REQUIREMENTS FOR INDUSTRIAL ACCELERATOR RADIATION PROCESSING FACILITY (IARPF)

A.1 SCOPE

A.1.1 Industrial Accelerator Radiation Processing Facility (IARPF) uses either an electron beam directly or electron beam generated high-energy photons for radiation processing. These facilities are notable for absence of inventory of any radioactive source material in the plant, and associated handling hazards.

A.1.2 For direct electron beam use, the beam energy shall be limited to 10 MeV; and for generating high-energy photons, the primary electron beam energy shall be limited to 7.5 MeV. A beam power of several kW is used in various radiation processing applications in an IARPF. Radiation shielding and personnel-safety interlocks shall be provided to limit the radiation exposure to workers and member of public, and prevent accidental exposure respectively.

A.1.3 AERB Safety Guides No. AERB/SG/IS-5 and AERB/RF/SG/G-3 should be appropriately used for layout, design, construction and operation of IARPF.

A.1.4 Electron accelerators of the following types shall be used in an IARPF:

(i) High-voltage DC accelerator from 0.5 to 3 MeV beam energy.

(ii) Radio-frequency (RF) electron linear accelerator (RF Linac) from 3 MeV upwards.

(iii) Other electron accelerators such as microtron, betatron, rhodotron and induction-linac shall be utilized in radiation processing facility with the specific permission of Competent Authority.

A.1.5 This Safety code shall be applicable to the land-based installations only.

A.2 Common Requirements

Design and operational safety details for IARPF, which are common for any of above types of accelerator, shall meet following requirements:

A.2.1 Siting Requirements

(i) The applicant shall submit authenticated documents issued by relevant Government agencies showing the status of ownership/lease of the premises for the proposed IARPF. All the statutory requirements of central and state governments, as applicable for the facility, shall be complied with.

(ii) The building of IARPF shall be engineered on the basis of seismic characteristic of the site taking into account the maximum intensity of a likely earthquake as specified in IS-1893 (Part-1), 2002 or an updated version.

(iii) A minimum distance of 30 meters shall be maintained from the boundary wall of the IARPF to any nearby residential area and/or public places.

(iv) Geological and geotechnical requirements for design and construction of the IARPF shall take into account all applicable requirements specified in **Appendix-A** of AERB Safety Standard No. AERB/RF-IRRAD/SS-6 (Rev.1), 2007.

(v) The civil works structures of the IARPF shall be designed such that the soil and ground characteristics do not cause any deterioration in its strength and integrity during the useful life of the IARPF.

(vi) The maximum level of ground water and design basis flood level shall be taken into account in the radiological safety aspects of the design of the IARPF.

(vii) The access road to the site shall be strong enough to take the load of heavy parts of the IARPF.

A.2.2 Engineered Safety Design Requirements

A.2.2.1 Biological Shielding

(i) Adequate thickness of biological shield around the accelerator beam channel and radiation cell shall be provided such that the dose rate in full occupancy areas does not exceed 1 $\mu Sv.h^{-1}$ while accelerator beam is in 'Switched- ON' mode.

(ii) Any penetrations provided in biological shielding for services and access shall not cause increase in the radiation levels out side the shielding.

(iii) Concrete used for the construction of the biological shielding shall have density stipulated in the shielding calculations. Adequate quality control shall be ensured during pouring of concrete into the walls to achieve the minimum specified density, and exclusion of formation of porosity and voids.

A.2.2.2 Personnel Access Control System

Exclusion of any personnel presence in the accelerator beam channel and radiation cell areas shall be positively achieved before the accelerator beam is 'switched-on'. This shall be achieved through a few engineered layers of barrier involving design features, provision of sensors and associated instrumentation, as well as adherence to strict procedural sequencing. Design policy of defence in depth shall be adhered to, and demonstrated in the safety assessment reports submitted to the Regulatory Body. Essential design provisions for this are outlined below:

(i) Personnel Access Door

(a) Entry into accelerator beam channel and radiation cell areas shall be regulated through personnel access door/s. Each personnel access door shall be accessible / visible to the plant operator/RSO from their respective work places, e.g. control room. In addition, CCTV surveillance shall be provided.

(b) Material and construction of the access door shall be such that it can withstand fire in the plant for at least half an hour

(c) The product entry/exit shall be so designed that by suitable interlocks it precludes the possibility of entry by personnel.

(ii) Beam Switch-on Interlocks

Control system for IARPF shall be designed to ensure complete exclusion of any person in the accelerator beam channel and radiation cell when electron beam is switched-on and accelerated. This shall be achieved through a series of engineered safety interlocks as mentioned below:

(a) Provision of limit switches to ensure complete closure of access doors before beam is switched-on.

(b) The above limit switch shall be designed to switch-off the electron beam when anyone tries to open the access door during radiation processing.

(c) A sequential 'search and secure' procedure by the operator himself, to ensure that nobody is present in the accelerator beam channel and radiation cell, by activating the safety buttons located therein. At the end of search, the access doors shall be secured in the closure mode, and accelerator controls are activated into operational standby mode.

(d) The standby mode shall not have dwell time lasting more than a few minutes, after which the 'search and secure' condition shall become deactivated.

(e) The close-circuit TV monitoring of access doors and secured areas shall be provided in the control desk/console. Any unauthorized entry into the monitored areas shall prompt operator to turn the accelerator beam into 'switched off' mode, with or without rendering plant in standby mode for investigation of the incident.

(iii) Radiation Monitoring Instrumentation

All access doors to the monitored areas shall be provided with display of beam mode (OFF, STANDBY, ON) and local radiation monitoring instrumentation. Any increase above the prescribed dose rate limits shall activate audio-visual alarms at these locations and warning to the operator.

A.2.2.3.Work Area Zoning (for graded safety)

Radiation hazards in the IARPF plant areas shall have graded safety requirements. Access to these work areas is regulated by categorising the areas into different zones. Access control gates shall be put at inter-zone boundaries where entry of authorised persons is regulated e.g. with finger print impression or magnetic card. Various IARPF plant areas shall be categorized into one of the following zones:

(i) Zone- 1: Normal Area of Full Occupancy

These places shall be accessible all the time and irrespective of whether accelerator beam is in OFF, STANDBY or ON mode. These include places such as- control room, corridors and passages, plant process equipment rooms and product loading/unloading and storage areas. The biological shielding shall be so designed as to ensure that the radiation dose rate in such areas of full occupancy at any time, is below 1 μSvh^{-1}.

(ii) Zone-2: Controlled/Restricted Entry Area

These places are accessible during beam ON mode with appropriate administrative controls in place. Appropriate area monitoring and personnel radiation monitoring shall be provided for workers visiting these areas during beam ON mode. In these places, the dose rate during beam 'ON' may exceed 1 μSvh^{-1} but shall not exceed 10 μSvh^{-1}.

(iii) Zone-3: Inaccessible Areas

These areas, having high dose rate during beam ON mode shall be designed and engineered with safety interlocks and administrative controls to exclude access and/or breach of safety during beam STANDBY/ON mode. Such places include accelerator beam channel and irradiation cell areas that have very high dose rates during beam ON mode.

(iv) Only authorised persons shall be allowed to enter zone-2 and 3 areas and when so allowed they shall wear appropriate personnel radiation monitoring devices.

A.2.2.4 Fire Safety

A.2.2.4.1Fire hazards in product processing

In case of interruption of beam versus product movement, engineered safety systems shall be designed with suitable monitoring and interlocks such that:

(i) In case of failure of scanning magnetic field, the beam shall be immediately switched off to preclude overheating of beam window and product which may lead to fire hazard.

(ii) In case of interruption of conveyor movement for any reason, the beam shall be immediately switched off similarly.

(iii) There shall be a suitable provision for non-interceptive monitoring of beam at or near the processing location to limit the maximum beam energy and current used in the product processing, as per specifications of the safety envelope of the IARPF.

A.2.2.4.2 Plant Fire Safety

(i) Flammable substances, solvents, oils, hydrogen, acetylene etc. shall be carefully stored and care shall be taken in housekeeping and storage of other materials, to avoid and control fire hazard in the IARPF.

(ii) Fire protection shall be planned in terms of prevention, provisions for prompt detection and containment. Smoke detectors shall be installed at appropriate locations with alarm annunciation in control room.

(iii) Adequate fire extinguishers around the fire susceptible areas shall be maintained. Proper training in firefighting shall be provided to operation personnel. Periodic demonstrations and fire drills shall be conducted.

(iv) Power cables for use in the electron beam irradiation cell shall be of cross-linked fire-retardant low-smoke (FRLS) type. Other cables shall be protected against the degrading effects of ozone present therein.

A.2.2.5 Ventilation System

A.2.2.5.1 Beam Window Air-cooling

This shall require interlocking of beam window cooling by air/water circulation with the beam switch-ON. The exhausted air from beam window cooling contains high ozone content, and this shall be led to the exhaust stack of plant ventilation system.

A.2.2.5.2 Plant Ventilation System

(i) Ozone (O_3) and nitrogen oxides (NO_x) and other toxic gases generated during radiation processing shall be continuously scavenged by means of a suitable ventilation system to minimize the concentration in the irradiation cell and likely gaseous diffusion into the occupied areas.

(ii) Air handling units (AHU) of the ventilation system shall be designed to supply fresh air to various zones such that concentration of noxious gases are within permissible limits and also ensuring dissipation of heat from various power supply equipment.

(iii) Ventilation (induced draft type) in the radiation cell shall be achieved by providing fresh air entry through grills/louvers and also incorporating exhaust fans (with standby provision) in the system.

(iv) There shall be adequate number of fresh air changes in the radiation cell to prevent the concentration of O_3, NO_x and other toxic gases exceeding three times their Threshold Limit Values (TLV) during radiation processing.

(v) Ozone monitors shall be provided in installations where Ozone concentrations are likely to be significant.

(vi) Discharge point of the duct (stack outlet) of exhaust fans shall be located at a height appropriate to achieve dilution of Ozone to its Threshold Limit Value (TLV) while reaching ground level, but at least 2.5 m above the tallest part of the radiation processing facility.

(vii) Time delay interlock shall be provided to prevent personnel entry into the radiation processing cell immediately after the beam switch off. The delay time shall be adequate to allow dissociation of Ozone and bring down its concentration below TLV (i.e. below 0.1 ppm for normal human activity, and 0.05 ppm for heavy work).

(viii) Plant ventilation system shall consist of ventilation dampers to stop and isolate air-circulation in an area affected by fire. This shall stop spread of smoke and toxic fumes to other occupied areas, which shall be subsequently scavenged in a controlled manner after extinguishing the fire.

A.2.2.6 Electrical Safety

It shall be ensured that the plant design and operation are in compliance with the safety requirements of the applicable government regulations and local statutory body/agency on electrical equipment (both high and low voltage systems, radiofrequency and magnetic devices etc.) used in the IARPF.

A.2.2.7 Low-conductivity Cooling Water (LCW) System

The following safety provisions are required in an LCW system:

(i) Accelerating cavity and RF power system of linac and internal tank systems of DC accelerator shall use cooling water which is conditioned for very low electrical conductivity, as per limits specified by equipment supplier to minimize the leakage of current from high voltage devices to the ground.

(ii) There shall be safety interlocks with regulating instruments for temperature, flow and pressure of LCW, such that these shut the beam current under abnormal conditions.

A.3 Accelerator-Type Specific Requirements

Two types of electron accelerators shall be applicable for use in the radiation processing facilities, namely (i) the DC high-voltage accelerator and (ii) the Linear RF accelerator. Specific facility configuration of plant equipment in these two types shall conform to the requirements as specified below:

A.3.1 DC High-voltage Accelerator Systems

This system utilizes high voltage DC power supply of rectifier-multiplier enclosed in a separate or the same tank as the accelerator channel.

A.3.1.1 High-voltage Power System

High-voltage power system shall be engineered to protect against arcing, electrical discharge and inadvertent contact with live/charged components by operation and maintenance personnel.

A.3.1.2 Insulation and Cover System

Insulation and cover gas systems shall use either sulphurhexa-fluoride (SF_6) gas or, mixture of nitrogen and carbon di-oxide ($N_2 + CO_2$). For any other cover gas system, specific approval of Competent Authority shall be required.

The following provisions for safety shall be implemented in the plant while using cover gases in an IARPF:

(i) Gases shall be monitored for maintaining their purity in usage as recommended by the equipment supplier e.g. for moisture content, impurities, products of dissociation under likely high-voltage discharges.

(ii) Gas temperature and pressure shall be continuously monitored, recorded and maintained within maximum and minimum specified for normal operation.

(iii) Containment pressure vessels and connecting piping shall be provided with overpressure relief devices (e.g. safety valves, rupture disks), as recommended in the certification/statutory codes applicable for pressure vessel construction and operation.

(iv) Gas-monitoring instrumentation and oxygen deficiency monitors with alarms shall be installed at locations where the likelihood of gas leakages or release due to overpressure safety device actuation exists.

(v) The ventilation system shall have exhaust ducts running from the lowest elevation to collect and scavenge the leaked heavier-than air gases in the plant where the such gases are concentrated.

(vi) All pressure components of the gas handling system shall be tested periodically for integrity of pressure as per the applicable statutory regulations.

A.3.2 RF Linac Systems

A.3.2.1 The accelerating RF cavity which is subjected to heating due to RF power dissipation in its internal walls shall be provided with air/water cooling system to accurately maintain its temperature for satisfactory operation as electron linear accelerator.

A.3.2.2 RF Power System

(i) RF power leakages being a potential source of electromagnetic interference, causing malfunction of sensitive instrumentation for radiation monitoring and process controls, shall be checked during testing of accelerator systems, before and during commissioning of operations.

(ii) For human exposures, limits of allowable RF radiation leakages shall be maintained as per internationally accepted limits such as those prescribed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). In general, leakage RF radiation power density limit of 1 $mw.cm^{-2}$ shall be maintained at all times.

(iii) RF power system and equipment shall be provided with separate ground/ earthing to avoid electromagnetic interference with other devices.