GUIDELINES NO. AERB/HWP/SG-1

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GOVERNMENT OF INDIA

AERB SAFETY GUIDELINES

SAFETY ASPECTS IN DESIGN AND OPERATION OF HEAVY WATER PLANTS

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDELINES NO. AERB/HWP/SG-1

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Atomic Energy Regulatory Board
Mumbai-400 094
India

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Price:

Order for this Guide should be addressed to:

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FOREWORD

Activities concerning establishment and utilisation of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective of ensuring safety of members of the public and occupational workers as well as protection of environment, the Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility of laying down safety standards and enforcing rules and regulations for such activities. The Board, therefore, has undertaken a programme of developing safety standards, codes and related guides and manuals for the purpose. While some of these documents cover aspects such as siting, design, construction, operation, quality assurance, decommissioning of nuclear and radiation facilities, other documents cover regulatory aspects of these facilities.

Safety codes and safety standards are formulated on the basis of internationally accepted safety criteria for design, construction and operation of specific equipment, systems, structures and components of nuclear and radiation facilities. Safety codes establish the objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised when necessary, in the light of experience and feedback from users as well as new developments in the field.

AERB issued a safety code on 'Regulation of Nuclear and Radiation Facilities' (AERB/SC/G) to spell out the requirements/obligations to be met by a nuclear or radiation facility to qualify for the issue of regulatory Consent at every stage. This 'safety guidelines' provides relevant requirements and guidance for ensuring safety in site selection, design, construction, commissioning, operation, maintenance, waste management and decommissioning of the heavy water plants. It addresses administrative, legal and regulatory framework, occupational health and emergency preparedness for heavy water production facilities.

Consistent with the accepted practice, 'shall' and 'should' are used in the 'guidelines' to distinguish between a firm requirement and a desirable option, respectively. Industrial safety is to be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

This 'safety guidelines' applies to all the existing and future heavy water plants based on the processes outlined herein.

This 'safety guidelines' has been prepared by specialists in the field drawn from Atomic Energy Regulatory Board, Bhabha Atomic Research Centre and Heavy Water Board.

It has been reviewed by experts, Heavy Water Plants Safety Committee and the Advisory Committee on Safety Documents relating to Fuel Cycle Facilities other than Nuclear Reactors' (ACSD-FCF).

AERB wishes to thank all the experts and organisations who have prepared and reviewed the draft and helped in its finalisation. The list of persons, who have participated in this task, is included for information.

(S. S. Bajaj)
Chairman, AERB

DEFINITIONS

Accident

An unplanned event resulting in (or having the potential to result in) personnel injury or damage to equipment which may or may not cause release of unacceptable quantities of radioactive material or toxic/hazardous chemicals.

Applicant

Any person who applies to the competent authority for consent to undertake any of the actions for which consent is required.

Atomic Energy Regulatory Board (AERB)

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear and radiation facility and to perform safety and regulatory functions, including their enforcement for the protection of site personnel, the public and the environment against undue radiation hazards.

Audit

A documented activity performed to determine by investigation, examination and evaluation of objective evidence, the adequacy of, and adherence to applicable codes, standards, specifications, established procedures, instructions, administrative or operational programmes and other applicable documents, and the effectiveness of their implementation.

Competent Authority

Any official or authority appointed, approved or recognised by the Government of India for the purpose of the Rules promulgated under the Atomic Energy Act, 1962.

Consent

A written permission issued to the "consentee" by the regulatory body to perform specified activities related to nuclear and radiation facilities. The types of consents are 'licence', 'authorisation', 'registration' and 'approval', and will apply according to the category of the facility, the particular activity and radiation source involved.

Emergency Exercise

A test of an emergency plan with particular emphasis on coordination of the many inter-phasing components of the emergency response, procedures and emergency personnel/agencies. An exercise starts with a simulated/postulated event or series of events in the plant in which an unplanned release of hazardous material is postulated.

In-service Inspection (ISI)

Inspection of structures, systems and components carried out at stipulated intervals during the service life of the plant.

Inspection

Quality control actions, which by means of examination, observation or measurement determine the conformance of materials, parts, components, systems, structures as well as processes and procedures with predetermined quality requirements.

Occupational Worker

Any person, working full time or part time in a nuclear or radiation facility, who may be employed directly by the 'consentee' or through a contractor.

Regulatory Body

See 'Atomic Energy Regulatory Board'.

Responsible Organisation

An organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning of a facility.

Significant Event

Any event, which degrades system performance function(s) without appreciable damage to either the system or life or limb.

Surveillance

All planned activities viz. monitoring, verifying, checking including in-service inspection, functional testing, calibration and performance testing carried out to ensure compliance with specifications established in a facility.

SPECIAL DEFINITIONS

(Specific for the Present Guidelines)

Threshold Limit Value-Time Weighted Average (TLV-TWA)

The time weighted average airborne concentration of a chemical substance for a conventional 8-hour workday and a 40 hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse health effect.

Threshold Limit Value - Short-Term Exposure Limit (TLV-STEL)

A 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLA-TWA. The airborne concentration of a chemical substance to which it is believed that workers can be exposed continuously for a short period of time without suffering from (1) irritation, (2) chronic or irreversible tissue damage, (3) dose-rate-dependent toxic effects, or (4) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency.

Threshold Limit Value - Ceiling (TLV-C)

The airborne concentration of a chemical substance that should not be exceeded during any part of the working exposure.

ABBREVIATIONS

ACGIH	-	American Conference of Governmental Industrial Hygienists
API	-	American Petroleum Institute
DM	-	De Mineralized
HWP	-	Heavy Water Plants
IBR	-	Indian Boiler Regulation
IEC	-	International Electrotechnical Commission
IS	-	Indian Standard
LEL	-	Lower Explosive Limit
PESO	-	Petroleum and Explosives Safety Organisation
TDL	-	Toxic Dose Limit
SG	-	Steam Generator
TG	-	Turbine Generator
UEL	-	Upper Explosive Limit

CONTENTS

1. INTRODUCTION

1.1 General

This ‘safety guidelines’ is prepared under the programme of Atomic Energy Regulatory Board to publish safety codes, standards and guides/guidelines for various facilities of nuclear industry.

Heavy water (D_2O) is a compound of an isotope of hydrogen called deuterium and oxygen. Since its molecular mass is higher than that of ordinary water, it is called heavy water. Deuterium is a non-toxic, non-radioactive isotope of hydrogen present in hydrogen and all hydrogen bearing substances like water, hydrocarbons albeit in trace concentrations. The difference in molecular composition and mass of the isotopic heavy water molecules gives rise to only slight differences in their physical properties but the nuclear properties are markedly different. Heavy water is used as moderator and primary heat transfer medium (coolant) in pressurised heavy water reactor (PHWR). Heavy water has also significant applications in life sciences, electronics and as a diagnostic tracer.

Heavy water of isotopic purity above 99.8% is nuclear grade heavy water which amounts to deuterium enrichment of about 7000 - 9000 times from the available resources. This amount of enrichment poses a technological challenge of processing large quantities of feed material. There are two processes which have been successfully exploited for the large-scale production of heavy water in India namely, isotopic chemical exchange between hydrogen sulphide - water and ammonia - hydrogen. These processes are energy intensive.

This document outlines industrial and environmental hazards and various aspects of monitoring and controls during heavy water production.

1.2 Objective

The objective of this document is to lay down the safety criteria and procedures to be followed at various stages of development of the projects/plants such as siting, design, construction, commissioning, operation and decommissioning as well as to identify appropriate monitoring and control techniques with an overall objective of protecting workers, public and environment from industrial hazards associated with these operations.

1.3 Scope

This document deals with safety aspects related to heavy water production facilities. It describes the siting, design, construction, commissioning, operation, maintenance, modifications, decommissioning and emergency preparedness aspects of heavy water production facility. Operational safety requirements, maintenance and modification procedures are outlined for safe operation of the plant.

The document includes the monitoring programme in brief for controlling occupational hazards of the employees working in heavy water production facilities.

Industrial safety requirements to minimize the hazards are addressed in the document. Management of gaseous emissions, liquid effluent and solid waste generated during heavy water production are also discussed in subsequent Sections of the document.

2. SITE SELECTION

2.1 General

Siting of a heavy water plants (HWP) needs review by regulatory body as it involves aspects of industrial and environmental safety. The consent for siting involves review of the safety aspects based on the conceptual design (or actual design, if available) of the facility and the site characteristics that have been considered for the location of the facility at the specified site. In this context, AERB code on 'Regulation of Nuclear and Radiation Facilities' (AERB/SC/G), AERB safety code on 'Site Evaluation of Nuclear Facilities' (AERB/NF/SC/S (Rev. 1)) and AERB safety guide on 'Consenting Process for Nuclear Fuel Cycle Facilities Other than Nuclear Power Plants and Research Reactors' (AERB/NF/SG/G-2) should be referred. A detailed list of documents to be submitted to the regulatory body for obtaining consent is given in Appendix-1.

Preliminary evaluation of site characteristics should be made for identification of any restrictions in terms of chemical and environmental factors and formulation of preliminary design concepts, to shortlist a number of locations.

2.2 Important Considerations for Site Selection

The final choice of the site should be made by optimising the conceptual designs and the safety assessment. The environmental impact aspects should form a part of the site evaluation report to be submitted to the regulatory body for review.

Site evaluation report (SER) forms the main document for review by the regulatory body in respect of siting clearance and the contents of the same is available in Annexure-1 of the above mentioned safety guide AERB/NF/SG/G-2.

In selecting the site for HWP the important considerations in the optimization process that should be taken into account, particularly in reducing the needs for long-term institutional controls after closure are following:

(a) Geography and land use

(b) Demography

(c) Topography

(d) Meteorology

(e) Hydrology

(f) Geology

(g) Seismicity

(h) Mineralogy and geo-chemistry.

The site selection for HWP should ensure that the plants are located in sparsely populated area to minimise the risk of exposure to the public.

2.2.1 Geography and land use

Existing or planned industrial and public facilities in the vicinity such as roads, railways, waterway, chemical plants, military installations, gas pipelines, airports, archaeological monuments and places of pilgrimage should be described. Anticipated changes in their utilisation and distance from the proposed facility should also be mentioned.

Present and foreseeable use of land in the surrounding area, data on food/ milk production, dietary habits and presence of food processing or any other sensitive industry around that area should be described.

2.2.2 Demography

The current and the forecast population of permanent, transient and seasonal residents in the surrounding area for dealing during emergency, emergency access for ease of sheltering and/ or evacuation of personnel or members of the public and hazards associated with chemical releases should be described.

2.2.3 Topography

The topography of the surrounding area and the site should be described along with surface run-off pattern.

2.2.4 Meteorology

Meteorological conditions having an influence on the consequences of normal and accidental release of hazardous materials should be described. The information should include data on frequency of occurrence and possible consequences of extreme meteorological conditions, such as cyclones, heavy precipitation, tsunami, flood, distribution of wind velocity and direction, atmospheric stability conditions, annual/monthly average data on temperature, humidity and rainfall.

2.2.5 Hydrology

(a) Information should be submitted, giving quantity and quality, about the water at and around the site. This information should include, in particular, sources of cooling water and their availability, ground water movement, river or lake current dispersion conditions , potable and service water supplies etc.

(b) Attention should be given to the present and projected uses of water originating in or flowing through the area, taking into account possible contamination by the facility in normal operation and accident conditions.

(c) The effect of natural phenomena such as tidal effects, floods and coastal cyclones should be evaluated wherever applicable. The consequences of failure of installations such as dams (up-stream or downstream) should also be evaluated.

2.2.6 Geology

(i) Information should be provided on the geological features of the site and its surrounding area and the effect it may have on the design of the foundations and structures.

(ii) This information should include investigation of surface faulting, stability of sub-surface material and stability of slopes and embankments. Such features as geological anomalies and underground workings should be identified.

2.2.7 Seismicity

Information should be provided on seismicity of the site and its surrounding area, the behaviour of the ground during tremors in the past, a seismic history of the area, presence of active faults within a radius of 5 km and seismo-tectonic data of the site. Site-specific design basis vibratory ground motions should be derived accordingly.

2.2.8 Mineralogy and Geo-chemistry

The mineralogy of soils and sub-surface areas of waste management facilities with respect to channelling of dissolved contaminants or minerals should be described.

2.3 Interaction of the facility with its environment

Environment safety is a prime concern for the HWP as they are handling large volumes of hazardous gases and other hazardous chemicals. In order to protect environment from any untoward event, safety measures should be considered from design stage itself. Environmental protection and conservation of natural resources should be considered on priority in the design and operation. The quantity of liquid effluents leaving the plants should be brought down to near zero by implementing schemes for reducing, recycling and reusing the effluents. Solid wastes should be disposed without affecting the environment adversely.

For heavy water projects, information should be provided on:

(a) necessary ecological data such as biological systems, critical pathways from the site and its surrounding area,

(b) program for the generation of off-site data or use of conservative assumptions/approaches with respect to the release of toxins and other discharges in case data needs to be generated and

(c) an environmental monitoring program to establish base line data on chemical release levels.

Environmental impact assessment (EIA) report and environment management plan (EMP) should be prepared in accordance with the guidelines issued by the ministry of environment and forests (MoEF) of the central government from time to time.

The EIA should address the potential environmental problems/concerns at an early stage of project planning and design. EIA/EMP should include baseline studies; identification of the key impacts/issues w.r.t. environment along with risk assessment and formulation of mitigation measures.

The preparation of the EMP is required for formulation, implementation and monitoring of environmental protection measures during and after commissioning of projects. The plan should indicate the details as to how various measures have been or are proposed to be taken including the cost of components as may be required. Cost of measures for environmental safeguards should be treated as an integral part of the project cost and environmental aspects should be taken into account at various stages of the projects.

3. PROCESS DESCRIPTION

3.1 General

Heavy water (D_2O) production involves both physical and chemical processes, in view of separating two isotopes namely hydrogen and deuterium having distinct behaviour. In view of the concentration of deuterium in the feed sources being very low (approx. below one part in 6000), the process with which it can be extracted depends on feed, technology availability and economics. Table 3.1 compares some of the possible processes for D_2O production against the criteria's like separation factor, energy needed, natural exchange rate and feed. The processes which have been successfully exploited for the large-scale production of heavy water in India includes electrolysis of water, distillation of hydrogen/water and isotopic chemical exchange between hydrogen sulphide - water and ammonia - hydrogen. In view of availability of synthesis gas as feed stock from certain fertiliser industries and abundant water source, both ammonia - hydrogen and hydrogen sulphide - water isotopic exchange processes have been commercially exploited in India. Alternate technology of water - ammonia dual temperature chemical exchange has also been successfully demonstrated.

TABLE 3.1 : D_2O PRODUCTION PROCESSES OVERVIEW

Process	Separation Factor	Energy needed	Natural Exchange Rate	Counter-Current Flows	Feed
At lab scale					
Distillation of H_2O	1.015 to 1.055	Very high	Moderate	Yes	Water
Distillation of liquid H_2	~1.5	Moderate	Slow	Yes	Very pure H_2 required
Water-hydrogen	2 to 3.8	Moderate	Almost non- existent. Catalyst needed. Development of hydrophobic catalyst is the constraint.	Yes	Water
Amino methane-hydrogen exchange	3.5 to 7	Moderate	Slow-catalyst needed	Yes	H_2
Water electrolysis	5 to 10	Very high	Fast	No	Water

TABLE 3.1 : D_2O PRODUCTION PROCESSES OVERVIEW (Contd.)

Process	Separation Factor	Energy needed	Natural Exchange Rate	Counter-Current Flows	Feed
Laser Isotope Separation	Huge; can be > 20000	Moderate	Slow	Un-important	Chlorofluorocarbons (CFCs) which is not environmentally friendly
At commercial scale					
Water - Hydrogen sulphide exchange	1.8 to 2.3	Moderate	Fast	Yes	Water
Ammonia - hydrogen	2.8 to 6	Moderate	Slow - catalyst needed	Yes	H_2 available in synthesis gas can be used

3.2 Ammonia - Hydrogen (NH_3 - H_2) Exchange Process

HWP based on ammonia - Hydrogen isotopic chemical exchange process are generally located adjacent to the ammonia plants of fertilizer industries for supply of feed synthesis gas from these industries which contains around 110 ppm deuterium. These plants handle large quantities of ammonia, which is toxic (TLV 25 ppm), synthesis gas (mixture of $N_2 + 3H_2$) that has potential hazard of explosion (LEL 4%, UEL 74 % v/v in air) and other hazardous chemicals like potassium amide, hexane, potassium metal, natural gas/ naphtha, chlorine etc. The plants are operated at pressures up to 260 kg/cm^2 and temperature ranging from minus 25 degree celsius to 600 degree celsius.

The heavy water plant based on mono-thermal ammonia-hydrogen chemical exchange process comprises of gas booster, dryer unit, purification unit, isotopic exchange unit (XU), catalyst separation unit, ammonia cracker units, ammonia synthesis unit, final enrichment unit and final production unit.

Feed synthesis gas from the adjacent ammonia plant is routed through the HWP for extraction of deuterium. Generally the exchange unit is operated at a pressure of about 180-200 kg/cm^{2}g. The pressure of the feed synthesis gas received from the fertiliser plant is first raised by a booster compressor to compensate the pressure drop in the HWP. It is then cooled in a heat exchanger by the outgoing cold gas back to the fertiliser plant. The gas is thereafter passed through a purification unit where the oxygenated impurities contained in the gas are removed and the gas is saturated with ammonia. The purified synthesis gas saturated with ammonia is then passed through the first isotopic exchange tower working at minus 25 degree celsius where deuterium in the gas is transferred to a counter current stream of liquid ammonia containing potassium amide catalyst fed from the top of the tower. The deuterium enriched liquid ammonia from the bottom of the exchange tower is then fed to the second isotopic exchange tower where it gets further enriched by coming in contact with the enriched synthesis gases obtained by cracking of enriched liquid ammonia in ammonia cracker unit. A part of the enriched synthesis gas and liquid ammonia from the second isotopic exchange tower is then taken to the final enrichment section where the concentration of deuterium in the ammonia can be further increased to nuclear grade. However, for reasons of better recovery efficiency, the concentration of deuterium in ammonia in the final enrichment section is kept low so as to produce heavy water of about 40 to 50 % isotopic purity. Finally, the enriched liquid ammonia so obtained is made free of the catalyst and is cracked in mini cracker unit. A portion of this enriched synthesis gas is burnt with dry air to produce heavy water of about 40 to 50 % isotopic purity which is then vacuum-distilled to produce heavy water of nuclear grade.

The cold synthesis gas depleted in deuterium from the first exchange tower, before its return to the fertiliser plant, is heated by the incoming feed gas from the fertilizer plant and is passed through an ammonia synthesis unit. In this unit, a portion of the synthesis gas equivalent to the amount of the ammonia cracked in the ammonia cracker is converted into liquid ammonia and fed to the top of first isotopic exchange tower. The rest of the depleted synthesis gas equivalent to the feed gas supplied is returned to the ammonia unit of the fertilizer plant.

The following reaction is indicative of the exchange process and the Fig-3.1 below provides the schematic flow diagram of mono-thermal ammonia-hydrogen isotopic chemical exchange process.

$$\text{HD (gas)} + \text{NH}_3 \text{ (liquid)} \rightleftarrows \text{H}_2 \text{ (gas)} + \text{NH}_2\text{D (liquid)}$$

The potassium amide solution which is used as catalyst and fed along with ammonia in the exchange tower is prepared by dissolving potassium metal in ammonia as per following reaction,

$$\text{K} + \text{NH}_3 \longrightarrow \text{KNH}_2 + 1/2\ \text{H}_2 + 15250 \text{ calories}$$

Potassium metal reacts with ammonia in a vessel and subsequently washed with hexane. Hexane is used to flush the paraffin oil from potassium metal before the reaction with ammonia.

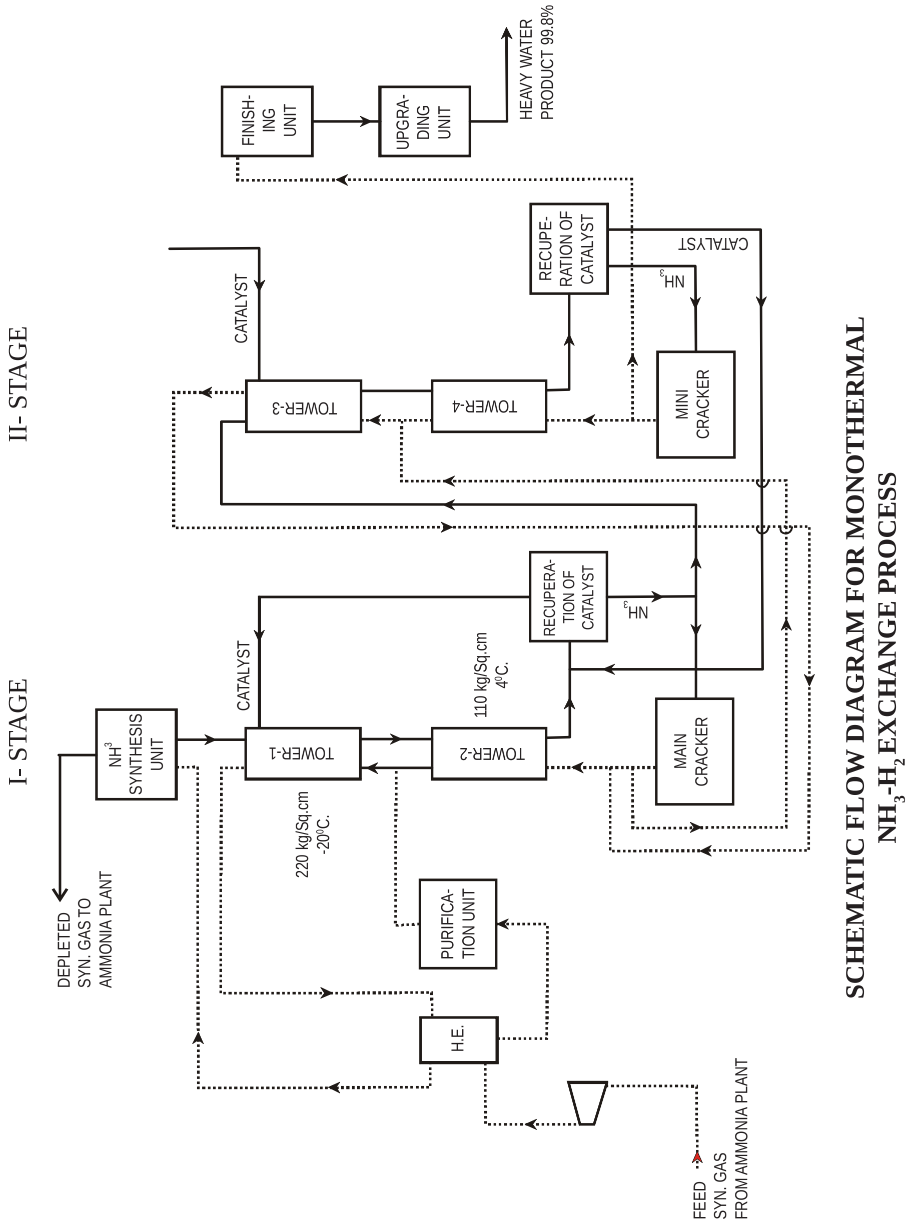

Fig. 3.1 : Schematic Flow Diagram of Mono-thermal Ammonia - Hydrogen Isotopic Chemical Exchange Process

3.2.2 Critical Equipment in the NH_3 based Heavy Water Plants

3.2.2.1 Isotopic Exchange Towers

The isotopic exchange tower is a multi wall/layered vessel and designed for a temperature of minus 33 degree celsius and a pressure of around 280 kg/cm^{2}g. The deuterium exchange between synthesis gas and the liquid ammonia in the presence of homogenous catalyst potassium amide takes place in fifteen exchange stages of the tower. The stage at the top of the tower (i.e. 16th) acts as the washing stage for the synthesis gas going out of the tower and ensures complete washing of potassium amide from the gas going to ammonia synthesis unit. To overcome the pressure drop across the ejector trays, two hermitically sealed submerged canned motor pumps, one in service and other as standby are provided on each stage to pump the liquid to the next lower stage. Pure liquid ammonia required for reflux is pumped from ammonia synthesis unit to 16th stage where it also washes the uprising synthesis gas. Potassium amide solution is pumped from catalyst separation unit directly into the feed stage. In high pressure isotopic exchange towers and purifiers the electrical and instrumentation cable connections to canned motor pumps and level sensors are provided through glass seals.

Safety valves and trip logics shall be provided to prevent over pressurisation and excessive differential pressures between medium pressure sections and high pressure sections. Trip logics should also be incorporated for taking safe shutdown during emergency conditions. The glass seals being a part of pressure boundary, adequate care should be taken to ascertain their integrity.

3.2.2.2 Ammonia Cracker

Ammonia cracker unit is used for cracking enriched liquid ammonia into synthesis gas. The enriched synthesis gas is used as bottom reflux in the exchange towers. Natural gas/Naphtha fired burners mounted on the furnace walls provide the heat for cracking. The ammonia cracking is carried out in presence of iron catalyst filled inside INCONEL 625 tubes at a temperature of around 600 degree celsius and pressure of around 120-145 kg/cm^2(g). The tubes are designed for maximum skin temperature of 717 degree Celsius at a pressure of 146.5 kg/cm^2(g). A forced draft fan supplies the air for combustion. An induced draft fan maintains the draft in the furnace by discharging the flue gases from furnace to stack. As the cracker operates at a temperature of around 600 degree Celsius, monitoring of catalyst bed and tube skin temperature (both inside and outside furnace) should be done continuously. The protection measures like steam sparging, dampeners should be provided to prevent explosion inside furnace in addition to tripping of cracker on high furnace pressure.

Trip logics shall be provided to ensure safety of cracker due to overheating, over pressurization and accumulation of the combustible gases inside the furnace. Extensive monitoring of bed/ skin/ pigtail temperatures of cracker tubes in cracker unit should be carried out and cracker trip-logic should be provided with trip interlocks for auto action in case of unsafe temperatures. Monitoring of flue gas temperature should also be carried out. Auto isolation of fuel (Naphtha/natural gas) and controlled enrich ammonia feed to cracker unit should be ensured on application of cracker trip command.

3.2.2.3 Ammonia Converter

The ammonia converter converts a portion of the synthesis gas equivalent to the amount of the ammonia cracked in the ammonia cracker into liquid ammonia, which is fed to the top of first Isotopic Exchange Tower. The deuterium lean synthesis gas from the top of the exchange tower reacts in the presence of iron catalyst to produce ammonia in the 'Ammonia Synthesis Converter'. The reaction is highly exothermic and the heat of reaction is utilized for producing process steam in waste heat boiler. The ammonia converter operates at high pressure in the range of 120 to 250 kg/cm^2 and temperature in the range of 150 to 400 degree Celsius.

The converter is generally multi-walled vessel provided with weep holes on the outer wall for monitoring of hydrogen diffusion at high temperature. The converter inlet gas before entering into the catalyst beds passes through the converter annular space for cooling the converter shell so as to limit the shell temperatures within the design temperature. The quench gas arrangement should be provided for controlling the bed temperatures. The internal surface of the bottom-dished end should be refractory lined to keep the skin temperature within limits.

3.2.2.4 Finishing and Up gradation Unit:

In this unit synthesis gas rich in deuterium concentration ($N_2 + 3D_2$) is burned with air. The deuterium in synthesis gas is oxidized to heavy water. The product heavy water is condensed by chilling. This heavy water is further processed in a vacuum distillation unit to produce the nuclear grade heavy water (i.e. >99.8%).

Fire is the major hazard involved in this up gradation process, due to the presence of synthesis gas and oxygen. Adequate safety interlocks with respect to burner management and feed etc. should be provided. Suitable fire/ flame detectors should be installed in the unit.

3.2.3 Operational Hazards

The hazards in the plants based on NH_3 - H_2 exchange process are mainly due to the hazardous chemicals handled in the plant and high pressure energy.

These hazardous chemicals involve synthesis gas, ammonia, potassium, potassium amide, natural gas hexane etc. Substantial quantities of synthesis gas and ammonia are used in the production of heavy water by NH_3 - H_2 process. Ammonia is a highly toxic and flammable chemical.

Table no. 3.2 describes the physiological effects of various concentrations of ammonia.

TABLE 3.2 : TOXIC EFFECTS OF NH_3

S. No.	Atmospheric concentration	Physiological effects
1.	20 ppm	First perceptible odour
2.	40 ppm	A few individual may suffer slight eye irritation.
3.	100 ppm	Noticeable irritation of eyes and nasal
4.	400 ppm	Severe irritation of the throat, nasal passages, and upper respiratory tract.
5.	700 ppm	Severe eye irritation. No permanent effect if the exposure is limited to less than half an hour.
6.	1700 ppm	Serious coughing, bronchial spasms, less than a half hour of exposure may be fatal.
7.	5000 ppm	Serious oedema, strangulation, asphyxia, fatal almost immediately.

The mucous lining of the mouth, throat, nose, and lungs is particularly sensitive to ammonia attack.

Potassium is another hazardous chemical used in this process that gets spontaneously ignited forming potassium hydroxide and evolving hydrogen gas on coming into contact with water, moisture or steam. Potassium is stored under paraffin oil to avoid contact with air or moisture. Potassium and its alloys with other alkali metals, if brought into contact with halogens, inorganic halogen compounds (e.g. halides of sulphur, silicon, phosphorous, tin etc.) or organic halogen compounds (e.g. acid chlorides) may cause very violent detonations.

Hexane, which is used to remove the traces of paraffin oil from potassium (the paraffin oil, if not removed, may cause frothing in the exchange towers) increases the fire hazard multi-fold with its high flammability.

Synthesis gas and natural gas are also used in Ammonia - Hydrogen mono thermal exchange process. Synthesis gas is a mixture of hydrogen and nitrogen, hydrogen being highly inflammable and explosive when mixed with air or oxygen. The LEL and UEL of hydrogen in air (by volume) are 4 to 74% respectively, while natural gas, being a mixture of methane as major constituent with different hydrocarbons, is highly inflammable; it forms explosive mixture if the concentration of the gas in air is within 5.3% to 15% by volume.

3.3 Hydrogen Sulphide Water (H_2S-H_2O) Exchange Process

The hydrogen sulphide water exchange process mainly consists of initial enrichment exchange units followed by vacuum distillation, feed water supply & processing unit and hydrogen sulphide generation unit. The process being energy intensive, reliable supply of both steam and electricity is essential.

Production of nuclear grade heavy water using hydrogen sulphide-water (H_2S-H_2O) bi-thermal isotopic exchange process is accomplished in two steps. In first step, the deuterium oxide (D_2O) content of water is enriched from 0.015 % to about 15 % in exchange units and in the second step, it is further enriched to nuclear grade D_2O ($\geq$ 99.8 %) in distillation column. Exchange unit is a cascade consisting of cold towers and hot towers in three stages operating at two different temperatures of 30 degree Celsius and 130 degree Celsius respectively and at an operating pressure of about 20 kg/cm^2(g).

The demineralised and de-aerated water is fed to the top of the first stage cold tower from where it flows down and meets the counter current stream of circulating H_2S gas flowing upward. Isotopic exchange of deuterium, which is reversible process, occurs between these two counter current streams on a number of specially designed contacting devices between gas and liquid. Water gets enriched and H_2S gets depleted of deuterium in cold towers while reverse of this occurs in hot towers.

The separation takes place due to difference in their equilibrium constant (K) at 30 and 130 deg celsius respectively. The following reaction is indicative of the exchange process.

$$\text{HDS (g)} + H_2O\text{ (l)} \quad \underset{\text{130 deg. C (K= 1.86)}}{\overset{\text{30 deg. C (K= 2.2)}}{\rightleftarrows}} \quad \text{HDO (l)} + H_2S\text{ (g)}$$

Product from the exchange unit having around 15% D_2O is made free of H_2S in product stripper using steam. This is further sent for final enrichment to produce nuclear grade heavy water.

The deuterium-depleted water from the bottom of first stage hot towers containing dissolved H_2S is fed to the waste stripper to remove the H_2S below permissible limits. This is further cooled to the permissible limits and discharged/recycled. The schematic flow diagram of bi-thermal hydrogen sulphide - water isotopic chemical exchange process is given in the Fig- 3.2.

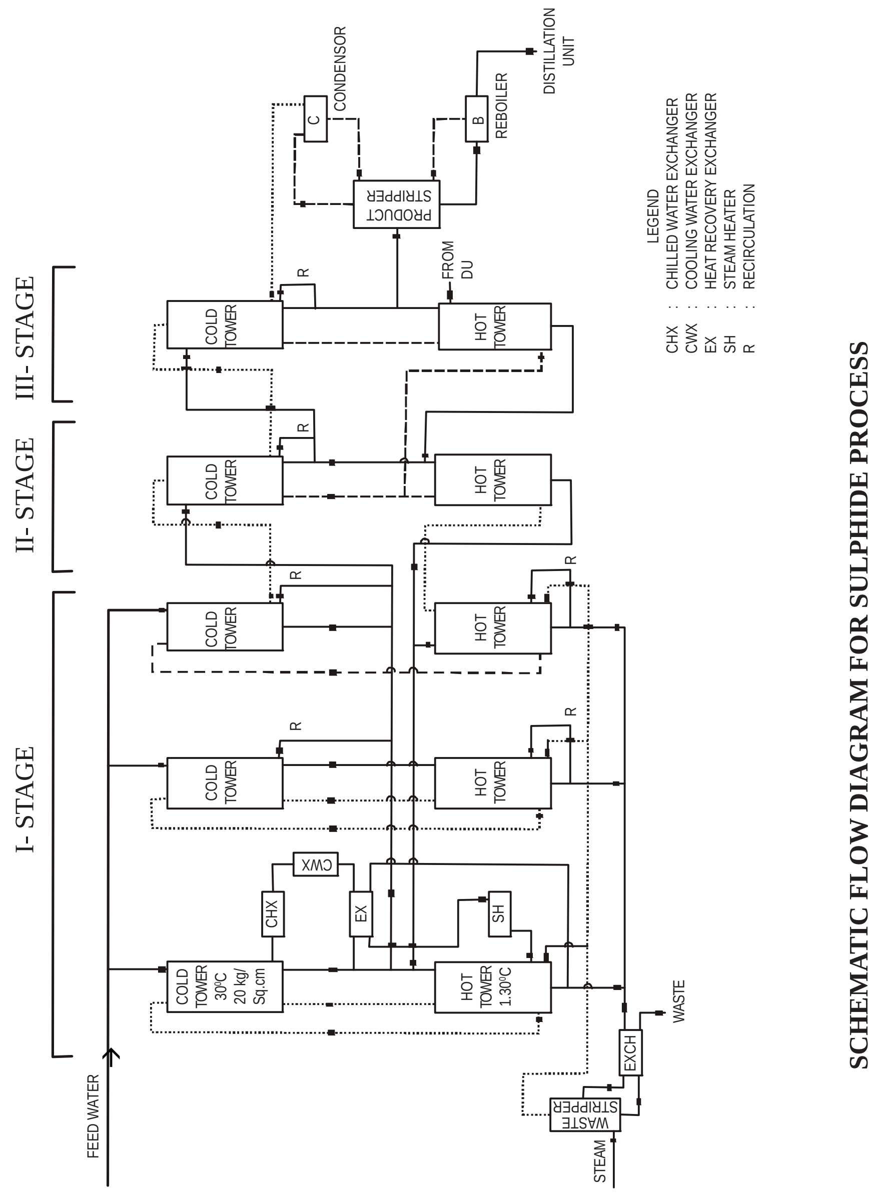

Fig. 3.2 - Schematic Flow Diagram of Bi-Thermal Hydrogen Sulphide - Water Isotopic Chemical Exchange Process

3.3.1 Hydrogen Sulphide Generation

The hydrogen sulphide is prepared by the reaction of 30% dilute sulphuric acid (H_2SO_4) and 14% technical grade sodium sulphide (Na_2S) solution. Dilute H_2SO_4 and Na_2S are pumped at a controlled ratio to the reactor. The reaction is instantaneous and H_2S gas is produced along with the solution containing Na_2SO_4 and un-reacted Na_2S. The solution from the bottom goes to stripper for stripping of un-dissolved H_2S. The H_2S gas from the product separator is cooled, compressed and condensed. The liquid H_2S is stored in storage tanks designed for storage of H_2S under ambient conditions. The Na_2SO_4 solution is then converted into solid form. The schematic flow diagram of hydrogen Sulphide generation process is given in the Fig. 3.3.

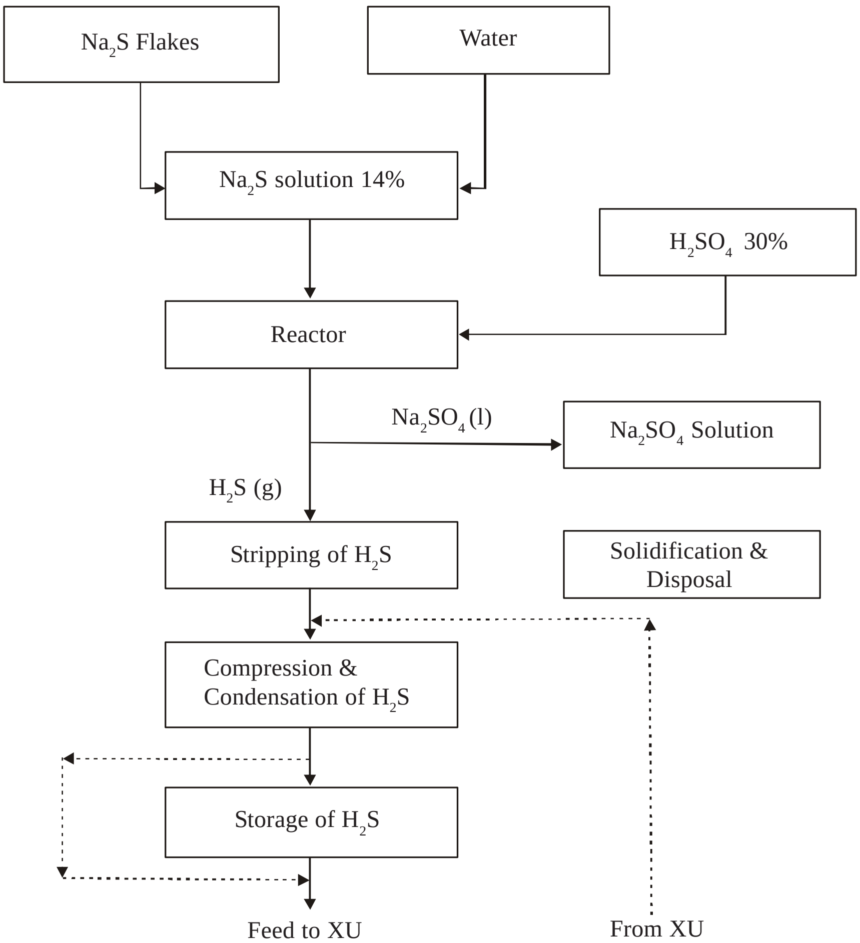

Fig. 3.3 Schematic Flow Diagram of Hydrogen Sulphide Generation Process

3.3.2 Critical Equipment in H_2S based Heavy Water Plants

3.3.2.1 Exchange Unit Towers (Cold and Hot towers)

The exchange unit usually consists of three pairs of hot and cold tower in first stage and one pair each of hot and cold tower in second and third stage. The enrichment of D_2O in first, second and third stage is in order of 4 N, 40 N and 1000 N respectively (where N is the initial concentration of D_2O in natural water, 1N = 150 ppm). Feed is at first stage cold tower top and product is withdrawn from third stage cold tower bottom.

Each exchange tower is provided with suitable tower internals for better mass transfer in mass transfer and humidification sections. Appropriate material of construction should be used for tower internals considering its compatibility with the process materials and process conditions.

All the towers in exchange unit are generally designed for 22.4 kg/cm^2g pressure. The towers should be provided with control relief valve and safety valves to avoid over pressurization and gas dump facility for dumping of tower content in case of significant leakage within first isolation. Inlet and outlets of all the exchange towers should be provided with appropriate isolation valves (e.g. remote operated double disc valves) having high pressure water sealing facility to ensure complete isolation from other system during emergency. The gas dumping should be done through tall flare stack for adequate dispersion into atmosphere.

3.3.2.2 H_2S Gas Booster and its Auxiliaries

The gas boosters in exchange unit are used to circulate hydrogen sulphide gas in a closed loop and are meant to make up the pressure drop across the loop of cold and hot towers of exchange unit. Generally, the booster compressor is centrifugal type with Class-F insulation for motor winding.

The gas booster should be provided with mechanical safety interlocks as well as process safety interlocks and trip logics. The local control panel of gas booster should be kept under positive pressure to avoid ingress of H_2S inside the panel enclosure. The gas booster should be provided with an elaborately designed seal oil system for sealing of H_2S gas inside. Seal oil pressure should be maintained higher than system gas pressure. Entry of the oil into booster casing should be prevented by suitable measures like positive pressure drop across labyrinths etc. The seal should be so designed that oil and gas pressures match each other at the balancing point.

3.3.2.3 Waste Stripper

Waste stripper is provided to bring down H_2S content in waste water below the permissible limit. It receives deuterium depleted waste liquid from the bottom of first stage hot towers (3 nos.). Dissolved hydrogen sulphide gas is stripped by direct injection of primary steam in waste stripper. The stripped H_2S gas along with excess steam is recycled back to the first stage hot towers.

The top pressure of waste stripper should be regulated to avoid over pressurization. In order to prevent release of H_2S gas into environment during process disturbance in the waste stripper, adequate process safety like interlock logics and trip of entire exchange unit for inadequate steam flow/ pressure should be provided. Provision should be made for monitoring H_2S content in the waste stripper discharge as effluent.

When the H_2S content in effluent is more than permissible limit (0.05 ppb), arrangement should be made to divert and hold up the effluent in separate system for dilution (for e.g. delay tank) and also trip the exchange unit.

3.3.2.4 H_2S Storage Bullets

In case of any emergency or planned shutdown, the inventory of H_2S needs some storage arrangement. Mainly for planned shutdown purpose storage tanks are provided to store the H_2S under ambient conditions. These storage tanks should be provided with safety relief valves which are connected to flares, sprinkler system etc. Design and safety requirements for H_2S storage tanks are discussed in Section 4.

3.3.3 Operational Hazards

The hazards in the plants based on H_2S-H_2O exchange process are mainly due to high toxicity of Hydrogen Sulphide (H_2S), which is used in large quantity in this process. Effects of H_2S poisoning depend on level of exposure. Following are the limiting values indicating toxicity of H_2S:

(a) Threshold Limit value (TLV)[1] - 10ppm (15 mg/m^3)

(b) Short-term Exposure Limit (STEL)[2] - 15ppm

(c) Odour threshold - 0.13ppm (0.215 mg/m^3)

(d) LC_{50} (inhale-rat)[3] - 444ppm

(e) IDLH[4] - 100ppm.

The acute toxic effects of hydrogen sulphide in human exposure are summarized in Table - 3.3.

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1 Threshold Limit Value - Threshold Limit Value refers to airborne concentrations of substances and represents conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.

2 Short Term Exposure Limit (STEL) - A 15- minute TWA exposure which should not be exceeded at any time during a workday even if the 8-hour TWA is within the TLV-TWA. Exposures above the TLV-TWA upto the TLV-STEL should be less than 15-minutes and should occure no more than four times per day, and there should be atleast 60 minutes between successive exposures in this range.

3 LC_{50} - Lethal Concentration, 50% - LC_{50} is the dose of the chemical that killed 50% of the test animals when administered by inhalation route during the observation period. The concentrations of the chemicals (usually gases) are expressed as parts per million (ppm) or milligram per cubic meter (mg/m^3). The observation period is usually set for 4 hours but may apply depending upon specific laws.

4 IDLH – Immediately Dangerous to Life and Health, means an atmospheric concentration of any toxic, corrosive or asphyxiate substance that poses an immediate threat to life or would interfere with an individual's ability to escape from a dangerous atmosphere.

TABLE 3.3 : TOXIC EFFECTS OF H_2S

S. No.	Concentration of H_2S, ppm	Duration of Exposure			
		15 min	**>15 min - 1h**	**>1h - 4h**	**>4h - 8h**
1.	10				Eye irritation
2.	50-100	Loss of olfactory perception	Eye irritation	Eye and bronchial irritation	Danger in case of continuous exposure
3.	150-250	Loss of olfactory perception	Eye and bronchial irritation	Serious respiratory distress and asthenia	Serious respiratory distress and asthenia
4.	300-400	Loss of olfactory perception, Eye and bronchial irritation	Severe respiratory distress, acute asthenia	Pulmonary edema and risk of death	Pulmonary edema and risk of death
5.	500-1000	Loss of consciousness, respiratory distress	Risk of pulmonary edema and death		
6.	>1000	Immediate loss of consciousness and respiratory distress			

H_2S is corrosive and flammable also (LEL 4.3%, UEL 46 % v/v in air, Auto ignition temperature is 260 degree celsius). In view of the high toxicity and large quantities handled, stringent safety precautions should be considered during planning and have to be followed during operation of H_2S facilities.

3.4 Captive Power Plant

For reliable steam and electricity supply, captive power plant (CPP) is installed at some sites, especially in the energy intensive hydrogen sulphide based HWP. In coal fired CPP, steam is generated by firing pulverised coal in steam generators. The CPP consists of pulverised coal fired boilers and extraction condensing turbine generators each capable of generating electricity and process steam. The steam extracted from the turbines is distributed to the high/medium/low pressure steam headers. While part of high pressure steam is used for indirect heating in intermediate steam generator (ISG) for generating secondary steam used for indirect heating in exchange units (XU), the balance quantity is used for direct heating and gets mixed with the process fluid having dissolved H_2S. The high pressure (HP) condensate from ISG is returned to the flash tank of de-aerator. Low pressure (LP) condensate from demineralised unit (DU) is returned to LP condensate storage tank in CPP and fed into steam generators (SG), via de-aerator, as feed water. Fig. 3.4 shows the typical flow sheet of CPP.

To support the operation of steam generators and turbine generators, various station auxiliaries like DM plant, cooling water system, fuel handling system and ash handling system are required to be installed. The coal is transported from collieries to CPP either by a combination of belt conveyor and bi-cable aerial ropeway system or trucks.

The operational hazards associated with CPP are multi-fold by virtue of the following reasons:

(i) Transportation of coal in public domain

(ii) Storage of coal

(iii) Fire hazards due to handling and storage of large amount of coal

(iv) Dust hazards

(v) Fire hazards associated with handling of inflammable petroleum products like light diesel oil, furnace oil, turbine oil and transformer oil

(vi) Handling of bulk acids/alkalis in the de-mineralised water processing plants

(vii) High pressure steam, operation of high speed rotary equipment like turbines and electrical hazards

(viii) Disposal of ash through ash pond/dry fly ash handling system.

3.4.1 Critical Equipment and Safety Features in Captive Power Plant

3.4.1.1 Steam Generators (SG)

The steam generators are designed to deliver the steam based on maximum continuous rating at pressure of around 106 ata and 485 degree Celsius taking boiler feed water at 160 degree celsius. The pressure parts of SGs shall be designed to meet current Indian Boiler Regulation (IBR) specifications and installations approved by the statutory body for boilers. For safety of equipment/piping handling steam, adequate relief systems like electromatic relief valves and safety valves, sized to meet IBR stipulations should be provided. Instrumentation and Control (I & C) logic trips should be provided to trip SG on conditions leading to improper atomisation, flame break out from furnace and possible explosion in furnace. For ensuring purging of the furnace before light up, operation of induced and forced draft fans and presence of flame/ failure of flame detection system during fuel injection to furnace, hard wired 'Burner Management System' (BMS) should be provided. The BMS should ensure cut-off of fuel supply (oil/ pulverized coal) in the event of flame failure or on unsafe firing condition in the SG or on manual tripping of SG. Adequate instrumentation provision should be provided for drum level and furnace pressure (draft) measurement with alarms and trip logic determined by 2 out of 3 logic circuitry.

3.4.1.2 Turbine Generators (TG)

The turbine takes inlet steam from SG steam header outlet at controlled pressure and drives a direct coupled generator. The turbine should be designed confirming to API 612/IEC 45 and relevant codes and standards. The turbines should be provided with both electronic and hydraulic type governor. The governor regulates the extraction steam pressure, controls the power output when synchronized with grid and tries to keep the speed of the turbine constant varying the output power to meet load requirement when in island mode. The governor performance characteristic should meet standards like National Electrical Manufacturing Association (NEMA) SM 23 etc. A load shedding relay should be provided to support the functioning of turbine speed governor. Trip logics should be provided on parameters like over speed, very high axial displacement, very low lube oil pressure, very low condenser vacuum, very low steam pressure and very high extraction pressure. In addition to electrical trips, direct operated mechanical back-up trips should be provided.

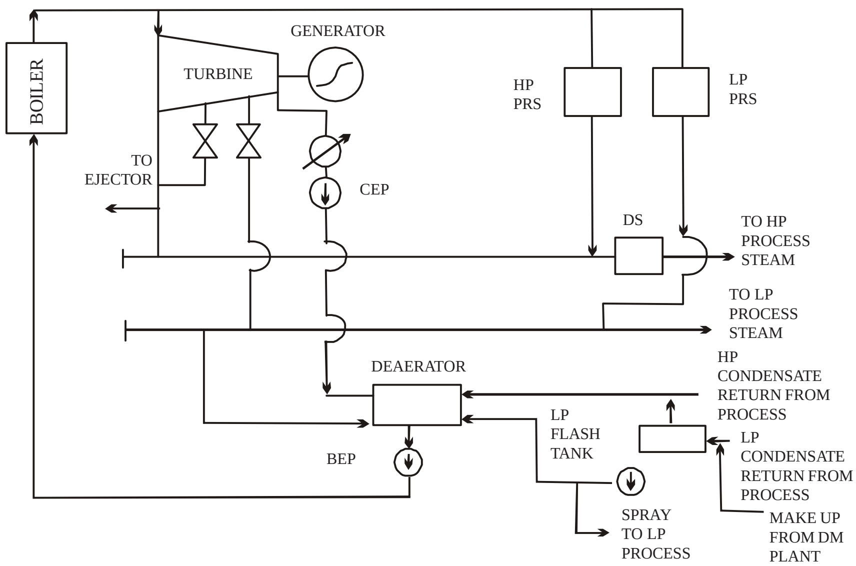


Fig. 3.4 Captive Power Plant Flow Sheet

3.4.1.3 *Aerial Rope Way System*

A bi-cable aerial ropeway system is used as one of the method for transportation of coal from the coal mine to intake coal handling plant for supplying coal to the CPP. The coal is transported through buckets covering a large distance from coal mine to CPP. The bi-cable ropeway system consists of two track ropes for full and empty buckets and one continuous haulage rope. The entire rope length is divided into sections with distance between sections varying from 1.3 km to 1.8 km. The aerial ropeway system should be designed and constructed as per standards IS 9706. The structural design should be done as per IS 800 and IS 875. The selection, installation and maintenance of wire rope should be done as per current standards like IS 3973. In general, the track ropes are joined together by a line coupling and sleeves coupling for smooth passage of buckets. Socketing of ropes should be done as per standards like IS 3937 (Part 3).To prevent any accident due to fall of buckets in public domain like cross over roads, rails etc., protection bridges should be provided above cross over roads, rails etc. Emergency tripping facility for entire length of the ropeway should be provided to ensure safety of the system in case of any unsafe conditions. The safety of the ropes should be ensured as per IS 3792 and IS 3793 and surveillance should be adhered as per the technical specification for the operation of aerial rope way. Communication should be provided around the entire length of the ropeway.

3.4.1.4 *Ash Pond and Dry Fly Ash Handling System*

Ash is generated in SG units in which it is partly collected at SG bottom and balance mainly fly ash is collected in the hoppers of economiser, air-preheater and electrostatic precipitator (ESP). The collected ash is made into slurry with water and pumped to ash disposal area/ash pond located outside the plant area. In the ash pond, the ash settles and clean water overflows into the nearby discharge point through skimmer.

The main safety issue w.r.t. ash pond bund is breaching of earthen bund which may release large quantities of ash slurry in the public domain thereby affecting vegetation, crops etc. Detailed exercise should be carried out considering various factors governing the stability such as ash composition, seismicity of the area, meteorological and geological conditions of the area, availability of the suitable construction materials, height of the dam to be constructed etc. The design should be based on ‘Criteria for Design of Small Embankment Dams’ (IS: 12169:1987 (reaffirmed 1997)), indian standards like ‘Code of practice for drainage system for earth and rock-fill dam’ ((IS: 9429:1999 (reaffirmed 2003)) etc. The slope stability analysis should be carried out as per indian standard on ‘Code of Practice for stability analysis of earth dam’ (IS 7894).

The ash pond should be provided with decanting system, sand filter, rock toe and toe drain for starter bund to remove seepage water and prevent the softening of foundation soil. The starter bund should have a vertical sand chimney and horizontal sand blanket. The vertical sand chimney will trap all water and ensure that the downstream side of starter bund is free from water. The horizontal sand blanket should be designed to trap water from the vertical sand chimney and discharge into the toe drain of starter bund. This also releases uplift pressure acting on the downstream of the starter bund due to seepage from the foundation. The spillway should be provided for effective discharge of water. It should be at least 1 m above the ash level. Rock mattress and toe drain should be provided throughout the bund section to ensure that there is no erosion of downstream slope due to seepage of water and seepage water, if any, is efficiently removed. Provision of garland pipes for discharging ash slurry from the top of bund should be made for reducing direct water pressure on the bund. It should be ensured that optimum water ash slurry ratio is maintained so that the volume of water discharged into the pond is minimum. To detect any signs of leakage at downstream side of the starter bund, relief wells should be provided. The relief well system should be designed as per "Code of Practice for design, construction and maintenance of relief wells. Casagrande type piesometers (stand pipes) should be provided to measure the excess pore water pressure. The installation of piesometers should be based on IS 7356/Part 1-1992 'Code of practice for installation, maintenance and observation of instruments for pore pressure measurements in earth dams and rock fill dams'. In addition roads should be provided on the dam for surveillance using vehicles.

4. DESIGN SAFETY

4.1 General

Heavy water plants handle large volumes of hazardous chemicals such as ammonia, hydrogen and hydrogen sulphide. The plants operate at relatively higher pressure and temperature conditions. In view of single barrier between hazardous process fluids and the environment, the pressure components become more critical. The plants should be designed with adequate in-built safety features.

Hydrogen sulphide based heavy water plants handle large quantity of H_2S gas, which is highly toxic besides being corrosive, inflammable and explosive in certain concentrations. An uncontrolled release of this gas could mean serious danger to the surroundings in some cases.

The ammonia based HWP contain ammonia and hydrogen under high pressure and operating temperatures ranging from minus 25 degree Celsius to 600 degree Celsius. Because of hydrogen being highly inflammable/ explosive, the plants have high risk of fire incidents in addition to the hazard due to the toxic nature of ammonia.

The design of HWP in general should take into consideration the internal and external corrosive environment, high wind velocities, seismicity, floods, tsunami and other local applicable external events. The design of plants and structures of supporting buildings like utilities and common services should be as per national/international standards.

4.2 Civil Engineering Design

The plant buildings, equipment and structures should be designed and constructed in compliance with the current applicable codes and statutes in vogue. The plant structures and control room building shall be designed to be safe against earthquake in accordance with IS 1893 (Part 4) as per the specified categorization of structures and importance factors therein. For design loads other than earthquake, ‘Code of practice for design loads (other than earthquake) for building structures’ i.e. IS 875 shall be followed. For general buildings and structures, IS 1893 (Part1) should be followed. The design should take into account:

(a) superimposed dead loads,

(b) dynamic loads, and

(c) loads arising out of various combination of seismic and wind loading conditions, including those due to external events.

Safety of site shall be assessed against ground failure like slope and embankment failure, local instability, liquefaction, soil erosion, etc. The safe design of foundation system and safety assessment of site against ground failure shall be done in accordance with AERB safety guide ‘Geotechnical Aspects for Buildings and Structures important to safety of Nuclear Facilities’ (AERB/SG/CSE-2). Anchorage in foundations shall be designed for taking into consideration all possible loads during dynamic conditions of the machine or explosion in case of vessels/tanks containing such inflammable materials or any other accident possible in the case.

Concrete structures important to safety shall be designed in accordance with the provision of IS 456 or AERB safety standard ‘Design of Concrete Structures Important to Safety of Nuclear Facilities’ (AERB/SS/CSE-1) and Steel structures important to safety shall be designed in accordance with the provision of IS 800 or AERB safety standard ‘Design, Fabrication and Erection of Steel Structures Important to Safety of Nuclear Facilities’ (AERB/SS/CSE-2). In view of handling flammable material like synthesis gas, hydrogen sulphide gas, the minimum dimensions of RCC members and concrete cover therein will be as required under IS 456 for fire resistance of two hours or more, considering critical heat flux of 38 kW/m^2.

All materials to be used in construction and maintenance of civil engineering structures shall conform to AERB safety guide ‘Materials of construction for Civil Engineering Structures important to safety of Nuclear Facilities’, (AERB/SG/CSE- 4). A list of typical codes and standards for civil structures is given in Annexure-IV.

4.3 Mechanical Engineering Design

The mechanical design, construction, fabrication of pressure vessels, heat exchangers and pipelines should conform to the national and international codes such as ASME, ANSI, British Standards, API, DIN, AFNOR (French), JIS codes, ASTM, Indian Standards , TEMA , NACE etc. and with rigorous inspection. The Rule 36 (3) of the Atomic Energy (Factories) Rules, 1996 provides guidelines for design and construction of pressure vessels and the same shall be followed. The categorisation of structures and seismic design should be done as per IS 1893 (Part 4). Typical categorisation of HWP structures is given in Table 4.1.

TABLE 4.1 : CATEGORIZATION OF HEAVY WATER PLANT STRUCTURES (TYPICAL)

S. No.	Category	Structures/Components in ammonia based HWP	Structures/Components in hydrogen sulphide based HWP
1.	Category 1	Exchange towers and piping up to first isolation valves and interconnection valves on the gas lines, ammonia converter, cracker, process and dump tanks, civil structures and load bearing mechanical structures, control room building etc.	All exchange unit towers, Piping up to first isolation valves, waste stripper, H_2S storage tanks, flare stack and interconnection valves on the gas lines, process and dump tanks, civil foundations, main control room building, and load bearing mechanical structures etc.
2.	Category 2	Large heat exchangers, large vessels, emergency dump valves, compressors, waste heat boilers, fire station building, power supply panels in main power receiving stations, emergency instrument air system for critical control operation etc.	Seal pot tank, nitrogen storage vessel, booster compressors, Breathing air shelter building, fire station building, H2S monitors and their support structures, power supply panels in main power receiving stations, large heat exchangers, cooling water supply pumps, large vessels, emergency dump valves, turbine casing and generator stators, emergency instrument air system for critical control operation etc.
3.	Category 3	General heat exchangers, control relief valve, safety relief valves, start-up transformers, emergency and black out diesel generator sets, Class I, II, III power supplies etc.	General heat exchangers, control relief valve, safety relief valves, emergency and black out diesel generator sets, Class I, II, III power supplies etc.
4.	Category 4	Main entry guard house gate building, D_2O upgrading unit, raw water system etc.	Main entry guard house gate building, D_2O upgrading unit, raw water system etc.

All the material handling systems should be designed and manufactured according to the relevant standards. The process should be ~~so~~ designed and selected such that minimum manual handling of the material would be required. A list of typical codes and standards for mechanical equipment is given in Annexure - IV.

4.3.1 Mechanical Design Aspects in H_2S based Heavy Water Plants

Hydrogen Sulphide being highly toxic and corrosive chemical, extreme care has to be taken for the mechanical design and safety systems of the plant. In view of corrosive nature of H_2S and associated release of hydrogen due to its reactivity with ferrous/ferrous compounds, selection of appropriate material of construction is the key factor in mechanical design of equipment/piping. sulphide stress corrosion (SSC) cracking, hydrogen attack, hydrogen embrittlement, hydrogen blistering are some of the degradation mechanisms involved in the course of operation. In general, low temperature criteria should be considered to obviate hydrogen related damages. The sulphide stress corrosion should be mitigated by selecting high toughness/impact strength and restrict the hardness of carbon steel plates to R_C-22. Fine grain structured, low temperature, silica killed and normalized grade carbon steel (CS) material is generally used for the equipment and process piping with adequate positive tolerance w.r.t. thickness of the material as per the recommendation of NACE and ASME standards. The selection of the materials should be supplemented by a stable passive coating of iron sulphide on carbon steel by film formation. The passive coating provides protection and inhibits corrosion. The crystallographic forms, pyrite and pyrhotite being highly adherent and having very low differential solubility at different temperatures are the desired film coating for inhibiting corrosion. The cases where this requirement is met are vessel, tanks and straight length piping i.e. wherever turbulence is minimum. Wherever high velocities/ turbulence are unavoidable, as in control valves, through bubble cap trays and heat exchanger tubes, austenitic stainless steel (SS) of grade 316/316L should be preferred in absence of welding requirements.

For shell and channel materials for process heat exchangers CS with SS 316L cladding could be used. In case of welding requirement, SS 316 L should be used. Stainless steels should be used for all important process applications.

Spring hangers and supports should be provided wherever the vertical expansion at the support location warrants the use of the spring hanger supports. The springs for the spring hangers and support coming on the H_2S gas lines should be designed for the normal operating loads while components such as hanger rods, spring bags, locking arrangements etc. should be designed for the hydro test load coming at that location. The spring hangers should be protected from external corrosion by providing appropriate long lasting coating.

In view of flange joints being a potential source of leakage, use of flanges in H_2S service should be minimized as far as possible. However areas where sulphur deposits are expected resulting in choking, flange joints can be provided for ease of maintenance. Proper valves and gaskets should be used in the plants handling corrosive and toxic fluids. Gaskets are the weakest element of any plant. Spiral wound gasket with inner ring should be used in the pipe lines. However spiral wound gaskets with inner and outer ring should be used wherever fluctuation in operating temperature is encountered and in the process pipe lines handling H_2S.

4.3.2 Mechanical design aspects in Ammonia based Heavy Water Plants

The ammonia based HWP handle large amount of ammonia (along with amide) and hydrogen under high pressure and operating temperatures ranging from minus 25 degree Celsius to 600 degree celsius. Because of hydrogen being highly inflammable/explosive, the plants have high risk of fire incidents, supplemented with presence of amide. The equipment should be designed according to codes and standards like ASME, TEMA C & R etc.

Suitable and compatible materials of construction should be chosen while designing, inspection and quality control requirements as specified in the relevant codes. The general materials of construction preferred for all equipment, heat exchangers, piping and valves handling ammonia and synthesis gas is low temperature carbon steel. Copper, tin, zinc, and their alloys are attacked by moist ammonia and thereby should not be used in ammonia based HWP. In view of handling hydrogen of high purity (after removing oxygen bearing impurities) which may bring down the notch impact strength of high grade steels, special steels such as nickel-alloyed steels (which have a good ductility and low strength even at low temperatures) are generally preferred.

INCONEL 625 (either wrought or cast) designed to produce high temperature strength against creep (through solid solution strengthening of nickel-chromium matrix of molybdenum and niobium) is also used as material of construction for cracker tubes. However, INCONEL 800 can be used as MOC for cracker outlet hairpin and outlet header etc.

As operating temperature of the pipelines from convertor to waste heat boiler is in the range of sensitisation zone for SS, stabilised SS/INCONEL 600 or better material of construction should be used.

For high pressure vessels, bi-conical gaskets having self sealing properties should be used to reduce initial tightening requirement and over-stressing of studs thereby preventing leakage during start up/shutdown.

For multi wall and multi layered construction through and through vent holes (tale- tell holes) drilled from outermost layer to the innermost layer at various orientation and elevations shall be provided to facilitate release of trapped air during pressurisation of the equipment. These holes are also used to monitor the leakages of process gas in case of failure of innermost layer.

Use of flange joints in synthesis unit should be minimised to prevent fire hazard due to high operating temperature and pressure. The soft iron gaskets with tongue and groove design shall be used for high pressure pipe lines. For medium pressure service SS 304 twin O-Ring gaskets are generally used in the pipe lines. For low pressure service handling potassium amide and synthesis gas, SS 304 twin O-Ring gaskets are generally used in the pipe lines. The material of O-Ring used should preferably be ethylene propylene diene monomer (EPDM) rubber.

The above are based on present operating experience. In case better materials are available, they may be given due consideration.

4.4 Chemical Safety Design

Hazardous chemicals like hydrogen sulphide, synthesis gas, ammonia, potassium amide, natural gas, hexane, chlorine, sulphuric acid/ hydrochloric acid, coal, liquefied petroleum gas (LPG), diesel etc. are used during the manufacturing of heavy water. Activities involving handling, processing, transportation and storage of these chemicals having potential for significant fire, explosion and toxic gas release shall be identified. Toxicity, flammability and explosion hazards of these chemicals should be taken into account during design for chemical safety.

The critical equipment and storage tanks should be installed within open structures. For closed buildings like compressor house, amide vessels, potassium metal storage and handling units in ammonia based HWP, D_2O production unit, the ventilation system shall be designed to maintain at least minimum number of air changes for protection from chemical fumes, escaped gases and dust such that the concentration of hazardous materials are within the threshold limit value-time weighted average (TLV-TWA). The atmospheric hazard in case of volatile organic/flammable products should be controlled by forced air ventilation sufficient to keep atmospheric concentration of flammable materials below 10% of its lower explosive limits (LEL).

4.5 Storage of Chemicals

Separate area should be earmarked for storage of hazardous chemicals. Fire detectors should be installed in the storage places of flammable chemicals. Adequate provision should be provided for transferring of stored chemicals in case of emergency. Adequate venting facility should be provided on the storage tanks wherever required. All the chemical storage tanks should display name of the chemicals, its threshold limit value (TLV) and identification number on the tank.

The hazardous chemicals storage tanks should be designed as per requirements of regulatory bodies such as Petroleum and Explosives Safety Organisation (PESO), wherever applicable.

Suitable gas and fire detectors should be provided for LPG, ammonia handling systems, synthesis gas and hydrogen sulphide storage and operating area.

Hexane, potassium, calcium carbide metal should be stored in a separate well-ventilated shed. The inventory of the chemicals stored inside the plant should be on minimum functional requirement basis. Suitable fire detectors should be provided inside the hazardous chemicals store room. The storage tank should be above expected flood level in the plant.

In case of storage of hydrogen sulphide, an emergency dump tank should be provided at lower elevation to quickly transfer liquid H_2S from other tanks by gravity during any leakage in the tanks storing H_2S. Remote operated dump valves should be provided which can be actuated from the control room during any emergency. H_2S monitors should be installed at various locations in the H_2S storage tank area for continuous monitoring of H_2S concentration in ambient air.

Water sprinkler system should be provided for hydrogen sulphide, LPG and ammonia storage bullets. Deluge valves should be provided on the main fire water header to the storage tank area so that whenever fire is noticed, these valves can be actuated either from control room or from field to deluge each of the storage tanks.

4.6 Electrical Safety Design

All electrical installations should be in conformity with the Indian Electricity Acts and Rules. In the absence of Indian Standards, relevant IEC standards shall be complied with. All electrical fittings should be provided as per area classification. All transformers should be provided with oil soak pits either below the transformer or outside the transformer room. Sprinkler system should be provided to the transformers wherever necessary considering their capacities and oil content. If two or more transformers are installed side by side, they should be separated by fire separation walls. Earthing for equipment and metal structure should be provided. Double earthing should be used for the machines operating on electrical power. All cable should be routed neatly and in an orderly fashion through the cable trays. Cable trays should be separated into power cable trays, control cable trays and instrumentation cable trays. Power cable trays should again be segregated based on the voltage grades keeping the cables used for higher voltages on top and lower one at bottom. Cable penetration sealants, fire retardant spray, fire barriers should be used whenever the cables penetrate walls, ceiling or floorings within a plant. The penetration should be closed and sealed with fire retardant sealing material/fire barrier from both sides. In addition, the cables should be coated with fire retardant material on both sides of the penetration. Fire retardant paint should be applied at appropriate distances. Cable galleries should be provided with fire and smoke detection system. Lightning arresters should be provided at appropriate locations. AERB's document 'Fire Protection Systems for Nuclear Facilities' [AERB/NF/SS/FPS (Rev.1)] should be referred for the design aspects with respect to electrical circuits and equipment.

Design of the electric equipments should take into account the auto-ignition temperatures, flammable ranges and minimum ignition energy of hazardous chemicals like hydrogen, ammonia and hydrogen sulphide. The design should be based on maximum temperature (temperature class) and grouping of flammable gas (gas group, which is function of maximum experimental safe gap). The electrical equipment should be designed as per IS 5572/ NEC Code/ Zone 2, T3 rating for hydrogen sulphide based HWP and T1 rating, IIC for hydrogen and T1 rating, IIA for ammonia. The extent of hazardous area classification should be in line with IS-5572. All the electrical motors/ fittings in areas handling inflammable chemicals should be as per IS 2148:2004 code.

The equipments located in hazardous areas shall be suitable for hazards involved and shall have requisite degree of protection. All the equipment in indoor area should be generally provided with IP-54 enclosures and in outdoor area are generally IP-55 enclosure as per IS: 2147. Switchboards installed inside building should be of IP-42 or better. All motors generally are with class F insulation with temperature rise limited to that of class B. All cables should be fire resistant low smoke (FRLS) type.

All the electrical equipment are earthed in accordance with IS 3043. In addition, the process equipments located in hazardous area should be earthed.

All tall structures, equipment and flammable storage vessels should be given protection against lightening. The lightening protection scheme should be as per IS 2309. As far as possible, lightning protection should be provided to cover the plant premises. Refer the list of typical codes and standards for electrical systems, given in Annexure-IV.

4.7 Instrumentation and Control System Design

The design must include Instrumentation and Control (I & C) systems to monitor the health of equipment and various process parameters (flow, level temperature, pressure etc.) from a centralised control room that are essential and important for safety during normal operation, start up, abnormal operation and emergency shutdown of plant/unit.

I & C system at control room design shall have redundancy at processing, power supply, communication both input/output (I/O) and human machine interface (HMI) level. Redundancy at I/O level shall be considered for critical parameters.

Computers based I & C system shall be minimum certified for Safety Integrity Level (SIL)-2/3 to take care of control system reliability. The applicable guidelines of AERB on commercially off the shelf system (COTS) shall be complied to the extent applicable for HWP. Critical parameters, which can lead to full unit/plant trip, shall be considered for 2:3 voting system. I&C system design should include environment and effluent monitoring for toxic fluids, communication facility for easy communication for plant personnel. Remote operation of system/unit isolation devices for hazardous fluids shall be considered for quick isolation of unit/plant.

I&C field instruments shall be in compliance with material of construction, required area classification under electrical protection and environmental protections. The field instruments should be intrinsically safe for hydrogen atmosphere (area EX-IIC-ia/ib). The applicable codes and standards for each item shall be looked into while designing the system. The distributed control system/programmable logic controllers should be ensured for seismic qualification. Isolators/zener barriers should be provided to protect the field from over current/voltage hazard transmitted due to any fault in the system. The junction boxes located in the hazardous areas of the plant for connecting various field instruments to the control room and vice versa should be explosion proof type with adequate enclosure rating.

Solid state interlock logic systems should be provided for safety interlocks and emergency shutdown system. This system should be hard wired, independent of the distributed digital control system with respect to field instrumentation and power supply and capable to achieve trip of the plant.

All instruments including solenoid valves should be supplied with 115V A/C uninterrupted power supply (Class-II). Wherever other voltages are required, two numbers of dedicated power supply units for each such system should be provided operating in floating condition. Each power supply should be rated for full capacity and also supplied from Class-II power supply.

As an inherent safe approach, the control room should be located away from the process area. The building should be designed to ensure ‘air tight’ with provision of suitable locking doors. In case the control room needs to be located near to the process area, blast proof walls should be provided near control room to ensure integrity of the control room building during accident involving explosion hazards. The control room should be maintained with regulated air supply for maintaining positive pressure and sourced from a high location on top of the building, away from gases that might cause safety issue. If there is a possibility of ingress of toxic or flammable gases inside the control room through ventilation/air-conditioning system, air intakes of these systems should be provided with toxic/smoke/flammable gas detection system to close dampers in the air intake and the system goes into internal circulation. In addition to the above, a water curtain arrangement should be made around the control room, especially near the entrance area, to prevent ingress of hazardous gases inside the control room. Breathing air system should be provided to the control room personnel during emergency to allow operators to continue with their control duties unimpeded. Suitable fire protection systems should be provided for extinguishing any fire inside control room. For reference, a list of codes and standards for instrumentation systems is given in Annexure-IV.

4.8 Fire Safety Design

The fire safety design aspects should follow AERB safety standard 'Fire Protection Systems for Nuclear facilities' [AERB/NF/SS/FPS (Rev.1)], Atomic Energy (Factories) Rules, 1996 and applicable national/international codes, standards and guidelines acceptable to AERB.

Extensive systems for smoke and heat detection covering various parts of the plant should be provided besides the well equipped fire station, fire hydrant systems and sprinklers. Special deluge system should be provided for H_2S and LPG storage tanks. Sprinkler systems should be provided for critical equipment like towers, converter in ammonia based HWP.

The concept of defence-in-depth against fire and its consequences should be applied to fire prevention by giving emphasis on the following:

(a) Limiting the use of combustible materials

(b) Separation of critical areas from non-critical areas so that a single fire in non-critical area cannot prevent the performance of safety function for either of the areas

(c) Design should be such that the spread of fire and smoke is minimum

(d) Structure and building design considering special design features for protection of equipment foundation from the effects of fire

(e) Ducts and fire dampers

(f) Electrical circuits and equipment.

For design of fire detection and alarm system following points should be considered:

(i) Each fire area should be equipped with reliable and appropriate fire detection and specifically engineered alarm system based on the fire hazard analysis.

(ii) The detection system should have annunciation by audio-visual zonal alarms, which should be repeated in the control room and in-house fire station.

(iii) Reliable power supply should be ensured for fire detection and alarm system and for the electrically operated control valves meant for automatic suppression system.

Fire suppression system should be installed by considering:

(a) Speed of response

(b) Type of combustible materials present

(c) Possibility of thermal shock

(d) Items important to safety.

Fire water system should be designed to supply anticipated fire water requirements. Stand pipes with hose connections and nozzles should be provided for areas containing or exposing safety related structures, systems or components and should be spaced such that these areas are accessible to at least one hose stream. Distribution of water supply to fire equipment should be through a ring main such that water can reach each connection from two directions. Fire hydrant system should be preferably above ground. Proper corrosion protection measures should be taken for entire/fire hydrant system.

Fire water system shall be provided with different pump motor sets on Class IV power, Class III power and with diesel engine driven pumps with necessary auto logics.

Special dry chemical powder extinguishers should be provided to handle potassium metal fire in ammonia based HWP.

4.9 Design Requirement for Waste Disposal

Design should include processes to handle gaseous and liquid effluents generated from the process for safe disposal through closed vent and effluent drain system. In case of hydrogen sulphide based HWP, the closed vent system should be connected to flare stack.

The liquid effluent should be treated to meet the standards as prescribed by the Central/State Water Pollution Control Boards. The emission levels of pollutants from the different stacks should conform to the pollution control standards prescribed by central or state boards. Adequate control equipment should be installed for minimising the emission of pollutants from the various stacks. The stacks should be continuously purged with nitrogen/steam to prevent formation of explosive mixtures within the stack volume. Proper stack height as prescribed by the central/state pollution control board/on the basis of effective dispersion under worst wind conditions should be provided for better dispersion of pollutants over a wider area to minimise the effect of pollution. Community buildings and townships should be built up-wind of the plant with one-half to one kilometre greenbelt in addition to physiographical barrier.

The effluent treatment plant (ETP) should be designed to meet the requirements of Environmental (Protection) Rules 1986, national standards like IS-2490 and concerned statutory authorities.

For solid wastes, the site for waste disposal should be checked to verify permeability so that no contaminants percolate into the ground water or river/ lake. Waste disposal areas should be planned down-wind and downstream of villages and townships. Reactive materials should be disposed of by immobilising the reactive materials with suitable additives. The pattern of filling disposal site should be planned to create better landscape and be approved by appropriate agency and the appropriately pre-treated solid wastes should be disposed as per the approved plan. Intensive programs of tree plantation on disposal areas should be undertaken.

4.10 Layout Aspects

The layout of the equipment should be so designed as to provide easy access to the equipment and operating areas. The design should take into account the predominant wind direction for location of control room, office buildings etc. Escape routes should be provided and identified in hazardous zones in addition to the normal access. The hazardous and non-hazardous plant/units should be classified and adequate clearances maintained between such classified units for adequate isolation of one category of plant/units from other categories. Appropriate class of electrical power, lighting and I & C systems/equipment should be installed.

In order to facilitate in-service inspection, the design of facility layout must take care of the provision for accessibility of components to be examined. Approach routes for easy access of fire tenders should be ensured in the layout. Indian Standard: IS-8089 - 1976 elaborates on code of safe practice for layout and building structures inside as well as out-side facilities in an industrial plant. Layout considerations stipulated in section 3.4 of AERB/ SS/CSE shall also be followed.

4.11 Quantitative Risk Assessment (QRA)

Heavy water plants handle large quantities of hazardous chemicals for which a detailed quantitative risk assessment (QRA) should be prepared. QRA should include hazard identification, consequence analysis, risk estimation and hazard control. Indian standard on ‘Hazard Identification and risk Analysis - Code of Practice (IS 15656:2006) provides guidelines for carrying out QRA. Applicable external events should also be considered in QRA. The results of the QRA should be taken into account during design stage and also for formulating the emergency response planning for HWP and in mitigation of the risks. The detailed QRA flow sheet is attached as Annexure-1.

4.12 Special Design Safety Requirements for Ammonia (NH_3) based Heavy Water Plants

The design features dominantly should incorporate safety features for prevention of fire hazards arising out of handling flammable gases, over pressurisation and minimizing danger due to release of ammonia and hydrogen from the system. The important special design safety features required to be incorporated in ammonia-hydrogen based exchange plants are:

(a) Remote operated control valves should be provided to prevent over pressurisation of high and medium pressure loops by safe discharge/ dispersion of gases to high vent stacks by operation of these valves.

(b) Pre-programmed auto logic for safe shutdown of plant systems should be provided.

(c) Pre-programmed inter-locks/trip logic should be provided for isolation of the HWP from fertiliser plant in case of tripping of booster compressors in HWP and tripping of synthesis gas compressor of ammonia plant.

(d) The synthesis gas compressor and refrigeration compressor should be provided with seal oil system and emergency overhead tank for preventing synthesis gas leakage from the mechanical seal.

(e) Intrinsically safe relays with potential free contacts should be used in field switches to limit the power level within safe limit.

(f) The cable chambers and cable conduits of enrichment towers should be filled with special oil of low dielectric constant and low freezing point (less than minus 30 degree centigrade) to prevent entrapping moisture as well as synthesis gas entry.

(g) The ammonia cracker should be provided with adequate temperature monitoring cum scanning system. Skin/pigtail temperatures of cracker tubes and cracker trip-logic should be structured preferably for auto action in case of any abnormal operating temperatures. The cracker tubes outside the furnace should be provided with ceramic insulation/ chloride free insulation material. Arrangement should be made to prevent water ingress into the insulation to prevent corrosion.

(h) For facilitating isolation of HWP and the fertiliser plant in case of abnormal conditions, Class III powered remote controlled valves with separately laid underground cables should be provided.

(i) All process pipelines handling ammonia, hydrogen, hexane, natural gas, naphtha should consider accumulation of static electricity and provide electrical continuity strips.

(j) Vents and stacks should be provided with steam/nitrogen purge medium with flow monitoring. Adequate design features such as water seal arrangement to stack headers should be provided to prevent formation of explosive mixtures in vent stack. All the drains should be connected to a continuously circulating water stream leading to an effluent pit.

(k) Electrical connections are required for pumps, level sensors and temperature indicators located inside the exchange tower. These cables should be passed from outside atmospheric area into the high pressure area of the exchange tower through a specially constructed glass seals. These glass seals should withstand the high pressure and act as a barrier between the high and low pressure areas.

4.13 Special Design Safety Requirements of Hydrogen Sulphide (H_2S) based Heavy Water Plants

In view of the high toxicity of hydrogen sulphide gas, the principle behind engineering design of these plants should be zero leakage of H_2S in normal operating conditions. The important special design safety features required to be incorporated in a hydrogen sulphide - water exchange plant are:

(a) Sealant System

Valves should be provided with sealing fluid facility to prevent H_2S leak into the environment. Process pumps should be provided with double mechanical seals with arrangement of sealing with water at a pressure higher than the stuffing box. Adequate systems and logic should be provided to ensure that both pressure and flow of the sealant is maintained for mechanical seal on critical pumps at all point of time. Gas booster shaft sealing arrangement should be provided as per the applicable code.

(b) Closed Vent and Drain System

All liquid and gaseous effluents containing hydrogen sulphide should be collected and sent to drain tanks and flare stack respectively through closed systems for preventing pollution and H_2S release into the atmosphere. The drain pits should be provided with suitable ventilation system for preventing build up of H_2S concentration.

(c) Flare System

Flare stack(s) should be provided with continuously lit pilot burners and nitrogen purging (for preventing ingress of oxygen from air) for burning of H_2S (dumped during emergencies from the affected section of the plant) for effective dispersion at higher elevation and maintaining the ground level concentrations within the acceptable limit. Provisions should be made for monitoring the flame from control room through instrumentation and closed circuit camera. A standby flare stack designed for full load should be provided to handle any H_2S discharge in case of maintenance of one of the flare stack. The standby flare stack should be provided at a safe distance such that when any one flare is operating, the tip of the flame will not affect the personnel working at the tip of the other flare. The flare stack should be connected through a water seal drum located at the bottom of the flare stack.

(d) *Gas Monitoring System*

There should be an extensive gas monitoring system for detection of leakages of H_2S to the atmosphere. The H_2S monitors should be located at different areas inside the plant and also be located outside the plant area. The H_2S monitors should give audio-visual signals at pre-set values of H_2S concentration both locally and audio-visual annunciation in the control room. Off- site H_2S monitors should be provided as per the emergency plan. On-line H_2S analyzers should be provided in effluent discharge to the environment (both before and after dilution) in the effluent going to the outfall for monitoring liquid effluent. Similarly, such analysers should be provided on condensate/cooling water/chilled water system to check for shell to tube communications in steam heaters and coolers.

(e) *Scram and Dumping Facility*

Scramming facilities should be provided for isolation of sub-sections of plant containing H_2S. Remote operated isolation valves should be provided for emergency shutdown of the individual sections of exchange units to localize the leak. There should be a master scramming facility for shut down of entire exchange units. In case any operational or maintenance requirement of a section of exchange unit calls for depressurisation of the H_2S loop, facility to transfer H_2S to the H_2S tanks should exist. Dump valves should be provided on large vessels handling H_2S gas to dump the gas to flare stack during emergency. The gas dump valve and associate header should be designed such that the dumped gas exit velocity at flare tip doesn't blow off the flame during dumping.

(f) *Run Down Facility*

Provision should be made to store the H_2S gas from exchange unit towers in storage tanks in liquid form. Provision should be made to transfer liquid H_2S from the storage tanks to another tank by gravity (by providing the dump tank at lower elevation) in case of emergency.

(g) *Breathing Air System and Emergency Shelters*

Breathing Air system and emergency shelters for the plant/contractor personnel within the plant premises and emergency shelters for villagers outside the plant's premises should be provided as per emergency procedures. Adequate numbers of breathing air sets and personal protective equipment like canister masks suitable for H_2S, face mask etc. should be provided in the plant for operating and maintenance personnel.

(h) *Passive Relief Systems*

Rupture discs should be provided on upstream of the safety valves/ pressure relief valves (PRVs) in H_2S systems to avoid corrosion and loss of H_2S. The vent connections of the rupture discs should be provided with check valves to block the vent path, in case the rupture discs burst open.

5. CONSTRUCTION, FABRICATION AND ERECTION

5.1 General

The construction methodology for HWP should ensure that the design intent of the buildings/structures is met as per the codes and standards. The regulatory consents for construction of heavy water production facilities require submission of safety analysis reports (SAR)/safety report (SR) as described under section 4.3 of AERB safety guide on ‘Consenting Process for Nuclear Fuel Cycle Facilities Other than Nuclear Power Plants and Research Reactors’ (AERB/NF/SG/G2). The safety report is the principal document for regulatory body to determine whether the operation of the facility under review will result in unacceptable chemical and industrial hazards/risk to the plant/site personnel, the public and the environment. The formats and contents of safety report should follow AERB safety guide on ‘Preparation of Safety Report of Industrial Plants other than Nuclear Power Plants in the Department of Atomic Energy’ (AERB/SG/IS-2).

The responsible organisation (RO) should create a dedicated quality assurance (QA) organisation to enable effective implementation of QA programme.

5.2 Quality Assurance during Civil/Mechanical Fabrication and Erection

The organisation responsible for construction should develop and implement a QA programme, which describes the overall arrangement for the management, performance and assessment of facility under construction. This programme should also provide the means to ensure that all works are suitably planned, correctly performed, assessed and documented. The quality assurance manual which outlines the basis of the QA programme should be submitted to the regulatory body for review and any check or hold points required by regulatory body should also become a part of the QA plans. The QA Organization shall ensure that QA programme meets the requirements of the applicable codes and guides to the extent specified by the regulatory body. Following aspects should be considered for QA programme:

(a) The QA manual for construction should be prepared. Implementation of the QA manual should ensure that the quality of the work is as per the requirements of approved documents.

(b) The QA manual should emphasize the plant management’s policy on achievement of quality in all activities including the organisational structure, management functions and responsibilities.

(c) The manual should include information on quality assurance plans, specific to each phase of the project, qualification of the process and equipment, non-conformance control and corrective actions, internal audit and verification, maintenance of QA records and retrieval etc.

(d) The QA programme should cover in particular, all safety related structures, systems and components.

(e) Stringent quality control measures as specified by the code (for e.g. ASME Section VIII Div. 2 for pressure vessels and ANSI B 31.3 for piping etc.) should be followed.

(f) Critical butt-welding of SS components in H_2S service should be done using continuous argon purging with use of consumable inserts for sound root welding. All butt weld joints should be radio graphed. All weld joints of CS and SS should be stress relieved at appropriate temperatures.

(g) All plates should be tested by ultrasonic flaw detection and any flaws observed should be checked to be within acceptable limits and recorded as baseline data.

5.3 Industrial Safety during Construction

Requirements with respect to construction safety should conform to the following:

(i) AERB safety guide for control of works [AERB/NRF/SG/IS-1 (Rev. 1)].

(ii) Minimum safety precautions needed at any plant or site as specified by AERB.

(iii) Number and qualifications of safety officer and safety supervisor as specified by AERB.

(iv) Requirements of industrial safety as per the Atomic Energy (Factories) Rules, 1996 are satisfied.

(v) Any other applicable statutory requirement shall be followed.

Construction activities of any plant should not jeopardize the safety of the adjacent or nearby plants/structures or part of it, which have already been constructed. Adequate fire fighting arrangement should be established during construction.

The following documents on industrial safety for the construction phase, as applicable, should be submitted.

(a) Job Hazard Analysis Report

(b) Construction Safety Management Manual

This manual is required during construction of new heavy water plant and it should include the following:

(i) Safety policy, organisation chart and responsibilities of the departmental personnel as well as for contractors (principal contractor should be held responsible for sub contractors)

(ii) Safety manpower qualifications, experience, training and competency to perform assigned duties

(iii) Job safety procedures to prevent/control hazards due to activities of various agencies at site

(iv) Job control/work permits system

(v) Job inspection/supervision and enforcement methodology, agencies and accountability

(vi) Accident reporting and investigation system.

(c) Supporting documents for the industrial safety during construction should include the following:

(i) Procedures for controlling the movement of earth moving machinery, concrete mixing and pouring system, lifting machinery etc.

(ii) Procedures for carrying out inspection of excavation activities

(iii) Procedures for carrying out inspection of concrete handling, mixing, pouring, form work/shoring activities

(iv) Procedures for carrying out inspection of rigging operations, platforms, stair cases, ladders and ramps, working at heights, welding cutting and supporting

(v) Control measures to prevent cave-in, land slide, water accumulation, run-off due to rain, loose excavated material falling/rolling, etc.

(vi) Control measures to prevent failure of formwork/shoring

(vii) Control measures to prevent fall of personnel/material from height

(viii) Safety training procedure/manual for departmental/contractor's personnel

(ix) Test certificates for all lifting machinery, lifting tools and tackles

(x) Safety work permit procedures for blasting, excavation, concrete handling activities, all erection activities especially involving heights, etc.

(xi) List of competent persons under various sections of the Factories Act, 1948

(xii) Certification of concrete handling, mixing, pouring and form work/shoring by a competent civil/structural engineer

(xiii) Certification of platforms, scaffoldings, rigging methods, hand tools and powered tools by a competent engineer

(xiv) Fire order

(xv) Measures with respect to electrical safety

(xvi) ISI documents prepared by/for individual facility.

A detailed list of documents to be submitted to the regulatory body for obtaining the consent for construction stage is given in Appendix-1.

Reports on status of the construction activities should be periodically submitted to regulatory body. Any accidents/unusual occurrences should be promptly reported, investigated and reports submitted to the regulatory body.

6. COMMISSIONING

6.1 Commissioning Procedure

The commissioning programme should assure that after construction and installation of equipment, the HWP is made operational in a systematic and safe manner. The programme should verify that the performance criteria, design intent and QA requirements are satisfied. It should demonstrate that the plant could be operated in a safe manner through integrated testing of the systems. Carefully planned and executed commissioning is essential to the subsequent safe operation of a plant. Accordingly, a detailed programme of testing should be prepared and the responsibilities for implementing and reporting of the various parts of the commissioning programme should be clearly defined. The commissioning proposal should be submitted for the approval of regulatory body. Close liaison should be maintained between regulatory body and the operating organisation throughout the development and implementation of the whole commissioning programme. Reports on commissioning activities, accidents, if any, and any unusual occurrences should be promptly reported, investigated and the investigation report should be submitted to the regulatory body. A detailed list of documents to be submitted to the regulatory body for obtaining the consent for commissioning stage is given in Appendix-1.

6.1.1 Commissioning Tests Runs

The major test runs prescribed for heavy water plants are as follows:

(a) Flushing and degreasing of piping & equipment

(b) Sensitive leak test for system

(c) System hydro-test

(d) Nitrogen-water cold/hot run (H_2S based plant)

(e) Film formation/passivation (H_2S based plants)

(f) Effluent Treatment Plant Performance Test

(g) Simulation tests/checks.

6.1.2 Submissions for Commissioning Activities

The consent for commissioning involves the review of the safety aspects based on:

(i) QA compliance for all the critical equipments, turbines, compressors, components and systems after their erection/construction for demonstrating that they meet the design intent and required performance criteria;

(ii) test reports of the significant safety systems like I & C system, fire protection system, scram and dump system and flare stack system; and

(iii) test run reports of nitrogen cold trial run, film formation/passivation done in H_2S based HWP, technical specifications for operation of plant, security aspects and operational data and related documents. In this context AERB safety guide on 'Consenting Process for Nuclear Fuel Cycle Facilities Other than Nuclear Power Plants and Research Reactors' (AERB/NF/SG/G-2) should be referred.

6.1.3 Commissioning Schedule

(a) A comprehensive commissioning programme should be prepared for the testing of the components and systems after their erection/construction and submitted to the regulatory body in order to demonstrate that they are in accordance with the design intent and meet the required performance criteria.

(b) For hydrogen sulphide based HWP, the scram and dump system and flare stack system should be tested. In case of ammonia based HWP scram and stack system should be tested. The programme should lay down clearly defined procedures for the performance test of the plant equipment both static as well as rotary.

6.2 Training and Authorization of Operating Personnel

A training programme should be established to ensure that personnel involved in the commissioning and operation have the requisite competence and safety awareness is developed at all levels of the organization. Training plans and schedules should be prepared for various categories of personnel taking into account their job assignments. The effectiveness of the training should be evaluated through assessment of general results. The retraining should be ensured on periodic basis in order to limit the risk of human error. Records of training of all personnel should be maintained. Feedback information on commissioning experience obtained should form a part of the training programme. A separate programme for training the contract employees should be implemented. In, Section 14, requirements and procedures of training and authorization of plant personnel are elaborated.

6.3 Emergency Plan

The on-site emergency plan for the facility should be prepared as per AERB safety guideline 'Preparation of On-Site Emergency Preparedness Plans for

Non-Nuclear Installations' (AERB/SG/EP-3) to take care of any unusual condition or situation arising due to accident. All the persons working in the plant should be familiar with the on-site emergency plan and emergency exercise should be conducted periodically. If the inventories of the chemicals stored exceed the threshold limit specified in the Manufacture, Storage and Import of Hazardous Chemicals Rules-1989 amended in 2000, then an off-site emergency plan shall be available. The off-site emergency preparedness plan should be prepared in line with AERB safety guideline on 'Preparation of Off-site Emergency Preparedness Plans for Non-Nuclear Installations' (AERB/SG/EP-4).

For the ammonia based HWP located within the complex of fertilizer plants, the emergency preparedness plan of these HWP should reflect the impact of each plant on the other. Detailed information about the emergency preparedness plan is given in Section 13.

7. OPERATION

7.1 General

The occupier is responsible for all aspects of operation of the facility and for establishment and implementation of safety in the plant. The occupier shall apply to regulatory body for obtaining the licence for operation of the plant under the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996. The plant management shall ensure compliance with the necessary statutory requirements and directives/notifications issued by the regulatory body. A detailed list of documents to be submitted to the regulatory body for obtaining the consent for operation is given in Appendix-1.

7.2 Operating Procedure

Detailed operating procedures/standard operating procedures should be prepared by the facility. The approved operating procedures should be circulated among the operating personnel in the plant. Operating procedure should address both normal and off-normal operating conditions. The operating procedure should assure that the person/worker assigned to perform each activity knows the precautions to be taken for his/her own safety, the safety of the plant and the environment. The operation manual should also address the procedure to be followed in the event of failure of utilities, power, strained operation, safety shut down normally and during emergency.

Operation manual should be reviewed at specified intervals of time. Any process/operation, modification required or carried out, should be included during periodic review of operation manual. All copies of such revision should be authenticated.

7.3 Technical Specifications for Operations

Technical specifications for operations of the facility should be prepared prior to starting of operation. Technical specifications for operations should include safety limits (SL), limiting safety system settings (LSSS) and limiting conditions for operation (LCO), shutdown and administrative controls in order to ensure safety of the plant, the workers and general public. Safety aspects of the operations should be subjected to the rules and guidelines stipulated by the regulatory body and other statutory organizations. The technical specifications for the operation should be reviewed at specified intervals of time to include process/operation modification carried out, if any and approved by the regulatory body.

7.4 Periodic Safety Review

The plant management should review the plant performance, which should include significant events and violation of technical specifications for operations. The report on safety status, health and environment along with the plant performance report should be submitted to AERB for review.

7.5 Plant Area Monitoring and Control

Plant area monitoring surveys should be directed towards obtaining the data for the purpose of detection and evaluation of the principal sources of exposure and to initiate appropriate safety measures in the plant. A suitable environmental monitoring programme should be established to assess the impact of the HWP operations on the environment.

The programme may include on-line monitors for continuous monitoring. These instruments help in monitoring/detecting any leakage etc. from the process system. Some of the important monitoring equipments installed in the plant are monitors for gases like hydrogen, ammonia, hydrogen sulphide, oxygen in flue gas, chlorine, NO_x, and pH meters etc.

Smoke and heat detectors should also be installed at various vulnerable locations in the plant. They help in early detection of fire, giving alarm in fire station and control room.

7.6 Operational Safety Features

The essential features of an operational safety programme in heavy water plants are given below:

(i) *Surveillance*

Routine survey of the plant should be conducted in every shift. The field personnel working in hydrogen sulphide based plants should enter the exchange unit/hydrogen sulphide generation premises in buddy system and wearing necessary personal protective equipment (PPE) like self-contained breathing air sets etc.

The personnel working in ammonia based HWP should wear eye goggles and use proper PPE for safe escape from ammonia leakage area.

The plant should form a leak survey team and rescue team for proper surveillance and during emergency situations in plant respectively.

(ii) *Environmental Aspects*

The ambient air quality should be regularly monitored in and around the plant area of hydrogen sulphide based HWP. All treated effluents should be monitored for pH, temperature, sulphide and sulphate contents before their discharge into public water bodies. Stack emissions should be monitored for H_2S, NH_3 content etc.

(iii) *Safety Work Permit System*

Safety work permit and electrical work permit systems should be strictly enforced. Special work permits should be issued for works in hazardous area, hot work, work at height, confined space/vessel entry etc. Also the procedures for operation and maintenance should be well established and strictly practiced.

(iv) *Authorisation*

AERB approved system of authorisation of operating personnel of HWP should be enforced. The operation staff should be authorised by examining them through checklist, written test, walk through and interview before giving them charge of the work.

(v) *Technical Specifications for the Operation of Plant*

Approved technical specifications for the operation of the plant should be available and strictly followed.

(vi) *Safety Audit and Inspection*

Safety audits, Fire audits and inspections should be carried out to identify procedural lapses, potential hazards and for continual improvement.

(vii) *Emergency Preparedness*

A well documented approved plant/on-site/off-site emergency preparedness plan as applicable should be prepared and adhered to. Periodic mock-drills at stipulated frequencies should be carried out for effective emergency response. These include communication drills, Fire drills and plant/ on-site/off-site emergency drills. Details of the emergency preparedness plan are described in Section 13.

(viii) *Public Address System*

Public address system should be provided to communicate from control room to plant units & auxiliary buildings and back.

(ix) *Statutory Requirements*

All applicable statutory requirements like clearances from inspectorate of explosives, boiler inspector, AERB, Ministry of Environment and Forests (MoEF), Central Electrical Authority (CEA)/electrical inspector etc. shall be obtained and get renewed periodically.

(x) *Training*

The fresh appointed persons should be trained for plant operation/ authorization for one year in various plant aspects. Safety training should be imparted on regular basis to the entire operations and maintenance (O&M) personnel. Refresher training as well as special training should also be imparted to them.

(xi) *Health Aspects*

Proper medical control measures should be adopted as an important part of health and safety programme. The medical control measures fall into three categories namely, pre-employment medical examinations, periodic examinations and treatment of exposure cases.

Pre-employment and periodical medical examination of all the employees should be carried out. Health education and first aid training should be imparted to all the employees. The work environment should be monitored for dust, noise, illumination and toxic gases concentration. The preventive and protective measures should be continuously taken to eliminate/ minimise the occupational hazards.

Considering the severity of exposure to toxic chemicals like hydrogen sulphide, ammonia, chlorine etc. the plants should have a well-organized medical facility.

8. MAINTENANCE

8.1 General

The responsible organisation (RO) should establish a maintenance programme before commencement of operation. Detailed and up-to-date maintenance schedule should be made for all the machinery/equipment, instrumentation, electrical system etc. and should be strictly followed. The guidelines given by the manufacturers with respect to the equipment supplied by them should be considered and followed for the maintenance. RO should review the schedule periodically. It should be ensured that the maintenance programme is based on good maintenance practice and to accomplish this, the RO should arrange for personnel with maintenance experience to interact regularly with design organization right from design stage.

The plant management should provide appropriate training, resources, safety appliances and necessary information for carrying out maintenance works. Management should also carry out adequate review before carrying out maintenance work.

8.2 Maintenance Programme

Maintenance programme should be established sufficiently in advance prior to the commissioning stage. Programme considering safe way of carrying out individual maintenance work should be planned and should use modern techniques of work-study, inspection, scheduling, planning and statistics.

Maintenance programme should include regular inspections, checking and testing of protective devices and instruments. Emphasis should be on setting the inspection programme on a firm and rational basis by considering not only the consequence of failure of the components but also the factors that determine the likelihood of such failures.

Schedule of preventive maintenance programme should be planned and followed. Preventive maintenance for equipment should be carried out as per machine manufacturers schedule and schedule developed in-house. Conditioning monitoring of machine should be done periodically for trend monitoring, condition checking and diagnosing defects by using vibration signature analysis, lubricating oil analysis, electrical circuit analysis, thermo graphic imaging and other emerging techniques. Based on the results, appropriate actions should be taken to rectify the defects.

Periodic testing of lifting machines and tackles (such as EOT cranes, hoists, chain pulley blocks, fork lift etc)/hydro test of pressure vessels should be carried out and records should be maintained. These records should be certified by the competent person appointed by AERB as per Atomic Energy

(Factories) Rules 1996. Apart from hydro testing, sensitive leak testing should also be carried out before start up to check the overall integrity of the components especially in H_2S service (H_2S is considered category 'M' service as per ANSI code no. B31.3). For certain critical equipment, acoustic emission technique should be used during hydro testing of these equipment. Safety valves shall be tested periodically as per periodicity specified in the technical specifications. Surveillance of safety related installations shall be done as specified in the technical specifications for operation of respective HWP. Spring hangers should be periodically inspected and maintained. All valves should be maintained periodically.

8.3 Maintenance Data and Record

The RO should collect sufficient information on maintenance needs from designers, manufacturers and from other operating facilities. The data on operation and maintenance experience should also be maintained so that it will be helpful for review and modification. Appropriate arrangements should be made for systematic collection of records and production of reports on maintenance activities. Records and reports are required to provide objective evidence that the maintenance programme is being implemented fully. In addition, records such as equipment history cards and the results of maintenance experience should be used as input to a continuing review of maintenance schedule and procedure effectively on component reliability. The record of field equipment failure and failure mode should be maintained by respective HWP in prescribed formats as per the Atomic Energy (Factories) Rules, 1996.

8.4 In-service Inspection (ISI)

The in-service inspection (ISI) involves periodic examination of safety related systems and components of heavy water plant during its lifetime. The examinations required to determine the health of components form a part of ISI programme. The ISI programme should also be prepared and implemented for civil engineering aspects like concrete structures, buildings, ash ponds if any, etc.

ISI programme involves various methods of testing (including leakage testing of systems) at proper time intervals and administrative measures necessary thereof. The extent and stringency of in-service inspection programme should be appropriately connected to the significance of the safety systems and safety related systems and components. Results of in-service inspection should be compared with original construction examination records and those, which do not meet current acceptance standard, have to be replaced or repaired to the extent necessary to meet such standard.

A comprehensive ISI manual, specific to each individual plant in the facility should be prepared and issued for implementation.

The personnel performing ISI should be qualified and certified as per the requirements of ASME Sec XI. Certificates of ASNT (American Society for Non-destructive Testing) or ISNT (Indian Society for No-destructive Testing) should be acceptable. The examination, inspection, recording, evaluation and acceptance shall be as per clause IWA-2000, IWA- 3000, IWA-4000, IWC-2000, IWC-3000, IWC-4000 (class A and class B components) and IWD-2000, IWD-3000, IWD-4000 (class C components) of ASME Sec XI.

The general tests to be carried out to know the extent of degradation as per damage mechanisms are tabulated below:

TABLE 8.1 : FAILURE CAUSES AND TYPICAL EXAMINATION METHODS

S.No.	Failure Causes	Examination Methods
1.	Uniform corrosion	Visual testing (VT), thickness measurement (MT4)
2.	Hydrogen attack	Volumetric examination, ultrasonic testing and eddy current examination mainly for heat exchangers tubes (UT), surface examination - LPT (ST), hardness measurement (MT1), in-situ metallography (MT2) and tensile testing (MT3).
3.	Fatigue related crack growth	VT, UT, ST
4.	Stress corrosion cracking	VT, UT, ST
5.	High temperature creep (mainly in cracker tubes in ammonia based HWP)	UT, ST, MT1, MT2, MT3
6.	Corrosion and erosion due to high velocity	UT, MT4

8.5 Preservation

The plant and equipment required to be depressurized and decontaminated should be kept under nitrogen pressure. The rotating equipments should be periodically checked for its functionality. The electrical system should be tested at periodical intervals.

8.6 Work Permit

HWP should prepare and implement Safety Work Permit (SWP) system for carrying out maintenance jobs during operation and shutdown. A work permit should be given as a written document initiated by Shift In-Charge control room/Area in-Charge, authorizing maintenance section to take up jobs in hazardous/non-hazardous areas under the control of Shift In-Charge, Production/Electrical control room. The work permit should be properly classified based on the hazards involved in the job. For example hot work in hazardous areas, vessel entry, working in confined space, working at height, opening an instrument panel in hazardous area, etc. may be classified as Class-I work permit and all maintenance jobs (excluding the those identified under Class- I permit) as Class- II work permit. Electrical work permit should be given for all electrical distribution systems, electrical sub-stations, transformers, switchyard etc. Excavation work permits should be prepared and implemented for jobs involving excavation and thereby obtaining clearances from the concerned sections like fire, electrical, production, mechanical, instrumentation, civil etc.

Maintenance should be carried out with all safety precautions and documented. During maintenance, a work permit system should be employed to ensure that equipment; vessels or areas are not approached or worked until certified safe. Adequate supervision and applicable PPEs should be provided during the execution of the jobs mentioned in the SWP.

9. MODIFICATION

9.1 Necessity of Modification

Modification based on operational experience or new technological developments should be implemented as per approved procedures after ensuring operational safety of the plant. Modifications may affect structures, systems and components, operational limits and conditions, instructions and procedures or a combination thereof.

As per rule 3 of the Atomic Energy (Factories) Rules, 1996, every proposal for obtaining the previous permission even for expansion of the factory, shall be made to the competent authority in writing along with relevant documents specified in sub-rule 2 of the above rule.

Any major modification/where a proposed modification is judged to affect safety, a further independent review and assessment should be carried out and the proposed modification should then be submitted to AERB for prior approval. The modification that requires approval from the regulatory body is elaborated in the AERB guidelines on 'Consenting Process for Nuclear Fuel cycle facilities and related industrial Facilities Other than Nuclear Power Plants and Research Reactors' (AERB/NF/SG/G2). It elaborates on the modifications that requires approval from AERB namely,

(a) Modification to the process, plant design and operating procedures, having a bearing on safety and relevant to the consenting process and

(b) Modification may also include augmentation, expansion, life extension, etc. Relevant documents on the modification, together with justification and safety implication, should be submitted to the regulatory body for safety review and assessment.

9.2 Submission of Proposals

Proposals for modifications submitted by the plant for independent assessment should specify the functional and safety requirements of the proposed modifications and show how these requirements are met. The modification proposal should demonstrate the improvement over the previous system. For major modifications, which would have implications on safety systems of the plant, revised safety reports and HAZOP reports are to be submitted to the AERB.

9.3 Implementation and Documentation

All reviews and assessments should be documented and only those modifications that have successfully gone through the appropriate process should be approved for implementation. Implementation of modifications should be subject to usual maintenance procedures together with any special requirement recommended by the reviewing agencies.

All documents such as operation manual, technical specifications, safety manual, on-site emergency plan, drawings, procedures, P&I diagrams, etc. should be updated according to the modifications made in the operating system or equipment.

10. OCCUPATIONAL HEALTH AND SAFETY

All persons employed in the HWP should be medically examined before commencing such work and at appropriate intervals thereafter as per statutes. The medical examinations shall be carried out by the Certifying Surgeon appointed by AERB under Section 10 of the Factories Act, 1948 (as amended in 1987) and Rule 5 of Atomic Energy (Factories) Rules, 1996. The duties of the Certifying Surgeon are prescribed in Rule 7 of Atomic Energy (Factories) Rules, 1996.

10.1 Pre-employment Medical Examination

Pre-employment medical examination should be carried out to provide information on the general health of the worker and to detect changes which may be related to his/her occupational exposure. The type of medical examination should be as per AERB guidelines on 'Pre-employment Medical Examination' (AERB/SG/IS-4).

10.2 Periodic Medical Examination

Periodic medical examination shall be carried out as per the Atomic Energy (Factories) Rules, 1996. The periodic medical examination should pay attention to the organs/systems likely to be most affected by exposure to chemical contaminants and high noise areas in the HWP. The periodic medical examination should consist of a general examination and functional checks and should include blood pressure measurement, haematological examination, pulmonary function test and audiometric examination.

10.3 Handling Emergency Cases of Exposures

Considering the highly toxic nature of hydrogen sulphide handled in the H_2S-H_2O based HWP, the toxic properties of ammonia, ammonia-amide fluids and flammable chemicals handled in NH_3-H_2 HWP should have a well-organised medical facility and a number of first-aid posts depending on the size of the plant.

Exposure to hazardous chemicals may produce a wide range of adverse health effects. The likelihood an adverse health effect occurring, and the severity of the effect, is dependent on the toxicity of the chemical, route of exposure, and the nature and extent of exposure to that substance. In order to understand potential health effects, emergency department personnel should have an understanding of the basic principles and terminology of toxicology. They should also be aware of community resources that could be called upon to assist in emergency response. Every member of the emergency department should be familiar with the hospital's hazardous materials response plan and be required to participate in scheduled drills. Preparation for arrival of the exposed patient should include: notification of all services involved, preparation of a decontamination Area and suiting up of the decontamination team.

The details of medical management during hydrogen sulphide and ammonia exposure are attached as Annexure-II.

11. INDUSTRIAL SAFETY

11.1 General Safety Practices

(a) The Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996 shall be followed.

(b) Good housekeeping should always be maintained in the plants by periodic cleaning of the floor area, machinery and equipment, preventing leakage and spillage of the material and proper storage of infrequently used materials. The combustible, metallic and non-biodegradable wastes should be segregated, collected and kept in the proper colour coded/labelled bins for disposal.

(c) Equipment tag numbers should be marked prominently on all major equipment for the identification purposes. Also pipelines for process and utility should be colour coded as per IS: 2379-1963 and IS: 5-1978. Colour code should be standardized for other pipelines not listed in the Indian Standards, and same shall be followed. Also, flow directions should be indicated on the pipeline. Electrical conduit panels should be colour coded as per IS: 375-1951 and IS: 5-1978.

(d) All lifting machines, chains, ropes, lifting tackles, pressure vessels used in the plants shall be tested as per the Atomic Energy (Factories) Rules, 1996 by the Competent Persons authorized by the Competent Authority.

(e) Compliance to the requirements of all other regulatory authorities should be ensured.

(f) Adequate illumination should be provided in all the areas. Emergency light should be made available at appropriate locations to provide required illumination automatically in the event of an interruption to the normal lighting system. Panic lighting should be provided in the critical areas and control room. Alternate source of power supply should be provided and periodically tested.

(g) ISI marked personal protective equipment should be provided to all the employees, including contract workers and their use should be strictly enforced.

(h) Thermal insulation should be provided for hot exposed surfaces as per relevant Indian standard.

(i) Free space should always be maintained all around the equipment for the easy access of operation and maintenance personnel.

(j) All moving/rotating parts such as coupling, belt-pulley drives, shaft should be guarded properly.

(k) Periodic painting should be done to all the metallic structures in the plant to avoid corrosion. A schedule for painting should be prepared and strictly adhered to.

(l) All staircases should be made as per Indian Standard/standard engineering practice to avoid accident while running in hurry or during material movement. Fluorescent/Self illuminating signs should be provided along the escape routes.

11.2 Safety Manual

The safety manual is a document which provides a fair knowledge to the employees about the various hazards and the safety measures in place for the same.

A safety manual should be prepared addressing topics like site conditions, process details, operational aspects, operation limits and conditions, quality assurance, hazardous chemicals involved and hazard control mechanism, safety systems, safety organisation, emergency preparedness, safety training and crisis management, mitigation of accidents and medical facilities etc. The manual should serve as a guide for the plant personnel in observing safe working practices for prevention of accidents and for preserving the environment while achieving high level of productivity.

11.3 Standing Fire Order

A standing fire order should be prepared for respective HWP based on the format for fire order provided as Appendix D of the AERB standard ‘Fire Protection Systems for Nuclear Facilities’ [AERB/NF/SS/FPS (Rev.1)]. This standing fire order should be displayed at common places.

11.4. Safety Training

HWP should be operated by licensed/authorised operating personnel. For this the plant should prepare and implement an authorisation programme approved by AERB. The authorisation programme envisages training of individuals in basics of plant operation, safety, design details of operating units, operating procedures/instructions etc. These should be incorporated in the checklists, followed by plant walk-throughs, written examinations and final interviews. Plant officers should also be deputed for specialised training programs to various institutions. The safety procedures should be included in the syllabus of the authorisation scheme. Safety, health and environment related training/re-training should be conducted periodically. Safety training should be imparted to all workers (including contract workers) before assigning any job.

11.5 Electrical Safety

Rules and regulations specified in the Electricity Act, 2003 and the Indian Electricity Rules, 1956 and latest amendments therein should be strictly followed in electrical installations. All work on major electrical installations should be carried out with safety work permit and electrical work permit systems. No work should commence on live mains unless it is specifically intended to be so done by specially trained staff and under supervision. In such cases all possible precautions should be taken to ensure the safety of the staff engaged for such work, and also of others who may be directly or indirectly connected with the work. Such work should only be carried out with proper equipment provided for the purpose and after taking necessary precautions, by specially trained and experienced persons who are aware of the danger that exists when working on or near live mains or equipment.

All electrical medium, high and extra high voltage installations should be fixed with a danger notice in hindi, english and local language.

Wild growth of plants/vegetation should be prevented and removed periodically in transformer and switchyard areas. Transformer oil should be periodically tested for its dielectric strength and acidity.

All portable power tools should be periodically inspected for electrical insulation, earthing and integrity etc. Double earthing should be used for the machines operating on electrical power. Earth resistance should be measured every year and preferably during dry or summer season. Rubber mats should be provided in front of all electrical panel boards. Metal ladders with insulating rubber shoes should only be used for working with electrical lines or in places where they may come in contact with such wires. Maintenance schedule should be prepared and followed for all electrical equipment and installations.

11.6 Fire Safety

The plants based on ammonia-hydrogen exchange process are integrated with the neighbouring fertilizer plants from which feed synthesis gas and other utilities are obtained, whereas the hydrogen sulphide-water exchange process based plants are independent in nature. In all these plants, toxic, inflammable and explo-sive materials like hydrogen sulphide, ammonia, and hydrogen under high pressure are handled in bulk quantities both as dynamic and static storages. Apart from these, the plants also have a sizable inventory of chemicals like n-hexane, liquefied petroleum gas, coal, furnace oil, chlorine, calcium carbide, sulphuric and hydro-chloric acids, sodium hydroxide etc. The main objective of the fire prevention measures in the HWP is in the strict avoidance of release of flammable materials and prevention and containment of fire by proper design, construction, well-defined operation and maintenance, and administrative controls etc. The above should also ensure that in the event of a fire, the resulting damage is to be kept to the barest minimum and the fullest protection is given to the plant personnel, general public, environment and the plant machinery.

The management shall establish and implement a fire protection programme, which complies with the AERB standard on 'Fire Protection Systems for Nuclear Facilities' [AERB/NF/SS/FPS (Rev.1)]. The HWP specific requirements are provided in section 10, para10.5 of the standard. The responsibility for implementation of the fire protection programme shall be ensured through the design, construction, commissioning, operation and decommissioning phases.

The feasibility of mutual aid scheme with neighbouring industries should be worked out by the management for effective mitigation of fire emergencies.

The construction and commissioning phases are very critical with respect to fire potential in view of simultaneous working of many agencies at the site, difficulty in controlling the transient fire loads, volume of cutting and welding works, absence of a fully operable fire protection system and trained work force etc. Adequate supervision should be ensured during these phases.

The management should ensure:

(a) coordination of fire protection programme requirements, including consideration of potential hazards associated with building layout and system design;

(b) design, testing and maintenance of fire detection and suppression systems;

(c) fire prevention activities, including the preparation of plant procedures and administrative controls;

(d) training of plant personnel and fire brigade personnel on fire fighting activities;

(e) pre-fire planning;

(f) effective implementation of the overall fire protection quality assurance programme; and

(g) safety assessment of the proposed changes in the existing fire protection systems and approval prior to implementation of the change.

A firewater reservoir should be made available for fire fighting purpose. A firewater ring main should be installed in the plant and this should always be kept charged with water. All fire hose boxes available at hydrant post should always be provided with hoses and nozzles.

Fire extinguishers should be provided at appropriate places in various plant areas that contain or have fire hazard to safety related equipment. Portable fire extinguishers should be placed as near as possible to exit or staircase landings. Buckets filled with clean, dry and fine sand should be placed at convenient and easily accessible locations. Appropriate fire/smoke and gas detectors should be provided at storage and flammable material handling areas like LPG storage areas, hydrogen sulphide, hydrogen gas etc.

All fire fighting equipment should be inspected and tested periodically as per the AERB standard on 'Fire Protection Systems for Nuclear Facilities' [AERB/NF/SS/FPS (Rev.1)].

Adequate numbers of self-contained breathing apparatus with full-face mask should be provided and maintained for the operating personnel in addition to those maintained by fire brigade.

The plant emergency lighting system should be able to illuminate fire escape routes with light having an intensity of not less than 11 lux measured at floor level.

The plant fire protection training programme should be developed and fire brigade personnel as well as plant employees be trained accordingly. Fire drill should be conducted periodically. Fire squad should be identified and trained periodically.

A standing fire order should be prepared and made available to the employees.

Fire exit doors should be provided in the plant buildings at appropriate locations and be marked in a language understood by the majority of the workers.

In long run of horizontal cables, fire stops at suitable intervals shall be provided to check the spread of fire. Cable and cable tray penetration fire barriers shall be sealed to give protection at least equal to that of fire barrier.

11.7 Personnel Safety

Use of personal protective equipment (PPE) is an important and necessary consideration in the development of a safety programme. It becomes essential to select the right type of PPE and the management should ensure that the workman not only uses it but maintains it correctly.

All PPE as considered necessary should be made available for use of the persons employed on the site and maintained in a condition suitable for immediate use. All PPEs in use should be as per relevant indian standards as referred in the AERB safety guidelines on 'Personal Protective Equipment' (AERB/SG/IS-3). Respiratory equipment should be always carried by the persons working within the premises of exchange unit (restricted area) and hydrogen sulphide generation unit of hydrogen sulphide based HWP. Adequate number of canisters vis-à-vis the capacities of the shelters should be available in all shelters provided for hydrogen sulphide release emergency. Adequate respiratory equipment should be available to field persons handling/escaping during emergency in ammonia based HWP. Respiratory equipments are essential for persons handling chlorine toners. Eye goggles, PVC suits and face shields are very important PPE to be used during handling acids/alkalis and in the ammonia amide handling areas. In case of coal fired captive power plant, dust mask should be provided to the persons involved in handling coal and ash.

11.7.1 Quality of PPE

PPE must meet the following criteria with regard to its quality:

(a) Provide absolute and full protection against possible hazard

(b) It be so designed and manufactured out of such material that it can withstand the hazard against which it is intended to be used.

11.7.2 Selection of PPE

Selection of the right type of PPE requires consideration of the following factors:

(a) Nature and severity of the hazard

(b) Type of contaminant, its concentration and location of contaminated area with respect to the source of air for respiration

(c) Expected activity of workman and duration of work

(d) Comfort of workman while using PPE

(e) Operating characteristics and limitations of PPE

(f) Ease of maintenance and cleaning

(g) Conformity to indian/international standards and availability of test certificate.

11.8 System of Accident Investigation and Reporting

System of investigation of any significant events/dangerous occurrences in the plant affecting personnel or otherwise should be structured and adopted. All the accidents should be investigated by safety committees to identify the root cause and suggest the corrective and preventive measures. The implementation of the corrective measures should be monitored. The notification of accident should be done as per the Atomic Energy (Factories)

Rules, 1996 and their investigation reports should be submitted to AERB, within the specified period. The significant event reports shall be submitted to AERB.

11.9 Plant Safety Organisation

The plant should have a safety organisation to establish safety in the plant and to create good safety culture among the employees. Safety organisation plays an important role in implementing and promoting safety practices through safety audits, safety work permit systems, training and promotional activities. To achieve this, adequate manpower should be employed for the safety organisation. A plant level safety and sectional level safety committees representing various sections shall be constituted as per the Atomic Energy (Factories) Rules, 1996 to supplement the safety functions of the organisation for the sorting out safety related or process related issues.

12. WASTE MANAGEMENT

12.1 General

As an essential objective of waste management, generation of waste should be kept to the minimum practicable. Waste minimization relates to reduction of both volume and activity. The chemical characteristics of the waste should also be controlled at the source to facilitate subsequent processing of the waste. Waste management should justify the adequacy of the measures proposed for the safe management of waste of all types that is generated throughout the lifetime of the plant. The objective of waste management is protection of the workers, public and environment. Environmental surveillance programme should be put in place for waste management facilities.

12.2 Characterisation of Waste

12.2.1 Solid Waste

Solid waste is generally generated from the use of potassium in HWP. This solid waste contains calcium carbide, potassium fluoride and unrecovered potassium. Spent catalyst of ammonia converter, cracker, spent resins, damage woods of cooling tower, ash and other waste is another source of solid waste.

12.2.2 Liquid Effluents

The liquid effluent generated in the plant includes cooling tower blow down, boiler blow down, waste water from processing, waste water from other uses etc. The composition of liquid effluent discharged from the plant should be maintained within the permissible limit as mentioned in the Water (Prevention and Control of Pollution) Act, 1974 and stipulated by central/state pollution control board. For liquid effluent from H_2S - H_2O based HWP, the limit on total sulphide (presently, 2 ppm) and un-dissociated H_2S (presently, 20 micrograms per litre) as specified by statutory bodies should be strictly adhered to. The effluent from waste stripper generally contains less than 0.1 ppm of H_2S concentration. This effluent should be cooled and H_2S concentration reduced to 0.01 ppm. The liquid effluent collected in drain tanks should be disposed in main liquid effluent in controlled manner to limit the H_2S content to value specified, in final discharge.

The liquid effluent in ammonia based HWP contains NH_3. The liquid effluent should be treated to maintain NH_3 within the permissible limit before final discharge.

12.2.3 Gaseous Emissions

The gaseous emission contains air, steam, H_2, ammonia vapour, H_2S gas and flue gases such as CO_2, O2, SO_X, H_2O, N_2 and NO_X. The H_2S concentration in the ambient air should be monitored in the H_2S based HWP. The gaseous releases after treatment (if any) are discharged through stacks.

12.3 Treatment, Storage and Disposal of Waste

12.3.1 Solid Waste

The un-reacted raw material (calcium carbide, potassium fluoride) and unrecovered potassium metal present in solid waste should be removed/ killed by quenching of solid waste in water. After quenching this waste for 24 hours, the same should be disposed off. As solid waste contains fluoride, the same should be disposed by storing in underground reinforced concrete cement (RCC) storage tank with impervious wall finished from inside. The external surface of RCC tank should be checked for its integrity. Other solid wastes generated in HWP like spent catalyst from ammonia converter and cracker, spent resins, sodium sulphate, wood from cooling tower etc. should be disposed in a proper safe manner. A standard procedure may be made for solid waste disposal.

The hazardous waste shall be handled as specified in the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.

Disposal of old batteries from battery banks has hazard potential owing to its content. These batteries should be either recycled or disposed off as per statutory requirements like the Batteries (Management and Handling) Rules, 2001 amended in 2010.

12.3.2 Liquid Effluents

Design and operation of the plant envisage maximum amount of conservation of process fluids. In case of ammonia - hydrogen process, the blow down water from the waste heat boilers is mixed with the cooling tower blow down and is pumped to the drain from which the same is taken up for disposal. All the process drains resulting from draining/washing of pump/equipment are drained into a circu-lating water stream leading to an effluent pit, from where ammonia is stripped in a stripper column and ammonia free water joins other effluent streams in an effluent disposal tank. The DM water plant should be designed with self-neutralisation scheme and effluents from this unit are also taken for disposal.

The water in the storm water channels are also collected together with other blow down and sent for final disposal through drain. A system for removal of oil, if any, should also be provided. Liquid effluent generated in potassium metal plant contains fluoride. As the quantity is very small, the generated liquid effluent should be sprayed on RCC tank for solar evaporation. The effluent water is discharged to drain for final disposal to ETP. The provisions made under the Water (Prevention and Control of Pollution) Act, 1974 amended in 1988 and the Water (Prevention and Control of Pollution) Rules, 1975 amended in 2011 shall be strictly adhered to.

12.3.3 Gaseous Emission

The furnaces should be provided with air and fuel control devices by which the gaseous emission from flue gas stack is controlled within authorised limits. The fuel gas should always burn with excess air to achieve complete burning.

The gaseous release from effluent unit stack mainly contains ammonia vapours in ammonia based HWP and hydrogen sulphide gas in the hydrogen sulphide based HWP. The quality of ambient air with respect to pollutants such as NOx, NH_3, and H_2S should be monitored. The provisions made under the Air (Prevention and Control of Pollution) Act, 1981 as amended in 1987 and the Air (Prevention and Control of Pollution) Rules, 1982 shall be strictly adhered to.

12.4 Design Requirement for Gaseous and Liquid Waste Disposal

12.4.1 Liquid Waste Disposal

The liquid effluent system should be designed to take care of following effluents generated from the heavy water plant during operation of the plant:

(a) Cooling tower blow down

(b) Process drains, effluents

(c) Boiler blow down

(d) Sludge cum back wash water from raw water Pre-Treatment Plant (PTP).

The effluent water should be discharged to drain for final disposal to effluent treatment plant (ETP). The samples of effluent water should be analysed at regular interval and quality should be monitored and controlled within permissible limits before discharge from the plant. An on-line pH meter should also be installed to monitor the pH of discharge water. The ETP should be designed so as to meet the norms as stipulated by central/state pollution control board on the limits of various constituents in effluent discharge.

12.4.2 Gaseous Waste Disposal

All processes generating dust and fumes should be provided with exhaust ventilation systems.

The vent system, which comprises of stacks in various sections, should be provided for safe disposal of gaseous effluents in case of plant-upset condition. The height of the stack should be decided considering the effectiveness of dispersion under worst condition. The dispersion of gaseous effluents present in the atmosphere depends upon several parameters such as wind direction, speed, emission modalities, and chemicophysical characteristics of the gaseous effluent. Wind speed has an inverse and linear effect on their concentration at the emission height of effluents. Ratio between release heights compared with that of the surrounding building should be more than 2.5 otherwise turbulence of buildings cause a discharge carryover within the vortex produced by the same buildings. Stacks should be installed alongside the main structure of the plant for the purpose of minimizing length of piping from various sources to these stacks so as to minimize pres-sure drops. Lowest point of all piping leading to all nozzles of stacks should be connected to stacks separately in order to avoid water hammering during sudden venting. Filters, scrubbers or other screening devices should be installed to bring down the airborne contaminants below the discharge norms. The stacks should be continuously purged with steam and/or nitrogen in order to avoid formation of explosive mixtures within the stack volume.

Gaseous effluents released through air route should be continually monitored qualitatively and quantitatively and discharged as per the prescribed limits of central/state pollution control board.

12.5 Zero Discharge

In a waste water treatment facility, zero discharge theoretically means no discharge of any kind of pollutants into the environment. For all practical purposes, the concept of zero discharge necessarily means the following:

(a) Recovery of reusable water/other materials from waste water. The treated liquid effluents should be conveniently and safely used back into the process like; makeup of cooling tower water/process water after treating the effluent by suitable process, irrigation of lands, plants and fields for growing non-edible crops.

(b) Minimisation or, no discharge of polluting substances into the environment away from the waste water treatment facility.

Efforts should be made by HWP to achieve zero discharge and conserve the natural resources.

13. EMERGENCY PREPAREDNESS

13.1 General

Though the heavy water plants are sited, designed, constructed, commissioned and operated as per stringent requirements and regulations; a remote possibility of some equipment failure or operational error, which may result in accidental condition, cannot be ruled out. These emergency situations may result into the release of toxic gas like H_2S/NH_3. These emergency situations may be classified according to the nature and severity of the incident and its consequences, as follows:

(a) Personnel Emergency - Consequences of an abnormal situation are confined to some personnel working in plant, without affecting plant

(b) Plant Emergency Alert - Abnormal condition with a possibility of aggravating to Plant/Site/Off-Site emergency

(c) Plant Emergency - Emergency involving those excessive releases of toxic gases in which consequences are confined within the plant only

(d) Site Emergency - Emergency involving excessive release of toxic gas, in which consequences extend beyond plant premises but are confined to the site

(e) Off-Site Emergency - Emergency involving consequences extended to public domain away from the site.

HWP based on hydrogen sulphide - water exchange process may encounter off-site emergency, owing to the volume of H_2S gas being handled more than the threshold quantity i.e. 5 Te, as specified in the Part-I of Schedule 3 of the ‘Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989’ (MSIHC Rules, 1989).

The objective of the emergency preparedness and response plan is to ensure that arrangements are in place for a timely, managed, controlled, coordinated and effective response at the site to any toxic gas emergency. The site emergency preparedness plan (SEPP) for HWP should be available as per statutory requirements by the ‘Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989’ [Rule-13] as amended in 2000, the Chemical Accident (Emergency Planning, Preparedness and Response) Rules, 1996 and the ‘Atomic Energy (Factories) Rules’, 1996. The site emergency preparedness plan (SEPP) should be prepared as per the AERB safety guidelines on ‘Preparation of On-Site Emergency Preparedness Plans for Non-Nuclear Installations’ (AERB/SG/EP-3). The AERB safety guideline on, ‘Preparation of Off-Site Emergency Preparedness Plans for Non-Nuclear Installations’ (AERB/SG/EP-4) provides guidelines on the requirements for preparation of off-site emergency preparedness plan.

13.2 Documentation of Emergency Plan

Each emergency plan should indicate how its ongoing maintenance and revision would be controlled. These document control procedures should be suitably vigorous so as to ensure that the quality and relevance of the plan is maintained. Any relevant agreement with other agencies or parties regarding emergency preparedness and response should also be referenced in or annexed to the emergency plan. SEPP for a particular HWP in general should include description of the facility and site, organisation and responsibilities, accident scenarios, communication systems, resources available, sequence of action for declaration and termination of emergency, Action plan and public awareness programme. Emergency plans should include provisions to assure that the emergency equipment, facilities or materials remain in acceptable condition at all times. These provisions should also include inspection, testing, maintenance or replacement of emergency equipments, within formal systems of quality control and inventory control and accounting.

13.3 Basis for Emergency Planning

Design basis accidents should be considered while preparing SEPP. Emergency plans for HWP should be based on accidental release scenarios and external events that have or could have adverse impact on the environment and the health and safety of on-site personnel or the public. The plans should also be based on those worst case scenarios assumed in the safety analysis/ quantitative risk assessment report submitted in support of the licensing of the respective facility. The main objective of evolving SEPP is to create a procedure and infrastructure based on the combined resources of factory as well as external services with the view to minimise losses arising out of disastrous situations in plant premises, which may directly affect the employees, property of company and environment. The philosophy in the emergency planning for H_2S based HWP is early warning and sheltering of plant personnel and public.

13.4 Key factors for emergency planning

The site emergency preparedness plan should be prepared as stated above and should be periodically updated to ensure its state of readiness. Following points shall be included in site emergency preparedness plan:

(a) List of key personnel/emergency agencies/resources groups along with their contact telephone numbers should be updated periodically.

(b) The equipment at emergency control centre, which is identified to be used during emergency, should be checked once in a week.

(c) Fire tender and ambulance should be checked at the beginning of every shift.

(d) Emergency siren should be checked once in a week.

(e) Public address (PA) system should be checked once in a fortnight.

(f) Adequate training shall be imparted to plant personnel on emergency preparedness on regular basis.

(g) Emergency drills/exercise should be conducted periodically for checking the effectiveness of plan.

13.5 Emergency Crew

Emergency plans for HWP should ensure that sufficient numbers of qualified personnel are available at all times to maintain the facilities in a safe condition and to respond emergencies effectively. The success of emergency response in handling emergency depends in part on the competence and actions of the persons involved. To be effective, these persons must be adequately qualified through training or experience, must be empowered with the necessary authority, and must be equipped with adequate resources.

13. 6 Emergency Preparedness and Response Organisations

The emergency plans should assign and define formal responsibilities for developing, maintaining and implementing emergency preparedness and emergency response activities. For both the emergency preparedness and emergency response organisations, the plan should clearly describe the qualifications, duties, authorities and accountabilities of the personnel involved and their respective organisational and reporting relationships. These descriptions should include all persons with a significant role; including the emergency response teams involved in rescue, damage control, first aid and fire fighting.

For handling personnel emergency, a well established procedure which includes buddy system, use of breathing air set, rescue and first aid, should be prepared. In case of multi-facility sites, the types of accidents where the external organisations would involve in remedial actions and information about mutual aid scheme between units should be mentioned in the SEPP.

Usually off-site emergency is handled by district authorities with technical input and guidance from the responsible organisation, Crisis Management Group of Department of Atomic Energy (DAE), State Level Emergency Response Committee (SLERC) and National Level Emergency Response Committee (NLERC). The action plan, including individual responsibilities of various organisations in case of off-site emergency, should be prepared by the responsible organisation in liaison with above mentioned organisations.

13.7 Emergency Training and Exercise

The emergency plans should specify the requirements with respect to training and testing of individuals or organizational units necessary to assure and demonstrate that they are qualified and able to completely fulfil their assigned emergency preparedness and response roles. Emergency training may consists of both formal and informal instruction, including workspace and classroom instruction and emergency exercises.

Emergency drills/exercise shall be conducted periodically to:

(a) test effectiveness of communication system,

(b) test the speed of mobilisation of plant emergency team,

(c) test effectiveness of search, rescue and treatment of casualty,

(d) test emergency isolation and shutdown and remedial measures taken on system,

(e) conduct full rehearsal of the action to be taken during the site emergency, and

(f) record the observations during the on-site exercise for improvement and maintenance of emergency equipment and upgrade the plan for handling the emergency both effectively and efficiently.

13.8 Emergency Facilities and Equipment

Emergency plans should describe the services, equipment, supplies and facilities that are to be available in acceptable condition at all times to cope with emergencies. The facilities that could be needed in an emergency include:

(a) administration facilities,

(b) communication system,

(c) monitoring system,

(d) intervention levels for declaring each type of emergency,

(e) technical support and control centers,

(f) personnel/public assembly areas,

(g) emergency shelters at the facility,

(h) an emergency operations coordination centre,

(i) a centre to integrate on-site activities with off-site programs,

(j) first aid or medical facilities,

(k) laboratory facilities,

(l) fire fighting facility, and

(m) clean up and restoration facilities.

The following equipment and materials may also be needed:

(a) An emergency source of electrical power; portable loud speakers and siren etc.

(b) Reference materials such as accurate versions of charts, maps, plans, drawings, diagrams, specifications and procedures

(c) Safety and personnel protective equipment and supplies (e.g. fire fighting, physical and respiratory protection)

(d) Administrative aids such as status boards and reference materials

(e) Fixed or portable instruments or equipment, as required to warn, detect, measure, monitor, survey, analyse, record, assess, process, treat, transport, announce, communicate and compute.

Emergency plans should include provisions for inspection, testing, maintenance or replacement of emergency services, equipment, supplies etc.

13.9 Activation and Termination of Emergency Responses

The emergency plan should describe the procedures for initiating and terminating responses to both on-site and off-site emergencies associated with facility operations.

13.10 Public Information Systems

The emergency plan should include directly or by reference appropriate provisions to communicate pertinent information to the public during an emergency. The plan should also take into account any need for education of the public with respect to the emergencies at the facility and their implications. HWP should effectively implement 'Public Awareness Programme' for local people including contract labours and casual labours to develop the sense of awareness regarding the hazards associated with HWP and emergency procedures helping to mitigate the emergency situations. The awareness programme should include mass education, conducting seminars on regular basis and for effective propagation.

14. TRAINING AND AUTHORISATION/LICENSING

14.1 Training Requirements

The training requirements of plant personnel should be identified. The training objectives and priorities, training needs for different employees, training methods etc. should be established and implemented. The training programme should include training in plant operations, safety procedures, chemicals, industrial and fire safety aspects. Also separate training for all operating personnel in safety, health and environment should be conducted periodically. Training and retraining needs of employees should be identified by their reporting officer and reviewing officer based on performance of the persons while they are on job. Plant officers should also be regularly deputed for specialized training programs to various institutions/workshops/symposium/ seminar for updating their technical and management knowledge. Refresher lecture program for re-training of the plant personnel should also be conducted periodically.

14.2 Authorisation/Licensing Requirements

The operating personnel of the HWP should be authorised initially before deployment in the operation of plant and subsequently on regular intervals, to ensure operating staff is fully conversant with the operating procedures, safety procedures and changes incorporated with respect to system, procedure etc. The training program for operating personnel should cover general and on-the job training specific to job. An authorisation scheme and document approved by AERB should be implemented for operating personnel. The scheme should envisage training of individuals in basics, safety, design details of operating units, operating procedures/instructions etc. The technical expertise and competence of the operating personnel to carry out plant specific operation should be assessed by conducting checklist test, written examination, interview and plant walk-through test as per approved authorisation document for operating personnel of HWP. Final assessment should be through an interview by an AERB authorisation committee for officers and Plant authorisation committee for field operators. Subject to scoring passing marks in final interview conducted by the appropriate authorisation committee, the operating personnel are authorized to work in the specified position. The safety procedures should also be included in the syllabus of the authorization scheme.

15. DECOMMISSIONING

Decommissioning is the process by which a facility is finally taken out of operation in a manner that ensures safety of the workers, public and the environment. Decommissioning of the HWP should be done either at the end of the plant life or when the plant is no longer safe and economical to continue the operation.

Before the start of decommissioning, a decommissioning plan including hazard identification, job hazard analysis and mitigation measures should be prepared and got approved by the regulatory body and the facility should be first rendered to a state that it will no longer cause any concern regarding release of toxic/flammable material to the environment. The decommissioning plan should be prepared to take care of any abnormal conditions.

Decommissioning involves dismantling, decontamination, cutting and packing, transportation and handling of equipment/material, storage and disposal.

During decommissioning care should be taken to minimise the exposure to decommissioning staff and public. Decommissioning should be done in such a way that maximum material will be recovered for reuse. It also involves disposal of left over operating fluids, chemicals and materials in safe manner.

All necessary utilities such as ventilation system, electric power supply, compressed air system, waste handling and treatment system, fire fighting system, service water system, mechanical handling equipment, monitoring system should be available during decommissioning.

Prior to decommissioning, decommissioning procedure should be developed for disposal of hazardous inventories and dismantling of plant.

APPENDIX-1

(Refer Sections 2.1, 5.3, 6.1, 7.1)

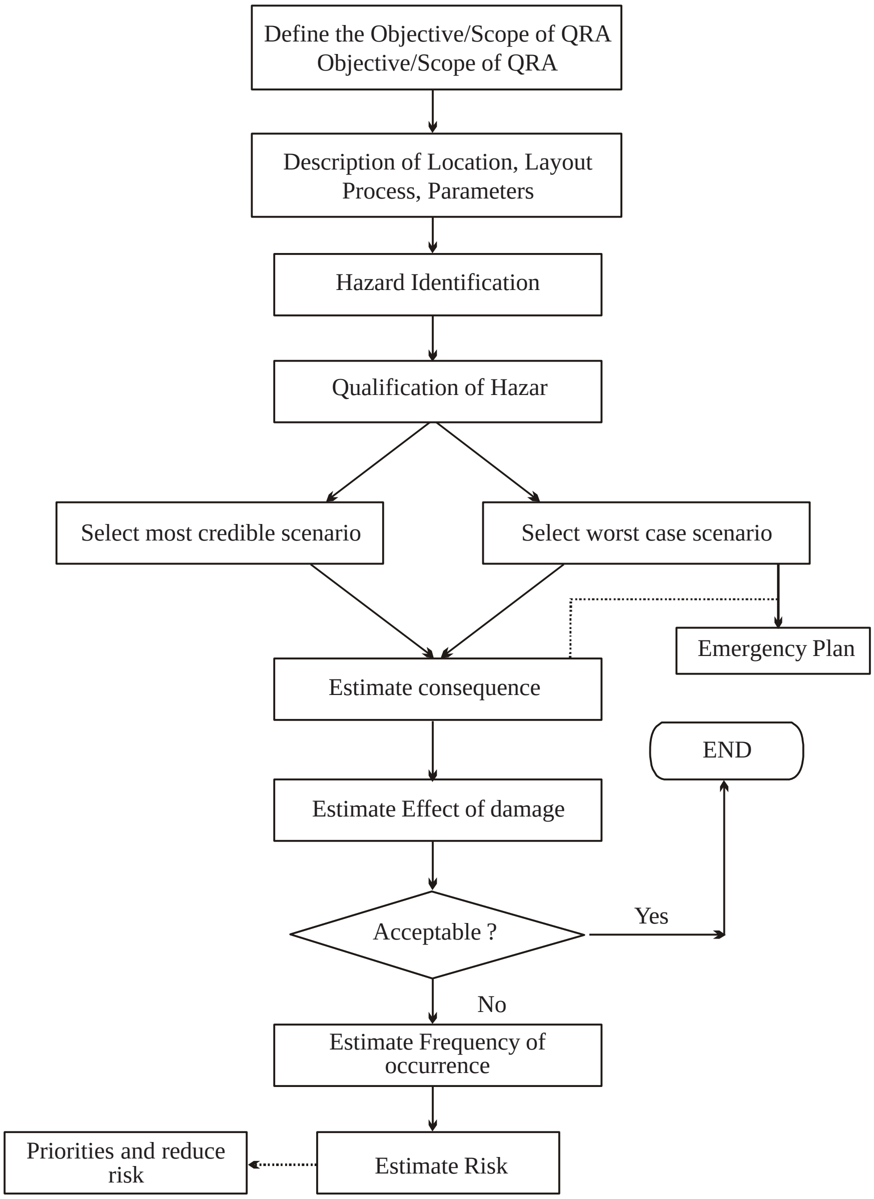
SUBMISSION OF DOCUMENTS FOR VARIOUS CONSENTING STAGES

S. No.	Consenting stages for regulatory clearance	Reports to be submitted to AERB
1.	Siting	(a) Site evaluation report (b) Siting layout (c) Executive summary of environmental impact assessment report
2.	Construction	(a) Safety report (preliminary safety analysis report) (b) Design basis report (c) Job hazard analysis report (d) QA manual for construction (e) Preliminary fire hazard analysis report
3.	Commissioning	(a) Commissioning schedule (b) Site emergency preparedness plan (c) Fire hazard analysis report (d) HAZOP report (e) Quantitative risk assessment report (f) Technical specifications (g) Document on licensing operating personnel
4.	Operation	(a) QA manual for operation (b) Commissioning tests and results (c) Technical specifications for operation (d) Operation and maintenance manual (e) Training manual (f) Manual on security system (g) Quantitative risk assessment report (h) Revised safety report/final safety analysis report (i) Documents specified in sub-rule (3.2) of the Atomic Energy (Factories) Rules, 1996

ANNEXURE-I

(Refer Section 4.11)

QRA FLOW SHEET



ANNEXURE - II

(Refer Section 10.3)

TYPICAL MEDICAL MANAGEMENT OF HYDROGEN SULPHIDE/ AMMONIA EXPOSURE

II.1.0 Medical Control Methods

Medical control measures are an important part of the health and safety programme. An effective medical programme will help to prevent occupational disease and can also serve as a check on the engineering controls.

II.1.1 Medical Treatment

The acute and sub-acute poisoning cases demand immediate attention from the medical unit and the first-aid team in a plant handling hydrogen sulphide.

First-aid treatment is required for acute exposures in most cases in the form of giving artificial respiration and cardiac massage. Artificial resuscitation units or Ambu bags' (with air cylinders) should be provided in all the potentially dangerous areas and trained persons should use these if need arises. Mouth-to-mouth respiration should not be given to the victims of H_2S inhalation; there is a possibility of the rescuer getting affected by the inhaled H_2S. Occasionally fractures and other injuries, which occur because of falls due to inhalation of the gas, will be encountered.

The general lines of medical treatment are given below for information. The details of the treatment and actual execution of the same should be left to a medical doctor.

II.1.1.1 Acute Poisoning

In case of acute poisoning, the person will generally be unconscious and will not be breathing. The rescuer should wear an air-pack and bring person to an uncontaminated area.

Amyl nitrite should be given to the victim for inhalation by crushing the ampule in front of the nostrils of the victim. Artificial respiration should be simultaneously started with oxygen mask. Amyl nitrite inhalation can be repeated every five minutes for twenty minutes.

The first aid centre should maintain stock of drugs like coramine etc. which could be needed to be injected in victim's body by authorized medical doctors.

If carotid pulse is not felt, cardiac massage should be given. In case of cessation of breathing coupled with cardiac failure as indicated by absence of carotid pulse, cardio-pulmonary resuscitation (CPR) should be resorted to. The victim should be immediately shifted to hospital for further treatment.

II.1.1.2 Sub-acute Poisoning

The contaminated clothing should be removed. Any hydrogen sulphide that has fallen into the eyes should be removed. Similarly hydrogen sulphide that has fallen on other parts of the body be removed with copious amount of water. Steroid eye drops should be put to the eyes. Steroid ointment should be applied on the portion of skin affected by hydrogen sulphide. In case of breathing difficulties, artificial respiration should be started.

II.2.0 Medical Management of Ammonia Exposure

Considering the nature of ammonia, and the immediate effects of exposure to high concentrations, each plant handling ammonia should have a well-organised medical facility and a number of first-aid posts depending on the size of the plant.

The periodic medical examination in an ammonia facility should be similar to the one done for pre-employment stage, but should look into details about possible effects on general health, neurosis, eye-disorders and lung impairment

II.2.1 Pathophysiology

The tissue effects of anhydrous ammonia are due to one or both of two mechanisms: (1) the freeze-dry effect and (2) the caustic effect. Released super cooled ammonia liquid vapour freezes and desiccates tissue that it contacts, causing tissue destruction similar to frostbite.

Ammonia is easily dissolved in water, forming strongly alkaline solution that causes extensive tissue destruction due to its corrosive nature. Unlike acids that coagulate tissues, alkalis produce liquefaction that allows greater penetration, thereby increasing damage.

Anhydrous ammonia victims primarily have lesions of the eyes, respiratory tract, skin, and gastrointestinal tract to degrees depending upon the mechanism, concentration, and length of exposure.

II.2.2 Pre-Hospital Phase

The primary four duties of those at the scene of an ammonia leak are evacuation, decontamination, first aid, and alert, the order depending upon the prevailing circumstances.

II.2.2.1 Evacuation

If respiratory equipment is available, it should be donned immediately. If not, one should breathe as little as possible, open eyes as little as possible, and remain close to the floor or ground while escaping, preferably upwind. A wet cloth, if available, over the mouth can provide some protection.

II.2.2.2 Decontamination

Beginning with the eyes, decontamination must be started immediately. Speed is essential and the eyes and skin should be flushed with copious amount of water for at least fifteen minutes. Eyelids must be opened while a constant stream of water flushes out ammonia. Flushing the eyes with water will not damage the eyes any more than already done and there are no effective antidotes. Contaminated clothing must be removed, although weather conditions may make this difficult. The mouth should also be rinsed. Salves and creams must not be used under any circumstances and the victim should be removed to fresh air. In extensive exposures, one must be aggressive with decontamination: the ears should be rinsed, skin rolls opened and irrigated, the arm-pit (axilla) and groin irrigated and the under-chin carefully rinsed.

II.2.3 First Aid

Cardio pulmonary resuscitation (CPR) should be initiated immediately at the signs of cardiac or respiratory arrest and can be started along with evacuation or decontamination. Control of bleeding and treatment of shock should begin immediately.

II.2.4 Emergency Medical Department (EMD) Care

The EMD care will be divided into the four main exposure areas (respiratory, ocular, skin and gastro-intestinal) with the understanding that in reality an integrated approach is advised.

II.2.4.1 Respiratory

Burns of the respiratory tract account for most acute problems in ammonia emergencies. Animal studies and human autopsies have documented a progression of changes: (1) initial pulmonary congestion, haemorrhage, oedema, etc., (2) late bronchitis, early bronchopneumonia, a blistering condition of air vesicles (interstitial emphysema and bullous emphysema), and (3) long-term obstructive and constructive pulmonary disease.

By clinical presentation and subsequent course of treatment, respiratory effects due to exposure to ammonia are categorised into mild, moderate, and severe as explained below.

II.2.4.1.1 Mild Group

Patients falling in this group show mild catarrhal (discharging of fluid from inflammation of a mucous membrane especially of nose) symptoms including stinging in the eyes and mouth, pain on swallowing, and tightness of the throat. Vital signs in these patients are normal and the physical examination is normal with the exception of conjunctival and mucosal erythema.

The EMD must assure that these patients have been decontaminated, have received tetanus prophylaxis, and that there are no corneal lesions. The patient's smoking history should be recorded to help document pulmonary health status. In the elderly and very young, a chest x-ray and blood gases may be helpful in making a decision, but generally people in the mild group have reportedly been sent home.

II.2.4.1.2 Moderate Group

These patients report burning of eyes, mouth and throat, with tightness of the chest, hoarseness, and difficulty in swallowing. Vital signs in this group will be variable, either normal or abnormal. Physical examination reveals blood stained sputum (hemoptysis), conjunctivitis, swollen eyelids, mucous membrane damage and evidence of pulmonary oedema.

In this group the EMD must assure that these patients have been decontaminated, received tetanus prophylaxis, and have a stable respiratory status. Blood gases, radiography and spirometry may be helpful in this regard. The eyes need to be carefully examined and measurement of eye-tension (tonometry) may .be indicated. Burns are treated as chemical burns and these patients are usually admitted for observation.

II.2.4.1.3 Severe Group

These patients are either unconscious or in extreme pain. Their vital signs will be unstable and abnormal and physical examination will reveal shock, pulmonary oedema, and respiratory distress with corneal and skin burns.

These patients are in respiratory distress and an airway must be assured. Endotracheal insertion of tube (intubation) may be impossible due to oedema or tissue destruction so opening into the windpipe through the neck (tracheostomy) may be necessary.

These patients usually have severe chemical burns requiring aggressive fluid replacement and skin care. The pulmonary oedema and respiratory failure experienced by these patients may present as an adult respiratory distress syndrome (ARDS) requiring aggressive treatment for this.

II.2.4.2 Ocular Lesions

Moderate concentration or brief exposure may produce a stinging sensation with lacrimation, photophobia and conjunctival hyperemia. More extreme exposure to gases or direct sprays may produce a dull looking cornea with spasmodic twitching of the eyelids (blephorospasm) and severe pain. Increasingly severe exposure will present with corneal anaesthesia due to destruction of the corneal nerves. If haemorrhage has taken place, there may be a beefy red appearance; otherwise, there may be a pale cooked appearance if thrombosis occurred without haemorrhage.

A direct spray may result in a semi-dilated, oval, non-reacting pupil simulating angle-closure glaucoma and, with any degree of injury; there may be an elevation of the ocular pressure to oedema.

II.2.4.2.1 Treatment

Aggressive decontamination with copious amounts of normal saline is of utmost importance. The application of 0.5% proparacaine or similar ophthalmic anaesthetic may eliminate blephorospasm and allow the eyelids to be retracted.

Use of cycloplegic such as 0.2% scopolamine or atropine is recommended. Intraocular pressure should be measured and, if elevated, acetazolamide 500 mg every twelve hours is recommended in all but mild exposures.

II.2.4.3 Skin Lesions

Ammonia skin burns vary from a mild erythemic irritant rash to full thickness burns with areas of blisters (bullae) and peeling of skin (denudation). The burn areas themselves most commonly appear as grey-yellow area with a soft texture. More extensive wounds appear black and have a leathery consistency and there may be areas of blisters.

Ammonia spray is freezing cold and frostbite is a concern. Clothing may be frozen to skin and injudicious removal may lead to the destruction of whole slabs of flesh.

Cases of nettle-rash (urticaria) following exposure to ammonia fumes have been reported.

II.2.4.3.1 Treatment

After decontamination, the wounds should be left open to the air, with more extensive ones covered only with saline-soaked gauze. Creams or ointments are not recommended under any circumstances in any degree of injury as they lock in the residual ammonia causing extension of liquefaction.

II.2.4.4 Gastrointestinal Lesions

Acute burns of the GI tract resemble those found in the respiratory tract with liquefaction necrosis and sloughing of mucosa seen in heavy exposures.

In children, lesions are commonly limited to the pharynx and upper oesophagus because the material, usually aqua ammonia, is commonly spit out. Consequently, oesophageal and antral strictures are less commonly seen with ammonia as compared to other caustics. In industry and agriculture, lesions are ordinarily limited to the mouth as the mechanism of injury is usually a direct spray.

In adults who have taken ammonia in suicide attempts, tissue destruction is more extensive. Cases have been reported where the ammonia has destroyed the oesophagus and caused extensive mediastinal and thoracic injury. Oesophageal replacement has been utilised in several of these cases.

Visible lesions will appear in the oral mucosa, pharynx, and tongue with a spectrum of damage from mild hyperaemia to frank tissue destruction and intense swelling.

II.2.4.4.1 Treatment

Rapid dilution with water may prevent extensive burns. Vomiting is to be discouraged. Early endoscopy and aggressive treatment for oesophageal burns including steroids, antibiotics, and intravenous fluids until the patient can swallow saliva are recommended. Careful observation and chest radiographs are recommended to rule out oesophageal leakage into the mediastinum.

II.2.5 Hospital Care

In severely injured patients all studies have stressed the need for a multidisciplinary approach involving internists, plastic surgeons, intensivists, ophthalmologists, and pulmonary specialists. The need for continuous monitoring and care needed for severely injured patients mandates that care be provided by intensive care, trauma or burn units.

II.2.6 Long-Term Complications

Prolonged heavy exposure may result in bronchospasm, anxiety neurosis, residual inflammation and chronic obstructive pulmonary disease. It was reported that corneal opacities, small airway obstruction and vocal cord injury were observed in a few prolonged heavy exposure cases. Various reports on ammonia exposure cases concluded that long-term disability was mainly due to corneal and respiratory injuries; in-patients with severe injury there was a picture of chronic obstructive pulmonary disease of varying degrees with bronchitic changes as well as cataracts and corneal opacities. Intermittent antibiotics, cessation of smoking, steroids and bronchodilators achieved satisfactory improvements in most cases.

(Source: Minutes of Advisory Committee on Occupational Health, AERB, meeting no. 29 and with concurrence from Certifying Surgeon, HWP – Baroda)

ANNEXURE- III

IMPORTANT ACTS AND RULES

1. The Factories Act, 1948
2. The Atomic Energy (Factories) Rules, 1996
3. The Environmental (Protection) Act, 1986
4. The Environmental (Protection) Rules,1986
5. The Water (Prevention & Control of Pollution) Act, 1974
6. The Water (Prevention & Control of Pollution) Rules, 1975
7. The Water (Prevention & Control of Pollution) Cess Act, 1977
8. The Water (Prevention & Control of Pollution) Cess Rules, 1978
9. The Air (Prevention & Control of Pollution) Act, 1981
10. The Air (Prevention & Control of Pollution) Rules, 1982
11. The Electricity Act, 2003
12. The Indian Electricity Rules, 1956 and Latest amendments.
13. The Indian Boilers Act, 1923
14. The Indian Boiler Regulations, 1956
15. The Indian Explosives Act, 1884 & The Explosives Rules,1983
16. Static and Mobile Pressure Vessels (unfired) Rules, 1981.
17. The Petroleum Act, 1934 and Petroleum Rules, 2002.
18. The Gas Cylinder Rules, 2004.
19. Manufacture, Storage and Import of Hazardous Chemicals Rules -1989 and Latest amendments
20. The Chemical Accident (Emergency Planning, Preparedness and Response) Rules, 1996
21. The Hazardous Wastes (Management, Handling and Trans-boundary Movement) Amendment Rules, 2000
22. The Public Liability Insurance Act, 1991
23. The Public Liability Insurance Rules, 1991

24. The Noise Pollution (Regulation and Control) Rules, 2000
25. Ozone Depleting Substances (Regulation and Control) Rules, 2000
26. The Energy Conservation Act, 2001
27. Bio-Medical Waste (Management & Handling) Rules, 1998
28. The Central Motor Vehicles Act,1986 & The Central Motor Vehicles Rules, 1989

ANNEXURE-IV

(Refer Sections 4.2, 4.3, 4.6, 4.7, 4.9)

LIST OF ABBREVIATIONS OF IMPORTANT CODES AND STANDARDS

S. No.	Abbreviation	Details
1.	ANSI	American National Standard Institute
2.	API	American Petroleum Institute
3.	ASME	The American Society of Mechanical Engineers
4.	AWWA	American Water Works Association
5.	MSS	Manufactures Standardisation Society of the valves and fittings
6.	BSI	British Standard Institution
7.	ISI	Indian Standard Institution
8.	DIN	Deutsches Information S Zemtrun Fur Technische Regelnim
9.	IEC	International Electrotechnical Commission
10.	TEMA	Tubular Exchanger Manufacturers Association

LIST OF TYPICAL CODES AND STANDARDS USED FOR ELECTRICAL SYSTEMS

S. No.	Standard Number	Description
1.	IEC 298 & IEC 529	Degree of Protection
2.	IEC 529	Degrees of Protection Provided by enclosures (IP Code)
3.	IEC 414	Safety Requirements for Indicating and Recording Electrical Measuring Instruments and their Accessories
4.	IEC 79	Electrical Apparatus for Explosive Gas Atmosphere
5.	IS : 5571 - 1979	Guide for Selection of Electrical Equipment for Hazardous Areas (first revision)
6.	IS : 5572 - 1994	Classification of Hazardous Areas (other than mines) having Flammable Gases and Vapours for Electrical Installation (second revision)

7.	IS 3202	Code of Practice for Climate-Proofing of Electrical Equipment
8.	IS 3231 (Parts 1 to 3)	Electrical Relays for Power System Protection
9.	IS 8320	General Requirements and Methods of Tests for Lead Acid Storage Batteries
10.	IS 4029	Guide for Testing of 3 Phase Induction Motors
11.	IS 12065	Permissible Limits of Noise Level for Rotating Electrical Machines
12.	IS 2148	Specification for Flameproof Enclosures of Electrical Apparatus
13.	IS 2206 (Part- I&II)	Specification for Flameproof Electric Lighting Fittings
14.	IS 2189	Code of Practice for Installation of Automatic Fire Alarm System Using Heat Sensitive Type Fire Detectors
15.	IS 2147	Degree of Protection Provided by Enclosures for Low Voltage Switchgear and Control Gear
16.	IS 3043	Code for Practice for Earthing
17.	IS 2309	Protection of Building and Allied Structures Against Lightning - Code of Practice

LIST OF TYPICAL CODES AND STANDARDS USED FOR MECHANICAL EQUIPMENT

S. No.	Standard Number	Description
1.	ASME Sec. VIII Div. 1 & Div. 2	For Pressure Vessels, Columns and Heat Exchangers
2.	ASME Sec. V	For Non Destructive Welding
3.	ASME Section XI Clause No IWB - 2420	Inspection Program
4.	ANSI B 31.3	Chemical Plant and Petroleum Refinery Piping
5.	API RP 520, Pt-I, Pt-II	Sizing and Selection of Pressure Relieving Devices in Refineries
6.	API RP 521	Guide for Installation Pressure Relieving and Depressurising Systems

7.	API 610	Canned Motor Pumps
8.	API 618	Standard for Reciprocating Compressors
9.	API 579	Standard Methods to Check Fitness for Service
10.	API 614	General Purpose Lube Oil System Components for Rotating Process Equipment
11.	API 675	Standard for Reciprocating Displacement Pumps
12.	TEMA (Class C)	Specifications for Exchangers in General Services
13.	TEMA (Class B)	Specifications for Exchangers in Chemical Services
14.	TEMA (Class R)	Specifications for Exchangers in Refinery Services
15.	ASTM - A370	Standard Methods and Definitions for Mechanical Testing of Steel Products
16.	IS 15656:2006	Code of Practice - Hazard Identification and Risk Analysis
17.	IS 875	For Wind Load Calculation
18.	IS 1893	For Seismic Design Consideration

LIST OF TYPICAL CODES AND STANDARDS USED FOR INSTRUMENTATION SYSTEMS

S. No.	Standard Number	Description
1.	ASTM	Material for Control Valves and Instruments
2.	IEC 61508	Functional Safety of Electrical/Electronic/ Programmable Electronic Safety Related Systems
3.	IEC 61000	Electromagnetic Compatibility for Industrial Process Measurement and Control Equipment
4.	IEC 60902	Industrial Process Measurement and Control terms and definitions
5.	ISA 5.X	Instrument Symbols on P&ID
6.	IEC 61508	Functional Safety of Electrical/Electronic Safety Related System
7.	IEC 61131	Programmable Logic Controller
8.	API RP 551	Process Measurement Instruments
9.	BS 5308	Instrument Cables

LIST OF TYPICAL CODES AND STANDARDS USED FOR CIVIL STRUCTURES

S. No.	Standard Number	Description
1.	IS : 1893 - 1975	Code for Earthquake Resistant Design of Structures
2.	IS : 875 - 1964	Code for Practice for Structural Safety of Building Loading Standards
3.	IS : 800	Code for Practice for Use of Structural Steel in General Building Construction
4.	IS : 226/IS : 2062	Steel Grade for General Purpose
5.	IS : 456	Code for Practice for Plain and Reinforcement Cement Concrete
6.	IS 8089 - 1976	Code of Safe Practice for Layout of Outside Facilities in an Industrial Plant

LIST OF TYPICAL CODES AND STANDARDS USED FOR GENERAL USE

S. No.	Standard Number	Description
1.	IS 2490:1985	Tolerance Limits for Industrial Effluents

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2. ATOMIC ENERGY REGULATORY BOARD, Standard for Fire Protection Systems of Nuclear Facilities, AERB Safety Standard No. AERB/NF/SS/FPS (Rev.1), Mumbai, India, 2010.

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LIST OF PARTICIPANTS

WORKING GROUP FOR PREPARING THE DRAFT DOCUMENT

Dates of meeting:	January 24, 2008	January 27, 2010
	February 12, 2010	March 10, 2010
	June 9, 2010	July 16, 2010
	August 12, 2010	September 16, 2010
	October 5 & 29, 2010	November 12, 2010
	January 13, 2011	July 5, 8 &18, 2011

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Shri K.T. Shenoy	:	BARC
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HEAVY WATER PLANTS SAFETY COMMITTEE (HWPSC)

Date of meeting:	March 26, 2012

Members of HWPSC:

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Shri S.K. Munshi	:	BARC (Former)
Dr. (Smt.) Sadhana Mohan	:	BARC
Shri R.D. Patel	:	HWB
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CONSISTENCY CHECKS (JUNE 2012 - SEPTEMBER 2014)

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ADVISORY COMMITTEE ON SAFETY DOCUMENTS RELATED TO FUEL CYCLE FACILITIES OTHER THAN NUCLEAR REACTORS (ACSDFCF)

Dates of meeting:	February 22, 2013 April 4 & 5, 2013 August 26, 2013 December 19 & 20, 2013

Members of ACSD-FCF:

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Shri H. K. Kulkarni (Invitee)	:	AERB
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PROVISIONAL LIST OF REGULATORY DOCUMENTS RELATED TO HEAVY WATER PLANTS AND INDUSTRIAL SAFETY

S. No.	AERB Document No.	Title
1.	AERB/NF/SS/FPS (Rev.1); 2010	Standard for Fire Protection Systems of Nuclear Facilities
2.	AERB/HWP/SG-1	Safety Aspects in Design and Operation of Heavy Water Plants
3.	AERB/HWP/SG-2	Life Management of Heavy Water Plants
4.	AERB/NRF/SG/IS-1 (Rev. 1); 2011	Control of Works
5.	AERB/SG/IS-2; 2001	Preparation of Safety Report of Industrial Plants other than Nuclear Power Plants in the Department of Atomic Energy
6.	AERB/SG/IS-3; 2004	Guidelines for Personal Protective Equipment
7.	AERB/SG/IS-4; 2005	Guidelines for Pre-employment Medical Examination and Fitness for Special Assignments
8.	AERB/SG/EP-3; 2000	Preparation of On-site Emergency Preparedness Plans for Non-nuclear Installations
9.	AERB/SG/EP-4; 2000	Preparation of Off-site Emergency Preparedness Plans for Non-nuclear Installations
10.	AERB/SM/IS-1; 1991	Safety Manual on Data Base Management for Accidents/Diseases Happening due to Occupation and Implementation of the same in the Department of Atomic Energy

AERB SAFETY GUIDELINES NO. AERB/HWP/SG-1

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