Risk Assessment for Talcher Thermal Power Project Stage-III (2x660 MW)

An industrial disaster arises when a major accident occurring in the factory becomes uncontrollable and its consequences go out of the factory boundaries. Hazards are inherent to all industrial operations since they involve handling of hazardous materials (flammable, explosive, corrosive and toxic materials).

Risk assessment is a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.

Risks are inherent in proposed thermal power plant operations since they involve working with

- High pressure super-heaters, re-heaters, economizer units exchanging heat with the hot flue gases
- Turbines that utilize the HP steam to generate power
- Fuel oil handling units
- Coal handling units
- Hydrogen as a coolant in turbo generators drawn from hydrogen cylinders
- Chlorine as water treatment chemical drawn from cylinders.
- Switchyard including transformers, isolators

Nevertheless, a properly designed and operated plant will have a very low probability (to a level of acceptable risk) of accident occurrence. Subsequently, a properly designed and executed management plan can further reduce the probability of any accident turning into an on-site emergency and/or an off-site emergency.

The four major steps in risk assessment are hazard identification, dose response assessment, exposure assessment, and risk characterization.

Hazard identification is a process that determines the potential human health effects that could result from exposure to a hazard. This process requires a review of the scientific literature. The literature could include information published by the Environmental Protection Agency (EPA), federal or state agencies, and health organizations. Identification of causes and types of hazards is the primary task for planning for risk assessment.

Identification of Hazardous Chemicals is done in accordance with the Manufacture, Storage and Import of Hazardous Chemical Rules, 1989. Schedule 1, of the Rule provides a list of the Toxic and Hazardous chemicals and the flammable chemicals. It defines the flammable chemicals based on the flash point and boiling point.

Dose-response or toxicity assessment is the determination of how different levels of exposure to a hazard or pollutant affect the likelihood or severity of health effects. Responses/effects can vary widely since all chemicals and contaminants vary in their capacity to cause adverse effects. The dose-response relationship can be evaluated for either carcinogenic or non carcinogenic substances.

Exposure assessment is the determination of the magnitude of exposure, frequency of exposure, duration of exposure, and routes of exposure by contaminants to human populations and ecosystems. There are three components to this step.

- Identification of contaminants being released.
- Estimation of the amounts of contaminants released from all sources or the source of concern.
- Estimation of the concentration of contaminants.

Risk characterization is the final step in which toxicology and exposure data/information is combined to obtain a qualitative or quantitative expression of risk.

1.1 Scope of the Study

The risk analysis/ assessment study covers the following:

- Site assessment
- Identification of potential hazard areas;
- Identification of representative failure cases;
- Visualisation of the mode of chemical releases and the resulting accident scenarios
- Assess the overall damage potential of the identified hazardous events and impact zones from the accident scenarios;
- Furnish specific recommendations on the minimisation of the worst accident possibilities;
- Preparation of Disaster Management Plan (DMP), On-site and Off-site Emergency Plan; and
- Preparation of the Occupational and Health safety plan

1.2 Brief Description

1.2.1 Hazard Identification

Identification of hazards is of primary significance in the analysis, quantification and cost effective control of accidents involving chemicals and processes. A classical definition of hazard states that it is the characteristic of system/process that presents potential for an accident. Hence, all the components of a system/process need to be thoroughly examined to assess their potential for initiating or propagating an unplanned event/sequence of events, which can be termed as an accident.

Estimation of probability of an unexpected event and its consequences form the basis of quantification of risk in terms of damage to property, environment or personnel. Therefore, the type, quantity, location and conditions of release of a toxic or flammable substance have to be identified in order to estimate its damaging effects, the area involved, and the possible precautionary measures required to be taken. Based on the areas and unit operations involved in generation of power various hazards are identified which are given in **Table 1.**

Table 1. : Potential Risk Areas Due to Proposed Thermal Power Plant

	Blocks/Areas	**Hazards Identified**
1.	Coal storage in open yard	Fire, Spontaneous Combustion
2.	Coal Handling Plant including Bunker area	Fire and/or Dust Explosions
3.	Boilers	Fire (mainly near oil burners), steam; Explosions, Fuel Explosions
4.	Turbo-Generator Buildings	Fires in - a) Lube Oil systems b) Cable galleries c) Short circuits in i) Control Rooms ii) Switchgears Explosion due to leakage of Hydrogen and fire following it. Fire in Oil Drum Storage
5.	Power Transformers	Explosion and fire.
6.	Switch-yard Control Room	Fire in cable galleries and Switchgear/Control Room.
7. a b c	Hydrogen Plant Hydrogen and oxygen holders in Open Hydrogen Cylinders in R.C.C. building Oxygen cylinders in R.C.C. building	Explosion and/or fire, Physical dangers
8. a	Tank Farms LDO	Fire
9. a b	Water Treatment of Chlorination plants Pre-treatment plants Hydrochloric Acid (HCl) Sodium Hydroxide (NaOH)	Release of Chlorine - Toxicity Corrosive
10.	Steam turbine	Hydrogen and lube oil leak leading to fire/smoke
11.	FGD	FGD effluent –Corrosive

1.2.2 Classification of Major Hazardous Units

Hazardous substances may be classified into three main classes namely flammable substances, unstable substances and toxic substances. The ratings for a large number of chemicals based on flammability, reactivity and toxicity have been given in NFPA Codes 49 and 345 M. The major hazardous materials to be stored, transported, handled and utilized within the facility have been summarized in the Table 2. The fuel storage details and properties are given in **Table 3** and **Table 4** respectively.

Table 2. : Hazardous Materials, Stored, Transported and Handled

Materials	**Hazardous Properties**
LDO	UN 1203. Dangerous Goods class 3 – Flammable Liquid

Table 3. : Category Wise Schedule of Storage Tanks

Material	**No. of Tanks**	**Design Capacity (KL)**	**Classification**
LDO	2	2000 (each)	Non-dangerous Petroleum

Table 4. : Properties of Fuels Used In the Plant

Chemical	Codes/Label	TLV	FBP	MP	FP	UEL	LEL
			°c			%	
LDO	Flammable	5 mg/m3	400	-	60-66	7.5	0.6

TLV	:	Threshold Limit Value	FBP	:	Final Boiling Point
MP	:	Melting Point	FP	:	Flash Point
UEL	:	Upper Explosive Limit	LEL	:	Lower Explosive Limit

1.2.3 Identification of Major Hazard Installations Based on GOI Rules, 1989

Following accidents in the chemical industry in India over a few decades, a specific legislation covering major hazard activities has been enforced by Govt. of India in 1989 in conjunction with Environment Protection Act, 1986. This is referred here as GOI Rules 1989. For the purpose of identifying major hazard installations the rules employ certain criteria based on toxic, flammable and explosive properties of chemicals.

A systematic analysis of the fuels/chemicals and their quantities of storage has been carried out, to determine threshold quantities as notified by GOI Rules, 1989 and the applicable rules are identified. Applicability of storage rules are summarized in Table 5.

Table 5. : Applicability of MSIHC Rules, 1989 to Fuel

Sr. No.	Chemical/Fuel	Listed in Schedule	Total Quantity (KL)	Threshold Quantity (T) for Application of Rules	
				5,7-9,13-15	10-12
1	LDO	3(1)	2x2000	25 T	200

1.3 Hazard Assessment and Evaluation

1.3.1 Methodology

An assessment of the conceptual design is conducted for the purpose of identifying and examining hazards related to feed stock materials, major process components, utility and support systems, environmental factors, proposed operations, facilities, and safeguards.

1.3.2 Preliminary Hazard Analysis (PHA)

PHA is based on the philosophy "Prevention Is Better Than Cure". Safety is relative and implies freedom from danger or injury. But there is always some element of danger or risk associated with anything we do or build. This calls for identification of hazards, quantification of risk and further suggests hazard-mitigating measures, if necessary.

The purpose of the preliminary hazard analysis is to identify first the potential hazards associated with design process, or inherent in a process design, thus eliminating costly and time consuming delays caused by design changes made later. This also eliminates potential hazard points at design stage itself. Hence, preliminary hazard analysis is more relevant when a plant is at design/construction stage. This analysis fortifies the proposed process design by incorporating additional safety factors into the design criteria.

An assessment of the conceptual design has to be conducted for the purpose of identifying and examining hazards related to feed stock materials, major process components, utility and support systems, environmental factors, proposed operations, facilities, and safeguards.

In the proposed plant, Hydrochloric acid, Sodium Hydroxide and Chlorine will be stored in tanks and cylinders to meet its requirement. Preliminary hazard analysis for fuel storage area and whole plant is given in **Table 6** and **Table 7.**

Table 6. : Preliminary Hazard Analysis for Storage Areas

Unit	Total Capacity (KL)	Hazard Identified
LDO	4000 (2x2000)	Fire/Explosion

The major hazards associated with the plant, have to be identified, followed by consequence analysis to quantify these hazards. Finally, the vulnerable zones have to plot for which risk reducing measures will be deduced and implemented.

The following scenarios have been considered for the Preliminary Hazard Assessment (PHA):

Spillage of chemicals while handling Leakage of chlorine

Table 7. : Preliminary Hazard Assessment for Power Plant: Environmental Factors

PHA Category	**Description of Plausible Hazard**	**Recommendation**
Environmental factors	Spillage of chemicals while handling (HCl, NaOH)	The spillage should be treated as per MSDS of each chemical. A copy of MSDS should be kept in chemical laboratory and stores
	Spillage of chemicals or baths into trench	The source of the spillage should be immediately identified and plugged. The spilled chemical should be washed with copious water and the washed water should be collected in floor wash tank and should be treated as per waste treatment procedure till it is exhausted
	Chlorine leakage	An automatic chlorine leak absorption system should be provided for chlorination plant to neutralise chlorine leakage. Chlorination plant should be provided with required chlorine containers, instrumentation panels, chlorine leak detectors etc. Use ammonia spray or swab for identifying leakage. (A white cloud indicates Chlorine leakage) For persistent leakage, connect a flexible hose pipe and put the pipe in the tank containing Caustic soda Isolate the area until the gas has dispersed

1.3.3 Fire Explosion and Toxicity Index (FE&TI) Approach

Fire, Explosion and Toxicity Indexing (FE & TI) is a rapid ranking method for identifying the degree of hazard. The application of FE & TI would help to make a quick assessment of the nature and quantification of the hazard in these areas. However, this does not provide precise information.

The degree of hazard potential is identified based on the numerical value of F&EI as per the criteria given below:

Sr. No.	F&EI Range	Degree of Hazard
1	0-60	Light
2	61-96	Moderate
3	97-127	Intermediate
4	128-158	Heavy
5	159 and above	Severe

By comparing the indices F&EI and TI, the unit in question is classified into one of the following three categories established for the purpose (**Table 8).**

Table 8. : Fire Explosion and Toxicity Index

Category	Fire and Explosion Index (F&EI)	Toxicity Index (TI)
I	F&EI < 65	TI < 6
II	65 < or = F&EI < 95	6 < or = TI < 10
III	F&EI > or = 95	TI > or = 10

Certain basic minimum preventive and protective measures are recommended for the three hazard categories.

Results of FE and TI for Storage/Process Units

Based on the GOI Rules 1989, the hazardous fuels used by the proposed power project were identified. Fire and Explosion are the likely hazards, which may occur due to the fuel storage. Hence, Fire and Explosion index has been calculated for in plant storage. Estimates of FE&TI are given in **Table 9**.

Table 9. : Fire Explosion and Toxicity Index

Chemical/ Fuel	Total Capacity (KL)	F&EI	Category	TI	Category
LDO	2 x 2000	0-60	Light	Nil	-

1.3.4 Conclusion

Results of FE&TI analysis show that the storage of LDO fall into Light category of fire and explosion index with a Nil toxicity index.

1.4 Maximum Credible Accident Analysis (MCAA)

Hazardous substances may be released as a result of failures or catastrophes, causing possible damage to the surrounding area. This section deals with the question of how the consequences of the release of such substances and the damage to the surrounding area can be determined by means of models. Major hazards posed by flammable storage can be identified taking recourse to MCA analysis. MCA analysis encompasses certain techniques to identify the hazards and calculate the consequent effects in terms of damage distances of heat radiation, toxic releases, vapour cloud explosion, etc. A host of probable or potential accidents of the major units in the complex arising due to use, storage and handling of the hazardous materials are examined to establish their credibility. Depending upon the effective hazardous attributes and their impact on the event, the maximum effect on the surrounding environment and the respective damage caused can be assessed. The reason and purpose of consequence analysis are many folds like:

- Part of Risk Assessment;
- Plant Layout/Code Requirements;
- Protection of other plants;
- Protection of the public;
- Emergency Planning; and
- Design Criteria.

The results of consequence analysis are useful for getting information about all known and unknown effects that are of importance when some failure scenario occurs in the plant and also to get information as how to deal with the possible catastrophic events. It also gives the workers in the plant and people living in the vicinity of the area, an understanding of their personal situation.

Selected Failure Cases

The purpose of this listing (refer Table 10) is to examine consequences of such failure individually or in combination. It will be seen from the list that a vast range of failure cases have been identified. The frequency of occurrence of failure also varies widely.

1.4.1 Damage Criteria

The fuel storage and unloading at the storage facility may lead to fire and explosion hazards. The damage criteria due to an accidental release of any hydrocarbon arise from fire and explosion. The vapors of these fuels are not toxic and hence no effects of toxicity are expected.

Tank fire would occur if the radiation intensity is high on the peripheral surface of the tank leading to increase in internal tank pressure. Pool fire would occur when fuels collected in the dyke due to leakage gets ignited.

- **Fire Damage**

A flammable liquid in a pool will burn with a large turbulent diffusion flame. This releases heat based on the heat of combustion and the burning rate of the liquid. A part of the heat is radiated while the rest is convected away by rising hot air and combustion products. The radiations can heat the contents of a nearby storage or process unit to above its ignition temperature and thus result in a spread of fire.

The radiations can also cause severe burns or fatalities of workers or fire fighters located within a certain distance. Hence, it will be important to know beforehand the damage potential of a flammable liquid pool likely to be created due to leakage or catastrophic failure of a storage or process vessel. This will help to decide the location of other storage/process vessels, decide the type of protective clothing the workers/fire fighters' need, the duration of time for which they can be in the zone, the fire extinguishing measures needed and the protection methods needed for the nearby storage/process vessels.

Table-1.10 tabulates the damage effect on equipment and people due to thermal radiation intensity.

Table 10. : Damage Due to Incident Radiation Intensities

Incident Radiation (kW/m2)	Type of Damage Intensity	
	Damage to Equipment	Damage to People
37.5	Damage to process equipment	100% lethality in 1 min. 1% lethality in 10 sec.
12.5	Minimum energy to ignite with a flame; melts plastic tubing	1% lethality in 1 min.

Incident Radiation (kW/m2)	Type of Damage Intensity	
	Damage to Equipment	Damage to People
4.5	--	Causes pain if duration is longer than 20 sec, however blistering is un-likely (First degree burns)

Source: Techniques for Assessing Industrial Hazards by World Bank.

The effect of incident radiation intensity and exposure time on lethality is given in **Table-11**.

Table 11. : Radiation Exposure and Lethality

Radiation Intensity (kW/m2)	Exposure Time (seconds)	Lethality (%)	Degree of Burns
1.6	--	0	No Discomfort even after long exposure
4.5	20	0	1 st
4.5	50	0	1 st
8.0	20	0	1 st
8.0	50	<1	3 rd
8.0	60	<1	3 rd
12.0	20	<1	2 nd
12.0	50	8	3 rd
12.5	Inst	10	--
25.0	Inst	50	--
37.5	Inst	100	--

1.4.2 Scenarios Considered for MCA Analysis

Fuel Storage

The details of storages in the proposed power plant are given in Table- 2 above. In case of fuel released in the area catching fire, a steady state fire will occur. Failures in pipeline may occur due to corrosion and mechanical defect. Failure of pipeline due to external interference is not considered as this area is licensed area and all the work within this area is closely supervised with trained personnel.

Modelling Scenarios

Based on the storage and consumption of various fuels the following failure scenarios for the proposed power plant have been identified for MCA analysis and the scenarios are discussed in **Table- 12**. The fuel properties considered in modelling are given in **Table-13**.

Table 12. : Scenarios Considered for MCA Analysis

Sr. No.	Fuel/Chemical	Total Quantity	Scenarios considered	Diameter(m)	Height (m)
1	Failure of LDO tank	2 x 2000 KL	Pool fire	18	10

Table 13. : Properties of Fuels Considered for Modeling

Parameters	Values
Name of Auxiliary Fuel	LDO (AS PER IS 15770-2008)
Pour Point (max)	21 °C & 12°C for Summer and Winter respectively
Kinematic viscosity in centistokes at 40 deg.C	2.5 to 15.0
Sediment percent by mass (max)	0.10
Total sulphur percent by mass (max)	1.5
Ash percentage by mass (max)	0.02
Carbon residue (Rams bottom) percent by pass (max.)	1.50
Acidity inorganic	Nil
Flash point (Min.) - Pensky Martens	66 deg.C

1.4.3 Pool Fire Models used for MCA Analysis

Storage tank at the plant area store LDO. The gas/liquid released in the vicinity of the storage area may be as a result of rupture in tank, mechanical defect and external interference. Radiation Pool fire model has been used to estimate radiation intensity distances for Fuel Oil.

The consequence analysis of maximum credible scenarios done by Pool Fire Radiation software.

1.4.4 Results and Discussion

The results of MCA analysis are tabulated indicating the distances for various damages identified by the damage criteria, as explained earlier. Calculations are done for radiation intensities levels of 37.5, 12.5 & 4.5 kW/m², which are presented in **Table-14** for different scenarios. The distances computed for various scenarios are from the center of the pool fire.

Table 14 : Occurrence of Various Radiation Intensities- Pool Fire

Radiation and Effect	Radiation Intensities (kW/m2)/Distances (m)		
	37.5	12.5	4.5
Failure of LDO tank	35.5	69.3	90.3

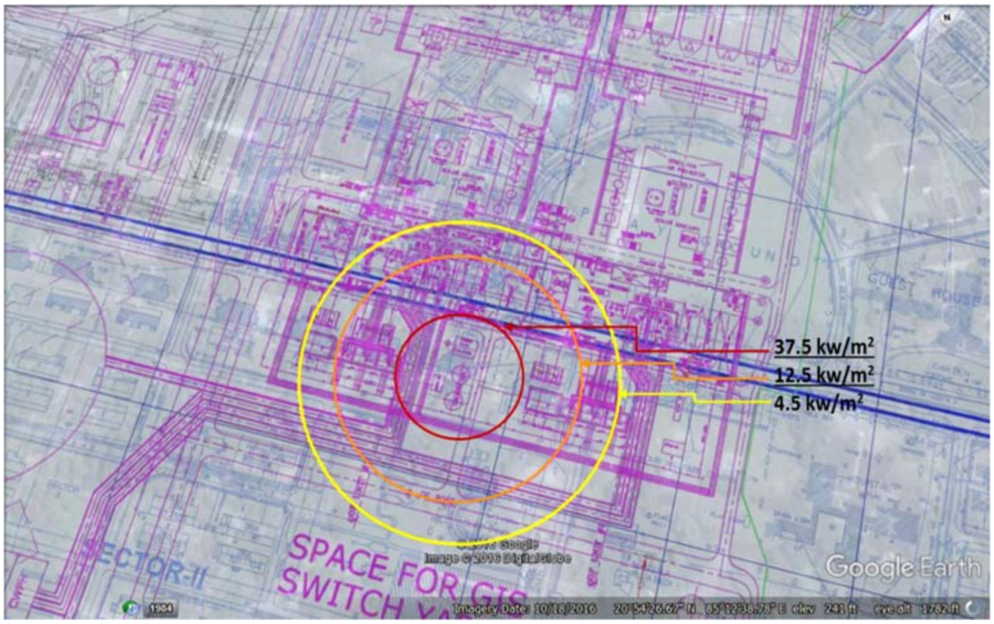

Figure 1. : Risk Contour overlay on Plant Layout

1.4.5 Conclusions on MCA Analysis

LDO Tank Farm

There will be LDO storage tank of 2 x 2000 KL capacity will be provided in the LDO tank farm. The results of MCA analysis indicate that the maximum damage distances for 37.5 Kw/m² thermal radiations extends upto 35.5 m in the case of full tank of 2000 KL on fire during worst meteorological conditions. As the fire resistant dyke walls will be created, no cumulative effect of one tank form on fire to create fire on other tank farm is envisaged.

Pool Fire Due to Failure of LDO Storage Tank

The maximum capacity of storage of LDO in a storage tank will be 2X2000 KL. The most credible failure is the rupture of the largest pipe connecting to the storage tank. As the worst case, it is assumed that the entire contents leak out into the dyke forming a pool, which may catch fire on finding a source of ignition. The radiation intensities have been computed using software based pool fire model and the results are tabulated in **Table 14**.

A perusal of the above table clearly indicates that 37.5 kW/m² (100% lethality) occurs within the radius of the pool which is computed at 35.5 m tank on pool fire. This vulnerable zone will damage all fuel storage equipment falling within the pool radius.

1.5 Coal Handling Plant - Dust Explosion

Coal dust when dispersed in air and ignited would explode. Crusher house and conveyor systems are most susceptible to this hazard. To be explosive, the dust mixture should have:

- Particles dispersed in the air with minimum size (typical figure is 400 microns);
- Dust concentrations must be reasonably uniform; and
- Minimum explosive concentration for coal dust (33% volatiles) is 50 gm/m³.

Failure of dust extraction and suppression systems may lead to abnormal conditions and may increase the concentration of coal dust to the explosive limits. Sources of ignition present are incandescent bulbs with the glasses of bulkhead fittings missing, electric equipment and cables, friction, spontaneous combustion in accumulated dust. Dust explosions may occur without any warnings with Maximum Explosion Pressure upto 6.4 bar. Another dangerous characteristic of dust explosions is that it sets off secondary explosions after the occurrence of the initial dust explosion. Many a times the secondary explosions are more damaging than primary ones. The dust explosions are powerful enough to destroy structures, kill or injure people and set dangerous fires likely to damage a large portion of the Coal Handling Plant including collapse of its steel structure which may cripple the life line of the power plant.

Stockpile areas shall be provided with automatic garden type sprinklers for dust suppression as well as to reduce spontaneous ignition of the coal stockpiles. Necessary water distribution network for drinking and service water with pumps, piping, tanks, valves etc will be provided for distributing water at all transfer points, crusher house, control rooms etc. A centralized control room with microprocessor based control system (PLC) has been envisaged for operation of the coal handling plant. Except for locally controlled equipment like traveling tripper, dust extraction/ dust suppression / ventilation equipment, sump pumps, water distribution system etc., all other in-line equipment will be controlled from the central control room but will have provision for local control as well. All necessary interlocks, control panels, MCC's, mimic diagrams etc. will be provided for safe and reliable operation of the coal handling plant.

1.5.1 Control Measures for Coal Yards

The total quantity of coal will be stored in separate stock piles, with proper drains around to collect washouts during monsoon season.

Water sprinkling system will be installed on stocks of coal in required scales to prevent spontaneous combustion and consequent fire hazards. The stock geometry will be adopted to maintain minimum exposure of stock pile areas towards predominant wind direction.

1.5.2 Fire Detection & Protection System

A comprehensive fire detection and protection system is envisaged for the complete power station. This system shall generally be as per the recommendations of TAC (INDIA)/ IS: 3034 & National Fire Protection Association (NFPA)- 850. The following protection systems are envisaged:

- Hydrant system for complete power plant covering main plant building, boiler area, turbine and its auxiliaries, coal handling plant, all pump houses and miscellaneous buildings of the plant. The system shall be complete with piping, valves, instrumentation, hoses, nozzles, hose boxes/stations etc.
- Automatic high velocity water spray system for all transformers located in transformer yard and transformers having oil capacity above 2000 L located within the boundary limits of plant, main and unit turbine oil tanks and purifier, Oil canal, generator seal oil system, lube oil system for turbine driven boiler feed pumps, boiler burner fronts, etc. This system shall consist of QB detectors, deluge valves projectors, valves, piping & instrumentation.
- Automatic medium velocity water spray system for cable vaults and cable galleries of main plant, switchyard control room and ESP control room consisting of smoke detectors, linear heat sensing cable detectors, deluge valves, isolation valves, piping, instrumentation, etc.
- Automatic medium velocity water spray system for coal conveyors, coal galleries, transfer points, Stacker reclaimer, etc. This system shall consist of QB detectors, linear heat sensing cables, deluge valves, nozzles, piping, instrumentation, etc

- Automatic medium velocity water spray system for un-insulated fuel oil tanks storing fuel oil having flash point 65o C and below consisting of QB detectors, deluge valves, nozzles, piping, instrumentation, etc.
- Automatic fire detection cum sprinkler system for crusher house along with alarm valves, sprinkler nozzles, piping, instrumentations etc.
- Automatic Foam injection system for fuel oil / storage tanks consisting of foam concentrate tanks, foam pumps, in-line inductors, valves, piping & instrumentation, etc.
- For protection of central control room, Control equipment room, Programmer room and UPS, Inert Gas extinguishing system as per NFPA-2001 (edition 2004 or latest) would be opted.
- Fire detection and alarm system- A computerized analogue, addressable type Fire detection and Alarm system shall be provided to cover the complete power plant. Following types of fire detection shall be employed.
    - Multisensor type smoke detection system
    - Photo electric type smoke detection system.
    - Combination of both multi sensor type and photo electric type smoke detection systems.
    - Linear heat sensing cable detector.
    - Quartzoid bulb heat detection system.
    - Infra-red type heat detectors (for selected coal conveyors)
- Portable and mobile extinguishers, such as pressurized water type, carbon-dioxide type, foam type, dry chemical powder type, will be located at strategic locations throughout the plant.
- Cooling water blow down shall be used for supply of fire water. An alternate connection from clarified water make-up line shall also be provided as a back-up source for fire water. It is proposed to provide two numbers of Steel tanks for storage of fire water system. Fire water pumps shall be located in the fire water pump house and horizontal centrifugal pumps shall be installed in the pump house for hydrant and spray system and the same shall be driven by electric motor and diesel engines as per the regulations of Technical Advisory Committee. The water for foam system shall be tapped off from the hydrant system network.
- For the above fire water pumping station, automatic pressurization system consisting of jockey pumps shall be provided.
- Complete Instrumentation and Control System for the entire fire detection and protection system shall be provided for safe operation of the complete system