GUIDELINES NO. AERB/FE-FCF/SG-3

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GOVERNMENT OF INDIA

AERB SAFETY GUIDELINES

URANIUM OXIDE FUEL FABRICATION FACILITIES

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDELINES NO. AERB/FE-FCF/SG-3

URANIUM OXIDE FUEL FABRICATION FACILITIES

Atomic Energy Regulatory Board
Mumbai-400 094
India

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Order for this guidelines should be addressed to:

The Administrative Officer
Atomic Energy Regulatory Board
Niyamak Bhavan
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India

FOREWORD

Activities concerning establishment and recognized 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 has, therefore, undertaken a programme of developing safety standards, codes of practice and related guides, guidelines and manuals for the purpose. While some of the documents cover aspects such as siting, design, construction, operation, quality assurance, decommissioning of the nuclear and radiation facilities, other documents cover the regulatory aspects of these facilities.

Safety codes and standards are formulated on the basis of nationally and internationally accepted safety criteria for design, construction and operation of specific equipment, structures, systems 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 and guidelines 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 the experience and feedback from users as well as new developments in the field.

These guidelines provide guidance for ensuring safety in site selection, design, construction, commissioning, operation, maintenance, waste management and decommissioning of the plants. This document addresses administrative, legal and regulatory framework, radiological monitoring, occupational health aspects and emergency plan for uranium oxide fuel fabrication 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. Appendix is an integral part of the document, whereas bibliography is included to provide further information on the subject that might be helpful to the user. Approaches for implementation, different to those set out in the guidelines may be acceptable, if they provide comparable assurance against undue risk to the health and safety of the occupational workers and the general public, and protection of the environment.

For aspects not covered in this document, applicable national and international standards, codes and guidelines acceptable to AERB should be followed. 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 document applies only to uranium oxide fuel fabrication facilities built after the issue of the document. However, during periodic safety review, a review for applicability of the current guidelines for existing facilities would be performed.

The document has been prepared by specialists in the field drawn from Atomic Energy Regulatory Board, Bhaba Atomic Research Centre, Nuclear Fuel Complex and Heavy Water Board. Experts have reviewed the guidelines and Advisory Committee on Safety Documents relating to Fuel Cycle Facilities other than Nuclear Reactors (ACSDFCF) have vetted it before issue.

AERB wishes to thank all individuals and organisations, who have prepared and reviewed the document and helped in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.

(S. K. Sharma)
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.

Accident conditions

Substantial deviations from operational states, which could lead to release of unacceptable quantities of radioactive materials. They are more severe than anticipated operational occurrences and include design basis accidents as well as beyond design basis accidents.

ALARA

An acronym for 'As Low As Reasonably Achievable'. A concept meaning that the design and use of sources, and the practices associated therewith, should be such as to ensure that exposures are kept as low as reasonably practicable, with economic and social factors taken into account.

Annual Limit on Intake (ALI)

The intake by inhalation, ingestion or through the skin of a given radionuclide in a year by the reference man, which would result in a committed dose equal to the relevant dose limit. The ALI is expressed in units of activity.

Approval

A type of regulatory consent issued by the regulatory body to a proposal.

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.

Commissioning

The process during which structures, systems and components of a nuclear or radiation facility, on being constructed, are made functional and verified in accordance with design specifications and found to have met the performance criteria.

Competent Authority

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

Construction

The process of manufacturing, testing and assembling the components of a nuclear or radiation facility, the erection of civil works and structures, the installation of components and equipment and the performance of associated tests.

Critical Pathway

The dominant environmental pathway through which members of the critical group are exposed to radiation.

Derived Air Concentration (DAC)

That activity concentration of the radionuclide in air (Bq/m^3) which, if breathed by reference man for a working year of 2000 h under conditions of light physical activity (breathing rate of 1.2 m^3/h), would result in an inhalation of one ALI, or the concentration, which for 2000 h of air immersion, would lead to irradiation of any organ or tissue to the appropriate annual dose limit.

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 radioactive material is postulated.

Fire Detector

Devices designed to automatically detect and indicate the presence of fire.

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.

Items Important to Safety

The items which comprise:

- Those structures, systems, equipment and components whose malfunction or failure could lead to undue radiological consequences at plant site or off-site;
- Those structures, systems, equipment and components which prevent anticipated operational occurrences from leading to accident conditions;
- Those features which are provided to mitigate the consequences of malfunction or failure of structures, systems, equipment or components.

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.

Technical Specifications for Operation

A document approved by the regulatory body, covering the operational limits and conditions, surveillance and administrative control requirements for safe operation of the nuclear or radiation facility. It is also called as 'operational limits and conditions'.

Worker

Any person who works, whether full-time, part-time or temporarily, for an employer and who has recognised rights and duties in relation to occupational radiation protection. (A self-employed person is regarded as having the duties of both an employer and worker).

SPECIAL DEFINITIONS

(Specific to 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 working lifetime without adverse effect.

CONTENTS

1. INTRODUCTION

1.1 General

This 'Guidelines' on 'Uranium Oxide Fuel Fabrication Facilities' is prepared under the programme of Atomic Energy Regulatory Board in publishing safety codes and guides/guidelines for various facilities of nuclear industry.

Proper design and fabrication of nuclear fuel is one of the important steps in safe and efficient operation of nuclear power plants. Uranium isotopes undergo fission in nuclear reactors releasing large amounts of energy. Uranium oxide has high melting point, good chemical stability and fission product retention, excellent irradiation stability and excellent compatibility with cladding materials and hence is the preferred form for use as fuel in most of the water-cooled nuclear reactors.

The document outlines radiological, industrial and environmental hazards and various aspects of monitoring and controls during uranium oxide fuel fabrication.

1.2 Objective

The major objectives of the document are:

(i) To create among members of the public and occupational workers awareness regarding radiological, industrial and environmental hazards associated with uranium oxide fuel fabrication.

(ii) To lay down safety procedures and methods to be followed at various stages of design, construction, operation and decommissioning with an overall objective of protecting workers, public and environment from radiological and industrial hazards associated with these operations.

(iii) To emphasise the need for adopting appropriate monitoring and control techniques by the plant authorities.

1.3 Scope

The document deals with safety aspects related to uranium fuel fabrication facilities. It describes the siting, design, construction, commissioning, operation, maintenance, modifications, decommissioning and emergency preparedness aspects of the facility. Operational safety requirements are mentioned in detail. Maintenance and modification procedures are suggested for the effective functioning and trouble free operation of the plant.

Radiological safety aspects to be considered during natural uranium fuel fabrication to minimise the exposure to the employees and public are described along with monitoring programme and control measures for the same.

The guidelines also explain the monitoring programme in brief for occupational hazards of the employees working in uranium fuel fabrication facilities.

Industrial safety requirements to be followed in the natural uranium fuel fabrication are included in detail to reduce the hazards and their consequences.

Management of gaseous emissions, liquid effluent and solid waste generated during natural uranium fuel fabrication are also discussed. Safety measures to be taken during commissioning and decommissioning are explained in detail in the guidelines.

Methodology to control an emergency situation arising out of any abnormal condition is also included in the guidelines.

Safety requirements to be followed during production of cladding material are also discussed.

2. SITE SELECTION

2.1 General

The consent for siting involves the 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) 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) may be referred. Site evaluation report (SER) forms the main document for review by the Regulatory Body in respect of siting clearance.

2.2 Salient Features of the Proposed Site

The site evaluation report should cover all items under the following broad categories:

2.2.1 Geography, Demography and Topography

(i) The site and its location should be described with the aid of maps of suitable scale. The present and foreseeable uses of surrounding area should be described. Data on food/milk production and on dietary habits of people in the area should be compiled, with special attention to food processing or any other sensitive industry.

(ii) Existing or planned industrial and public facilities in the neighborhood (5-10 km depending on the hazardous nature of the facility), such as roads, railways, waterways, transport of dangerous goods, chemical plants, military installations, gas pipelines, airports, archaeological monuments and places of pilgrimage, including anticipated changes in their utilisation and distance from the proposed facility should be described in such a way as to facilitate the evaluation of the risks which they may pose to the nuclear facility and vice versa.

(iii) The current and the projected population of permanent residents in the surrounding area should be tabulated as a function of distance and direction, in such a way as to demonstrate the feasibility of emergency plans to protect the population against the accidental release of radioactivity. Similar information should also be given for transient and seasonal population.

(iv) Access to the site should be discussed, where it may influence outside intervention in case of emergency, ease of evacuation of personnel or members of the public, or hazards associated with the shipment of fuels or radioactive waste. The topography of the surrounding area and the site should be described.

2.2.2 Meteorology

(i) Meteorological conditions having an influence on the consequences of normal and accidental releases of radioactive/hazardous materials should be described and discussed.

(ii) The frequency of occurrence and possible consequences of extreme meteorological conditions, such as cyclones and heavy precipitation, should be discussed.

(iii) The information should include the distribution of wind velocity and direction and atmospheric stability conditions. Annual/ monthly average data on temperature, humidity and rainfall should be included.

(iv) The effect which meteorological considerations have in establishing design bases and operating conditions for the plant should be shown.

2.2.3 Hydrology

(i) 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.

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

(iii) Where applicable, the effect of natural phenomena such as tidal effects, floods and coastal cyclones should be evaluated. The consequences of failure of installations such as dams (upstream or downstream) should also be evaluated.

2.2.4 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 subsurface material, and stability of slopes and embankments. Such features as geological anomalies and underground workings should be identified.

2.3 Site Characteristics Affecting Safety

2.3.1 Seismicity

(i) Information concerning the seismicity of the site and its surrounding area, and the method followed for establishing the design basis vibratory ground motions, should be discussed and the data given.

(ii) This information should include a description of the behavior of the ground during tremors in the past, a seismic history of the area, an indication and evaluation of the active faults within a significant radius, and data on the seismic tectonics of the site.

2.4 General Description of the Plant Covering Basic Design Features

The information on general description of plant covering basic design features such as:

(a) overall safety approach,

(b) codes and standards applicable to the design, and

(c) safety provisions under of mal-operating conditions such as red oil formation and explosion.

needs to be submitted along with site evaluation report (SER).

2.5 Nuclear Security

Information on nuclear security aspects such as:

(a) impact of site and surroundings on nuclear security, and

(b) physical protection system, physical barrier, communication, etc.

needs to be submitted along with SER.

2.6 Interaction of the Facility with its Environment

2.6.1 Radiological and Chemical Impact

(i) All necessary ecological data from the site and its surrounding area, that are important for review and assessment of the radiological/ environmental impact of the nuclear facility, such as biological systems and critical pathways, should be presented.

(ii) In case such data still needs to be generated, program for the generation of the same may be given. In the mean time, conservative assumptions/ approaches could be used with respect to the radiological impact. The purpose is to ensure that the requirement regarding specified dose limits are met.

(iii) A description should be given of the organisation and conduct of an environmental monitoring program, to establish baseline data on radioactivity levels.

3. PROCESS DESCRIPTION

3.1 General

Uranium for reactor use has to conform to specified standards of purity. Particularly, impurities such as rare earths, boron, and cadmium which are high neutron absorbers have to be brought down to less than a part per million. Uranium dioxide (UO_2) is used in reactors in the form of high density sintered pellets. Presently in India, ceramic grade UO_2 powder is produced by the Ammonium Uranate (AU) route following wet and dry processes. In AU route, magnesium di-uranate is dissolved in nitric acid, purified by solvent extraction with Tri-Butyl Phosphate (TBP) and kerosene, stripped with demineralised (DM) water, precipitated by ammonia, filtered, dried, calcined, reduced and stabilised. The UO_2 pellets are produced by precompaction, final compaction, sintering at high temperature (1700^{0}C) and centreless grinding to desired dimension.

Alternatively UO_2 powder can be produced by Ammonium Uranyl Carbonate route (AUC). In the AUC route, ammonium uranyl carbonate is precipitated from uranyl nitrate solution with CO_2 and NH_3 followed by calcination and reduction. Operations like precompaction and granulation are avoided and the powder is directly pelletised.

Uranium generates heat and fission products while undergoing fission in a reactor. The fission products, which are radioactive, should be contained and not allowed to mix with the coolant water. Hence the UO_2 pellets are contained in zircaloy tubes with both ends sealed by resistance welding.

3.2 Uranium Oxide Powder Production

3.2.1 Wet Process

Wet process comprises of various operations starting from dissolution of magnesium di-uranate (MDU) up to production of ammonium uranate (AU) powder. Major operations carried out in a typical wet process are described below.

3.2.1.1 Dissolution

Concentrated solution of crude uranyl nitrate is obtained by dissolving magnesium di-uranate and plant recycles in nitric acid. This crude uranyl nitrate slurry will form feed for solvent extraction. Concentration of uranium in the feed is maintained at the optimum level typically 300-450 gm/litre. Free acidity is adjusted to 1 to 3.5 N.

3.2.1.2 Solvent Extraction

This crude uranyl nitrate solution is purified in a slurry extractor by counter current solvent extraction using TBP (30-35 % v/v) as solvent diluted with kerosene. TBP extracts 'U' from the feed solution, while the impurities go into the raffinate. The extract is stripped with DM water to obtain uranyl nitrate pure solution (UNPS). The acidic raffinate leaving the extractor contains some uranium and other decay chain products like radium etc. So the aqueous uranyl nitrate raffinate is treated with ammonia/sodium hydroxide to neutralise the acidity and fix the uranium activity in solid form. After neutralisation of uranyl nitrate raffinate, the precipitate is removed by filtration as uranyl nitrate raffinate cake (UNRC). This UNRC may be processed for recovery of uranium.

Extraction:

$$[UO_2(NO_3)_2]_{aq} + 2\ TBP_{org} \longrightarrow [UO_2(NO_3)_2\ 2\ TBP]_{org}$$

Stripping:

$$[UO_2(NO_3)_2\ 2\ TBP]_{org} + DM_{water} \longrightarrow [UO_2(NO_3)_2]_{aq} + 2\ TBP_{org}$$

3.2.1.3 Precipitation

UNPS from solvent extraction is heated to about 60^0C and precipitated in semi-batch process with ammonium hydroxide solution or gaseous ammonia to get uranium in the form of ammonium uranate slurry.

Precipitation Reaction:

$$2\ UO_2\ (NO_3)_2 + 6\ NH_3 \longrightarrow (NH_4)_2U_2O_7 + 4\ NH_4NO_3 + 3\ H_2O$$

3.2.1.4 Filtration

The slurry is filtered in a rotary vacuum filter to get wet AU cake.

3.2.1.5 Drying

Wet AU cake obtained after filtration contains about 20-30% of moisture. This wet cake is dried in turbo/spray drier.

Process flow sheet of wet process is given in Fig .1

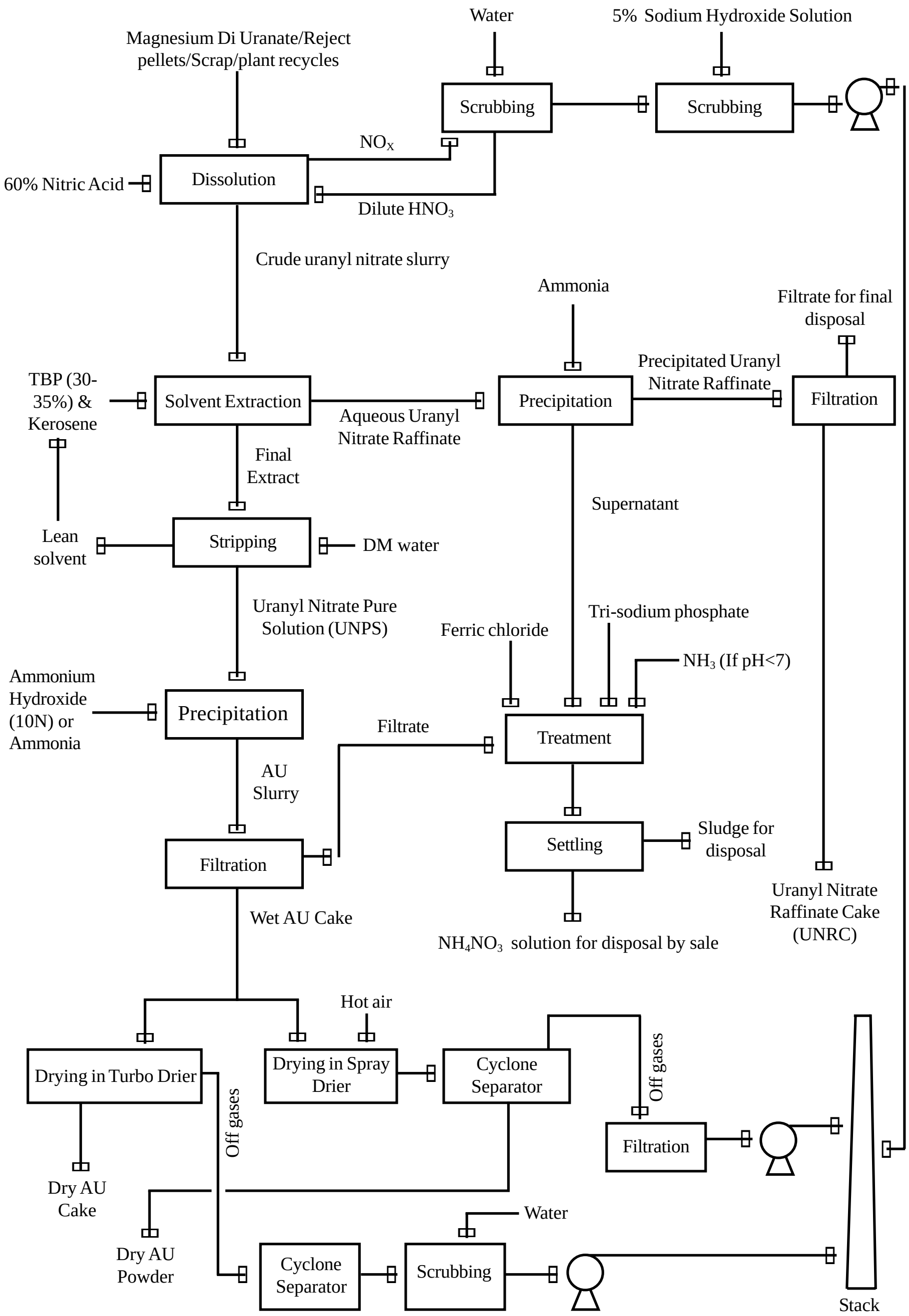

FIG 1 : PROCESS FLOW SHEET OF WET PROCESS

3.2.2 Dry Process

Dry process comprises of various operations starting from calcination of dried AU powder up to production of stabilized UO_2 powder. Major operations carried out in dry process are described below.

3.2.2.1 Calcination

Calcination is a process of heating a metal salt at high temperature to decompose to its oxides. The dried AU powder is calcined to U_3O_8 in tunnel /rotary furnace at around 600 to 750^{0}C maintained under negative pressure. The exhaust gas, consisting mainly of moisture and ammonia, is scrubbed with water.

3.2.2.2 Reduction

The U_3O_8 powder obtained after calcination is reduced to uranium dioxide at about 500-650^{0}C in rotary tubular furnace in the presence of cracked ammonia (N_2 + 3 H_2). Furnace pressure is maintained positive.

3.2.2.3 Stabilisation

Freshly reduced UO_2 is pyrophoric in nature and has a tendency to revert back to the more stable higher oxides. In order to prevent this, controlled surface oxidation of UO_2 powder is carried out in rotary tubular equipment to get ceramic grade powder which becomes feed material for UO_2 pellet fabrication.

Process flow sheet of dry process is given in Fig. 2

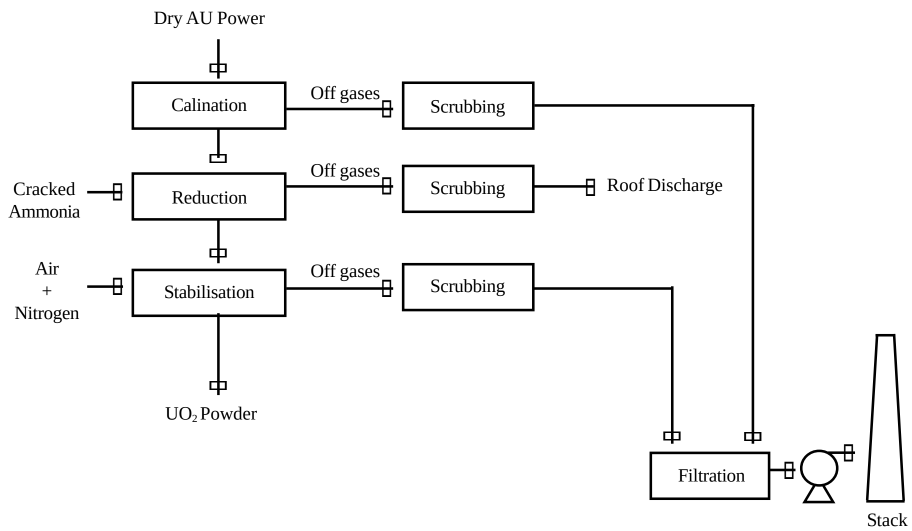

FIG 2 : PROCESS FLOW SHEET OF DRY PROCESS

3.3 Production of Uranium Oxide pellets

3.3.1 Pre-Compaction and Granulation

The ceramic grade UO_2 powder produced through the AU route is amorphous, fine, irregular and non-free flowing with a particle size in the range of 0.5 to 1.5 microns. This powder is pre-compacted and granulated to increase the agglomerate size and to make it free flowing.

3.3.2 Blending

Granules collected after pre-compaction are admixed with powdered lubricant/ binder by soft blending.

3.3.3 Final Compaction

The blended mixture is finally compacted to obtain green pellets in the density range of 5.6-5.9 g/cc.

3.3.4 Sintering

The green pellets with about 55% theoretical density are sintered in electrically heated furnaces using molybdenum heating elements, under reducing atmosphere of hydrogen/cracked ammonia at around 1700^0C. Sintering furnace has various zones with zone wise temperature distribution. The lubricant gets eliminated in the lower temperature zone and then the pellets get densified in the high temperature zone. Density of the sintered pellets lies in the range 10.45-10.75 g/cc (95-97% theoretical density).

3.3.5 Grinding

Sintered pellets are surface ground for uniform diameter, on centreless grinders. The diameters are ground according to the ID of the fuel tubes. The sludge is processed for uranium recovery through dissolution.

3.3.6 Washing and Drying

The pellets obtained after centreless grinding are cleaned to remove any fine powder adhering to the surface by ultrasonic cleaning with DM water. Water is recycled back after settling and filtration. The pellets are then dried in drying oven set at about 120^0C.

3.3.7 Inspection

The dried pellets are then inspected for density, end chipping, end capping, pitting, cracks etc.

3.3.8 Stacking and Loading

Accepted pellets are segregated and stacked as per the ground diameter. The pellets are then loaded inside the Zircaloy fuel tubes, already appendage welded and graphite coated.

Process flow sheet for fabrication of UO_2 pellets from UO_2 powder is given in Fig.3

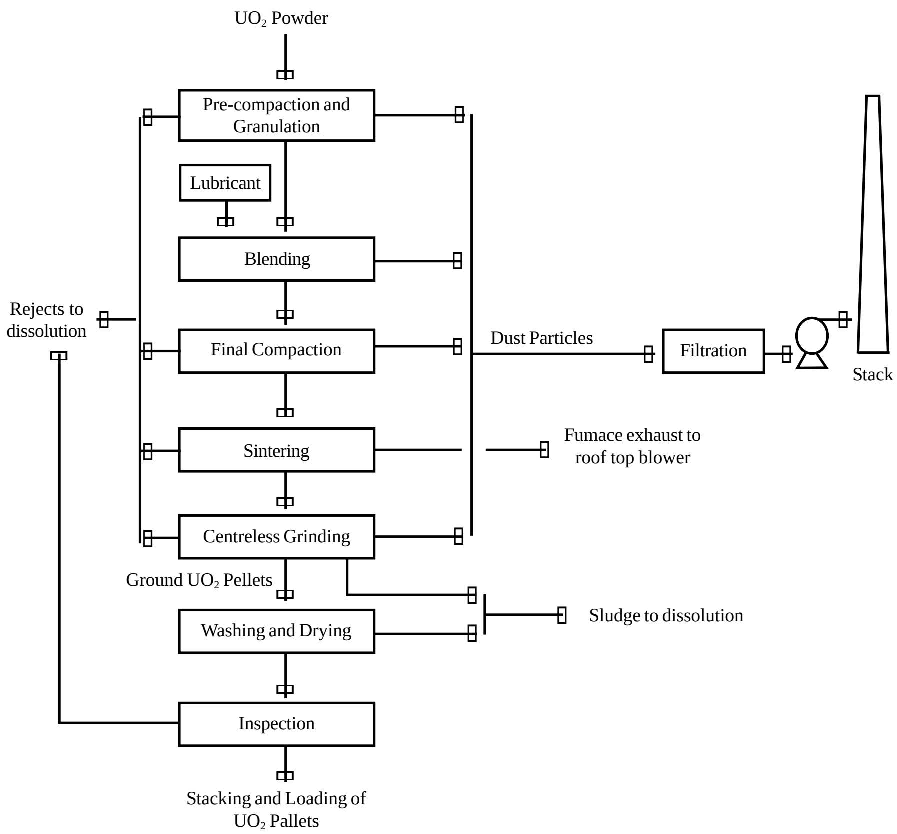

FIG 3 : PROCESS FLOW SHEET FOR FABRICATION OF UO_2 PELLETS

3.4 Assembly

By virtue of its high melting point, excellent corrosion resistance, adequate high temperature strength and low neutron absorption cross section, zirconium alloy (zircaloy) is used as cladding material for fabrication of fuel elements. Natural uranium oxide pellets are loaded in zircaloy tube for making fuel elements. Generally the following operations are carried out:

(i) The zircaloy tubes prior to loading are chamfered to the specific profile at both ends.

(ii) Tubes after machining are cleaned to remove contaminants during machining.

(iii) End caps are degreased, spacer pads, bearing pads and end plates are pickled and degreased.

(iv) Spacer pads and bearing pads are welded at specified locations in different helical patterns along the length on the clad surface.

(v) Appendage welded fuel tubes are coated at the inner surface with 3 to 8 micron thin layer of graphite. Both the ends are kept uncoated up to approximately 5 mm.

(vi) After graphite coating fuel tubes are baked under vacuum of the order of 10^{-4} mbar at about 350^0C for around three hours.

(vii) Baked tubes arranged in trays are sent to pellet plant for pellet loading. Cleaned and dried pellets are loaded into the tubes.

(viii) The loaded tubes are evacuated and cleaned at both ends.

(ix) All the elements are welded by resistance welding to end caps with helium as cover gas and atmosphere.

(x) The elements are machined to specific profile at both the ends and are machined to a specific length.

(xi) The machined elements are degreased, inspected, back filled with helium and leak tested.

(xii) These elements are assembled into 19-element or 37-element circular configuration and fabricated to bundles using zircaloy end plates on either side, which are spot-welded to the elements.

(xiii) The fuel bundle is then subjected to autoclave test at 400^0C and 50 kg/cm^2 steam on a sample basis to ensure clean clad surface, inspected, duly packed and then transported to the reactor site.

Process flow sheet of fuel assembly section is given in Fig. 4

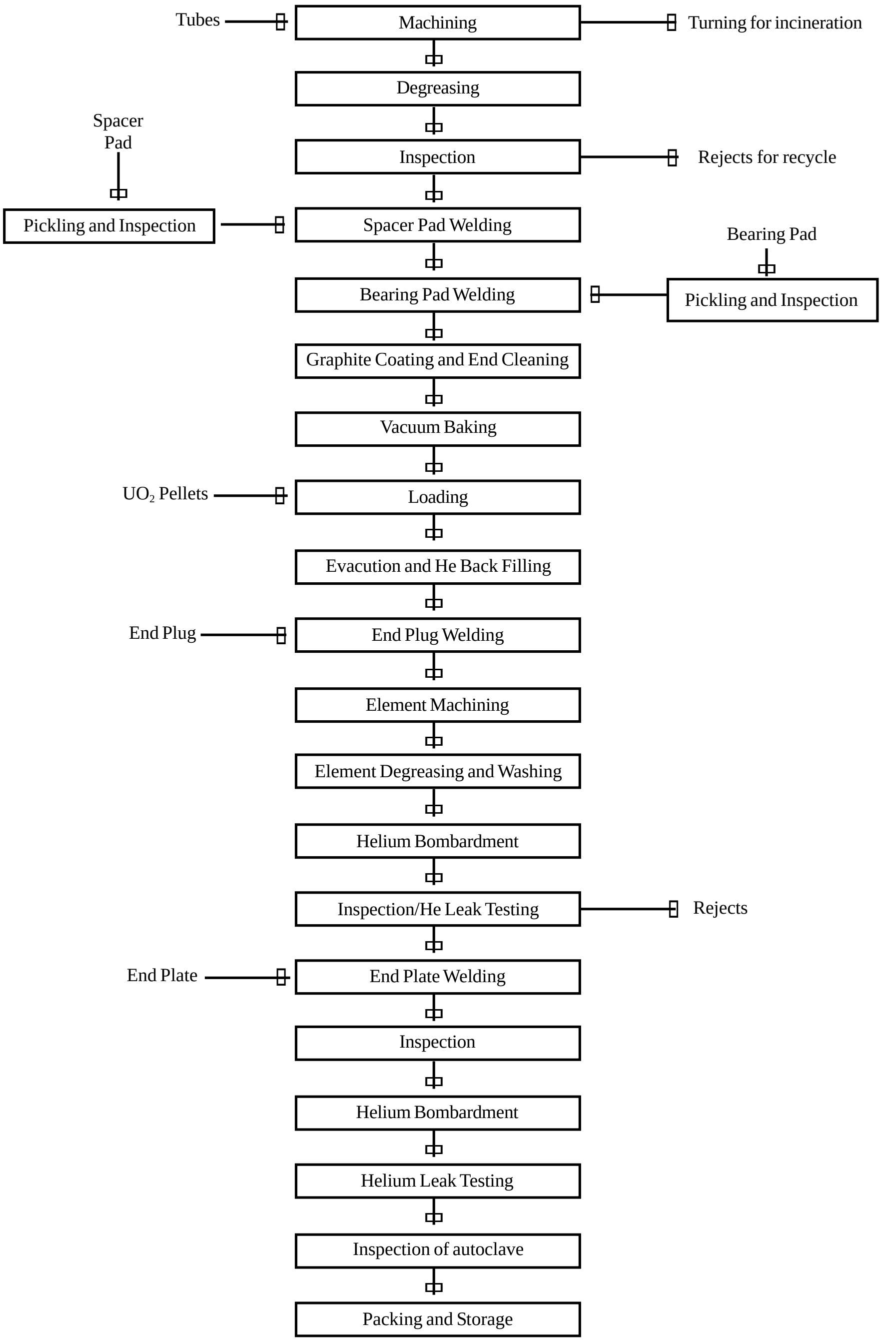

FIG 4 : PROCESS FLOW SHEET FOR FUEL ASSEMBLY

4. DESIGN

4.1 Introduction

The design of uranium fabrication facilities should consider following design features:

(i) The design should provide automated operations of equipment and processes wherever possible to minimise exposures to working personnel.

(ii) The primary confinement system should be constructed of fire resistant materials, and the process equipment and the process should be designed to prevent or minimise the potential flammable or explosive conditions.

(iii) Processing steps should be performed in individual process confinements to reduce the amount of hazardous material that can be released by a single or local failure of confinement system.

(iv) The layout of the equipment should be so designed as to provide easy access to the equipment and operating areas.

(v) Drives of the equipment should be located at non-operating sides.

(vi) The plant should be designed and constructed to ensure that adequate safety features are incorporated.

(vii) Required zoning should be established for radiological and industrial operations in the design and lay out of the plant.

(viii) Adequate primary and secondary ventilation should be designed for process equipment/areas.

(ix) Design should include processes to handle contaminated scrap/waste up to its final disposal.

(x) Hazard identification studies should be carried out to supplement existing design. Checklists should be used to ensure that the design conforms to the appropriate codes. More searching techniques like hazard and operability studies (HAZOP) are being widely used in chemical and metallurgical plants to identify process hazards. It is a technique to critically examine a proposed process scheme systematically in a given procedural order for every conceivable and credible deviation of process variables to find out the consequence. The technique could be used for hazard identification.

4.2 Radiological Safety

The design of plants and equipment in uranium oxide fuel fabrication should be such that the radiation exposures of occupational workers and members of the public are within the dose limits specified by AERB. The exposures should be kept as low as reasonably achievable (ALARA) by the following measures such as

(i) The plant lay out should enable demarcation of plant areas into different zones with regard to the potential for radioactive contamination of area/air.

(ii) Design of ventilation system should ensure air activity levels in the plant areas to be preferably below the 0.1 DAC value for radionuclides of concern under normal operating conditions.

4.3 Chemical Safety

Activities involving the handling, processing, transporting and storing of chemicals having potential for fire, explosion and toxic gas release should be identified. Flammability, explosion and toxicity of the chemical material used in the plant should be taken into account during the design for chemical safety. Hazardous chemicals like nitric acid, ammonia, caustic soda, TBP, kerosene etc. are used during fabrication of uranium oxide fuel. The design of the plant should incorporate safety features for the storage and use of these hazardous chemicals in the plant. The ventilation system should be designed in such a way that at least six to ten air changes will always be maintained for the protection from chemical fumes, escaped gases and dust such that the concentration of hazardous materials are within the threshold limit value (TLV).

4.4 Electrical Safety

All electrical installations should be in conformity with the Indian Electricity Acts and Rules. 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 from both sides. In addition, the cables should be coated with fire retardant material on both sides of the penetration. Fire barriers should be provided at appropriate distances. Cable galleries should be provided with fire and smoke detection system. Lightning arresters should be provided at appropriate locations. AERB document titled ‘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.

4.5 Ventilation System

The airborne uranium activity is a significant radiological hazard in fuel fabrication facilities. The activity should be well contained using suitable design for the facility. The building ventilation should be designed to prevent spread of activity from contaminated areas to uncontaminated areas. Six to ten air changes should be maintained by supplying filtered fresh air to the building and exhausting the process area through stack after suitable treatment. The design of the ventilation system should be effective through primary and secondary ventilation to keep the working areas within the limits for airborne uranium activity and toxic fumes.

4.6 Storage of Chemicals and Radioactive Materials

Separate area should be earmarked for storage of chemicals and radioactive materials. All storage and equipment containing solvents should be provided with tight lids. Fire detectors should be installed in the storage places. Chemical corrosive property of the stored material should be considered while selecting the materials for the storage tanks. Adequate provisions should be kept for transferring of stored chemicals in case of any emergency situation. Adequate venting facility should be provided on the storage tanks wherever required. All the chemical storage tanks should display name of the chemicals, it's TLV and identification number on the tank.

The storage tank containing radioactive material should display the name of the material, radiation symbol and dose rate on the surface of the tank. Radioactive materials should be stored in such a way that dose on the outside surface of the storage tanks are as low as possible. Sufficient instrumentation should be provided on the storage tanks for day to day monitoring and also for alarm in case of accidental release.

Hazardous chemicals like HNO_3, NH_3 and bulk storage kerosene should be stored in vessels or tanks surrounded by dykes outside the plant building. TBP should be stored in a separate shed. If any chemical is stored inside the plant, it should be on minimum functional requirement basis. The storage dykes should be designed for single largest tank containment. Necessary unloading/ transfer pumps or compressors should be kept outside the dyke but adjacent to the dyke. However, the first isolation should be installed on the nozzle of the tank. The dyke area including foundation for tanks/pumps should be provided with acid/alkali proof tiles as required.

Kerosene storage tanks should be as per relevant codes to prevent vapour losses to atmosphere and to reduce the formation of explosive mixture. LPG, ammonia detectors should be provided for liquefied petroleum gases/ammonia storage area. Ammonia and LPG storage bullets should be provided with pressure relief valves to safeguard the equipment from over pressurisation. All the electrical motors/ fittings in the TBP, Kerosene, LPG, and NH_3 storage areas should be as per IS 2148:2004 (Flameproof enclosures for electrical apparatus) codes. Water sprinkler system should be provided for LPG and ammonia storage bullets. Requirements of regulatory bodies such as petroleum and Explosives Safety Organisation (PESO) should be followed wherever applicable for storage of these chemicals.

4.7 Fire Safety

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

(i) Limiting the use of combustible materials.

(ii) 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.

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

(iv) Building design

(v) Ducts and fire dampers

(vi) Air filters

(vii) 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 the 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

(i) speed of response,

(ii) type of combustible materials present,

(iii) possibility of thermal shock, and

(iv) items important to safety.

Fire water supply should be designed to furnish anticipated firewater 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 so that these areas are accessible to at least one hose stream. The pump heads should be such as to give a minimum residual pressure of 3.5 kg/cm^2 at the hydraulically farthest point while delivering 100% flow. However, the maximum operating pressure at the nozzle should be limited to 4.5 kg/cm^2. 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.

For detailed requirements on the above, AERB safety standard titled 'Fire Protection Systems for Nuclear Facilities' [AERB/NF/SS/FPS (Rev. 1)] should be followed.

4.8 Corrosion Monitoring and Control

The corrosion in the equipment should be controlled by proper selection of material of construction, preventive maintenance and pre and in-service inspection of the equipment. All equipment/machinery/pipelines should be designed/fabricated as per national/international codes/standards. After erection of the plant all structures should be properly cleaned and immediately painted with suitable primer followed by appropriate surface treatment. Effect of nearby industries handling corrosive substances and releasing into environment should also be considered.

4.9 Instrumentation and Centralised Control System

The design should include instrumentation and centralised control systems to monitor the proper functioning of the equipment and various parameters (temperature, pressure, flow, density etc.) for different operations. Centralised control room should have the facility of auto start and stop of any rotating equipment. Centralised control room should be provided with facilities for level indication of various storage tanks and alarm system for quick response. Effective instrumentation and control system is all the more essential for remote operations. Schedule for in-service inspection of instruments and control systems should be specified.

4.10 Material Handling Equipment

All the material handling systems should be designed and manufactured according to the relevant standards. The layout of the equipment should provide easy access to the equipment and operating areas. As far as possible, drives of the equipment should be designed and located at non-operating side. The process should be so designed and selected that minimum manual handling of the material will be required.

5. SPECIAL DESIGN FEATURES OF WET PROCESS

5.1 Radiological Safety

In wet process of uranium oxide fuel fabrication, active materials like magnesium di-uranate, ammonium uranate slurry and powders etc. are handled. Design of plant and equipment should be suitable to take care of generation of radioactive aerosols and prevention of spillages/leakages of active solutions. Appreciable quantity of radioactive uranyl nitrate raffinate cake (UNRC), contaminated ammonium nitrate, sodium nitrate and other solid wastes are also generated. Design should take care of hold up, treatment and disposal of these active wastes according to the approved procedure and limits prescribed by AERB. Radiation exposure should be minimised by safe design considerations, good house keeping, graded ventilation, effluents treatment and disposal.

5.2 Ventilation System

Equipment producing gaseous contaminants and toxic releases should be kept at negative pressure by engineered features and ventilation system. MDU transfer to dissolver should be under enclosure system. To prevent the spreading of NO_X fumes into the atmosphere during dissolution, stand by blower should be available with class-III power supply and a scrubber system to scrub the off gases. Six to eight air changes should be maintained in the dissolution area. Primary and secondary exhaust system should be made available in the solvent extraction area. Exhaust blower should be provided to take out off gases from precipitation tanks and fresh air supply should be ensured to prevent spread of ammonia fumes into working atmosphere.

5.3 Operational Hazards

Most hazardous condition in wet process is possibility of “Red Oil Explosion” which should be considered in design of plants and equipment.

Red oil is defined as a substance of varying composition formed when an organic solution, typically tri-butyl phosphate (TBP, an agent used for extracting uranium through solvent extraction) and its diluent kerosene, comes in contact with concentrated nitric acid at a temperature above 120^0C. Although TBP is a highly robust chemical in the solvent extraction environment, it decomposes very slowly in the presence of water and nitric acid by hydrolysis to lower organo-phosphoric acids at normal operating temperatures. Even small amount of degradation products can reduce the effectiveness of the extraction of the actinides. Also, the presence of these TBP degradation products also contributes to the red oil phenomenon. The hydrolysis of TBP proceeds with the stepwise reactions to form dibutyl phosphoric acid, butyl phosphoric acid, phosphoric acid, and butanol as follows:

$$(C_4 H_9)_3 PO_4 + H_2O \longrightarrow H(C_4H_9)_2PO_4 + C_4H_9OH$$

$$H(C_4H_9)_2PO_4 + H_2O \longrightarrow H_2C_4H_9PO_4 + C_4H_9OH$$

$$H_2C_4H_9PO_4 + H_2O \longrightarrow H_3PO_4 + C_4H_9OH$$

The above TBP degradation reactions proceed very slowly at normal operating extraction temperatures. Over a period of time, there is a slow build up of decomposition products. Also, at very slow rates, the tramp organics in the diluent react with components in the aqueous phase to form nitro-aromatic compounds. The butanol from the TBP degradation also reacts with nitric acid to form butyl nitrate, an explosive material. At temperature above 120°C, degradation rates are high enough to produce high concentrations of nitrated organics that change the colour of the organic phase from amber to dark red, hence it is called “red oil”.

The simplest process condition for the formation of red oil is nitric acid heated while in contact with TBP. Equipment like evaporators, acid concentrators, dissolvers meet the conditions for red oil formation. The first sign of red oil formation and progression of red oil decomposition is the development of brown fumes caused by nitrogen dioxide in the evolved gases. The generation of these fumes is non-violent below 130^0C. But above 130^0C, rate of the decomposition of the red oil becomes rapid enough to generate voluminous explosive gas.

Controls for prevention or mitigation of a red oil explosion are generally effected through temperature, pressure, mass, and concentration control. Maintaining a temperature of less than 130^0C is generally accepted as a means to prevent red oil explosions. Sufficient venting prevents over pressurisation of the process vessel, also provision of evaporative cooling keeps red oil from reaching the runaway temperature. Mass controls utilise decanters or hydrocyclones to remove organics by diluent wash from feedstreams entering process equipment capable of producing red oil. Limiting the total available TBP is another mass control that mitigates the consequence of a red oil explosion by limiting its maximum available explosive energy. Finally, concentration control can be utilised to keep the nitric acid below 10 M (moles/ liter).

5.4 Fire Safety

In wet process, flammable materials like TBP and kerosene are used for solvent extraction. So solvent handling area is a major fire hazard prone area of wet process. This should be treated as a separate fire zone. The electrical fittings should be of appropriate safety type. Motors used for rotating the equipment should be of flameproof type. Fire/smoke detector and alarm systems of suitable type (ionisation, UV and I/R type) having adequate sensitivity should be mounted in sufficient numbers to cover the entire area. Manually operated fixed fire suppression system using CO_2 should be provided to cover mixer settler area. Suitable precautionary signboards highlighting the need for fire prevention in this area should be prominently displayed. Personnel entry should be restricted in this area. A separate fire-escape route should be provided for personnel to escape in case of accidental fire. This should be fitted with automatic self-closing devices with doors opening outside the fire/smoke area. Bulk quantity of TBP/Kerosene should not be stored in this area.

6. SPECIAL DESIGN FEATURES OF DRY PROCESS

6.1 Radiological Safety

Radiation exposure should be minimised by graded ventilation design. Powder transfer should be such that there is no possibility of powder getting airborne. The exhaust gases generated during calcination, reduction and stabilisation should be passed through scrubbers. Scrubbing system, filtration system, primary and secondary ventilation should be designed in such a way that activity level in the environment remains below prescribed limit.

Uranium with U^{235} content less than that in natural uranium is termed as depleted uranium (DU). It is produced either as a result of enrichment process or in reactor where a fraction of U^{235} in natural uranium undergoes fission. In low burnup reactors like research reactors DU with around 0.6% U^{235} is generated. In power reactor, where burn up is high, the irradiated fuel with around 0.3% U^{235} obtained is termed as deeply depleted uranium (DDU).

Since reactor generated DU is obtained from irradiated fuel, it is contaminated with plutonium and fission products. Power reactor generated DU also contains members of Th^{232} decay chain.

While handling DU, hazards associated with other toxic radio nuclides are required to be considered.

Appropriate limits for plutonium and fission product contamination of depleted uranium should be evaluated such that the radiation exposures in handling depleted uranium are within the limits prescribed for these operations and should be as stipulated by AERB.

6.2 Ventilation System

The ventilation system should consist of primary and secondary systems. In the primary ventilation system all equipment and processes producing airborne dust and gaseous contaminants should be kept at negative pressure by engineered containment and purge ventilation. Such equipment should not have any unintended openings. Intended openings, say, for operational or maintenance requirements, should be so designed that they passively remain closed during actual operations. Dedicated exhaust ventilation should achieve an inward air velocity of not less than 40 m/minute through the openings. Discharge to atmosphere should be treated suitably before release through a stack of appropriate height.

Whenever necessary, such dust generating/dust releasing equipment/processes should be enclosed in a primary containment, which will not be normally occupied. Access to this area should generally be through a double door airlock and with appropriate protection. Under normal operating or accidental conditions also the atmosphere of primary containment should remain properly isolated from the area outside the containment, which can be an unlimited occupancy zone. Mechanical exhaust ventilation should be provided to the primary containment for dynamic isolation from occupied area.

With above provisions, the occupied area can remain free from all toxic contaminants and dust. The operating areas are kept under secondary ventilation. These areas are provided with suitable exhaust ventilation with induced fresh air supply for industrial hygiene. Similarly, suitable exhaust should be provided for open flames, combustion products (for example hot gases from sintering furnace operation) of the process equipments if they are located in covered operational area. If volatile organic/flammable products are part of the process in covered area, then atmospheric hazard should be controlled by forced air ventilation sufficient to keep atmospheric concentration of flammable materials below 10% of its lower explosive limits (LEL).

Regular decontamination, cleaning and cosmetic maintenance of equipment and primary containment in particular and the entire plant in general will of course be needed.

6.3 Operational Hazards

Loss of integrity of the furnace along with other damages due to explosion in the reduction furnace are the main hazards of dry process. To prevent such hazard, air ingress should not occur inside the furnace. Reduction furnace should be designed in such a way that it should be always under positive pressure during operation. Furnace drive should be provided with emergency power supply in case of power failure. Seal of the furnace should be provided with positive nitrogen pressure. Explosion in sintering furnace is another hazard of dry process. Arrangement should be made for continuous supply of cracked ammonia/hydrogen to maintain positive pressure in the furnace and burning of excess hydrogen in the furnace exhaust even in case of power failure. To avoid entry of air, nitrogen gas curtain should be provided in the entry and exit door of the sintering furnace. Arrangement for flushing of sintering furnace bed should be available before starting the furnace.

7. CONSTRUCTION

7.1 General

The construction methodology for uranium oxide fuel fabrication facilities should ensure that the design intents of the buildings/structures are satisfied.

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

(i) AERB safety standard for 'Civil Engineering Structures Important to Safety of Nuclear Facilities' (AERB/SS/CSE).

(ii) AERB safety guide for 'Works Contract' (AERB/SG/IS-1).

(iii) Minimum safety precautions needed at any plant or site as per notification of Chairman, AERB dated November 29, 2004.

(iv) Number and qualification of safety officers and safety supervisors as per notification of Chairman, AERB dated July 8, 2002.

(v) Any other applicable statutory requirement.

Construction activities of any plant should not jeopardise the safety of the adjacent or nearby plants/structures or part of it, which have already been constructed. The organisation responsible for construction should develop and implement a quality assurance programme (QAP), which describes the overall arrangement for the management, performance and assessment of fuel fabrication facility construction. This programme should also provide the means to ensure that all the work is 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 authorities for their review and any check or hold points specified by the regulatory authorities should also become a part of the QA plans.

The organisation should prepare and implement a job hazard analysis report, which should include the following:

(i) Main activities/tasks.

(ii) Sub-activities.

(iii) Identification of hazards associated with each activity/task.

(iv) Cause and consequence analysis and

(v) Actions and action plans taken to prevent/control/mitigate the hazards.

The regulatory consents for the construction of uranium oxide fuel fabrication facilities require the submission of safety analysis report (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/G-2). The safety report forms the principal document for AERB to examine whether the construction and operation of the facility is safe with regard to radiological, chemical and industrial hazards/risk to the plant/site personnel, the public and the environment.

The formats and contents of safety report should follow Appendix-I of 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).

8. COMMISSIONING

8.1 General

The commissioning programme should assure that after construction and installation of equipment, the fuel fabrication facility 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 facility 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 facility. 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 AERB. Close liaison should be maintained between AERB 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 submitted to AERB.

8.2 Testing and Examination of Equipment

Commissioning programme of uranium oxide fuel fabrication facilities should include detailed testing and examination procedures in sequence in which they are expected to be performed. All commissioning tests should be performed in accordance with approved procedures. Applicable operational limits and conditions along with testing limit and conditions should be included in the testing and examination procedure. Required instrumentation and equipment should be specified for the testing and examination. Safety precautions necessary for the testing and examination should be clearly mentioned in the programme. All the testing and examination data and record should be maintained in required format. Final testing and examination report should be prepared and sent to AERB for review.

8.3 Training

A training programme should be established to ensure that personnel involved in the commissioning/operation of fuel fabrication facilities are trained to attain requisite competence and safety awareness at all levels of the organisation. The effectiveness of the training should be evaluated by assessment and re-training on periodic basis.

Feedback information on commissioning experience obtained should be used as a part of training programme. Records of training of all personnel should be maintained.

8.4 Emergency Plan

The on-site emergency plan should be prepared 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 for this purpose. No off-site radiological emergency is envisaged. However, 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 should be available.

9. OPERATION

9.1 General

The plant management is responsible for all aspects of operation of the facility and for establishment and implementation of radiological and industrial safety. It should apply to AERB for operating licence under the Atomic Energy (Factories) Rules, 1996 and the Atomic Energy (Radiation Protection) Rules, 2004. The plant management should ensure compliance with radiation protection procedures by all personnel in order to maintain occupational exposures within the specified limits and as low as reasonably achievable (ALARA) and also industrial safety in accordance with the statutes.

9.2 Operation Manual

Detailed operation manual should be prepared for the facility. Approved operation manual should be circulated among the operating personnel in the plant. Operation manual should address both normal and off-normal operating conditions. The operation manual should assure that the person/worker assigned to perform each activity knows the precautions to be taken for their own safety, the safety of the plant and the environment.

9.3 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) 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 Atomic Energy Regulatory Board (AERB), State Pollution Control Board and other statutory organisations.

9.4 Safety Review

The plant management should review the plant performance, which should include unusual occurrences and violation of technical specifications for operations. The report on radiation safety status and radioactive hazardous waste management and disposal along with the plant performance report should be submitted to AERB for review.

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

10. MAINTENANCE

10.1 General

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.

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 prior to carrying out maintenance work.

10.2 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 inspection, 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.

10.3 Maintenance Data and Record

Appropriate arrangements should be made for orderly collection of records and preparation of reports on maintenance activities. Records and reports are required to provide objective evidence that the maintenance programme is being implemented in accordance with quality assurance programme. In addition, maintenance records such as equipment history cards and the results of maintenance works are necessary inputs to a continuing review of maintenance effectiveness on component reliability. In general, the records should identify the maintenance and operational personnel concerned and include certification by supervisors or quality control personnel as appropriate.

10.4 In-service Inspection (ISI)

The in-service inspection involves periodic examination of safety related systems and components of fuel fabrication facility during its lifetime. The examinations required to determine the health of components form a part of in-service inspection (ISI) programme.

In-service inspection programme involves various methods of testing (including leakage testing of systems) at proper time intervals and administrative measures necessary thereof. 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. 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 manual should include the following:

(i) Responsibilities for implementation of programme.

(ii) Philosophy of ISI programme.

(iii) List of examination areas.

(iv) Methods of examination.

(v) Applicable codes and standards.

(vi) Extent of examination.

(vii) Examination interval.

(viii) Reporting of data.

(ix) Qualification of personnel.

(x) Analysis of data.

(xi) Periodically update ISI manual based on findings and analysis of data.

11. MODIFICATION

11.1 Necessity of Modification

Modification based on operational experience or new 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. 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.

11.2 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, revised safety reports are to be submitted to the AERB.

11.3 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, radiation protection manual, drawings, procedures, ISI manual and P and I diagrams should be updated according to the modifications made in the operating procedure or equipment.

12. RADIOLOGICAL SAFETY

12.1 General

Natural uranium consists of U^{238}-99.28%, U^{235}-0.71% and U^{234}- 0.0054%. All these isotopes emit primarily alpha particles. Their daughter products emit alpha or beta particles and low energy gamma radiation. Uranium chemically separated from its daughter products does not present external radiation hazard due to its negligible gamma radiation. Beta radiation, which contributes dose to skin, can be reduced by avoiding direct contact with uranium. Uranium presents either chemical toxicity or radiological hazard depending mainly on the solubility in the body fluids. The soluble compounds are harmful to kidney if ingested in large quantities. Inhaled insoluble uranium such as UO_2, U_3O_8 is retained in lungs for a long period exposing the tissue mainly to alpha radiation. Hence during design of the uranium oxide fabrication plants, measures to prevent the release of uranium oxide dust into the work area and to avoid the inhalation of dust by suitable means should be ensured.

12.2 Natural Uranium Oxide Powder Production (Wet Process)

12.2.1 External Radiation

The wet process starts from the dissolution of magnesium di-uranate till drying of filtered ammonium uranate. The radioactive isotopes of natural uranium are of low specific activity and are not high-energy gamma emitters. The immediate daughters of the series are neither high-energy gamma emitters nor have high yield. The external radiation comprising of β and γ is emitted by two immediate daughters (^{234}Th) and (^{234}Pa) which attains equilibrium in about 300 days. External radiation hazards are not dominant during the wet process. Hand gloves should be worn to avoid external skin contamination and skin dose.

Depleted uranium (DU) has gamma emitting fission products ^{137}Cs and ^{106}Ru but their concentrations as specified in feed material specifications are very low and therefore has no significant contribution in radiation dose. Deeply depleted uranium (DDU), in addition contains decay chain members of ^{232}Th series. Noted among them are thoron and thoron daughters. ^{208}Tl is a prominent gamma emitter with gamma energy of 2.64 MeV. External dose in contact with DDU container is 7-10 times higher than that for natural uranium container of same dimensions.

12.2.2 Airborne Radioactivity

The probability of uranium getting air borne is insignificant during wet operations. However, care should be taken while charging magnesium di-uranate in dissolution tanks to avoid any spillage and generation of air borne activity. The toxicity of natural uranium depends on its solubility. Kidney is the most sensitive organ for soluble U.

12.2.3 Surface Contamination

Surface contamination in wet operations depends on the operational methods used. The surface contamination is easily visible owing to yellow colour of MDU, uranyl nitrate solution and AU. Surface contamination can occur due to spillage of magnesium di-uranate powder, uranyl nitrate solution or ammonium uranate slurry, which can also act as a source of air contamination by resuspension.

12.3 Natural Uranium Oxide Powder Production (Dry Process)

12.3.1 External Radiation

Dry process starts from calcination of dried ammonium uranate till stabilisation of uranium dioxide powder. External radiation hazards are not dominant during the dry process either. Hand gloves should be worn while handling uranium powder to avoid external skin contamination and skin beta dose.

12.3.2 Airborne Radioactivity

U_3O_8 and UO_2 powder formed in the dry process operations are insoluble and biologically inert. Dry operations can lead to generation of air borne activity in the form of fine U_3O_8 and UO_2 aerosols which can lead to internal contamination either by inhalation, ingestion or injection. To keep air borne activity within prescribed limits, engineered control like enclosures of equipment (confinement of activity) should be implemented.

Confinement : As most of the operations involve handling of fine uranium powder, confinement of activity in processing equipment is essential for control of internal contamination hazards. All operations should therefore be done either in closed rotary furnaces or vessels.

Uranium powder from (1) AU drier, (2) calcination furnace, (3) reduction furnace and (4) stabilisation furnace should be directly collected in a closed container and connected to inlet point of next equipment through suitable sealed coupling device.

Mechanical ventilation : Primary ventilation system should be adopted to exhaust out the activity from the equipment enclosure and from inlet and outlet points of furnaces. Before stack discharge, it passes through scrubbers and HEPA filters for removing most of the activity. Air activity in exhaust should be restricted to specified discharge limit. Secondary ventilation should be provided in work areas by fresh air supply in the area with adequate exhausts. Exhaust air from work area is also let out after suitable scrubbers and filters.

12.3.3 Surface Contamination

Surface contamination in dry operations may arise due to spillage from hoppers used for transporting dried AU and uranium oxide powder at various stages.

Airborne activity by re-suspension of uranium oxide powder may result in significant internal contamination. Engineered measures should be taken to avoid spillage of powder in work area.

12.4 Natural Uranium Oxide Pellet Fabrication

12.4.1 External Radiation

The major processes in pellet fabrication involve pre-compaction of stabilised UO_2 powder, blending, final compaction to green pellets, sintering of green pellets, centreless grinding of sintered pellets, washing and drying of ground pellets and finally loading them into fuel pins. External radiation hazard in fuel fabrication is more dominant in pellet inspection and loading operations. Loading of uranium pellets inside the fuel pins involves handling of large number of uranium pellets and thereby there exists a potential for external gamma radiation exposure. Hand gloves should be worn to avoid skin beta dose.

12.4.2 Airborne Radioactivity

Processes like compaction, blending and centreless grinding can lead to significant generation of air borne activity. To keep airborne activity within prescribed limits, engineered controls like enclosures of equipment, provisions of primary and secondary ventilation and double door airlocks should be implemented. Mechanised spill free powder transfer system should be adopted for transfer of uranium oxide powder from one equipment to next equipment.

12.4.3 Surface Contamination

Potential of floor contamination, equipment contamination and cloth contamination exist in the pre-compaction and final compaction area as fine powder is handled in these areas. Entry of men and material in these areas should be through double door system. Use of personal protective equipment (PPE) like shoe covers, hand gloves should be essential in these areas.

12.5 External Radiation in Natural Uranium Oxide Fuel Assembly Area

Fuel assembly fabrication operations include evacuation of loaded fuel elements, end cap machining, degreasing and washing, appendages welding, burr- milling, testing and endplate welding. These operations require handling of fuel pins loaded with uranium fuel pellets in close proximity. Hence, there exists a potential for external gamma radiation exposure, which needs to be minimised. Hand gloves should be worn to avoid beta skin dose.

Potential of air activity and surface contamination in fuel assembly fabrication operations are negligible.

13. RADIOLOGICAL MONITORING

13.1 Monitoring Programme

The principal objective of radiation monitoring is to evaluate the occupational exposures of all plant personnel engaged in natural uranium oxide fuel fabrication and to ensure that the individual exposures are well below the limits specified by AERB and efforts are made to keep personnel exposures as low as reasonably achievable. The radiation hazards associated with various operations call for different monitoring techniques and prompt detection and evaluation of the source of exposure. Radiation monitoring within the plant can be broadly classified into personnel monitoring and plant/area monitoring and the two are closely interlinked for management of radiological safety in the plant. In addition, environmental monitoring programme should also be undertaken to assess the impact of plant operations.

13.2 Personnel Monitoring

Personnel exposures comprise of two components, viz. external exposures arising from external radiation sources and internal exposures arising mainly from inhalation, ingestion or injection. External dose estimate for individuals is done by thermo luminescent dosimeters (TLDs), which record the cumulative external radiation dose. Direct estimate of annual intake from lung burden data/bioassay data is restricted because of inadequate sensitivity of available techniques. Hence, internal dose should be computed from the data of (1) annual average air activity (2) annual occupancy period in work place and (3) the dose coefficient for the radionuclide.

13.2.1 External Exposure

Exposure to external radiation sources should be estimated periodically for all personnel engaged in radioactive work. Thermo luminescent dosimeters (TLDs) should be used at quarterly periodicity to estimate cumulative dose received by the individual, from external gamma sources and TLDs should also be packaged in thin material and used for measuring beta radiation.

13.2.2 Internal Exposure

Internal contamination hazards in fuel fabrication are more dominant in powder handling areas where there is potential for inhalation of air borne activity and also of ingestion through contact with contaminated surfaces on floor, equipment etc.. When radioactive source enters the body, it remains in the body till either it is eliminated through biological process or decays completely by radioactive decay. During resident period in body it continuously irradiates neighbouring body tissue imparting radiation dose to it. Uranium compounds have very long radiological half-life but biological elimination from body is fast.

DU has contamination of Plutonium, ^{137}Cs, ^{90}Sr and ^{106}Ru but their concentration as specified in feed material specifications is very low and therefore has no significant contribution in internal contamination hazards. DDU also contains decay chain members of ^{232}Th series.

Noted among them are thoron and thoron daughters. There can be measurable internal contamination hazards from inhalation of thoron daughters if the area is not adequately ventilated.

13.2.2.1 Uranium Lung Burden Estimate

Individuals working in powder handling areas of the plant should be monitored at uranium lung burden monitoring laboratory for estimation of uranium lung burden.The estimated intake from the measured lung burden should not exceed the annual limit on intake (ALI) specified for Uranium compounds.

13.2.2.2 Bio-assay

Urine analysis for uranium is normally limited to workers engaged in the wet operations of natural uranium oxide fuel fabrication process. Measurable fraction of uranium in body is likely to be released in urine for making the estimates. Twenty-four hours urine sample of the individual should be collected for analysis for estimation of internal contamination, if any. Bio-assay of each individual working in wet plants should be done once in a year.

13.3 Plant/Area Monitoring

Plant/area monitoring surveys should be directed towards obtaining the following data for the purpose of detection and evaluation of the principal sources of exposure and to initiate appropriate radiation safety measures in the plant:

(i) External radiation :

In fuel fabrication process amount of activity handled in different sections of the plant is not likely to vary much during a campaign. Any sudden steep rise in external radiation levels in an area is not expected. Hence, periodic radiation survey in plant areas should be adequate for assessment of external dose rate.

(ii) Air activity :

Though uranium in powder form is handled with suitable engineered measures, a loss of containment may occur during the process. So monitoring of air activity levels in uranium powder handling areas is essential and should be done on routine basis.

(iii) Surface contamination :

Surface contamination checks of exposed surfaces should be carried out in view of the possibility of resuspension of activity and potential internal contamination by ingestion. It is required to be done frequently depending on the plant condition. Equipment should be checked for loose contamination before it is taken up for maintenance work to prevent unnecessary exposures/contamination in uncontrolled areas.

13.3.1 Monitoring Methodology

External radiation in work area is monitored by radiation survey meters, which are generally based on Geiger Muller (GM) tube detectors. Instruments based on ionisation chambers can also be used for beta-gamma dose rate measurements but they are sensitive to moisture.

Airborne uranium activity or long lived alpha activity should be measured by drawing air sample through glass fiber filter paper with the help of vacuum pump or vacuum line provided at different locations in the plant. ZnS(Ag) based alpha counting systems are used for measurement of activity deposited on the filter paper during the sampling. For loose contamination on any surface, swipe sample from contaminated area should be taken and counted on alpha counter.

13.4 Environmental Monitoring

A suitable environmental monitoring programme should be established to assess the impact of natural uranium oxide fuel fabrication on the environment. The programme may include:

(i) Monitoring of water bodies such as river, stream or lake into which the low level liquid effluents, after treatment, may be discharged, though within the authorised limits.

(ii) Monitoring of ground water from wells and bore-wells within as well as outside the plant premises.

(iii) Analysis of soil samples from appropriate locations for radioactivity content.

(iv) Airborne activity and background radiation level survey outside the plant premises.

Based on the analysis of the above data, proper assessments can be made on the environmental impact of plant operations.

14. OCCUPATIONAL HEALTH SAFETY

14.1 General

All persons employed in fuel fabrication facilities should be medically examined before commencing such work and at appropriate intervals thereafter as per statutes.

14.2 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).

14.3 Periodic Medical Examination

The periodic medical examination should be carried out as per The Atomic Energy (Factories) Rules, 1996 and The Atomic Energy (Radiation Protection) Rules, 2004. The periodic medical examination should pay attention to the organs/systems likely to be most affected by exposure to occupational hazards in the radioactive areas of fuel fabrication. In addition to exposure to radioactive substances there may be exposure to chemical contaminants and to noise, etc. The periodic examination should consist of a general examination and functional checks and should include lung burden tests, blood pressure measurement, haematological examination, pulmonary function test, bio-assay test, radiochemical and other analyses and audiometric examination.

14.4 Medical Examination at Termination and Follow-up

All persons who have worked in the facilities should undergo a medical examination upon termination of their employment. It will be necessary to provide further follow-up depending upon the results of the examination and the records should be maintained as per statutes.

15. INDUSTRIAL SAFETY

15.1 General Safety Precautions

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.

Equipment numbers should be marked prominently on all major equipment for identification purposes and should be clearly visible. Also pipelines for water, air, oil and gases should be colour coded as per Indian Standard: 2379-1963 and Indian Standard: 5-1978.

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. Alternate source of power supply should be provided and periodically tested. Electrical conduit panels should be colour coded as per Indian Standard: 375-1951 and Indian Standard: 5-1978.

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

Thermal insulation should be provided for hot exposed surfaces at a temperature greater than 50^0C .

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

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

Cages should be provided to the monkey ladders used in the plant.

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.

All staircases should be made as per standard engineering practice to avoid accident while running in hurry or during material movement.

All cranes, hoists, lifts, chain pulley blocks, pressure vessels used in the plants should be tested as per the Atomic Energy (Factories) Rules, 1996.

There should be provision of escape route, alternate escape route and panic lights in all the plants for use in case of emergency and the escape routes should be visible even without electric power supply.

15.2 Electrical Safety

All work on major electrical installations should be carried out under safety work permit system. No work should commence on live mains unless it is specifically intended to be so done by specially trained staff. 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. Rubber mats should be provided in front of all 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.

15.3 Fire Safety

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 should be placed at convenient and easily accessible locations either on brackets or on stands and filled with clean, dry and fine sand. Fire detectors should be provided in the solvent extraction areas, LPG storage areas and Hydrogen storage areas.

As per AERB safety standard 'Fire Protection Systems for Nuclear Facilities' [AERB/NF/SS/FRS (Rev. 1)], all fire fighting equipment should be inspected and tested periodically.

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.

A standing fire order should be prepared and made available to the employees. Fire drill should be conducted periodically. Fire squad should be identified and trained periodically.

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

15.4 Personal Protective Equipment

All necessary personal protective equipment should be made available and maintained in a condition suitable for immediate use. AERB safety guidelines 'Personal Protective Equipment' (AERB/SG/IS-3) should be referred for details on personal protective equipment.

16. WASTE MANAGEMENT

16.1 General

As an essential objective of radioactive waste management, generation of radioactive waste should be kept to the minimum practicable. Waste minimisation 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.

Strategies for waste minimisation should include:

(i) Reducing the volume of radioactive waste to be managed by adequate segregation and by keeping non-radioactive material out of controlled areas.

(ii) The proper planning of activities and the use of suitable treatment procedure.

Wastes from fuel fabrication facilities can be a cause of concern for the environment and public health. These radioactive wastes are characterised by large volumes and low activity concentration of materials containing naturally occurring radionuclides with very long radioactive half-lives. In addition there are also hazards associated with non-radiological characteristics of the wastes generated from fuel fabrication facilities The objective of waste management is protection of the workers, public and environment.

Uranium oxide fuel fabrication facilities are required to apply to AERB for authorisation for radioactive waste disposal under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. The authorisation takes into consideration the administrative and technical aspects associated with the safe handling and management of radioactive waste and enlists the responsibilities of the waste generators/managers to protect workers, public and environment from impacts resulting from waste generated. Environmental surveillance programme should be put in place for waste management facilities.

Waste management includes the whole sequence of operations starting with the generation, segregation, treatment, storage, disposal of waste and ending with closure and post closure aspects. Treatment processes should be able to ensure maximum recovery of uranium from primary wastes and minimum generation of secondary wastes. They are to be collected, treated and disposed off as per stipulated procedures depending on the limits made by state pollution control board (SPCB) and AERB to minimise the environmental impact. The basic treatment concepts should take care of volume reduction, radionuclide removal and change of composition. Uranium recovered from effluents should be recycled.

16.2 Characterisation of Waste

16.2.1 Solid Wastes

Uranyl nitrate raffinate cake (UNRC) is generated during solvent extraction stage of uranium oxide production. This may be processed for recovery of uranium value. Non-process solid wastes like polythene sheets, cotton/rubber gloves, cotton mops, filter elements are also generated during uranium fuel fabrication.

16.2.2 Liquid Effluents

Process effluents, generated during production of uranium oxide powder, include ammonium nitrate, sodium nitrate solutions and process wastewater containing low level of uranium contamination. In addition, water used for decontaminating the tools, laundry water, floor washings, hand and foot washings, bathing by plant personnel and wash water from various operations contaminated with uranium are required to be treated.

16.2.3 Gaseous Emissions

The off gases from equipment consist mainly of acidic vapors like NO_X, ammonia and uranium particulate etc. The gaseous releases after treatment are discharged through stacks connected to primary and secondary ventilation systems.

16.3 Treatment, Storage and Disposal of Waste

16.3.1 Solid Wastes

Efforts should be made for recovery of uranium to the maximum extent from UNRC and the resultant waste should be suitably disposed off. Design should also consider reduction in volume of sludge generation.

Combustible solid wastes should be incinerated and ash should be treated for recovery of uranium. Suitable processes should be developed for disposal of non-combustible solid wastes.

Storage/disposal of waste should be done in accordance with the requirements of the Atomic Energy (Safe Disposal of Radioactive wastes) Rules, 1987. Low-level wastes may be stored in the underground trench within the plant premises under constant radiation surveillance.

16.3.2 Liquid Effluents

After filtration of ammonium uranate slurry in the uranium oxide manufacturing process, ammonium nitrate/sodium nitrate effluent is generated. This effluent is treated with tri-sodium phosphate (TSP) and ferric chloride. Precipitate containing uranium is allowed to settle for more than 8 hrs. Supernatant liquid meeting the specifications is transferred to a separate tank for disposal by sale.

Active effluents like ammonium nitrate, sodium nitrate should be treated to bring down the uranium content as per stipulation before disposal. Analysis of the effluent sample should be carried out before discharge within specified limits. Ammonium nitrate and sodium nitrate may be cleared for unrestricted use if it meets the specification of AERB for uranium content suitable for release.

Lean active water from hand wash, floor wash etc. are collected in sumps and treated for precipitation of uranium. The supernatant is sent to settling tank through storm drain, if the uranium content is less than 0.1 mg/l.

Water used for decontaminating the tools, laundry water, floor washings, hand and foot washings, bathing by plant personnel and wash water from various operations, contaminated with uranium, should be collected, treated, analysed and then disposed off suitably.

Drainage water, contaminated with uranium and chemical pollutants like nitrate, fluoride should be monitored regularly and suitably disposed off.

16.3.3 Gaseous Emission

The off gases consisting of mainly acidic, basic gases and particulate matter should be treated using equipment such as electrostatic precipitators (ESP), scrubbers, prefilters, HEPA filters etc. and discharged. The discharge should be within the prescribed limits.

The quality of ambient air with respect to pollutants such as NO_X, NH_3 and uranium should be monitored.

All processes generating dust and fumes should be provided with exhaust ventilation systems. Filters, scrubbers or other screening devices should be installed to bring down the airborne contaminants below the discharge norms.

Gaseous effluents released through air route should be continually monitored qualitatively and quantitatively and discharged after treatment as per the prescribed limits of State Pollution Control Board/AERB.

16.4 Solar Evaporation Pond

Aqueous effluents like laundry wash, sodium nitrate bearing wastes etc. generated during operation are concentrated in solar evaporation ponds. Dried salt so produced is packed and stored in covered sheds before disposal.

Design and construction of these ponds should be such that

(i) Wet surface/floors of the ponds should be lined with suitable impervious material.

(ii) Channels should be provided at the bottom of the ponds to collect leakages and these channels should be connected to monitoring pits.

(iii) Effluents collected in the pits should be regularly monitored to assess the integrity of the pond.

(iv) Pond should be constructed in such a way that during extreme rain, no overflow takes place.

(v) Proper access should be provided for inspection and maintenance of the ponds.

17. DECOMMISSIONING

17.1 General

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 fuel fabrication facility 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. The presence of radioactivity in the plant poses additional challenges in the decommissioning operations.

Before the start of decommissioning, a decommissioning plan should be prepared and got approved by regulatory body and the facility should be first rendered to a state that it will no longer cause any concern regarding release of radioactive 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 of active/non-active material etc.

During decommissioning care should be taken to minimise the radiation exposure to decommissioning staff and public. Decommissioning should be done in such a way that maximum material will be recovered for reuse.

Useful material arising out of decommissioning should be released for unrestricted use by members of the public, provided the resultant individual dose to members of the public should not exceed the limits specified by the AERB.

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.

18. EMERGENCY PREPAREDNESS

18.1 General

The site emergency preparedness plan (SEPP) for uranium oxide fuel fabrication should be available as per the statutory requirements by the 'Manufacture, Storage and Import of Hazardous Chemical Rules,1989 as amended in 2000', the 'Chemical Accident (Emergency Planning, Preparedness and Response) Rules,1996' and the 'Atomic Energy (Factories) Rules,1996'. The SEPP sections of the plan should correspond to the AERB safety guidelines on 'Preparation of On-Site Emergency Preparedness Plans for Non-Nuclear Installations' (AERB/SG/EP-3) and 'Preparation of Site Emergency Preparedness Plans for Nuclear Facilities' (AERB/SG/EP-1).

18.2 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.

18.3 Basis for Emergency Planning

Emergency plans for fuel fabrication facilities should be based on accidental release scenarios 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 scenarios assumed in the safety analysis report submitted in support of the licensing of the respective facility.

18.4 Emergency Crew

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.

18.5 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 first aid, fire fighting and radiation surveys.

Emergency plans for fuel fabrication facilities should ensure that sufficient number of qualified personnel are available at all times to maintain the facilities in a safe condition and to respond effectively to the emergencies.

18.6 Emergency Training and Exercise

The emergency plans should provide for any training and testing of individuals or organisational units necessary to assure and demonstrate that they are qualified and able to completely fulfill 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.

18.7 Emergency Facilities and Equipment

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

(i) administration facilities;

(ii) communication system;

(iii) technical support and control centres;

(iv) personnel/public assembly areas;

(v) an emergency operations coordination centre;

(vi) a centre to integrate on-site activities with off-site programs;

(vii) first aid or medical facilities;

(viii) laboratory facilities; and

(ix) fire fighting facility.

The following equipment and materials might also be needed:

(i) an emergency source of electrical power;

(ii) reference materials such as accurate versions of charts, maps, plans, drawings, diagrams, specifications and procedures;

(iii) safety and personnel protective equipment and supplies (e.g. fire fighting, physical and respiratory protection);

(iv) administrative aids, such as status boards and reference materials; and

(v) 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 to assure that the emergency equipment, facilities or materials remain in acceptable condition at all times. These provisions could include inspection, testing, maintenance or replacement, within formal systems of quality control and inventory control and accounting.

18.8 Activation and Termination of Emergency Responses

The emergency plan should describe the procedures for initiating and terminating responses to both onsite and offsite emergencies associated with facility operations.

18.9 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.

APPENDIX-I

PRODUCTION OF CLADDING MATERIAL

A1.1 Introduction

Zircaloy is used as cladding material of fuel. For making of zircaloy cladding material, starting material used is zircon sand. Hafnium is critical impurity since it has high neutron absorption cross section (105 barn) compared to zirconium (0.18 barn). Reactor grade zirconium contains not more than100 ppm of hafnium since the cross section is raised by about 0.01 barn for 100 ppm of hafnium present. Zircon sand is fused with caustic soda flakes, leached and filtered in filter press and dried to produce dry frit. This dry powder is dissolved in nitric acid, extracted with tri-butyl phosphate and kerosene to remove hafnium, stripped with DM water, precipitated by NH_4OH, filtered, repulped, dried, calcined, ground and blended to produce reactor grade ZrO_2 powder. Then ZrO_2 powder is converted to reactor grade Zr sponge by briquetting, oxide chlorination, reduction by magnesium and vacuum distillation by Kroll's process. Manufacturing of zircaloy tubes is carried by conversion of zirconium sponge to ingots, melting of ingots, piercing and extrusion, pilgering, annealing and finishing operations. Uranium oxide pellets are loaded in zircaloy tube.

A1.2 Process Description

A1.2.1 Production of zirconium oxide powder

Zircon sand is fused with caustic soda flakes at 700^0C. The resultant 'Frit'- a mixture of sodium zirconate and water soluble sodium silicate is cooled to ambient temperature and leached with water to remove the later. The leached slurry is filtered, washed to remove sodium silicate and the dewatered cake dried at 170^0C to obtain dry powder (sodium zirconate). The dry powder is then dissolved in 60% concentrated nitric acid (HNO_3) at 85^0C, the slurry filtered in a precoat vacuum drum filter to remove insoluble silica and sand. The clarified filtrate is crude zirconyl nitrate solution and the same is adjusted and extracted with 50% TBP-Kerosene solvent in a battery of mixer-settlers as a purification step. While hafnium goes along with the raffinate, pure zirconyl nitrate solution is obtained by stripping the pure extract with DM water. The pure nitrate solution is further diluted, acidified with sulphuric acid, precipitated with 10N ammonia solution. The hydroxide slurry is filtered, hot air dried, calcined around 800^0C, ground to -325 mesh as a starting material for zirconium sponge production.

Flow sheet for production of zirconium oxide powder is given in Fig.5

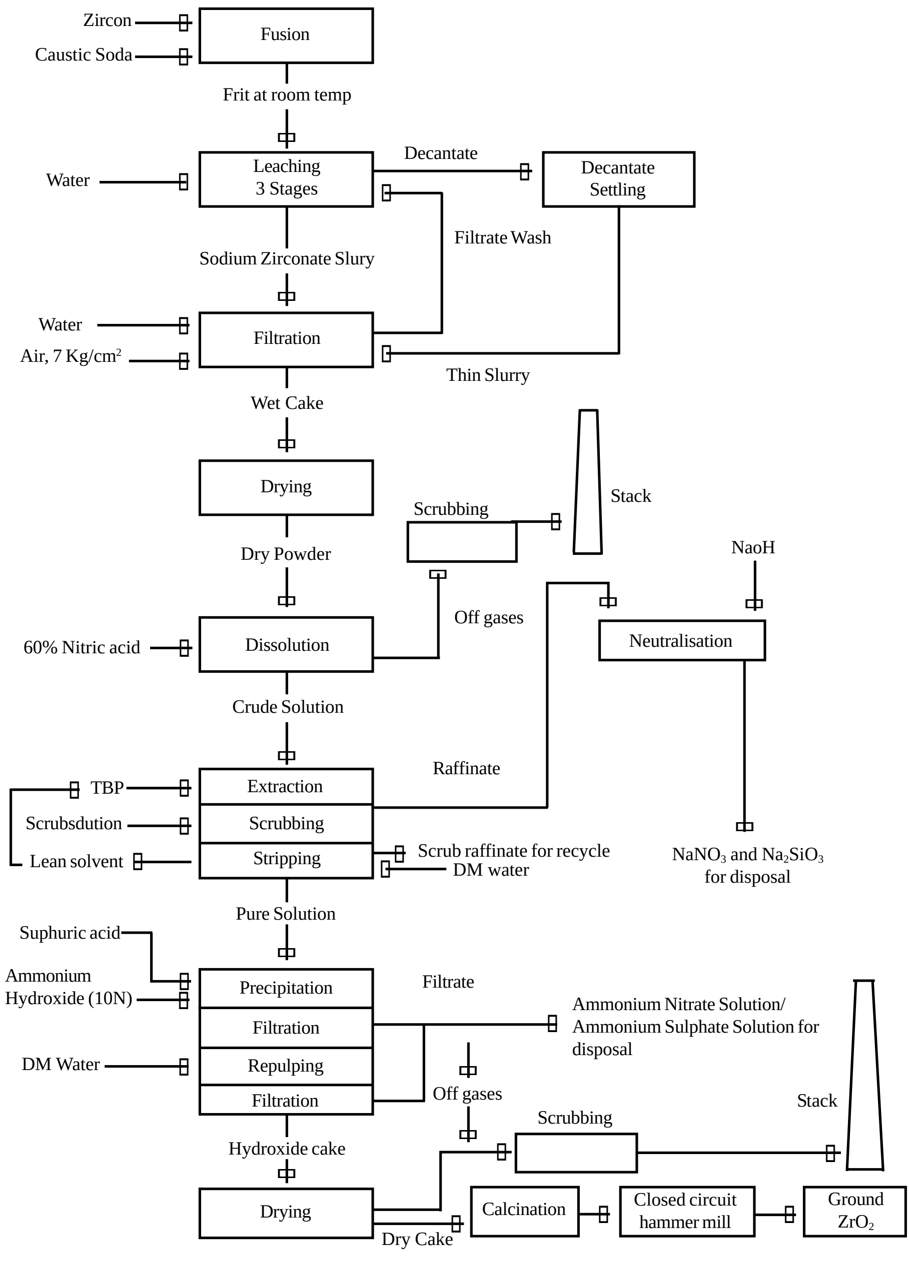

FIG 5 : PROCESS FLOW SHEET FOR PRODUCTION OF ZrO_2 POWER

A1.2.2 Production of Zirconium Sponge

Different operations for production of nuclear grade zirconium sponge from zirconium oxide powder are described below:

(a) Oxide feed preparation

This involves production of zirconium oxide-carbon briquettes, by kneading finely divided powders with starch solution followed by wet extrusion into briquettes, drying of briquettes in ovens and coking in nitrogen atmosphere at 650^0C .

(b) Oxide chlorination

Direct chlorination of oxide-carbon briquettes in a self-resistance heated silica brick lined furnace at about 1000^0C and desublimation of raw zirconium tetrachloride.

(c) Purification

Purification of zirconium tetra-chloride in a redistillation furnace. About 20% of the total chloride produced is purified by resublimation.

(d) Reduction

Magnesio-thermic reduction of zirconium chloride at 850^0C in a controlled inert atmosphere of argon at a pressure of 1.5 to 3.5 psig .

(e) Vacuum distillation

Isolation of zirconium sponge free from magnesium chloride, and unreacted magnesium at 950^0C by high vacuum distillation in vacuum distillation units .

(f) Sponge grading

Grading, crushing, screening and blending of zirconium sponge to reactor grade specification.

Flow sheet for production of nuclear grade zirconium sponge from zirconium oxide powder is given in Fig-6.

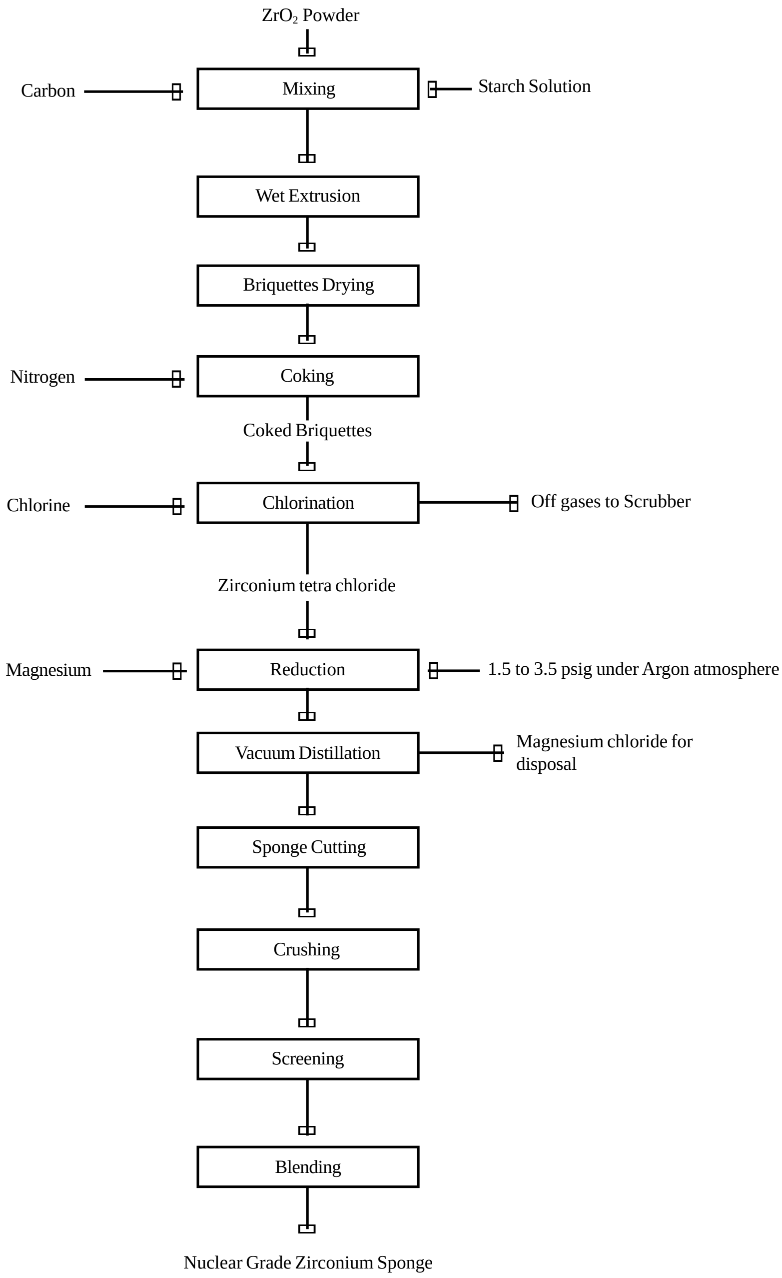

FIG 6 : PROCESS FLOW SHEET FOR PRODUCTION OF NUCLEAR GRADE ZIRCONIUM SPONGE

A1.2.3 Production of Zircaloy Fuel Tube

Crushed sponge is compacted with necessary alloying elements and consumable electrode is fabricated by welding together the compacted mass. The electrode is melted in vacuum arc furnace to get zirconium alloy ingots. Multiple melting is carried out to ensure thorough homogeneity of alloying elements. The zircaloy ingots are hot extruded in horizontal extrusion press to intermediate sizes. The cast structure is broken and the billets thus obtained are further hot extruded in the form of tube blanks. The extruded tube blanks are conditioned and subjected to pilgering in multiple passes with intermediate vacuum annealing to meet the specification of finished products in terms of dimensions, texture, microstructure and mechanical properties. Flow sheet of production of fuel tube is given in Fig-7.

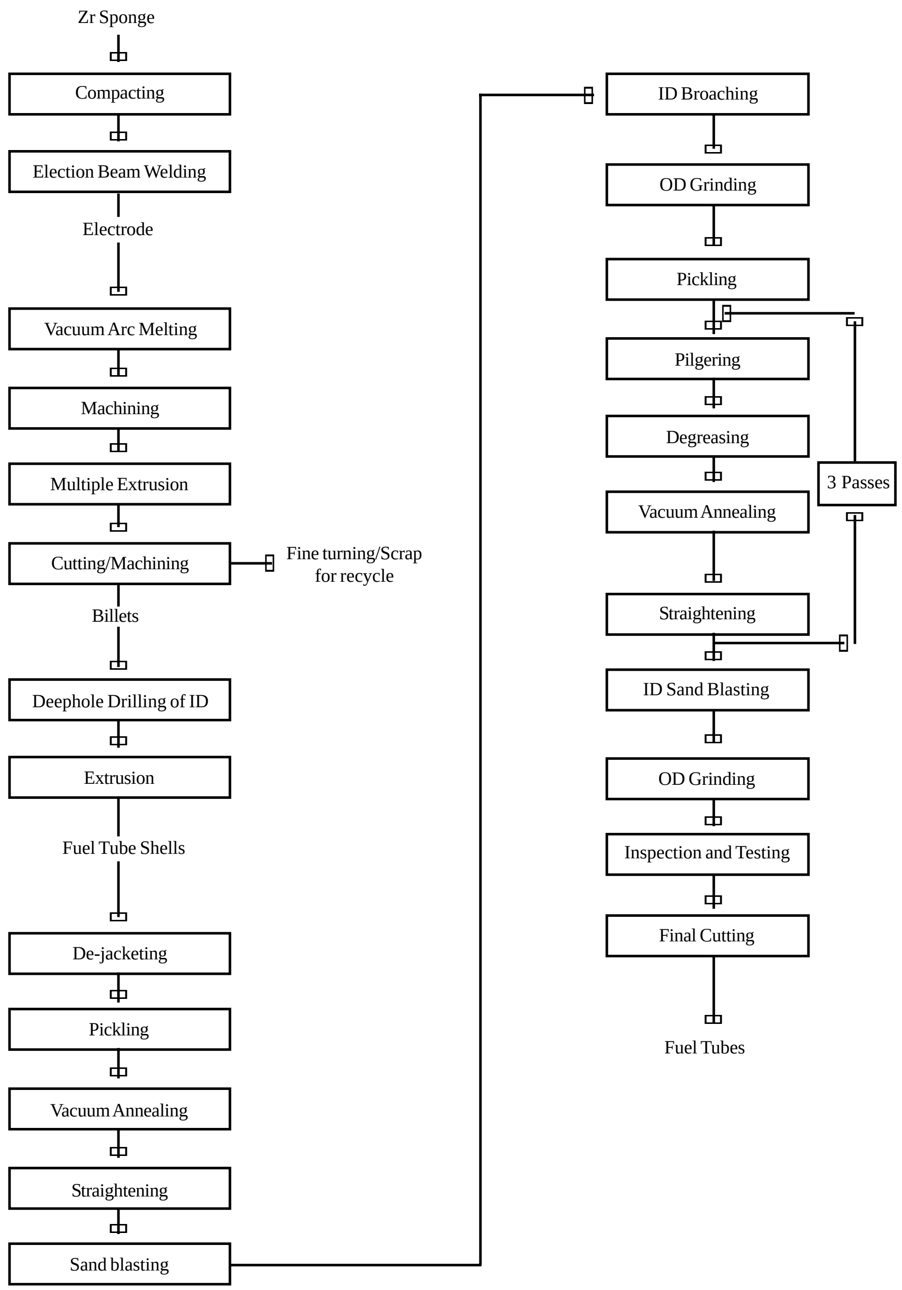

FIG 7 : PROCESS FLOW SHEET FOR PRODUCTION OF ZIRCALOY FUEL TUBES

A1.3 Safety Aspects

The following safety aspects should be considered during production of cladding materials.

Uninterrupted power supply (UPS) should be provided for the mechanical pumps of vacuum distillation units.

Exhaust system should be provided for feed preparation, chlorination, chlorine storage area, reduction and vacuum distillation section for removing the fumes produced during the operation.

Chlorine sensors should be installed at chlorine tonners and chlorination area to annunciate an alarm in case the limits are exceeded.

Emergency chlorine kits should always be ready and accessible in a chlorine storage area.

Control rooms should be maintained at a positive pressure and double door arrangement to prevent entry of toxic vapours.

Monitoring equipment for the detection of hazardous gases such as ammonia, should be placed in different areas of the plant to indicate concentration of the gases continuosly and to know the leakages if any before any major accident.

All critical equipment of the process and utilities should be supplied with dual power (Class III and Class IV) to ensure running of critical sections of plant in case of main power failure.

In hazardous areas with flammable gases and vapours and combustible substances, the electrical equipment should be of flameproof construction to avoid any fire hazard.

Chemicals storage tanks should be segregated and dykes should be provided around the storage tanks to collect leakages.

AERB safety manual 'Construction Methodology for Civil Engineering Structures Important to Safety of Nuclear Facilities' (AERB/SM/CSE-3) should be followed for construction of structures.

Ingress of water/air into reduction retort containing molten magnesium would lead to formation of hydrogen, which may lead to explosion. The water jacket of the reduction retort should be hydraulically tested to check its integrity before every batch.

Sodium silicate, acidic raffinate, ammonium nitrate and sulphate solutions, anhydrous magnesium chloride, zircaloy turnings are the main wastes generated during production of cladding material. Suitable holding, treatment and disposal plan should be made for solid and liquid wastes as per approved procedure of state pollution control board.

For gaseous wastes like vapours of NO_X, SO_X, ammonia and chlorine, appropiate exhaust ventilation system/scrubber should be provided.

Zircaloy turnings should be collected and stored under water until further treatment.

Adequate numbers of wall mounted exhaust fans and roof ventilators should be fitted in vapour and fume generating areas.

Solvent extraction is a major fire hazard in the production of cladding material. This should be considered as a separate fire zone. The electrical fittings should be of appropriate safety type. Motors should be of flameproof type. Fire/ smoke detector and alarm systems of suitable type (ionisation, UV and I/R type) having adequate sensitivity should be mounted in sufficient numbers to cover the entire area. Manually operated fixed fire suppression system using CO_2 should be provided to cover mixer settler area. Suitable precautionary signboards highlighting the need for fire prevention in this area should be prominently displayed. Personnel entry should be restricted in this area. A separate fire escape route should be provided for personnel to escape in case of accidental fire. This should be fitted with self-closing devices with doors opening outside the fire/smoke area. Adequate ventilation system (min. 6 air changes per hour) using required fire dampers should be provided. Bulk quantity of TBP/ Kerosene should not be stored in this area.

The nuclear grade ZrO_2 is converted to zirconium sponge by magnesio-thermic reduction of $ZrCl_4$ followed by high temperature vacuum distillation of zirconium sponge. Removal of zirconium sponge and crushing operation are potential fire hazard due to pyrophoricity of sponge. UV detector type fire alarm system should be mounted in crushing area and the detector supply should be always “ON”. Sufficient numbers of portable fire extinguishers like dry chemical powder (DCP) should be provided in this area to put out metal fires. Lighting in this area should be of flame proof. Special care should be taken to earth all the equipment and metal drums containing Zr-sponge should be sealed and kept in rows to avoid consequences of static electricity.

During zircaloy fabrication, zircaloy material is converted into different shapes like rods, sheets, thin and thick wall tubes etc. The operations involve machining, rolling, drawing, vacuum annealing, welding etc. The zircaloy scrap generated during the fabrication should be collected in drums and always stored under water. In pickling and degreasing area, where flammable/toxic materials like tetrachloro ethylene (TCE) and acetone are used, storage of such flammable liquids should be controlled. Adequate numbers of fire extinguishers for fighting class B fire should be available in this area. Fire detection and alarm systems of suitable type should be installed in this area.

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

Dates of meeting	:	February 17, 2006	January 09, 2007
		May 16, 2006	March 09, 2007
		September 25, 2006	April 16, 2007
		December 15, 2006	June 07-08, 2007
		December 26, 2006	September 06, 2007

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PROVISIONAL LIST OF REGULATORY DOCUMENTS ON NUCLEAR FUEL CYCLE FACILITES

Safety Series No.	Titles
AERB/FE&BE-FCF/ SG-1	Renewal of Licence for Operation of Nuclear Fuel Cycle Facilities other than Nuclear Power Plants & Research Reactors
AERB/NF/SG/IS-6 (To be renumbered as AERB/FE-FCF/SG-1)	Thorium Mining and Milling
AERB/FE-FCF/SG-2	Radiological Safety in Uranium Mining and Milling
AERB/FE-FCF/SG-3	Uranium Oxide Fuel Fabrication Facilities
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AERB/BE-FCF/SG-4	Decommissioning of Nuclear Fuel Reprocessing Facilities
AERB/BE-FCF/SG-5	Physical Protection of Nuclear Fuel Reprocessing Facilities
AERB/BE-FCF/SG-6	Emergency Preparedness Plan of Nuclear Fuel Reprocessing Facilities

AERB SAFETY GUIDELINES NO. AERB/FE-FCF/SG-3

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