tank.
Production minor Testing of the Well: Well testing leading to oil/gas spillage due to leakage from lines, valves, separator and tank failure, etc.

During the well testing operation, there exists a possibility of hydrocarbon gases being released from a failure upstream of crude stabilization facilities at the exploratory drilling location. Once the flow of oil from well is stopped, then on-site access for clean-up is possible. If flow from well can not be stopped, a blowout situation exists.

6.1.2.2 Major Oil Spill

Significant hydrocarbon inventories will not be maintained at a well site since only exploratory production testing is involved at present for 5 to 10 days at each well site. A major spill can, therefore, only arise as a result of an uncontrolled flow from a well either during drilling or exploratory production test resulting from a failure of the surface equipment.

For this to occur would require a combination of mechanical damage, such as, ruptured flow line coupled with failure of the emergency shut down (ESD) system. Oil is produced with some associated gas, therefore, an oil spill arising from a failure of the surface equipment upstream of the crude stabilization facilities will result in the release to atmosphere of hydrocarbon vapours together with oil droplets in the form of a mist.

Provided that ignition does not take place and the well head is not obstructed the well can be shut in manually at the wellhead. If ignition occurs or other damage prevents access to the wellhead then a blowout situation exists and appropriate measures must be implemented.

6.1.2.3 Blowout

Blowout means uncontrolled violent escape of hydrocarbon fluids from a well. Blowout followed by ignition which prevents access to the wellhead is a major hazard. Contributors to blowout are:

Primary

- Failure to keep the hole full
- Mud weight too low
- Swabbing during trips
- Lost circulation
- Failure of differential fill-up equipment.

Secondary

- Failure to detect and control a kick as quickly as possible;
- Mechanical failure of BOP
- Damage to or failure of wellhead equipment;
- Failure of casing
- Failure of formation or cement bond around casing.

If the hydrostatic head exerted by the column of drilling fluid is allowed to drop below the formation pressure then formation fluids will enter the
wellbore (this is known as a kick) and a potential blowout situation has developed.

Fast and efficient action by operating personnel in recognizing the above situations and taking precautionary measure can avert a blowout.

6.1.2.4 Hydrogen Sulphide (H$_2$S)

Hydrogen sulphide gas (H$_2$S) is extremely toxic, even very low concentrations can be lethal depending upon the duration of exposure. Without any warning, H$_2$S may render victims unconscious and death can follow shortly afterwards. In addition, it is corrosive and can lead to failure of the drill string or other tubular components in a well. Fortunately, crude oil and natural gas is likely to be sweet, that is, without any sulphur compounds including H$_2$S in the block area. However, following safety measures may become necessary as and when H$_2$S is detected while drilling and testing the exploratory wells in the block area and these are presented in Sub-section 6.1.3.2.

The Occupational Safety and Health Act (OSHA regulations) has set a 10 ppm ceiling for an eight hourly continuous exposure (TWA limit), a 15 ppm concentration for short term exposure limit for 15 minutes (STEL) and a peak exposure of 50 ppm for 10 minutes for H$_2$S.

Important characteristics of H$_2$S gas are given in the Table 6.1.

6.1.3 CONTROL MEASURES FOR MAJOR HAZARDS

Out of four hazards described in Sub-sections 6.1.2.1 to 6.1.2.4, occurrence of (a) blowout and (b) sour gas (H$_2$S) are the two major hazards. Occurrence of H$_2$S along with oil and gas, if detected in any new well, is the major hazard during exploratory production testing of the well. Control measures for occurrence of blowout and H$_2$S gas are discussed in following sub-sections:

6.1.3.1 Blowout

The precautionary and control measures used for blowout prevention are discussed below:

A. Precaution Against Blowout

1. The following control equipments for drilling mud system shall be installed and kept in use during drilling operations to prevent the blowout:
   - A pit level indicator registering increase or reduction in the drilling mud volume and shall include a visual and audio –warning device near the driller’s console.
   - A device to accurately measure the volume of mud required to keep the well filled at all times.
   - A gas detector or explosimeter at the primary shale shaker and connected to audible or visual alarm near the driller stand.
   - A device to ensure filling of well with mud when the string is being pulled out.
A control device near driller stand to close the mud pump when well kicks.

2. Blowout prevention drill shall be carried out once every week during drilling.

3. Suitable control valves shall be kept available near the well which can be used in case of emergency to control the well.

4. When running in or pulling out tubing, gate valve and tubing hanger shall be pre-assembled and kept readily available at the well.

B. Precaution after Blowout

On appearance of any sign indicating the blowout of well, all persons, other than those whose presence is deemed necessary for controlling blowout, shall be withdrawn from the well.

During the whole time while any work of controlling a blowout is in progress, the following precautions shall be taken:

1. A competent person shall be present on the spot throughout.

2. An area within the 500 meters of the well on the down wind direction shall be demarcated as danger zone.
   - All electrical installations shall be de-energized.
   - Approved safety lamps or torches shall only be used within the danger zone.
   - No naked light or vehicular traffic shall be permitted within the danger zone.

3. A competent person shall ascertain the condition of ventilation and presence of gases with an approved instrument as far as safety of persons is concerned.

4. There shall be available at or near the place, two approved type of self containing breathing apparatus or any other breathing apparatus of approved type for use in an emergency.

5. Adequate fire fighting equipment shall be kept readily available for immediate use.

C. Blowout Preventor Assembly

To prevent the blow out during drilling operations following steps are taken:

1. After the surface casing is set in a well no drilling shall be carried out unless blowout preventor assembly is securely installed and maintained.

2. Blowout preventor assembly shall consist of:
   - On bag type of preventor for closing regardless whether drilling equipment is in the hole or not.
   - One blind ram preventor closing against an open hole.
   - One pipe ram preventor closing against drill pipe in use in the hole.

3. In blow out preventor assembly, there shall be provided two seamless steel pipes at least 50 mm of diameter connected below each set of blow out preventor one for bleeding off pressure and the other for killing the well. These pipes shall be straight and lead directly in the well.

4. Each pipeline shall consist of component having a working pressure equal to that of the blowout preventor.
D. **Blowout Preventor (BOP) Control Units: Location and Conditions**

1. BOP control units should be located at a distance of nearly 30 m from well center.
2. Status of following should be checked and maintained in good condition:
   - Pressure Gauges;
   - Pressure steel lines/fire resistant hoses;
   - Level of hydraulic oil;
   - Charging of unit; and
   - Availability of sufficient number of charged bottles.

E. **Control System for Blowout Preventors**

1. All manual control for manually operated blowout preventor shall be located at least 0.60 meters outside the derrick substructures. Instructions for operating the controls shall be posted prominently near the control wheel.
2. A control of power operated blowout preventor shall be located within easy reach of driller floor:
3. A remote control panel for blowout preventors shall also be installed around floor level at a safe distance from the derrick floor.
4. All control for blowout preventors shall be clearly identified with suitable markers.

6.1.3.2 **Control Measures for H₂S during Drilling**

The following control measures for H₂S will become necessary if presence of H₂S is detected at an exploratory well.

A. **H₂S Detection System Presence**

A four channels H₂S gas detection system should be provided. Sensors should be positioned at optimum points for detection, actual locations being decided on site but are likely to be:

- Well Nipple
- Rig Floor
- Shaker header tank
- Substructure cellar

The detection system should be connected to an audio visual (siren and lights) alarm system. This system should be set to be activated at a concentration of 15 ppm H₂S.

The mud logging unit will have a completely independent detection system which is connected to an alarm in the cabin. This system will be adjusted to sound an alarm at a concentration level of 10 ppm H₂S as suggested in the Drilling and Production Safety Code for Onshore Operators issued by The Institute of Petroleum.

A stock of H₂S scavenger will be kept ready at drilling site for emergency use.
B. **Small Levels of H$_2$S**

Small levels of H$_2$S (less than 10 ppm) will not activate the well site alarms. Such levels do not create an immediate safety hazard but could be a first indication of high levels of H$_2$S to follow.

H$_2$S will cause a sudden drop of mud pH. The mud man will, therefore, organize and supervise continuous pH checks while drilling. Checks should be as frequent as required depending on ROP and always made following a formation change.

Following control measures will be taken in case of small level of detection:

- Add H$_2$S scavenger to mud.
- Check H$_2$S levels at regular intervals for possible increase.
- Inform all personnel of the rig about the presence of H$_2$S and current wind direction.
- Commence operations in pairs.
- Render sub base and cellar out-of-bounds without further checking levels in this area.

C. **High Levels of H$_2$S**

Higher levels of H$_2$S (greater than 10 ppm) do not necessarily cause an immediate safety hazard. However some risk does exist and, therefore, any levels greater than 10 ppm should be treated in the same manner. Occurrence of 10 ppm or greater H$_2$S concentration will sound an alarm in the mud logging unit.

If higher levels of H$_2$S greater than 10 ppm are found, following steps will be taken:

- One pre-assigned roughneck will go to doghouse and put on breathing apparatus. All other rig personnel will evacuate the rig and move in up-wind direction to designated muster point.

- Driller and roughneck will return to the rig floor and commence circulating H$_2$S scavenger slowly.

- The level of H$_2$S will be checked in all work areas. H$_2$S scavenger will be added to the mud and circulated. If H$_2$S levels drop, drilling will be continued with scavenger in the mud. Approximately 30% of hydrogen peroxide (H$_2$O$_2$) solution will neutralize H$_2$S gas in the mud at 20 gallons of H$_2$O$_2$ per 100 barrels of mud.

6.1.3.3 **Control Measures for H$_2$S during Production Testing**

As pointed out in Section 3.5.6 in Chapter 3, H$_2$S scavenging chemicals (caustic soda solution, calcium hydroxide or iron oxide slurry) are to be continuously injected in the recovered gas/oil/formation water after pressure reduction through choke before sending the same to separator, if H$_2$S is detected during drilling of any new exploratory well.
6.1.4 FIRE FIGHTING FACILITY

As per Oil Industry Safety Directorate (OISD) Standard, August 2000, for the drilling rigs and well testing following fire fighting system/equipments should be provided:

- Fire water system; and
- First aid fire fighting system.

6.1.4.1 Fire Water System

- One water tank/pit of minimum capacity of 50 kl should be located at the approach of the drilling site.
- For production testing, one additional tank/pit of 50 kl should be provided.
- One diesel engine driven trailer fire pump of capacity 1800 lpm should be placed at the approach area of drilling site.
- One fire water distribution single line with minimum 4” size pipe/casing should be installed at drilling site with a minimum distance of 15 m from the well.

6.1.4.2 First Aid Fire Fighting Equipments at Drilling Rig

Portable fire extinguisher will be installed as per IS: 2190 on the drilling rig. The minimum quantities of fire extinguishers at various locations should be provided as per the following:

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Type of Area</th>
<th>Portable Fire Extinguisher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Derrick floor</td>
<td>2 nos. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td>2.</td>
<td>Main Engine Area</td>
<td>1 no. 10 kg DCP type extinguisher for each engine</td>
</tr>
<tr>
<td>3.</td>
<td>Electrical motor/pumps for water circulation for mud pump</td>
<td>1 no. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td>4.</td>
<td>Mud gunning pump</td>
<td>1 no. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td>5.</td>
<td>Electrical Control Room</td>
<td>1 no. 6.8 kg CO₂ type extinguisher for each unit</td>
</tr>
<tr>
<td>6.</td>
<td>Mud mixing tank area</td>
<td>1 no. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td>7.</td>
<td>Diesel storage area</td>
<td>1 no. 50 lit mechanical foam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 no. 50 kg DCP type extinguisher</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 nos. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 nos. sand bucket or ½ sand drum with spade</td>
</tr>
<tr>
<td>8.</td>
<td>Lube Storage Area</td>
<td>1 no. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 no. sand bucket</td>
</tr>
<tr>
<td>9.</td>
<td>Air Compressor area</td>
<td>1 no. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td>10.</td>
<td>Fire pump area</td>
<td>1 no. 10 kg DCP type extinguisher</td>
</tr>
<tr>
<td>11.</td>
<td>Near Dill In-charge Office</td>
<td>One fire extinguisher/shed with 3 nos. 10 kg DCP type extinguisher and 2 sand buckets</td>
</tr>
<tr>
<td>12.</td>
<td>Fire bell near bunk house</td>
<td>1 no. 10 kg DCP type extinguisher</td>
</tr>
</tbody>
</table>
6.2 FIRE FIGHTING EQUIPMENTS FOR PRODUCTION TESTING FACILITIES

During production testing for an exploratory well, pressure control Christmas tree at well head to test the well at a controlled rate is placed. A flare pit is to be kept ready at a suitable place away from the exploration well at a safe distance as per safety requirement for ground flaring of associated gas especially in case of gas strike.

A temporary closed grid hydrant system with monitors, hydrant points and fire hose boxes should be installed to cover the exploratory well as per the need. Portable fire extinguishers of DCP, mechanical foam and CO\textsubscript{2} types of sufficient capacity and in sufficient numbers along with sand buckets should be placed at strategic locations at the exploratory drilling location.

Electrical and manual siren systems should be provided close to the exploratory production testing facility at the exploratory well. Electrically operated siren of 2000 to 3000 m range along with push buttons at appropriate location to operate the same should be installed and a manual siren of 1000 m range should also be available at the exploratory well site for emergency use.

Adequate personal protective equipments including sufficient number of breathing apparatus are to be kept ready in proper working condition.

It may be noted that the fire station may not be available anywhere near the exploratory well site in the block area except at major towns, namely, Sibsagar and Amguri. But these fire stations may require at least ½ to 1 hour to reach exploratory drilling well location to provide meaningful assistance. It is, therefore, necessary that adequate fire fighting facilities are kept in operating condition at the exploratory well site to take care of any emergency. Assistance for fire fighting can also be taken, if required, from following fire stations located within 100 km distance from Amguri block AA-ONN-2004/1:

1. Moran Fire Station of OIL: 03754-224063  
2. Duliajan Fire Station of OIL: 0374-2801795  
3. Sibsagar Fire Station of ONGC: 95357-17081

For further assistance in an emergency, General Manager (NEF Project) at Duliajan can also be contacted on telephone No. 0374-2800405.

6.3 MEDICAL FACILITIES

Eventhough negligible accident occurs during drilling and production testing at the well site since observation of necessary safety requirements has to be strictly followed. However, first aid should be made available at the drilling site and a 24 hour standby vehicle (ambulance) should also be available at the well site for quick transfer of any injured personnel to the nearest hospital, in case an accident occurs and medical emergency arises.
6.4 QUANTATIVE RISK ASSESSMENT

Quantitative risk assessment (QRA) is a formal systemized approach for hazards identification and ranking. The final rating number provides a relative ranking of the hazards. Fire and Explosion Index (F&EI) is an important technique employed for hazards identification process. Consequence analysis then quantifies the vulnerable zone for a conceived incident. Once vulnerable zone is identified for an incident, measures can be formulated to eliminate or reduce damage to plant and potential injury to personnel.

6.4.1 FIRE AND EXPLOSION INDEX & TOXICITY INDEX

Rapid ranking of hazard of an entire installation, if it is small, or a portion of it, if it is large, is often done to obtain a quick assessment of degree of the risk involved. The Dow Fire and Explosion Index (F&EI) and Toxicity Index (TI) are the most popular methods for Rapid Hazard Ranking. These are based on a formal systematized approach, mostly independent of judgemental factors, for determining the relative magnitude of the hazards in an installation using hazardous (flammable, explosive and toxic) materials.

The steps involved in the determination of the F&EI and TI are:

- Selection of a pertinent process unit
- Determination of the Material Factor (MF)
- Determination of the Toxicity Factor (Th)
- Determination of the Supplement to Maximum Allowable Concentration (Ts)
- Determination of the General Process Hazard Factor (GPH)
- Determination of the Special Process Hazard Factor (SPH)
- Determination of the F&EI value
- Determination of the TI value
- Determination of the Exposure Area

6.4.1.1 Hazardous Material Identification Methodology

From the preliminary appraisal of Material Safety Data Sheet, it is observed that both crude oil and natural gas are inflammable and hazardous. Furthermore, three phase separator (TPS) containing gas, oil and water may operate at above atmospheric temperature and large quantity (20 kl) of HSD will be stored at the drilling site. In view of hazards associated with TPS operation and large storage inventory (20 kl) of HSD, F&EI and TI values have been computed for these two units, TPS and HSD storage tanks.

In general, the higher is the value of material factor (MF), the more inflammable and explosive is the material. Similarly, higher values of toxicity factor (Th) and supplement to maximum allowable concentration (Ts) indicate higher toxicity of the material. The tabulated values of MF, Th and Ts are given in Dows Fire and Explosion Index Hazard Classification Guide. For compounds not listed in Dow reference, MF can be computed from the knowledge of flammability and reactivity classification, Th can be computed
from the knowledge of the National Fire Protection Association (NFPA) Index and Ts can be obtained from the knowledge of maximum allowable concentration (MAC) values. The MF, Th and Ts values are respectively 16, 0 and 50 for crude oil, 21, 0 and 50 for natural gas, and 10, 0 and 50 for HSD.

General process hazards (GPH) are computed by adding the penalties applied for the various process factor.

Special process hazards (SPH) are computed by adding the penalties applied for the process and natural factors.

Both General process hazards and Special process hazards corresponding to various process and natural factors are used with MF to compute F&EI value and with Th and Ts to compute TI value.

6.4.1.2 F&EI Computation

F&EI value computed for TPS and CTT from GPH and SPH values using the following formula are given in Table 6.1:

\[
F&EI = MF \times [1 + GPH \text{ (total)}] \times [1 + SPH \text{ (total)}]
\]

6.4.1.3 Toxicity Index (TI)

Toxicity index (TI) is computed from toxicity factor (Th) and supplement to maximum allowable concentrations (Ts) using the following relationship:

\[
TI = (Th + Ts) \times [1 + GPH \text{ (total)} + SPH \text{ (total)}]/100
\]

Table 6.2 also gives the toxicity index (TI) value for two units considered most hazardous at drilling site operational area.

6.4.1.4 HAZARDS RANKING

Table 6.3 gives the hazard ranking based on F&EI values and also on toxicity index values. Table 6.2 shows that for the two process units analyzed, the largest F&EI (48.51) and TI value (1.48) are obtained respectively for TPS in exploratory production testing area and HSD tank (20 kl) in fuel storage area. Therefore, both areas have Light Hazard Potential based on F&EI and Low Hazard Potential based on TI values.

In the present case since hazard potential is light/low, there is no cause for any concern.

6.4.2 CONSEQUENCE ANALYSIS

Consequence analysis quantifies vulnerable zone for a conceived incident and once the vulnerable zone is identified for an incident, measures can be proposed to eliminate damage to plant and potential injury to personnel. For consequence analysis both units chosen for hazards analysis are considered. The following likely scenarios considered for hazard analysis

1. Rupture of one of the nozzle of HSD storage tank in fuel storage area.
2. Bursting / catastrophic rupture of a three phase separator (TPS) at exploratory production testing area.
indicates that these incidents have light/low hazards potential and also have \(<10^6\) per tank per year frequency of occurrence which will be reduced further by OIL by ensuring safe design and operating procedures. Therefore, detailed calculations for vulnerable zone analysis are not considered necessary. It may, however, be noted that the vulnerable zones for these accident scenarios are unlikely to extend beyond 40 m from HSD tank dyke or BLEVE fire ball boundary and, therefore, may not extend much beyond the drilling area plinth boundary for each of the exploratory well proposed for drilling and testing in next 2 years. Furthermore, well testing is planned for a maximum of 5 to 10 days at each locations, therefore, chances of TPS rupture is further reduced.

6.4.2.1 Conclusions

Quantitative risk analysis presented above leads to following conclusions:

- Storage of HSD in 20 kl HSD storage tank area has a computed F&EI value of 37.60 and TI value of 1.48 and, therefore, indicates light fire and explosion hazard as well as low toxicity hazard.
- Operation in three phase separator in testing area has a computed F&EI value of 48.51 and TI value of 1.10 and, therefore, indicates light fire and explosion hazard as well as low toxicity hazard.

6.4.2.2 Recommendations for Risk Reduction

- Hydrocarbon vapour concentration detector should be installed at some critical locations near three phase separator. Lower flammability limits (LFL) and upper flammability limits (UFL) for some gaseous hydrocarbons are as under:

<table>
<thead>
<tr>
<th>Compound</th>
<th>LFL (% in air)</th>
<th>UFL (% in air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>5.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Ethane</td>
<td>3.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Propane</td>
<td>2.1</td>
<td>9.5</td>
</tr>
<tr>
<td>Butane</td>
<td>1.6</td>
<td>8.4</td>
</tr>
</tbody>
</table>

- Smoke sensors and thermal detectors may be installed at HSD storage tank area.
- Proper fire fighting system (hydrant and fire extinguishers) must be provided for drilling rig, exploratory testing and fuel storage area.
- Proper deluge system should be provided to all critical units, such as, three phase separator, HSD storage tank and crude oil storage test tank to avoid cascading effect of fire.
Table 6.1

Characteristics of H$_2$S Gas

1. H$_2$S is a toxic colourless gas heavier than air.
2. It has an odour of rotten eggs but see ‘point 6’ below.
3. In concentrations greater than 100 ppm, it will cause loss of senses in 3 to 15 minutes and death within 48 hours.
4. In concentrations greater than 600 ppm death occurs in less than 2 minutes.
5. The safe concentration for a normal working period without protection is 10 ppm.
6. In concentration greater than 10 ppm, the oil factory sense to smell the gas is lost, the need for detectors is apparent.
7. It attacks the body through the respiratory organs.
8. It dissolves in the blood and attacks through the nervous system.
9. It is very irritating for the eyes as it forms sulphurous acid together with water.
10. The Occupational Safety and Health Act (OSHA) sets a 10 ppm ceiling for an 8 (eight) hour continuous exposure (TWA limit), a limit of 15 ppm for short term exposure limit for 15 minutes (STEL) and a peak exposure concentration of 50 ppm for 10 minutes.
11. The best protection is breathing apparatus, with mask covering the whole face and a bottle containing breathing air.
12. It burns with a blue flame to sulphur dioxide which is almost as dangerous as H$_2$S.
13. It forms an explosive mixture with air at concentrations from 4% to 46%.
14. Short exposure of high tensile steel to as little as 1 ppm in aqueous solution can cause failures.
15. Concentrations greater than 15 ppm can cause failure to steel harder than Rockwell C-22. High stress levels and corrosive environments accelerate failures.
16. When pH is above 9 and solubility is relatively high, it is readily soluble in mud and especially in oil muds.
17. The compressibility factor (Z) is higher than that for natural gas and H$_2$S will thus expand at rather lower pressures; or further up in the bore hole than natural gas.
18. A 35% hydrogen peroxide solution will neutralize H$_2$S gas in the mud or 20 gallons of H$_2$O$_2$ per 100 barrels of mud.
19. It occurs together with natural gas in all oil provinces of the world.
20. In characteristic H$_2$S gas areas concentration above 42% in natural gas have been reported.
21. H$_2$S may also be formed in significant amounts from the degradation of modified lignosulphonates at temperatures exceeding 400°F or 204°C.
22. Coughing, eye burning and pain, throat irritation, and sleepiness are observed from exposure to low concentrations of H$_2$S.
23. Exposure to high concentrations of H$_2$S produces systems such as panting, pallor, cramps, paralysis of the pupil and loss of speech. This is generally followed by immediate loss of consciousness. Death may occur quickly from respiratory and cardiac paralysis.
Table 6.2
Determination of the Fire and Explosion Index and of the Toxicity Index

<table>
<thead>
<tr>
<th>MATERIAL FACTOR (MF)</th>
<th>Crude Oil/Natural Gas in Three Phase Separator</th>
<th>HSD Storage Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16/21</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GENERAL PROCESS HAZARDS (GPH)</th>
<th>Penalty Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exothermic Reactions</td>
<td>0</td>
</tr>
<tr>
<td>Endothermic Reactions</td>
<td>0</td>
</tr>
<tr>
<td>Material Handling and Transfer</td>
<td>0</td>
</tr>
<tr>
<td>Process Units within a Building</td>
<td>0</td>
</tr>
<tr>
<td>Centrifuging</td>
<td>0</td>
</tr>
<tr>
<td>Limited Access</td>
<td>0</td>
</tr>
<tr>
<td>Poor Drainage</td>
<td>0.10</td>
</tr>
<tr>
<td>Add: GPH(total)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

\[
\text{sub-factor} = (1 + \text{GPH(total)}) \times \text{Material Factor}
\]

\[
\text{sub-factor} = 23.1 \times 16.0 = 371.6
\]

<table>
<thead>
<tr>
<th>SPECIAL PROCESS HAZARDS (SPH)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Temperature</td>
<td></td>
</tr>
<tr>
<td>- above flash point</td>
<td>0.25</td>
</tr>
<tr>
<td>- above boiling point</td>
<td>0</td>
</tr>
<tr>
<td>- above auto ignition</td>
<td>0</td>
</tr>
<tr>
<td>Low Pressure</td>
<td></td>
</tr>
<tr>
<td>- Hazard of Peroxide Formation</td>
<td>0</td>
</tr>
<tr>
<td>- Hydrogen Collection Systems</td>
<td>0</td>
</tr>
<tr>
<td>- Vacuum Distillation at less than 0.67 bar abs.</td>
<td>0</td>
</tr>
<tr>
<td>Operation in or near Flammable Range</td>
<td></td>
</tr>
<tr>
<td>- Storage of Flammable Liquids and LPGs outdoor</td>
<td>0</td>
</tr>
<tr>
<td>- Reliance on Instrumentation and/or Air Purging to stay out Flammable Range</td>
<td>0</td>
</tr>
<tr>
<td>- Always in Flammable Range</td>
<td>0</td>
</tr>
<tr>
<td>Operating Pressure</td>
<td>0</td>
</tr>
<tr>
<td>Low Temperature</td>
<td>0</td>
</tr>
<tr>
<td>- Between 0 and –30 deg. C</td>
<td>0</td>
</tr>
<tr>
<td>- Below –30 deg. C</td>
<td>0</td>
</tr>
<tr>
<td>Quantity of Flammable Material</td>
<td></td>
</tr>
<tr>
<td>- In Process</td>
<td>0.65</td>
</tr>
<tr>
<td>- Storage</td>
<td>0</td>
</tr>
<tr>
<td>Corrosion and Erosion</td>
<td>0.10</td>
</tr>
<tr>
<td>Leakage joints and packing</td>
<td>0.10</td>
</tr>
<tr>
<td>Add: SPH</td>
<td>1.1</td>
</tr>
</tbody>
</table>

\[
\text{sub-factor} = (1 + \text{SPH(total)}) \times \text{sub-factor}
\]

\[
\text{sub-factor} = 1.1 \times 371.6 = 408.76
\]

<table>
<thead>
<tr>
<th>TOXICITY INDEX TI</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxicity Factor (Th)</td>
<td>0</td>
</tr>
<tr>
<td>(Ts)</td>
<td>0.50</td>
</tr>
<tr>
<td>Toxicity Index TI</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Toxicity Index TI} = \frac{(Ts + Th)}{100} \times [(1 + \text{GPH(total)}) + \text{SPH(total)}]
\]

\[
\text{Toxicity Index TI} = \frac{1.10}{1.48} = 0.74
\]

Note: 1. The term “process” includes handling as well as storage. 2. For a number of process hazard the penalty to be used is fixed and can be taken from the preceding column “penalty”.

Envirotech Consultants Pvt. Ltd.
### Table 6.3

**Hazard Ranking**

**I. Based on Dow Fire and Explosion Index (F & EI)**

<table>
<thead>
<tr>
<th>F &amp; EI Value</th>
<th>Hazard Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-60</td>
<td>Light</td>
</tr>
<tr>
<td>61-96</td>
<td>Moderate</td>
</tr>
<tr>
<td>97-127</td>
<td>Intermediate</td>
</tr>
<tr>
<td>128-158</td>
<td>Heavy</td>
</tr>
<tr>
<td>159-up</td>
<td>Severe</td>
</tr>
</tbody>
</table>

**II. Based on Toxicity Index (TI)**

<table>
<thead>
<tr>
<th>TI Value</th>
<th>Hazard Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6</td>
<td>Low</td>
</tr>
<tr>
<td>6 – 10</td>
<td>Moderate</td>
</tr>
<tr>
<td>10 – up</td>
<td>High</td>
</tr>
</tbody>
</table>

### Table 6.4

**Tolerable Radiation Intensities for Various Objects**

<table>
<thead>
<tr>
<th>Object</th>
<th>Tolerable Radiation Intensity (kW/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drenched Tank</td>
<td>38</td>
</tr>
<tr>
<td>Special Buildings (No windows, fire proof doors)</td>
<td>25</td>
</tr>
<tr>
<td>Normal Buildings</td>
<td>14</td>
</tr>
<tr>
<td>Vegetation</td>
<td>10-12</td>
</tr>
<tr>
<td>Escape Route</td>
<td>6 (upto 30 seconds)</td>
</tr>
<tr>
<td>Personnel in Emergencies</td>
<td>6 (upto 30 seconds)</td>
</tr>
<tr>
<td>Plastic Cables</td>
<td>2</td>
</tr>
<tr>
<td>Stationary Personnel</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Table 6.5

Damage Due to Incident Radiation Intensity

<table>
<thead>
<tr>
<th>Incident Radiation Intensity (kW/m²)</th>
<th>Type of Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>Spontaneous ignition of wood</td>
</tr>
<tr>
<td>38</td>
<td>Sufficient to cause damage to process equipment</td>
</tr>
<tr>
<td>25</td>
<td>Minimum energy required to ignite wood at infinitely long exposure (non piloted)</td>
</tr>
<tr>
<td>12.5</td>
<td>Minimum energy required for piloted ignition of wood, melting of plastic tubing, etc.</td>
</tr>
<tr>
<td>4.5</td>
<td>Sufficient to cause pain to personnel unable to reach cover within 20 seconds, blistering of skin (1st degree burns) is likely.</td>
</tr>
<tr>
<td>1.5</td>
<td>Will cause no discomfort for exposure upto 60 seconds.</td>
</tr>
</tbody>
</table>