

System number: CAEA-AA0002 Originated from: EJ/T 20078-2014

Safety requirement of nuclear fuel cycle facilities

CHINA ATOMIC ENERGY AUTHORITY

EJ Nuclear Industry Standard of the People's Republic of China

Translation of EJ/T 20078-2014

Safety requirement of nuclear fuel cycle facilities

lssue date:2014—11—17 Implementation date:2015—02—01

Translation issue date:XX-XX-XX

ENGLISH VERSION OF THIS STANDARD IS ISSUED BY CHINA ATOMIC ENERGY AUTHORITY

ntei	nts
	ntei

Foreword	III
Introduction	IV
1 Scope	. 1
2 Normative references	. 1
3 The safety objective and concepts	. 1
3.1 Safety objective.	. 1
3.2 Defence in depth	. 1
3.3Licensing documentation	. 2
3.4 Application	. 3
4 Management system and verification of safety	. 3
4.1 General	. 3
4.2 Safety, health and environmental policies	. 4
4.3 Organizational provisions	4
4 4 Safety culture	. 1
4.5 Accident management and emergency preparedness	• 1 5
A 6 Varification of soloty	. 0
4.0 Verification of safety	. 0
5 Station of the feetbalt	. 0
	. 0
5.1 Initial site evaluation and site selection	. 0
5.2 Ongoing site evaluation	. (
6 Design	. 8
6.1 General	. 8
6.2 Design basis.	. 8
6.3 Design assessment.	. 9
6.4 Safety requirements	10
6.5 Design for protection against radiological hazards	13
6.6 Non-radiological hazards	14
7 Construction of the facility	15
8 Commissioning of the facility	15
8.1 Commissioning programme	15
8.2 Organization and responsibilities	15
8.3 Commissioning tests and stages	16
8.4 Commissioning procedures and reports	16
9 Operation of the facility	17
9.1 General requirements during operation	17
9.2 Operating instructions	18
9.3 Maintenance, calibration, periodic testing and inspection	19
9.4 Control of modifications	19
9.5 Radiation protection during operation.	20
9.6 Criticality control during operation	21
9.7 Management of radioactive waste and effluents in operation	21
9.8 Management of industrial and chemical safety in operation	21
9.9 Emergency preparedness.	22
9.11 Verification of safety	22
10 Decommissioning of the facility	23
10.1General	23
10.2 Decommissioning plan	23
10.3 Decommissioning operation	20 22
	20

EJ/T	20078-2014	

10.4 Completion of decommissioning	24
ANNEX A (NORMATIVE ANNEX) Requirements Specific to Uranium Fuel Fabrication Facilities .	25
A.1 Scope	25
A.2 Design	25
A.2.1 Safety functions	25
A.3 Operation	26
ANNEX B (NORMATIVE ANNEX) Requirements Specific to Mixed Oxide Fuel Fabrication Facili	ities
	28
B.1Scope	28
B.2 Design	28
B.3 Operation	29
B.4 Decommissioning	30
ANNEX C (NORMATIVE ANNEX) Requirements Specific to Nuclear Fuel Reprocessing Plant	32
C.1 Scope	32
C.2 Siting.	32
C.3 Design	32
C.4 Commissioning	35
C.5 Operation	36
C.6 Decommission	38
ANNEX D (NORMATIVE ANNEX) Requirements specific to mixed oxide fuel fabrication facilities.	39
D.1 scope	39
D.2 Design	39
D.3 Construction.	42
D.4 Commissioning	42
D.5 Operation	42
D.6 Decommissioning	43
ANNEX E (NORMATIVE ANNEX) Requirements Specific to Fuel Cycle Reseach and Developm	ient
	44
	44
$E.2 \text{ Design} \dots \dots$	44
	45
	45
ANNEX F (informative annex) Selected Postulated Initiating Events	40
F.I External postulated initiating events	46
F.2 Internal postulated events	40
ANNEA G (INFORMATIVE ANNEA) Availability and Kenability Frinciples Used in Fuel Cy Encility Sofoty	
C 1 Dodundanov	
C 2 Indonondoneo	47
C = 3 Diversity	47
C 4 Double contingency	
C 5 Fail-safa dasian	
C 6 Tostability	
ANNEX H (INFORMATIVE ANNEX) Safety in the Design of a Fuel Cycle Facility	18
H 1 Scone	18
H.1 Scope	40
H 3 Identification of hazards	-10
11.J IUCHUHICAUVII VI HALAIUS	18
H 4 Hazard evaluation	48 48
H.4 Hazard evaluation	48 48 49
H.4 Hazard evaluation	48 48 49 49

Foreword

This standard is derived from the International Atomic Energy Agency (IAEA) Safety Standard NS-R-5 (2008 Edition) "SAFETY OF NUCLEAR FUEL CYCLE FACILITIES".

Compared with the IAEA safety standard NS-R-5 (2008 Edition), the main changes are as follows:

- The managerial requirement of the IAEA safety standard NS-R-5 (2008 Edition), for example, "the formation of management system" in chapter 4 "regulatory framework and management supervision" and "safety management system and certification" was deleted;
- ——Additional part of DS 439"Requirements for Nuclear Fuel Reprocessing Plant and Requirements for Nuclear Fuel Cycle Research and Development Facilities" of IAEA Safety Standard NS-R-5 (2008 edition) was added to this Standard;
- The Reference Standard changed to the Corresponding Domestic Standard, for example, "the International Basic Safety Standards for Ionizing Radiation Protection and Radiation Source Safety" was replaced by the GB 18871"Basic Standards for Ionizing Radiation Protection and Radiation Source Safety".

Annexes A, B, C, D and E of this standard are normative. Annexes F, G and H are informative.

Introduction

The IAEA Safety Standard NS-R-5 (2008 edition) "Safety Requirements for Nuclear Fuel Cycle Facilities" is a summary of the safety experience of nuclear fuel cycle facilities in various countries, reflecting the international consensus on high-level safety of nuclear fuel cycle facilities. This standard adopts the IAEA safety standard NS-R-5 (2008 edition), which will be conducive to the safety of domestic nuclear fuel cycle facilities. Due to the characteristics of IAEA Safety Standard NS-R-5 (2008 edition), some declarations of this standard are described as follows:

- ----- This standard does not replace any regulations or guidelines on the safety of nuclear fuel cycle facilities. It provides guidance and suggestions on how nuclear fuel cycle facilities meet the requirements of HAF301 "Safety Regulations for Civil Nuclear Fuel Cycle Facilities";
- ----- This standard does not fully reflect the experience of some domestic nuclear fuel cycle facilities;
- This standard does not reflect some changes in safety requirements for nuclear fuel cycle facilities after the Fukushima accident.

Safety requirement of nuclear fuel cycle facilities

1 Scope

This standard specifies the safety requirements for the site selection, design, construction, commissioning, operation and decommissioning of nuclear fuel cycle facilities.

This standard applies to refining, conversion, enrichment, fabrication of fuel, spent fuel storage, spent fuel reprocessing, waste conditioning, storage and related research facilities. This standard is applicable to new, renovated and extended facilities. This standard may also be applied to existing fuel cycle facilities as appropriate.

2 Normative references

The terms in the following documents become the terms of this standard by reference to this standard. For dated references, all subsequent amendments (not including errata content) or revisions do not apply to this standard. However, parties to agreements based on this standard are encouraged to study whether the latest versions of these documents are available. For undated references, the latest edition applies to this standard.

GB 14500 Regulations for radioactive waste management

GB 18871-2002 Basic standards for protection against ionizing radiation and for the safety of radiation sources

GB 19597 Safety requirements for decommissioning of nuclear facilities

EJ/T 1054 Physical Protection of Nuclear Materials and Facilities

HAD 002/07 Emergency Preparedness and Response of Operating Organization of Nuclear Fuel Cycle Facility

IAEA NS-R-3 Site evaluation of nuclear installations

3 The safety objective and concepts

3. 1 Safety objective

3. 1. 1 The safety objective is to protect operating personnel, the public and the environment from harmful effects of ionizing radiation.

3. 1. 2 To achieve this safety objective in 3.1.1, measures shall be taken:

- a) To control the radiation exposure of operating personnel, the public and the release of radioactive material to the environment;
- b) To restrict the likelihood of events /accidents;
- c) To mitigate the consequences of events / accidents.

3. 1. 3 In the context of fuel cycle facilities, the control of events initiated by chemical hazards shall be considered in the design, commissioning and operation of the facility.

3. 1. 4 Activities at fuel cycle facilities may also include industrial processes that pose additional hazards to site personnel and the environment. Purely industrial hazards are outside the scope of this standard, but they shall be considered by the operating organization.

3. 2 Defence in depth

3. 2. 1 The concept of defence in depth shall be applied at the facility for the prevention and mitigation of accidents. Defence in depth is the application of multiple levels of protection for all relevant safety activities, whether organizational, behavioural or equipment related. Application of the concept of defence in depth throughout the design and operation of a fuel cycle facility provides multilayer protection against a wide range of anticipated operational occurrence and accident conditions, including those resulting from equipment failure or human error within the facility, and from events that originate outside the facility.

3. 2. 2 The strategy for defence in depth shall be twofold: first, to prevent accidents, and second, if prevention fails, to limit the potential radiological and associated chemical consequences and to prevent any evolution to more serious conditions. Defence in depth is generally structured in five different levels, as set out in Table 1. If one level fails, the subsequent level comes into play.

3. 2. 3 The design features, controls and arrangements necessary to implement the defence in depth concept shall be identified mainly by means of a deterministic analysis (which may be complemented by probabilistic studies) of the design and operational regime. The analysis shall be justified by the application of sound engineering practices based on research and operational experience. This analysis shall be carried out during the design stage to ensure that the regulatory requirements can be met.

3. 2. 4 Defence in depth shall be implemented by taking into account the graded approach. The amount and type of radioactive material present, the potential for dispersion, the potential for nuclear, chemical or thermal reactions, and the kinetics of such events shall all be considered in determining the required number and strength of lines of defence (independence, diversity, redundancy, etc.).

3. 2. 5 The degree of application of each level of defence in depth shall be commensurate with the potential hazards of the facility and shall be established in the facility's licensing documentation.

3. 3 Licensing documentation

3. 3. 1 The operating organization shall establish and justify the safety of its facility through a set of documents known as the 'licensing documentation'. The licensing documentation shall provide the basis for the safe siting, construction, commissioning, operation and decommissioning of the facility, including the justification for changes.

3. 3. 2 The content of the licensing documentation for a facility shall at least include the safety analysis report and the operational limits and conditions or equivalent. Consideration of the application of the principle of optimization of protection in the design and operation of the facility shall be included in the licensing documentation.

3. 3. 3 The safety analysis report shall provide a detailed demonstration of the safety of the facility. It shall give a detailed description of those aspects having safety significance, such as information on the input feed and the products of the facility and the corresponding limits, and it shall discuss the application of the safety principles and criteria in the design for the protection of operating personnel, the public and the environment. The safety analysis report shall contain an analysis of the hazards associated with the operation of the facility and shall demonstrate compliance with the regulatory requirements and criteria. It shall also contain safety analyses of accident sequences and of the safety features incorporated in the design for preventing accidents or minimizing the likelihood of their occurrence and for mitigating their consequences.

3. 3. 4 The safety functions and the structures, systems and components (SSCs) important to safety shall be identified in the safety analysis report to the extent appropriate and in accordance with a graded approach. The SSCs important to safety provide means for the prevention of the occurrence of postulated initiating events, the control and limitation of accident sequences and mitigation of the consequences.

3. 3. 5 The operational limits and conditions are the set of rules that establish parameter limits, the functional capability and the performance levels of equipment and personnel for the safe operation of a facility.

3. 3. 6 The licensing documentation shall also define the required intervals for periodic testing and inspection of SSCs important to safety.

3. 3. 7 The licensing documentation shall be maintained and updated during the operational lifetime of the facility on the basis of the experience and knowledge gained and in accordance with the regulatory requirements, with account taken of modifications to the facility.

Level	Objective	Objective Essential means		
1	Prevention of abnormal operation and failures	Conservative design and high quality in construction, commissioning (including cold and hot commissioning) and operation (including management aspects)		
2	Control of abnormal operation and detection of failures	Set up protective barriers, systems and monitoring measures, and develop operational procedures to prevent or minimize damage from postulated initiating events		
3	Control of accidents within the design basis	Provide inherent safety features, fail-safe design, additional equipment and procedures to control the consequences of an accident		
4	Control of accident conditions beyond the design basis, including prevention of accident progression and mitigation of the consequences of such accident conditions	Complementary measures and accident management to prevent further development of the accident to protect the containment function and ensure as little radioactive release as possible		
5	Mitigation of radiological consequences of significant releases of radioactive materials	On-site and off-site emergency response, protect and mitigate the impact of the accident on the surrounding residents and the environment		

Table 1. levels of defence in depth

3.4 Application

3. 4. 1 Due to the diversity of devices and operations in nuclear fuel cycle facilities, the application of this standard shall be commensurate with the potential hazards of each facility, such as the use of grading methods to ensure that the facility is sufficiently safe throughout its life cycle.

3. 4. 2 See Annex A for specific requirements applicable to uranium fuel manufacturing plants, Annex B for specific safety requirements applicable to conversion and enrichment plants, Annex C for specific requirements applicable to nuclear fuel reprocessing plants, Annex D for specific requirements applicable to mixed oxide fuel manufacturing plants, and Annex E for nuclear fuel cycle research and development facilities.

4 Management system and verification of safety

4. 1 General

4. 1. 1 The operating organization shall establish, implement, assess and continually improve a management system that integrates safety, health, environmental, security, quality and economic elements to ensure that safety is properly taken into account in all the activities of an organization, and to fulfill its prime responsibility for safety throughout the lifetime of a fuel cycle facility.

4. 1. 2 The operating organization shall:

- a) establish and implement safety, health and environmental policies in accordance with national and international standards and shall ensure that these matters are given the highest priority;
- b) establish an organizational structure to enable these policies to be carried out with a clear definition of responsibilities and accountabilities, lines of authority and communication;
- c) specify and implement a management system covering all stages of the facility's lifetime;
- d) develop and maintain an effective safety culture;
- e) prepare accident management procedures and on-site emergency plans (in accordance with the hazard potential);
- f) perform a safety assessment of the facility;
- g) design and implement the physical protection of the facility.

4. 1. 3 The operating organization shall allocate suitable financial resources to fulfill its prime responsibility for safety and to implement safety requirements in 4.1.2.

4. 1. 4 The operating organization may delegate to other organizations work necessary for discharging its responsibilities, in accordance with the regulatory requirements, but the overall responsibility and control shall be retained by the operating organization.

4. 2 Safety, health and environmental policies

4. 2. 1 An essential step in setting the necessary standards for the health and safety of operating personnel and the public and for the protection of the environment is the statements by the operating organization of its safety, health and environmental policies. These policy statements shall be provided to staff as a declaration of the organization's objectives and the public commitment of corporate management.

4. 2. 2 To put these policies into effect, the operating organization shall also specify and put in place organizational structures, standards and management arrangements capable of meeting the organization's objectives and public commitments under the policies.

4. 3 Organizational provisions

4. 3. 1 The operating organization shall clearly specify the responsibilities and accountabilities of all staff involved in conducting or controlling operations that affect safety. The person with the responsibility for direct supervision shall be clearly identified at all times. This applies throughout the lifetime of the facility, from its siting to its decommissioning.

4. 3. 2 The operating organization management structure shall define clear lines of communication and shall provide the necessary infrastructure for facility operations to be conducted safely.

4. 3. 3 The operating organization shall maintain the capability in terms of staffing, skills, experience and knowledge to undertake competently all activities throughout the lifetime of the facility from siting to decommissioning. Where the resources and skills necessary to fulfill any part of these undertakings are provided by an external organization, the operating organization shall nevertheless retain within its organization the capability to assess the adequacy of the external organization's capabilities for ensuring safety.

4. 3. 4 The operating organization shall specify the necessary qualifications and experience for all staff involved in activities that may affect safety. It shall also specify appropriate requirements on training and its assessment and approval. The operating organization shall additionally ensure that the qualifications and training of contractors are adequate for the activities to be performed and that adequate control and supervision are in place. Records of the training shall be documented.

4.4 Safety culture

4. 4. 1 Fuel cycle facilities may require special considerations to achieve high safety, health and environmental standards by virtue of their size and the number of their staff, the distribution and the movement of radioactive material and other hazardous material throughout the installation, the frequent changes in operations, and the reliance on operator action in normal operation. The awareness by individuals of safety matters and the commitment of individuals to safety are therefore essential. The operating organization shall adopt and implement the necessary principles and processes to achieve an effective safety culture.

4. 4. 2 The operating organization shall explain the main elements of the safety culture in Fig. 1.



Fig. 1 Illustration of the presentation of safety culture

4. 4. 3 The operating organization shall report incidents significant to safety to the regulatory body in a timely manner.

4. 5 Accident management and emergency preparedness

4. 5. 1 The prevention of accidents is the first priority for safety of the operating organization. Nevertheless, the operating organization and the regulatory body shall make preparations to deal with accidents. Requirements for emergency preparedness and response are established in HAD 002/07.

4. 5. 2 The operating organization shall prepare accident management procedures and on-site emergency procedures, taking into account the potential hazards of the facility, before the introduction of hazardous material. Where necessary, in accordance with the degree of the hazards, the operating organization shall prepare off-site procedures in coordination with the relevant off-site organizations and competent authorities.

4. 5. 3 Periodic exercises for on-site emergencies shall be carried out.

4. 5. 4 The emergency procedures shall be updated on the basis of the lessons learned from these exercises.

4. 6 Verification of safety

4. 6. 1 The operating organization shall be responsible for verifying the safety of the facility. It shall establish or shall have access to an appropriate capability for safety analysis for ensuring that the necessary justifications are generated and maintained throughout the lifetime of the facility. It shall ensure that events that are significant to safety are reviewed in depth and the recurrence of accidents are prevented by that equipment is modified, procedures are revised, qualifications of personnel are reassessed and training is updated and provided.

4. 6. 2 When available, information about incidents and events at other installations of the same type as the facility shall also be investigated and the lessons learned shall be considered.

4. 6. 3 In accordance with the national regulatory requirements, the operating organization shall carry out periodic safety reviews to confirm that the licensing documentation remains valid and that modifications made to the facility, as well as the changes in its operating arrangements or utilization, have been accurately reflected in the licensing documentation. In conducting these reviews, the operating organization shall expressly consider the cumulative effects of changes to procedures, modifications to the facility and the operating organization, technical developments, operating experience and ageing.

4. 7 Physical protection

4. 7. 1 Appropriate measures shall be taken to prevent unauthorized actions, including acts of sabotage, that could jeopardize safety at the fuel cycle facility, and to respond to such actions if they do occur.

4. 7. 2 Recommendations on the physical protection of nuclear facilities and nuclear material are provided in EJ/T 1054.

4. 7. 3 The physical protection of the facility shall take account of the safety requirements and shall be in accordance with the facility's emergency plan.

5 Siting of the facility

5. 1 Initial site evaluation and site selection

5. 1. 1 The main safety objective in the siting of a facility shall be the consideration of external hazards and the protection of the public and the environment from the impacts of authorized discharges and accidental releases of radioactive and chemically hazardous materials.

5. 1. 2 The basis for the selection of a site for a facility will depend on a number of factors, including public acceptance.

5. 1. 3 The operating organization shall carry out a site evaluation, on the potential hazards presented by the facility, according to the requirements established in IAEA NS-R-3. In this site evaluation, consideration shall be given to the suitability of a particular site for such a facility, the site characteristics that may affect safety aspects of the facility, and the ways in which these site characteristics will influence the design and operating criteria for the facility.

5. 1. 4 For the site evaluation, the following requirements apply:

- a) Appropriate radiological monitoring of the site shall be conducted prior to carrying out any site activities in order to establish baseline levels of radiological parameters for assessing the future impact of the facility at the site. Natural and artificial radioactivity at the site in the air, the water and the ground and in flora and fauna shall be investigated and recorded.
- b) Environmental characteristics of the area that may potentially be affected by the radiological impacts and the associated chemical impacts of the facility in operational states and in accident conditions shall be investigated. An appropriate monitoring system shall be designed to verify the results obtained using the mathematical models of the radiological impacts and the associated chemical impacts.

- c) The possible locations near the facility where radioactive material and other hazardous material could be discharged or could pass to the environment shall be investigated. Hydrological and hydrogeological investigations shall be carried out to assess, to the extent necessary, the dilution and dispersion characteristics of water bodies. The models used to evaluate the possible impacts of the contamination of surface water and groundwater on the public and the environment shall be described.
- d) Models used to assess the dispersion of radioactive material and other hazardous material released to the environment in operational states and in accident conditions shall be in accordance with the requirements of the operating organization and of the regulatory body.
- e) Information shall be collected which, together with the anticipated discharges of radioactive material and other hazardous material from the facility and with the transfer behavior of the radioactive material, permits an assessment of doses to the public and of the contamination of biological systems and food chains.
- f) Site characteristics (e.g. soil properties, geology, hydrogeology) that may affect safety aspects of the facility shall be assessed, in particular the likelihood and the potential severity of the events that shall be considered in the design basis of the facility. These events include natural phenomena (e.g. earthquakes, tsunamis, flooding, high winds, extreme temperatures, lightning) or external human induced events such as accidental aircraft crashes, impacts, fires (e.g. forest fires) and explosions (e.g. at a nearby gas terminal).
- g) For a new facility, geological, hydrogeological and meteorological data concerning the site shall be collected and incorporated in the facility licensing documentation.
- h) The potential for accidental aircraft crashes, including impacts, fires and explosions on the site, shall be evaluated, with account taken of the foreseeable characteristics of air traffic(including those with special permission to fly over or near the facility such as firefighting aircraft and helicopters), the locations and types of airports, and the characteristics of aircraft.
- In the analysis of the suitability of the site, consideration shall be given to the storage and transport of radioactive material, processing chemicals, radioactive waste and chemical wastes, and to the existing site infrastructure.
- j) Foreseeable natural and human-made changes in the area that may have a bearing on safety shall be evaluated over a period that encompasses the projected lifetime of the facility.
- k) The influence of the siting decision on the need for, or the extent of, mitigatory actions such as accident management measures or emergency measures (e.g. the use of the firefighting service) that may be required in the event of an accident at the facility shall be considered.

5. 1. 5 The operating organization shall collect information in sufficient detail to support the safety analysis to demonstrate that the facility can be safely operated at the proposed site. The amount of detailed information shall be consistent with the potential hazard of the facility.

5. 1. 6 A site shall be deemed suitable only if the evaluation results lead to the conclusion that radioactive releases in operational states are within authorized limits and that the radiological consequences for the public of releases in accident conditions (including conditions that may lead to mitigatory actions being taken), are within acceptable limits and in accordance with national requirements.

5. 1. 7 The evaluation results shall be documented and shall be presented in sufficient detail in the licensing documentation.

5. 2 Ongoing site evaluation

5. 2. 1 The operating organization shall establish a programme of monitoring throughout the lifetime of the facility (including the decommissioning stage) to evaluate natural and human-made changes in the area and their impacts on the site characteristics and to compare them with the original predictions of such possible changes.

5. 2. 2 If the ongoing site evaluation identifies new information with regard to site characteristics, safety precautions, such as engineering controls and emergency preparedness arrangements, may need to be reviewed and changed.

6 Design

6. 1 General

6. 1. 1 A fuel cycle facility shall be designed in such a way that the fundamental safety objective quoted in Chapter 3 of this publication is achieved.

6. 1. 2 The safety requirements established in this Chapter shall be applied commensurate with the potential hazards of the facility in all stages of design, with account taken of the feedback from the results of the accompanying safety analysis.

6. 1. 3 In the design and safety justification for the facility, not only the facility itself but also the interfaces with other facilities and installations that may affect its safety shall be considered.

6. 2 Design basis

6. 2. 1 The operating organization shall establish explicit criteria for the level of safety to be achieved. The operating organization shall set limits on the radiological consequences and associated chemical consequences for the workforce and the public of direct exposures to radiation or authorized discharges of radionuclides to the environment. These limits shall apply to the consequences of operational states and the possible consequences of accident conditions at the facility and shall be set equal to, or below, international and national standards to ensure compliance across the full range of operating conditions and throughput. For new designs, targets shall be considered that are below these limits, since it is generally more effective to incorporate enhanced safety provisions at the design stage.

6. 2. 2 Limits and acceptance criteria shall be defined. As an example, in setting limits related to accident conditions, the risks from adverse events could be characterized as tolerable risks or unacceptable risks such that if the consequences for the public and the workforce increase, the acceptability in terms of the frequency or probability of occurrence has to decrease. Such limits may be represented in the form of an acceptability diagram (Fig. 2). Additional provisions can be made in accordance with the defence in depth principle.



Acceptability diagram

Fig. 2 Example of an acceptability diagram

6. 2. 3 The following hierarchy of design measures shall be used in protecting against potential hazards:

- a) Selection of the process (to eliminate the hazard);
- b) Passive design features;
- c) Active design features;
- d) Administrative controls.

6.2.4 The availability and reliability of the design measures and the administrative controls shall be commensurate with the significance of the potential hazards to be managed.

6. 2. 5 The operating organization shall identify postulated initiating events that could lead to a release of radiation and/or significant amounts of radioactive material and associated chemical substances. The resulting set of identified postulated initiating events shall be confirmed to be comprehensive and shall be defined in such a way that the events cover credible failures of the SSCs of the facility and human errors that could occur in any of the operating conditions of the facility. The set of postulated initiating events shall include both internally and externally initiated events. Examples of postulated initiating events are provided in Annex F.

6. 2. 6 A design basis accident approach (see Annex H), or an equivalent methodology, shall be used to identify significant accident sequences. For each accident sequence identified, the safety functions, the corresponding SSCs important to safety and the administrative safety requirements that are used to implement the defence in depth concept shall be identified.

6. 3 Design assessment

6. 3. 1 The responsibility for the production of a safe facility design shall lie with the operating organization. The operating organization may be supported by a facility designer; if so, the facility designer shall demonstrate that the established safety requirements can be met.

6. 3. 2 A close liaison shall be maintained between the facility designer and the operating organization for achieving the safe design of the facility; however, the operating organization shall implement an internal safety review of the facility design, as independently as possible from the designer.

6. 3. 3 The designer shall arrange for the orderly preparation, presentation and submission of design documents to the operating organization for its use in the preparation of the licensing documentation.

6.3.4 The evolution of the design may proceed concurrently with the development of the licensing documentation.

6. 4 Safety requirements

6. 4. 1 Criteria and rules

6. 4. 1. 1 Design criteria for all relevant parameters shall be specified for each operational state of the facility and for each design basis accident or equivalent.

6. 4. 1. 2 Design criteria for SSCs important to safety may be in the form of engineering design rules. Engineering design rules include requirements in relevant codes and standards and may be set and required explicitly by the regulatory body by requiring the use of applicable standard engineering practices already established in the State or used internationally. Design rules shall provide for safety margins over and above those foreseen for operations to provide reasonable assurance that no significant consequences would occur even if the operational limits were exceeded within the safety margin.

6. 4. 2 Codes and standards

6. 4. 2. 1 The operating organization shall identify the codes and standards applicable to SSCs important to safety and shall justify their use. In particular, if different codes and standards are used for different aspects of the same item or system, consistency between them shall be demonstrated.

6. 4. 2. 2 Typical areas covered by codes and standards are:

- a) Mechanical design, including design of pressure retaining components;
- b) Structural design;
- c) Selection of materials;
- d) Thermohydraulic design;
- e) Electrical design;
- f) Design of instrumentation and control systems;
- g) Software design and control;
- h) Inspection, testing and maintenance as related to design;
- i) Criticality;
- j) Shielding and radiation protection;
- k) Fire protection;
- 1) Chemical hazard protection;
- m) Seismically qualified design;
- n) Other designs for protection against natural phenomena.

6. 4. 3 Availability and reliability

6. 4. 3. 1 The operating organization shall ensure that the necessary levels of availability and reliability of SSCs important to safety, as established in the licensing documentation, are attained. The design principles(see Annex G)shall be applied as appropriate to achieve the required availability and reliability of SSCs important to safety in operational states and in accident conditions.

6. 4. 3. 2 For SSCs important to safety for which no appropriate established codes or standards exist, an approach derived from existing codes or standards for similar equipment may be applied. In the absence of such codes or standards, lessons learned from experience, tests (including tests at pilot plants), analyses and expert committee recommendations or a combination thereof may be applied. Such application shall be justified before being applied.

6. 4. 4 Ergonomics and human factors

6. 4. 4. 1 Human factors and human–machine interfaces shall be considered throughout the design process. Ergonomic principles shall be applied in the design of control rooms and panels. Operators shall be provided with clear displays and audible signals for those parameters that are important to safety.

6. 4. 4. 2 The design shall minimize the demands on operators in normal operations and in anticipated operational occurrences and accident conditions, for example through automating appropriate actions to promote the success of the operation. The need for appropriate control devices (e.g. interlocks, keys, passwords) to anticipate foreseeable human errors shall be taken into account in the design.

6. 4. 5 Material selection and ageing

6. 4. 5. 1 Since it is particularly important for fuel facilities that the range and characteristics of chemical and radiation conditions experienced in operational states and in accident conditions, design safety margins shall be adopted so as to accommodate the anticipated properties of materials at the end of their useful life in the design stage.

6. 4. 5. 2 Where details of the characteristics of materials are unavailable, a suitable material surveillance programme shall be implemented by the operating organization. Results derived from this programme shall be used to review the adequacy of the design at appropriate intervals. This may require provisions in the design for the monitoring of materials whose mechanical properties may change in service owing to factors such as fatigue (e.g. from cyclic mechanical or thermal loadings), stress corrosion, erosion, chemical corrosion or the induction of changes by irradiation.

6. 4. 6 Provision for maintenance, inspection and testing

6. 4. 6. 1 SSCs important to safety shall be designed to facilitate maintenance, inspection and testing for their functional capability over the lifetime of the facility.

6. 4. 6. 2 The design and layout of SSCs important to safety shall include provision to minimize exposures arising from maintenance, inspection and testing activities.

6. 4. 7 Use of computer based systems as SSCs important to safety

If a computer based system is important to safety or forms part of a system important to safety, appropriate standards and practices for the development and testing of computer hardware and software shall be established and shall be implemented throughout the lifetime of the system, in particular at the software development stage. The entire development shall be subject to an appropriate management system. The level of reliability necessary shall be commensurate with the importance of the system to safety.

6. 4. 8 Design for accident conditions

6. 4. 8. 1 SSCs important to safety shall be designed to withstand the effects of extreme loadings and environmental conditions (e.g. extremes of temperature, humidity, pressure, radiation levels) arising in operational states and in relevant design basis accident (or equivalent) conditions.

6. 4. 8. 2 If an emergency shutdown of the facility or part(s) thereof is necessary, the interdependences between different processes shall be considered. In cases where it is impractical to stop the process immediately, the design shall provide for the means to attain a safe and stable operational state.

6. 4. 8. 3 The design and arrangements for process control shall incorporate provisions for bringing the process operations to a safe and stable state.

6. 4. 8. 4 Where prompt, reliable action would be required in response to postulated initiating events, the design of the facility shall include the means to actuate automatically the necessary safety systems. In some cases, in accident conditions, it may be necessary for the operator to take further action to place the facility in a safe and stable long term state.

6. 4. 8. 5 Manual operator action shall be sufficiently reliable to bring the process to a safe state provided that:

- a) Adequate time is available for the operator to take actions for safety;
- b) The information available has been suitably processed and presented;
- c) The diagnosis is simple and the necessary action is clearly specified;
- d) The demands imposed on the operator are not excessive.

If any of these conditions may not be met, the safety systems shall be such as to ensure that the facility attains a safe state.

6. 4. 8. 6 A capability shall be provided for monitoring all essential processes and equipment during and following an accident. If necessary, a remote monitoring and shutdown capability shall be provided.

6. 4. 8. 7 The principle of independence shall be specifically addressed with respect to the segregation for purposes of operational control between SSCs important to safety and also within SSCs important to safety as appropriate.

6. 4. 8. 8 SSCs important to safety either shall be capable of performing their safety functions in spite of a loss of support systems (electrical power systems, compressed air systems or systems for the supply of cooling or heating fluids), if not, shall be designed to fail to a safe configuration.

6.4.8.9 The loss or excess of process reagents and diluent gases shall be considered during the safety assessment.

6. 4. 9 Design for emergency planning

6. 4. 9. 1 Specific design features for emergency planning purposes shall be considered, in accordance with the potential hazards presented by the facility. Such features may include simple escape routes with reliable emergency lighting, reliable means of communication and dedicated instrumentation for monitoring radiation levels and hazardous chemicals.

6. 4. 9. 2 Depending on the potential hazards posed by the facility, consideration shall also be given to providing an on-site emergency control center in a location separate from the operations area to maintain the chain of command and communication.

6. 4. 10 Design for radioactive waste management

6. 4. 10. 1 To the extent that is practicable at the design stage, the operating organization shall take measures to avoid or to optimize the generation of radioactive waste with the aim of minimizing the overall environmental impact. The predisposal and disposal routes for waste shall be considered with the same aim of minimizing the overall environmental impact.

6. 4. 10. 2 Requirements on the generation, processing and storage of radioactive waste are established in GB 14500.

6. 4. 11 Design for the management of aerial and liquid radioactive discharges

6. 4. 11. 1 Design provisions shall be established for ensuring that aerial and liquid radioactive discharges to the environment are in compliance with authorized limits and to reduce doses to the public and effects on the environment to levels that are as low as reasonably achievable.

6. 4. 11. 2 Design provisions shall be established for monitoring aerial and liquid radioactive discharges to the environment.

6. 4. 12 Design for decommissioning

6. 4. 12. 1 In the design of a fuel cycle facility, consideration shall be given to facilitating its ultimate decommissioning, so as to keep the exposure of personnel and the public, arising from decommissioning, as low as reasonably achievable and to ensure adequate protection of the environment, as well as to minimize the amount of radioactive waste generated.

6. 4. 12. 2 While ensuring the safe operation of the facility, to the extent practicable, the designer shall:

- a) minimize the number and size of contaminated areas to facilitate cleanup in the decommissioning stage;
- b) Shall choose materials that can be stored in the facility, that are resistant to all chemicals in use and that have sufficient wear resistance, to facilitate their decontamination at the end of their lifetime;
- c) design the facility to avoid undesired accumulations of chemical or radioactive materials;
- d) design the facility to allow remote decontamination where necessary;
- e) consider the amenability to treatment, interim storage, transport and disposal of the waste to be generated during the decommissioning stage;
- f) pay specific attention to keeping the design documentation and records available throughout the lifetime of the facility.

6.5 Design for protection against radiological hazards

6. 5. 1 Contamination control and protection against internal exposure

6.5.1.1 Consideration shall be given to protecting workers, the public and the environment against releases of radioactive material in both operational states and accident conditions.

6.5.1.2 The main design features for the control of contamination are confinement and leak detection. Confinement is achieved by means of physical barriers (static containment) and/or dynamic containment (e.g. by ventilation). The nature and number of the barriers and their performance, as well as the performance of air purification systems, shall be commensurate with the degree of the potential hazards, with special attention paid to the potential dispersion of alpha emitters.

6.5.1.3 Areas shall be classified according to foreseeable levels of surface contamination and atmospheric contamination, and equipment shall be installed in accordance with this classification in section 6.4 of GB 18871-2002. Means of monitoring and appropriate alarm systems for atmospheric contamination shall be installed. The need for appropriate provisions for specific operations in contaminated areas shall be taken into account in the design.

6. 5. 2 Protection against external exposure

6.5.2.1 Protection against radiation exposure shall be achieved by means of engineered provisions such as adequate shielding and the use of remote handling equipment.

6.5.2.2 The designer shall classify areas by taking into consideration the magnitude of the expected normal exposures, the likelihood and magnitude of potential exposures, and the nature and extent of the required protection and safety procedures. Access to areas where radiation levels may cause exposures that give rise to high doses for workers shall be restricted and the level of control applied shall be commensurate with the hazards.

6. 5. 2. 3 Radiation levels shall be monitored so that any abnormal conditions would be detected and workers may be evacuated. Areas of potential exposure for workers shall be appropriately identified and marked.

6.5.3 Criticality

6.5.3.1 Criticality accidents can result in high radiation doses to nearby personnel and widespread contamination. As far as reasonably practicable, criticality hazards shall be controlled by means of design.

6. 5. 3. 2 The achievement of criticality depends upon:

- a) The properties of the fissile material;
- b) The mass of fissile material present and its distribution among the components of the system in which it is present;

c) The mass, properties and distribution of all other materials associated with or surrounding the fissile material.

6.5.3.3 For the prevention of criticality by means of design, the double contingency principle shall be the preferred approach.

6.5.3.4 The most important factors in preventing criticality are mass, geometry, moderation, reflection, interaction, neutron absorption and concentration. These factors shall be considered both alone and in combination for a proper design.

6.5.3.5 Criticality evaluations and calculations shall be performed on the basis of making conservative assumptions.

6. 5. 3. 6 Specific attention shall be paid to those system interfaces for which there is a change in the method of criticality control.

6. 5. 3. 7 Methods of ensuring criticality safety in any process shall include, but shall not be limited to, any one of or a combination of the following:

- a) Passive engineered control involving equipment design;
- b) Active engineered control involving the use of process control instrumentation;
- c) Chemical means, such as the prevention of conditions that allow precipitation;
- d) Reliance on a natural or credible course of events, such as a process the nature of which is to keep the density of fissile material lower than the theoretical minimum necessary for a criticality event to occur;
- e) Administrative controls to ensure compliance with operating procedures.

6.5.3.8 States have adopted various approaches to mitigatory measures for, and consequence assessments of, criticality accidents. The need for the following measures shall be assessed for their suitability:

- a) The installation of a criticality detection and alarm system;
- b) The identification and marking of appropriate evacuation routes and regrouping areas;
- c) The provision of appropriate emergency equipment and the adoption of emergency procedures.

6. 5. 4 Radioactive decay heat

Heat generation shall be taken into account as appropriate in the facility design. The generation of heat by radioactive decay may result in the release of radioactive material.

6.5.5 Radiolysis

Radiolysis, if not adequately controlled, may result in the release of hydrogen with the risk of explosions. Radiolysis shall be taken into account in the facility design, to prevent the risk of explosions by the release of hydrogen.

6. 6 Non-radiological hazards

6. 6. 1 Chemical, toxic, flammable or explosive substances can affect nuclear safety. To prevent this from occurring, the following shall be considered in the design:

- a) Design requirements and guidance contained in international and national standards and guidance on chemical safety;
- b) The chemical compatibility of materials that are likely to come into contact;
- c) The safe storage of hazardous process materials;
- d) The initial process configuration and/or credible changes to it that may lead to the release of chemical compounds or toxic materials (e.g. hydrogen, solvents), fires or explosions;
- e) The detection and alarm capability for chemical or toxic releases;
- f) The minimization of inventories;

g) Personnel protective equipment to protect against exposures to chemical compounds or toxic materials.6. 6. 2 The operating organization shall make design provisions for fire safety on the basis of a fire safety analysis and the implementation of the concept of defence in depth (i.e. for prevention, detection, control and mitigation).

7 Construction of the facility

7. 1 Before the construction of a fuel cycle facility begins, the operating organization shall satisfy the regulatory requirements regarding the safety of the facility design.

7. 2 Before construction begins, the operating organization shall make adequate arrangements with the selected contractor(s) concerning the responsibility for ensuring safety during construction and the identification and control of any adverse impacts of the construction activities on facility operations. In addition, the impact of construction of the facility on the local population and the environment and on any adjacent operating plants and services shall be considered. In particular, hazards associated with vibration, movements of heavy loads and dust generation shall be assessed.

7. 3 The operating organization shall implement a management system in the construction stage to ensure that the design requirements and intent are properly met.

7. 4 Records shall be maintained in accordance with the management system to demonstrate that the facility and its equipment have been constructed in accordance with the design specifications.

7. 5 The operating organization shall specify a formal procedure for design changes such that those made to the facility during construction are accurately recorded and their impacts are assessed.

7. 6 'As built' drawings of the facility shall be provided to the operating organization. Following construction of the facility, the operating organization shall review the as built drawings to confirm that the design intent has been met and the safety functions specified will be fulfilled. The operating organization shall, as required, seek agreement by the regulatory body to proceed to the commissioning stage.

8 Commissioning of the facility

8. 1 Commissioning programme

8. 1. 1 Before the commencement of commissioning, an adequate commissioning programme shall be prepared for the testing of a facility to demonstrate that it meets the design objectives and the performance criteria. The commissioning programme, agreed as required with the regulatory body, shall cover the organization for and responsibilities for commissioning, the stages of commissioning, the suitable testing of SSCs on the basis of their importance to safety, the test schedule, the commissioning procedures and reports, the methods of reviewing and verification, the treatment of deviations and deficiencies, and the requirements for documentation.

8. 1. 2 The requirements in this chapter shall also apply to the restart of existing processes after a lengthy shutdown period.

8. 2 Organization and responsibilities

8. 2. 1 The involvement of the operating organization, designers and manufacturers in the preparation of the commissioning programme shall be established by the operating organization to familiarize the future operating personnel with the particular characteristics of the facility and its process operations, and to ensure the adequate transfer of knowledge and the feedback of lessons learned from experience to the facility staff.

8. 2. 2 The commissioning period shall be used to train the operators in all aspects of operation and maintenance of the facility. Integral to this training process shall be the verification of the operational documentation, including operating procedures, maintenance procedures, emergency procedures, administrative procedures and operational limits and conditions.

8. 2. 3 The handover from the commissioning workforce to the operating workforce shall be carefully managed to ensure that knowledge and experience are not lost. Commissioning is also an opportunity for the operating organization to become familiar with the facility and for the management to develop a safety culture (including positive behaviour and attitudes).

8. 2. 4 At all stages of commissioning, the operating organization shall ensure that the person or organization responsible for safety is clearly identified. When the responsibility for safety is transferred, the arrangements for the transfer of responsibility shall be clearly specified.

8. 2. 5 The operating organization shall establish a safety committee to review the commissioning programme and the results of commissioning tests and to provide technical advice to the operating organization.

8. 2. 6 Close liaison shall be maintained between the regulatory body and the operating organization throughout the commissioning process. The operating organization shall ensure that the results of tests directly concerning safety and their analyses are made available to the regulatory body for review and approval as appropriate.

8.3 Commissioning tests and stages

8. 3. 1 The commissioning programme shall be divided into stages. These stages shall include, as necessary, individual equipment tests, integrated facility tests and system tests relating to cold processing and hot processing.

8. 3. 2 Commissioning tests shall be arranged in functional groups and in a logical sequence, and, so far as is reasonably practicable, shall cover all planned operating aspects.

8. 3. 3 The operating organization shall specify a formal procedure for design change so that all modifications made to the facility are accurately recorded and their possible impacts are assessed.

8. 3. 4 At the commissioning stage, the operating organization shall specify the point at which the safety evaluation of modifications is transferred from a design stage evaluation process to an operation stage evaluation process.

8. 4 Commissioning procedures and reports

8. 4. 1 The commissioning programme shall include provisions and procedures for audits, reviews and verifications to confirm that the tests have been conducted as planned and that the programme objectives have been fully achieved. Provision shall also be made for remedying any deviation or deficiency that is discovered in the commissioning tests.

8. 4. 2 The effective testing of facilities and their equipment and systems without introducing the full chemical or radiological challenge to the facility may require the introduction of temporary commissioning aids into the software or hardware systems. The operating organization shall ensure that formal records of such aids are kept. The records shall be used to ensure that all the aids are removed on completion of the tests before the facility or system is brought into operation.

8. 4. 3 Commissioning activities shall be performed in accordance with written procedures. The procedures shall cover the purpose of the tests, the expected results and the criteria for success, the safety provisions required during the tests, the necessary precautions and prerequisites, and the test instructions.

8. 4. 4 If necessary, procedures shall include hold points for the notification and involvement of the safety committee (see para. 9.15), outside agencies, manufacturers and the regulatory body.

8. 4. 5 Reports covering the scope, sequence, expected results and criteria for the success of these tests shall be prepared in accordance with the management system and in appropriate detail. The test report shall include: a description of the test programme and the test results; a summary of the data collected and their analyses; an evaluation of the results (compared with acceptance criteria) and a statement on the success of the test; the

identification of deviations and deficiencies; and any corrective actions and the justifications for the corrective actions.

8. 4. 6 All commissioning test results, whether obtained by a member of the operating organization or a manufacturer, shall be available to the operating organization and the regulatory body and shall be retained for the lifetime of the facility.

9 Operation of the facility

9. 1 General requirements during operation

9.1.1 Structure and responsibilities of the operating organization

9.1.1.1 The operating organization shall have the overall responsibility for the safety of the facility during operation. The operating organization shall establish an appropriate management structure for the facility and shall provide the necessary infrastructure for operations to be conducted safely.

9.1.1.2 The operating organization shall ensure that relevant functions relating to the safe operation and utilization of the facility, such as maintenance, radiation protection, criticality safety, the application of the management system and other relevant supporting activities, are adequately covered, and shall take into account industrial and chemical safety.

9. 1. 1. 3 The operating organization shall be responsible for all safety aspects of any change in the facility design or any change in control, arrangements made, utilization or management of the facility. This responsibility shall not be delegated.

9.1.2 Interface arrangements

9. 1. 2. 1 The operating organization shall ensure that safety related interdependences between facilities on the same site are considered.

9.1.2.2 Boundary responsibilities shall be clearly specified and effective communication routes shall be established.

9. 1. 3 Qualification and training of personnel

9.1.3.1 Minimum qualifications for personnel shall be specified, and these minimum qualifications shall be commensurate with the assigned functional responsibility and authority. The training of personnel working at the facility shall be commensurate with their assigned functional responsibilities, their authorities and their safety related activities.

9.1.3.2 Training shall include the retraining of previously trained and qualified personnel. The training programme shall include the following aspects: analysis and identification of functional areas for which training is required; position training requirements; development of the basis for training (including objectives), evaluation of trainee learning; on the job training; and systematic evaluation of the effectiveness of the training.

9. **1**. **3**. **3** Training shall cover the operational states of the facility, including emergency procedures (see paras 9.9.1-9.9.5), and it shall be ensured that operators have sufficient understanding of the facility and its safety features. The primary importance of safety in all aspects of facility operation shall be emphasized.

9. 1. 3. 4 As the response time is crucial for firefighting in the event of a fire or an explosion, the operating team shall be properly and regularly trained in firefighting, and drills and exercises shall be carried out on a regular basis.

9. 1. 3. 5 With respect to training, special attention shall be paid to radiological hazards that may involve manual intervention. Workers shall be made aware of the hazards associated with the activities they are performing.

9. 1. 3. 6 Facility modifications shall be reflected in the training programme in a timely manner.

9. 1. 4 Minimum staffing

The operating organization shall define the minimum staffing levels for the various technical and functional areas necessary to ensure the safety of the facility in operational states (including inter-campaign periods) and in accident conditions, for persons and organizations involved in the implementation of the emergency plan.

9. 1. 5 Safety committee

9.1.5.1 The operating organization shall establish safety organizations to advise the management of the operating organization on safety issues related to the commissioning, operation and modification of the facility.

9.1.5.2 Such organizations shall have among their membership the necessary breadth of knowledge and experience to provide appropriate advice. The membership shall, to the extent necessary, be independent of the operations management raising the safety matter.

9.1.6 Feedback of operating experience

Arrangements shall be made so that available technical information on abnormal occurrences, incidents and accidents that have occurred at the facility or at similar facilities is analyzed for the feedback of lessons learned from experience and for preventive actions if necessary.

9.1.7 Document management

9. 1. 7. 1 The operating organization shall maintain, and shall ensure that the personnel use, a complete and up-to-date set of safety documentation, including the licensing documentation and procedures. Duplicates of essential documents shall be stored separately and shall be maintained as appropriate.

9. 1. 7. 2 The operating organization shall make arrangements for generating and controlling records and reports that have safety significance for the operation and decommissioning stages, including:

- a) The complete collection of revisions to the licensing documentation;
- b) Periodic safety reviews;
- c) Commissioning documents;
- d) Procedures and operating instructions;
- e) History of and data on modifications;
- f) Operational data for the facility;
- g) Data from maintenance, testing, surveillance and inspection;
- h) Reports on events and incidents;
- i) Radiation protection data, including personal monitoring data;
- j) Data on amounts and movements of radioactive material;
- k) Records of the discharges of effluents;
- 1) Records of the storage and transport of radioactive waste;
- m) Results of environmental monitoring;
- n) Records of the main work activities performed in each location of the facility.

9.1.8 Control of organizational changes

The operating organization shall put in place arrangements to ensure that changes to the organizational structure are considered in terms of their potential impacts on safety and on any actions necessary to mitigate consequences, as appropriate.

9. 1. 9 Communication with the regulatory body

In accordance with national requirements and practices, the operating organization shall develop and implement procedures for informing the regulatory body of proposals for modifications having major safety significance, and in case of anticipated operational occurrences or accident conditions.

9. 2 **Operating instructions**

9.2.1 Operational limits and conditions shall be prepared before operation of the facility commences.

9. 2. 2 Operating instructions shall be developed by the operating organization, in cooperation with the designer and manufacturer if necessary. Safety related operating instructions shall be prepared before operations commence. Operating instructions shall clearly describe the methods of operating, including all checks, tests, calibrations and inspections necessary to ensure compliance with the operational limits and conditions.

9.2.3 Operators shall be made aware of the special safety significance of the instructions and procedures necessary to ensure compliance with the operational limits and conditions and of the requirements for strict compliance with them.

9.2.4 Operating instructions and procedures shall be reviewed and updated periodically and shall be made accessible to users as necessary.

9. 2. 5 Arrangements shall be made to ensure that significant deviations from operating instructions are identified, and, where appropriate, an investigation is carried out into the cause and appropriate actions are taken to prevent recurrence. Such arrangements shall include notification to the regulatory body if the deviations result in the breach of an operational limit or condition.

9. 2. 6 The operating instructions shall provide for the facility to be brought into a safe operational state after an anticipated operational occurrence, which could necessitate shutting down the facility.

9. 2. 7 When an activity not covered by existing instructions is planned, appropriate instructions shall be prepared and reviewed, and shall be subject to appropriate approval before the activity is started. Additional training of relevant operating personnel on the instructions shall be provided.

9. 3 Maintenance, calibration, periodic testing and inspection

9.3.1 Maintenance, calibration, periodic testing and inspection shall be performed to ensure that SSCs important to safety are able to function in accordance with the design intent and with safety requirements.

9. **3**. **2** All maintenance, calibration, periodic testing and inspection shall be performed in accordance with a programme based on approved, written procedures. Before operation of the facility commences, the operating organization shall prepare and obtain approval for the programmes for maintenance, calibration, periodic testing and inspection of SSCs important to safety. These procedures shall specify any changes from the normal operational status of the facility and shall make provision for restoration of the normal configuration upon completion of the activity. A system of work permits in accordance with the management system shall be used for maintenance, calibration, periodic testing and inspection. Resumption of normal operation shall be permitted only after the person responsible for coordinating the maintenance work has approved the results of the maintenance assessment.

9. **3**. **3** The frequency of maintenance, calibration, periodic testing and inspection of SSCs important to safety shall be in accordance with the facility licensing documentation.

9. 3. 4 Equipment and items used for maintenance, calibration, periodic testing and inspection shall be identified and controlled to ensure their proper use.

9. 3. 5 The results of maintenance, testing and inspection shall be recorded and assessed.

9. **3**. **6** The maintenance, calibration, periodic testing and inspection programmes shall be reviewed at regular intervals to incorporate the lessons learned from experience.

9. **3**. **7** Special attention shall be paid to subordinate operations such as decontamination, washing and preparation for maintenance or testing, as there are many occurrences at facilities while such operations are taking place.

9. 4 Control of modifications

The operating organization shall establish a process whereby its proposals for changes to the design, equipment, feed material characteristics, control or management are subject to a degree of assessment and scrutiny appropriate to the safety significance of the change, so that the direct and wider consequences of the

modification are adequately assessed. The process shall include a review of possible consequences to ensure that a foreseen modification or change in one facility will not adversely affect the operability or safety of associated or adjacent facilities.

9.5 Radiation protection during operation

9. 5. 1 General

9. **5**. **1**. **1** The measures for protection against radiation exposure of operating personnel, including contractors, and members of the public shall comply with the requirements of the regulatory body and with the requirements established in GB 18871.

9. 5. 1. 2 For all operational states the radiation protection measures shall be such as:

- a) To ensure that exposures are kept below regulatory limits;
- b) To optimize radiation protection.

9.5.2 Radiation protection programme

9.5.2.1 The operating organization shall establish and implement a radiation protection programme to ensure that all activities involving potential radiation exposure are planned, supervised, executed and monitored. All documentation and activities relating to radiation protection shall conform to the integrated management system of the organization.

9. 5. 2. 2 The radiation protection programme shall specify responsibilities and arrangements for:

- a) Monitoring of radiation and contamination levels on and off the site, and alerting operators to any abnormalities;
- b) Control of radiation exposures, due to the operations of the facility, of persons present on the site;
- c) Control of off-site radiation exposures;
- d) Preparation, in accordance with the hazards posed by the facility, for the management of site emergencies;
- e) Control of the on-site and off-site transport of radioactive material.

9. **5**. **2**. **3** All operating personnel shall be individually responsible for putting into practice the measures for exposure control in the course of their work, as specified under the radiation protection programme.

The operating organization shall run the facility in such a manner as to optimize protection against external and internal exposures of the workforce. During operation, external and internal exposures shall be managed in accordance with the principle of optimization of protection, with an appropriate balance of rules and practices on:

- a) Housekeeping and decontamination of equipment and areas;
- b) Maintenance and modifications;
- c) Operation.

9.5.2.4 For potential accident conditions, the radiological consequences shall be kept low by means of engineered safety features, accident management procedures, and measures provided in the emergency plan.

9. 5. 2. 5 The monitoring results from the radiation protection programme shall be compared with the operational limits and conditions, and corrective actions shall be taken if necessary. In addition, goals for annual doses shall be determined annually. Results shall be compared with these goals and any divergences shall be investigated.

9.5.3 Radiation protection personnel

9.5.3.1 The radiation protection programme shall include the establishment within the operating organization of a radiation protection group with the appointment of qualified radiation protection officers who are technically competent in radiation protection matters and knowledgeable about the radiological aspects of the design, operation and hazards of the facility.

9.5.3.2 The radiation protection personnel shall provide advice to the operating personnel and shall have access to the levels of management within the operating organization with the authority to establish and enforce operational procedures.

9. 5. 4 Control of occupational exposures

All operating personnel who may be occupationally exposed to radiation at levels of significance for the purposes of radiation protection shall have their doses measured, recorded and assessed, as required by the regulatory body. These records shall be made available to those exposed and to the regulatory body or any other body designated by the regulatory body. Arrangements shall be put in place to retain these records for the period required under national legislation.

9. 5. 5 Contamination control

9.5.5.1 The spread of radioactive contamination shall be controlled and minimized as far as reasonably practicable. Access to areas where contamination levels may lead to high doses for workers shall be restricted and the level of control applied shall be commensurate with the hazard.

9.5.5.2 In particular, where there is a likelihood of exposure, the workforce shall be provided with personal protective equipment to protect against the hazards likely to be encountered.

9.6 Criticality control during operation

9. 6. 1 General

9. 6. 1. 1 All operations with fissile material shall be performed in such a way as to prevent a criticality accident.

9. **6**. **1**. **2** All operations to which nuclear criticality safety is pertinent shall be governed by written procedures. The procedures shall specify all the parameters that they are intended to control and the criteria to be fulfilled.

9. **6**. **1**. **3** Deviations from procedures and unforeseen changes in process conditions that affect nuclear criticality safety shall be reported to the management and shall be investigated promptly. The regulatory body shall also be informed. Action shall be taken to prevent their recurrence.

9. 6. 2 Criticality staff

9. 6. 2. 1 Where relevant, the operating organization shall appoint qualified nuclear criticality staff who are knowledgeable about the physics of nuclear criticality and the associated safety standards, codes and best practices, and who are familiar with the facility operations. This function shall, to the extent necessary, be independent of the operations management.

9. 6. 2. 2 The nuclear criticality staff shall give assistance for the training of personnel; shall provide technical guidance and expertise for the development of operating procedures; and shall check and validate all operations that may require criticality control.

9.7 Management of radioactive waste and effluents in operation

9. **7**. **1** A facility shall be operated so as to control and minimize, as far as reasonably practicable, the generation of radioactive waste of all kinds, to ensure that radioactive releases to the environment are as low as reasonably achievable, to facilitate the handling and disposal of waste, and to facilitate the decommissioning of the facility.

9. 7. 2 The management of solid, liquid and gaseous waste within, and its ultimate removal from, the facility shall fulfill the requirements established in GB 14500.Discharges of radioactive and hazardous chemical effluents shall be monitored and the details recorded in order to verify compliance with the applicable regulatory requirements. The details shall be reported periodically to the regulatory body in accordance with its requirements.

9.8 Management of industrial and chemical safety in operation

9. **8**. **1** Depending on the nature of the facility, the degree of risk to the public or the workforce posed by chemical and industrial hazards may be greater or less than that posed by radioactive material. The operating organization

shall, as appropriate, have access to the necessary safety expertise and shall introduce arrangements to minimize the risks posed by chemical and industrial hazards to the public, the workforce and the environment.

9.8.2 The operating organization shall make arrangements for ensuring fire safety on the basis of a fire safety analysis, which shall be reviewed periodically and updated as necessary. Such arrangements shall include: control of combustibles (limitation) and ignition sources (separation) in accordance with the licensing documentation; assessment of the potential impacts of modifications on the fire safety analysis or fire protection systems; maintenance, testing and inspection of fire protection measures; establishment of a manual firefighting capability; and training of facility personnel.

9.8.3 The operating organization shall:

- a) Written procedures and monitoring shall be used to ensure that the concentration in air of flammable gases (e.g. hydrogen) is below the corresponding lower flammability limit in air, with an adequate margin;
- b) The operating team shall be properly and regularly trained;
- c) Drills shall be carried out on a regular basis.

9. **8**. **4** Together with the conventional fire safety concerns associated with an industrial installation, fire safety issues relating to nuclear materials shall be assessed.

9. 9 Emergency preparedness

9.9.1 The operating organization, taking into account the potential hazards of the facility, shall develop an emergency plan in coordination with other bodies having responsibilities in an emergency (including public authorities); shall establish the necessary organizational structure; and shall assign responsibilities for managing emergency response. Requirements on planning for emergency preparedness and response are established in HAD 002/07.

9.9.2 The emergency plan shall, as necessary, include arrangements for responses to emergencies involving a combination of non-radiological and radiological hazards, such as a fire in conjunction with significant levels of radiation or contamination, or toxic and/or asphyxiating gases in conjunction with radiation or contamination, with account taken of the specific site conditions.

9.9.3 The emergency plan shall include a means of informing all persons on the site of the actions to be taken in the event of an emergency.

9.9.4 The emergency plan shall be approved by the regulatory body as appropriate and shall be tested in an exercise before radioactive material is introduced into the facility. There shall thereafter be exercises of the emergency plan at suitable intervals, some of which shall be observed by the regulatory body. Some of these exercises shall be integrated with local, regional and national response organizations, as appropriate, and shall involve the participation of as many of the organizations concernedas possible. The plans shall be subject to review and to updating in the light of the experience gained.

9.9.5 Instruments, tools, equipment, documentation and communication systems to be used in emergency responses shall be maintained in good operating condition and shall be kept available in such a manner that they are unlikely to be affected by, or made unavailable by, the occurrence of postulated accidents.

9. 10 Verification of safety

9. 10. 1 Periodic safety review

9. 10. 1. 1 The operating organization shall carry out a systematic reassessment of the safety of the facility at regular intervals, and in accordance with national regulatory requirements, to deal with the cumulative effects and implications of ageing, modifications, technical developments, operating experience and changes in the site characteristics.

9.10.1.2 The results of the periodic safety reviews shall be presented by the operating organization to the regulatory body and shall be reflected in updates of the facility licensing documentation.

9. 10. 2 Audit and review

9. 10. 2. 1 Central to the management and verification of safety is the ability of an organization to establish effective review and improvement as an ongoing process. To establish this process, the operating organization shall periodically conduct a review of the facility's operational and safety performance to identify, investigate and correct adverse trends that may have an impact on safety. Such a process shall also cover safety culture, and the improvement of attitudes and the operating environment for safe operation.

9.10.2.2 The operating organization shall carry out a self-assessment programme, including audits and inspections.

10 Decommissioning of the facility

10.1 General

The operating organization shall put in place arrangements for the eventual decommissioning of the facility (including funding arrangements), which shall be subject to approval by the regulatory body, well in advance of the shutdown of the facility. Requirements for the decommissioning of a facility are established in GB 19597.

10. 2 Decommissioning plan

10. 2. 1 The operating organization shall prepare and maintain a decommissioning plan throughout the lifetime of the facility, unless otherwise approved by the regulatory body. Although some existing facilities may not have been designed or operated with eventual decommissioning in mind, all operational activities, including maintenance, modification and experiments, shall be conducted by the operating organization in a way that will facilitate eventual decommissioning.

10. 2. 2 The decommissioning plan shall take into account the storage, treatment, transport and disposal of the waste that is generated during the decommissioning stage.

10. 2. 3 To facilitate the implementation of the decommissioning plan and completion of the decommissioning, the operating organization:

- a) Shall retain the necessary resources, expertise and knowledge for design and operation for decommissioning, and shall keep records and documentation relevant to the design, construction, operation and decommissioning processes so that such information can be transferred to any supporting or successor operating organization;
- b) Shall ensure the maintenance of records and documentation for a period of time as specified by the regulatory body following the completion of decommissioning, including key information such as the results of the final radiological survey;
- c) Shall report to the regulatory body on a scheduled basis any safety related information as required by the terms of the license.

10. 2. 4 The decommissioning plan shall be reviewed regularly and shall be updated as required to reflect, in particular, changes in the facility or in regulatory requirements, advances in technology and, finally, the needs of the decommissioning operation. If an abnormal event occurs, anew decommissioning plan or modification of the existing decommissioning plan shall be required.

10. 3 Decommissioning operation

10. 3. 1 When it has been decided to shut down a facility, the organization legally responsible for its decommissioning shall submit an application for permission to decommission the facility to the regulatory body, together with the final decommissioning plan.

10. 3. 2 If it is intended to shut the facility down and defer decommissioning, it shall be demonstrated in the final decommissioning plan that such an option is safe and that possible occurrences during this shutdown period are taken into account in developing the decommissioning plan. It shall be demonstrated that no undue burdens will be imposed on future generations. An adequate maintenance and surveillance programme, which shall be subject to the approval of the regulatory body, shall be developed to ensure safety during the period of deferment.

10. 3. 3 If the shutdown of a facility is sudden, as, for example, in the event of an accident, the facility shall be brought to a safe state before decommissioning is commenced in accordance with an approved decommissioning plan.

10. 3. 4 Decommissioning activities may generate large volumes of waste over short time periods, and the waste may vary greatly in type and activity and may include large objects. The operating organization shall ensure that appropriate means are available to manage the waste safely. Dismantling and decontamination techniques shall be chosen such that the generation of waste and airborne contamination are minimized.

10. 3. 5 Decommissioning activities such as decontamination, cutting and handling of large equipment and the progressive dismantling or removal of some existing safety systems have the potential for creating new hazards. The impacts on safety of these activities shall be assessed and managed so that these hazards are mitigated.

10. 3. 6 The operating organization shall ensure the protection of both workers and members of the public against exposure, not only in decommissioning but also as a result of any subsequent occupancy or use of the decommissioned site. The operating organization shall apply national radiation protection requirements, established in accordance with GB 18871.

10. 3. 7 Personnel who carry out the decommissioning of the facility shall be properly trained and qualified for such work. The operating organization shall ensure that personnel clearly understand and implement the relevant environmental, health and safety standards.

10.4 Completion of decommissioning

10. 4. 1 Before a site may be released for unrestricted use, a survey shall be performed to demonstrate that the end point conditions, as established by the regulatory body, have been met.

10. 4. 2 If a site cannot be released for unrestricted use, appropriate control shall be maintained to ensure protection of human health and the environment.

10. 4. 3 A final decommissioning report, including any necessary final confirmation survey, shall be prepared and retained with other records, as appropriate.

ANNEX A (NORMATIVE ANNEX) Requirements Specific to Uranium Fuel Fabrication Facilities

A.1 Scope

The following requirements are specific to uranium fuel fabrication facilities where fuel assemblies havea ²³⁵U concentration of no more than 6%. They do not apply to facilities that handle natural uranium or uranium metal fuels.

A.2 Design

A.2.1 Safety functions

The facility shall be designed to prevent a criticality accident and the accidental release of hazardous materials. The design shall keep radiation exposures from normal operations as low as reasonably achievable.

A.2.2 Engineering design

As with radioactive material, the containment of chemical hazards shall include the control of any route into the workplace or to the environment.

A.2.3 Criticality prevention

A.2.3.1 Criticality safety shall be ensured by means of preventive measures.

A.2.3.2 Preference shall be given to achieving criticality safety by design, to the extent practicable, rather than by administrative measures.

A.2.3.3 Criticality safety shall be achieved by keeping one or more of the following parameters of the system within subcritical limits in normal operations, for anticipated operational occurrences (e.g. the overfilling of a vessel) and for design basis accident conditions or the equivalent (e.g. due to fire, flooding or loss of cooling):

- a) Mass and enrichment of fissile material present in a process;
- b) Geometry (limitation of the dimensions or shape) of processing equipment;
- c) Concentration of fissile material in solutions;
- d) Degree of moderation;
- e) Control of reflectors;
- f) Presence of appropriate neutron absorbers.

A.2.3.4 The safety of the design for a uranium fuel fabrication facility shall be demonstrated by means of a specific criticality analysis in which the following important factors are considered both singly and in combination:

- a) Enrichment: the maximum authorized enrichment in any part of the facility shall be used in all assessments unless the impossibility of reaching this level of enrichment is demonstrated in accordance with the double contingency principle;
- b) Mass: criticality safety shall be assessed with significant margins;
- c) Geometry: the analysis shall include the layout of the facility and the dimensions of pipes, vessels and other process units;
- d) Concentration and density: a conservative approach shall be taken;
- e) Moderation: the analysis shall consider a range of degrees of moderation to determine the most reactive conditions that could occur;
- f) Reflection: a conservative assumption concerning reflection shall be made;
- g) Neutron interaction: consideration shall be given to neutron interaction between all facility units that may be involved;
- h) Neutron absorbers: when taken into account in the safety analysis, and if there is a risk of degradation, the presence and the integrity of neutron absorbers shall be verifiable during periodic testing.

Uncertainties in absorber parameters (e.g. mass and density) shall be considered in the criticality calculations.

A.2.3.5 In accordance with national regulations, criticality safety shall be demonstrated for uranium fuel fabrication facilities in areas where the mass of fissile material exceeds a threshold amount. SSCs important to safety and operational limits and conditions relating to criticality safety shall be derived from such analysis.

A.2.4 Confinement against internal exposure and chemical hazards

A.2.4.1 For the use of gloveboxes (for instance for the confinement of reprocessed uranium), specifications of design shall be commensurate with the specific hazards of the uranium fuel fabrication facility.

A.2.4.2 The efficiency of filters and their resistance to chemicals (e.g. HF), high temperatures of the exhaust gases and fire conditions shall be taken into consideration.

A.2.5 Postulated initiating events

A.2.5.1 Protection against internal fires and explosions

A.2.5.1.1 A detection and/or suppression system shall be installed that is commensurate with the risks of internal fires and explosions and is in compliance with national requirements.

A.2.5.1.2 The installation of automatic devices with water sprays shall be carefully assessed for areas where uranium may be present, with account taken of the risk of criticality.

A.2.5.1.3 In areas with potentially explosive atmospheres, the electrical network and equipment shall be protected in accordance with industrial safety regulations.

A.2.6 Instrumentation and control systems

A.2.6.1 Radiation detectors (gamma and/or neutron detectors), with audible and, where necessary, visible alarms for initiating immediate evacuation from the affected area, shall cover all the areas where a significant quantity of fissile material is present, unless it can be demonstrated that a criticality accident is highly unlikely to occur.

A.2.6.2 Detectors shall be installed in areas with a significant chemical hazard (e.g. due to UF_6 , HF) and with limited occupancy, unless it can be demonstrated that a chemical release is highly unlikely.

A.3 Operation

A.3.1 Qualification and training of personnel

A.3.1.1 For uranium fuel fabrication facilities, specific attention shall be paid to the qualification and training of personnel for dealing with radiological hazards (mainly criticality and contamination) and specific conventional hazards such as chemical hazards and fire hazards.

A.3.1.2 An inappropriate response to a fire or explosion at the facility could increase the consequences of the event (e.g. radiological hazards including criticality, chemical hazards). Specific training and drills for personnel and external fire and rescue staff shall be organized by the operating organization.

A.3.2 Facility operation

A.3.2.1 If the facility is designed to produce in parallel fuel pellets of different enrichments, operations shall be managed to exclude the mixing of powders, pellets and rods of different enrichments.

A.3.2.2 To minimize the number of events occurring, close attention shall be paid to their prevention in anticipated operational occurrences, non-routine operations and secondary operations such as decontamination, washing and preparation for maintenance or testing.

A.3.3 Criticality prevention

A.3.3.1 For the transfer of uranium powder or uranium solutions in a uranium fuel fabrication facility, 'double batching' (i.e. the transfer of two batches of fissile material instead of one batch in a fuel fabrication process) shall be prevented by design and by means of administrative control measures.

A.3.3.2 If uranium has to be removed from vessels or pipework, only approved containers shall be used.

A.3.3.3 Consideration shall be given to the impact of a fire on a solid UF_6 cylinder (e.g. fire involving a UF_6 cylinder transporter).

A.3.4 Radiation protection

Close attention shall be paid to the confinement of uranium powders and the control of contamination in the workplace.

A.3.5 Emergency planning and preparedness

A.3.5.1 Emergency arrangements shall be put in place for criticality accidents, the release of radioactive material and hazardous chemical materials, principally F_2 , UF_6 , HF and NH_3 , and the spread of fires and explosions. A.3.5.2 In dealing with a fire, a firefighting medium shall be used that does not itself create a criticality hazard.

ANNEX B (NORMATIVE ANNEX)

Requirements Specific to Mixed Oxide Fuel Fabrication Facilities

B.1 Scope

The following requirements are specific to conversion facilities and enrichment facilities that handle, process and store depleted, natural and low enriched uranium that has a ²³⁵U concentration of no more than 6%, which could be derived from natural, highly enriched, depleted or reprocessed uranium.

B.2 Design

B.2.1 Safety functions

The facility shall be designed to prevent a criticality accident and the accidental release of hazardous materials. The design shall keep radiation exposures from normal operations as low as reasonably achievable. engineering design

For criticality prevention, vessels shall be designed for the maximum authorized enrichment limit.

As with radioactive material, in conversion facilities and enrichment facilities, protection against chemical hazards shall include the control of any route for chemicals into the workplace and to the environment.

B.2.3 Criticality prevention

B.2.3.1 Criticality safety shall be ensured by means of preventive measures.

B.2.3.2 Preference shall be given to achieving criticality safety by design, to the extent practicable, rather than by means of administrative measures.

B.2.3.3 Criticality safety shall be achieved by keeping one or more of the following parameters of the system within subcritical limits in normal operations, for anticipated operational occurrences and for design basis accident conditions (or the equivalent):

- a) Mass and enrichment of fissile material present in a process;
- b) Geometry and interaction (limitations on dimensions, shape or spacing) of processing equipment;
- c) Concentration of fissile material in solutions;
- d) Degree of moderation;
- e) Presence of appropriate neutron absorbers.

B.2.3.4 The safety of the design for conversion facilities and enrichment facilities shall be demonstrated by means of a specific criticality analysis in which the following important factors are considered both singly and in combination:

- a) Enrichment: the maximum authorized enrichment in any part of the facility being able to process fissile material shall be used in all assessments, unless for a particular part of the facility it can be demonstrated, in accordance with the double contingency principle, that a lower enrichment can be used for the assessment;
- b) Mass: criticality safety shall be assessed with significant margins;
- c) Geometry: the analysis shall include the layout of the facility, and the dimensions of pipes, vessels and other process units. The potential for changes in dimensions during operation shall be considered;
- d) Concentration: a conservative approach shall be taken. A range of uranium concentrations for solutions shall be considered in the analysis to determine the most reactive conditions that could occur. Unless the homogeneity of the solution can be guaranteed, the worst case concentration of uranium in the processing and storage parts of the facility shall be considered;
- e) Moderation: the analysis shall consider a range of degrees of moderation to determine the most reactive conditions that could occur;
- f) Reflection: a conservative assumption for reflection shall be made in the criticality analysis;

- g) Neutron interaction: consideration shall be given to neutron interaction between all facility units that may be involved, including any mobile unit that may approach the array;
- h) Neutron absorbers: when taken into account in the safety analysis, and if there is a risk of degradation, the presence and the integrity of neutron absorbers shall be verifiable during periodic testing. Uncertainties in absorber parameters shall be considered in the criticality calculations.

B.2.3.5 In accordance with national regulations, criticality safety shall be demonstrated for conversion facilities and enrichment facilities in areas where the mass of fissile material exceeds a threshold amount. SSCs important to safety and operational limits and conditions relating to criticality safety shall be derived from such analysis.

B.2.4 Confinement of nuclear material

The care taken to minimize contamination shall be commensurate with the enrichment and the proportion of the uranium that is reprocessed uranium. The higher the enrichment (and thus the effect of 234 U) and the greater the proportion of the uranium that is reprocessed uranium (and thus the effects of 234 U and of traces of transuranic elements and fission products), the greater the care that shall be taken to minimize contamination.

The efficiency of filters and their resistance to chemicals (e.g. HF and NH₃), high temperatures of the exhaust gases and fire conditions shall be taken into consideration.

B.2.5 Postulated initiating events

B.2.5.1 Protection against internal fires and explosions

A detection and/or suppression system shall be installed, in accordance with the risks and relevant requirements.

The installation of automatic firefighting devices with water sprays shall be assessed with care for areas where UF_6 is present, with account taken of the potential risk of HF generation and criticality events for enriched material.

In areas with potentially explosive atmospheres, the electrical network and equipment shall be protected in accordance with industrial safety regulations.

B.2.6 Instrumentation and control systems

B.2.6.1 Safety related instrumentation and control systems in normal operations

Before heating a UF_6 cylinder, the weight of UF_6 shall be measured and shall be confirmed to be below the fill limit (e.g. by using a second independent weighing scale).

If the system has the capability of reaching a temperature where hydraulic rupture can occur, the temperature during heating shall be limited by means of two independent systems.

B.2.6.2 Safety related instrumentation and control systems for accident conditions

Radiation detectors (gamma and/or neutron detectors), with audible and, where necessary, visible alarms for initiating immediate evacuation from the affected area, shall cover all the areas where a significant quantity of fissile material is present, unless it can be demonstrated that a criticality accident is highly unlikely to occur.

Detectors shall be installed in areas with a significant chemical hazard (e.g. due to UF_6 , HF or ClF₃) and with limited occupancy, unless it can be demonstrated that a chemical release is highly unlikely.

B.3 Operation

B.3.1 Qualification and training of personnel

In conversion facilities and enrichment facilities, specific attention shall be paid to the qualification and training of personnel for dealing with radiological hazards and specific conventional hazards such as chemical hazards or fire hazards.

The operators shall be given training in the safe handling and processing of large quantities of UF_6 and other hazardous chemicals, the level of detail of which shall be commensurate with the risks associated with the operation. For releases of UF_6 and other chemical releases that result in visible clouds, periodic training shall be given to all site personnel to follow the procedure of "see, evacuate or shelter, and report".

Training shall be conducted on:

- a) Prevention and mitigation of fires and explosions that could result in radioactive releases;
- b) The implementation of criticality controls associated with operations involving enriched uranium.

An inappropriate response to a fire or explosion at the facility could increase the consequences of the event (e.g. radiological hazards including criticality, chemical hazards). Specific training of external firefighting and rescue staff shall be organized by the operating organization.

B.3.2 Maintenance, periodic testing and inspection

Long term deterioration of UF_6 cylinders and corrosion damage to the plugs and valves due to both internal and external influences are recognized as possible sources of leakage problems. An inspection programme shall be established at long term storage facilities to monitor and record the level of corrosion (particularly at plugs and valves and along the skirt welds).

B.3.3 Criticality prevention

Where there could be high concentrations of HF in the product stream of an enrichment facility, the pressure shall be maintained below the vapour pressure of HF at that temperature to avoid the condensation of HF during crystallization of UF_6 in a cylinder or intermediate vessel.

If uranium has to be removed from vessels or pipework, only approved containers shall be used.

B.3.4 Radiation protection

Adequate ventilation and/or respiratory protection shall be provided for protecting workers and for controlling the spread of contamination when equipment and containers holding radioactive material such as UF_6 cylinders are opened.

Adequate time, distance and shielding requirements shall be instituted for workers such as UF_6 cylinder handlers who could potentially be exposed to significant direct radiation fields.

B.3.5 Risk of overfilling and overheating of cylinders

Cylinder fill limits shall be established to ensure that heating of an overfilled cylinder does not result in the rupture of the cylinder.

Where there is a potential to heat a cylinder to a temperature above that of the UF_6 triple point, the weight of the cylinder shall be verified to be below its fill limit by means of a weighing scale, which shall be identified as important to safety.

If the system has the capability of reaching a temperature where hydraulic rupture can occur, the temperature during heating shall be limited by means of two independent systems. In the event of an overfilled cylinder, UF_6 in excess shall be transferred by sublimation only.

B.3.6 On-site solid UF6 handling

Consideration shall be given to the impact of a fire on a solid UF_6 cylinder (e.g. fire involving a UF_6 cylinder transporter).

B.3.7 Emergency planning and preparedness

An emergency plan shall be prepared and shall be focused on the following aspects for immediate response:

- a) The chemical toxicity of UF_6 and its reaction products (HF and UO_2F_2);
- b) The rapid progression, with no grace period, of most scenarios leading to toxicological consequences.

In dealing with a fire or a UF6 release, the actions taken or the medium used to respond to the emergency shall not create a criticality event or increase the chemical hazard.

B.4 Decommissioning

The uranium from the post-operational clean-out shall be recovered as far as is reasonably practicable.

In the decommissioning of conversion facilities and enrichment facilities, before wet cleaning, loss of criticality control shall be prevented by means of the following processes, which may be iterative:

a) Visually checking for uranium hold-up;

- b) Proceeding to dry cleaning if a uranium hold-up exists;
- c) Measuring 235U mass hold-up if visual inspection is not possible (further dismantling and dry cleaning shall be conducted if a significant amount of 235U is measured).

Special procedures shall be implemented to ensure that criticality control is maintained in dismantling equipment whose criticality is controlled by geometry.

ANNEX C (NORMATIVE ANNEX) Requirements Specific to Nuclear Fuel Reprocessing Plant

C.1 Scope

The following requirements are specific to reprocessing facilities using liquid-liquid extraction processes on an industrial scale. Reprocessing facilities are involved in the treatment of spent fuel from nuclear power plants and from research reactors to recover fissile material (uranium and plutonium) for manufacturing of fresh fuel, e.g. MOX fuel for light water reactors or fuel for fast breeder reactors. The processes covered here are: the shearing, decladding and dissolution of spent fuel; all the chemical cycles of separation and purification(including solvent removal from aqueous solutions, solvent treatment and rework); the concentration of fission products and plutonium and uranium nitrates; the conversion of plutonium and uranium nitrate to oxides; the storage of these products; interim waste storage from the process stream and prior conditioning.

In reprocessing facilities, the full range of radioactive materials and risks that may be encountered in the nuclear fuel cycle, are present.

C.2 Siting

C.2.1 In siting new reprocessing facilities on complex and large site areas, which may contain a number of facilities, account shall be taken of potential interactions with existing facilities regardless of their status, i.e. under construction, commissioning, operation, shutdown or being decommissioned.

C.2.2 Investigation and assessment regarding the safety aspects of site selection for a reprocessing plant shall be mainly focused on the site conditions through the potential effects of natural and man-induced events or aggressions on the facilities. The site shall also be evaluated with respect to:

- a) safety aspects of storage and transportation (both from and to the site) of materials or waste;
- b) the possibility for the environment to receive liquid or aerial radioactive and chemical discharges.

C.3 Design

C.3.1 Safety functions

Reprocessing facilities shall be designed to:

- a) Prevent a criticality accidents;
- b) Prevent the uncontrolled release of hazardous (including radioactive)materials;
- c) Keep radiation exposure during normal operation and accident conditions as low as reasonably achievable.

C.3.2 Engineering design

The design shall take into account the operating experience feedback of similar facilities.

C.3.2.1 Cooling

C.3.2.1.1Cooling systems, including any support features, shall have adequate capacity, availability and reliability to remove heat from radioactive decay and for removing heat due to chemical reactions.

C.3.2.1.1Cooling systems shall be designed for preventing coolant from leaking into moderation control areas designated for criticality safety.

C.3.2Sampling and analysis

C.3.2.2.1 Process sampling systems and post-accident sampling systems shall be provided for determining in a timely manner the concentration of specified radionuclides in fluid process systems, and in gas and liquid samples taken from systems or from the environment, in all operational states and in accident conditions and as required by material control and accounting.

C.3.2.2.2 Appropriate means shall be provided at the reprocessing facility for the monitoring of activity in fluid systems that have the potential for significant contamination, and for the collection of process and waste samples. The timescale of sample analysis and assessment shall be commensurate with any processing lag in the system.

C.3.2.2.3 Equipment shall be provided for monitoring, prior to or during discharges from the plant to the environment, radioactive effluents and effluents with possible contamination.

C.3.3 Criticality prevention

C.3.3.1Criticality accidents shall be prevented and controlled by means of design, as far as is reasonably practicable.

C.3.3.2 As part of the overall safety assessment of the facility, a criticality safety assessment shall be performed prior to the commencement of any activity involving fissionable material. The wide range of forms of fissionable material and their associated process conditions shall be taken into account in the assessment. Safety criteria and safety margins shall be developed to ensure sub-criticality based on controlled parameters, such as geometry, mass, enrichment or moderation.

C.3.3.3A reference fissionable material composition or medium shall be defined. The criticality safety assessment performed using this reference shall be a conservative bounding case of the actual fissionable material composition being handled or processed, e.g. mass, volume, isotope vector. Such a reference shall be used in engineering studies performed prior to the initial start-up of any process step. These studies shall be designed to assure that processes, in-process measurements, and analytical measurements perform within established limits.

C.3.3.4 If the design of the reprocessing facility accounts for burn-up credit, its use shall be appropriately justified.

C.3.3.5 In the criticality safety assessment, account shall be taken of the potential form is-direction, overflow, spills and leaks of fissionable material e.g. mis-transfer due to human error or potential carry over, e.g. from evaporators.

C.3.3.6 In the criticality safety assessment, the choice and safety of the use of fire extinguishing media, e.g. water or powder, shall be addressed.

C.3.3.7In the criticality safety assessment, account shall be taken of the effects of corrosion, erosion and vibration cracking in systems exposed to oscillations.

In the criticality safety assessment, consideration shall be given to the potential for internal and external flooding and other internal and external hazards that may compromise criticality prevention measures.

C.3.4 Confinement of radioactive material

C.3.4.1 Occupational protection

C.3.4.1.1 During normal operation, internal exposure shall be minimized by design as far as reasonably practicable.

C.3.4.1.2 The design and layout of plant equipment shall include provisions to minimize exposures arising from maintenance, inspection and testing activities as far as reasonably practicable. However, such measures shall be reviewed with safeguards staff before being finalized and installed.

C3.4.1.3 Systems shall be provided for the ventilation of buildings at the reprocessing facility with appropriate capability for cleaning of air:

- a) to prevent unacceptable dispersion of airborne radioactive substances within the plant;
- b) to reduce the concentration of airborne radioactive substances to levels compatible with the need for access by personnel to the area;
- c) to keep the levels of airborne radioactive substances in the plant below authorized limits and as low as reasonably achievable;
- d) to ventilate rooms containing inert gases or noxious gases without impairing the capability to control radioactive effluents.

In the design of a reprocessing facility, account shall be taken of the performance criteria for ventilation and containment systems, including the pressure difference between zones, the types of filter to be used, the differential pressure across filters and the appropriate flow velocity for operational states.

The efficiency of filters and their resistance to chemicals, high temperatures of the exhaust gases and fire conditions shall be taken into consideration.

C.3.4.2 Public and environmental protection

C.3.4.2.1 Systems shall be provided for treating solid radioactive waste and liquid radioactive waste at the reprocessing facility to keep the amounts and concentrations of radioactive releases below the authorized limits on discharges and as low as reasonably achievable.

C.3.4.2.2 Systems shall be provided at the reprocessing facility for treating liquid and gaseous radioactive effluents to keep their amounts below the authorized limits on discharges and as low as reasonably achievable.

C.3.4.2.3 In the design of the reprocessing facility it shall be ensured that radioactive liquids discharged from the reprocessing facility site are collected, treated and confirmed to be within authorized limits prior to discharge to the environment. Analytical results from such discharges shall be reported to material control and accounting personnel at the facility.

C.3.5 Postulated initiating events----internal initiating events

C.3.5.1 Fires and explosions

C3.5.1.1 The risk of fire, explosion or of excess internal pressure resulting from:

- a) the use of explosive gases, flammable liquids and chemical substances such hydrogen or hydrogen peroxide, nitric acid, tribute phosphate(TBP) and diluents, hydrazine nitrate;
- b) the generation of hydrogen by radiolysis in aqueous or organic solutions and solids;
- c) the forming of explosive products due to chemical reaction, e.g. nitrated organic substances (red oils), or thermal runaway reaction;
- d) pyrophoric materials (zircaloy fines).
- Shall be considered and appropriate safety measures implemented.

C.3.5.1.2 In areas with potentially explosive atmospheres, the electrical network and equipment shall be protected in accordance with industrial safety regulations.

C.3.5.1.3 A detection and/or suppression system shall be installed that is commensurate with the risks of fires and is in compliance with national requirements.

C.3.5.1.4 Extinguishing devices, automatically or manually operated, shall be installed in areas where a fire is possible.

C.3.5.2 Equipment failure

During the design of a reprocessing facility, plant equipment used in aradiological environment shall be suitably assessed for its actions or failure. Measures required for ensuring industrial safety of non-nuclear equipment, e.g. guards, fuses, seals, insulation, installed in glove boxes or hot cells shall be adapted to their radiological environment.

C.3.5.3 Leaks

Provisions to prevent, detect and collect leaks arising from corrosion, vibration and erosion shall be implemented. Specific attention shall be given to equipment containing concentrated acid solutions, especially when at high temperatures.

C.3.5.4 Flooding

Reprocessing facilities shall be designed to prevent the leakage of contaminated liquid to the environment in the event of internal flooding.

C.3.5.5 Loss of support systems

C.3.5.5.1 During the design of a reprocessing facility, the loss of safety related items and safety systems (including their supporting features) shall be considered and their impact on safety shall be assessed.

C.3.5.5.2 The design of electrical power supplies to reprocessing facilities shall ensure their adequate availability and reliability. In case of the loss of normal power, an emergency electrical supply shall be provided to the

relevant items important to safety, taking into account the reprocessing facility's operational status (e.g. normal operation, shutdown, maintenance and clean-out). The restoration of the electrical supply shall be pre-planned and exercised to ensure adequate and timely deployment.

C.3.5.6 Use of pressurised and vacuum equipment

Provision for in-service inspection and testing of equipment installed in high active areas shall be defined according to the national requirements on pressurized and/or vacuum equipment. Safety measures to minimize the consequences of potential failure or leak in high active area shall be implemented.

C.3.5.7 Load drops

Handling systems shall be designed to reduce the frequency of occurrence of load drops. The consequences of possible load drops shall be minimized.

C.3.6 Postulated initiation event-external initiation event

C.3.6.1 Provisions, e.g. instrumentation, support systems and procedures, for post-earthquake monitoring of the safety status and safety functions of the reprocessing facility shall be provided.

C.3.6.2 Extreme weather conditions shall be taken into account in the design of items important to safety, in particular cooling systems associated with the storage of heat generating high level waste.

C.3.7 Instrumentation and control systems

C.3.7.1 Adequate instrumentation shall be provided for measuring the variables that are relevant to the safety of the reprocessing facility, both:

- a) in normal operation to ensure that the process is being operated within the safety limits and to monitor its environmental impact;
- b) for detecting and managing accident conditions, such as criticality or earthquake detection.

C.3.7.2 Where prompt and reliable action is necessary, provision shall be made in the design for automatic safety control or action.

C.3.7.3 Automated safety control systems, e.g. safety interlock systems, shall be designed to ensure their adequate availability and reliability.

C.3.8 Radioactive waste and effluent management

The design of the reprocessing facility shall enable safe management of radioactive waste and effluents arising from operational states, maintenance and periodic wash-out of the facility. Due consideration shall be paid to the various nature, composition and activity level of the waste generated in the facility.

C.4 Commissioning

C.4.1 Commissioning programme

C.4.1.1 Due to the large size of commercial reprocessing facilities, handover from construction to commissioning is often phased.

C.4.1.2 Special attention shall be paid to ensuring that no commissioning tests are performed that might place the plant in an unanalyzed condition. Each safety function shall be verified as fully as practicable before the stage in which the function becomes necessary to ensure safe commissioning. If such verification is carried out at later stage the probability of problems occurring and the time and cost for its corrective action, may increase.

C.4.1.3 During inactive commissioning, the following activities shall, as a minimum, be performed:

- a) Confirmation of the performance of shielding and confinement systems, including confirmation of the weld quality of static containment;
- b) Confirmation of the performance of criticality control measures;
- c) Demonstration of the availability of criticality detection and alarm systems;
- d) Demonstration of the performance of emergency shutdown systems;
- e) Demonstration of the availability of emergency power supply.

C.4.1.4 The ability to test and maintain the reprocessing facility and its systems, once commercial operation has started, shall be addressed in the commissioning programme, especially for hot cells and remote equipment.

C.4.2 Organization and responsibilities

C.4.2.1 During commissioning, the safety committee shall include members with expertise in the design and construction of reprocessing facilities.

C.4.2.2 By the end of active commissioning, all the safety requirements for active operations shall be applied. Any exceptions shall be justified in the commissioning safety case.

C.4.2.3 The commissioning report shall identify any updates required to the safety case and identify any changes made to safety measures or work practices during commissioning.

C.4.2.4The emergency plan shall be prepared, tested and reviewed prior to the introduction of radioactive material to the reprocessing facility.

C.5 Operation

C.5.1 Spent fuel feeding limit

C.5.1.1 A spent fuel acceptance and reprocessing feed programme4 of a reprocessing facility shall be prepared and assessed to ensure that the requirements established in the operating license and in the safety assessment are met throughout the reprocessing processes, and to ensure that there is no unacceptable impact on the reprocessing facility products and waste/discharges generated.

C.5.2 Management system

C.5.2.1 Establish and maintain the quality of the interfaces &communication channels between different worker groups within the reprocessing facility and between the reprocessing facility and other facilities both on-site and off-site;

C.5.2.2 In addition to meeting the requirement of para 9.14, covering the minimum staffing for operation, define the minimum staffing level tonsure safety of the reprocessing facility in its shut-down state.

C.5.3 Receipt of radioactive material

Procedures shall be developed to ensure that radioactive material received at each facility is appropriately characterized and acceptable before it is allowed to be stored or used within the facility. The timescale of sample analysis and assessment shall be commensurate with any processing lag in the system.

C.5.4 Facility operation

C.5.4.1 The feed programme shall be supported by appropriate fuel data, prior to committing to dissolution of the fuel, to confirm that the fuel characteristics match the feed programme safety requirements.

C.5.4.2 For each reprocessing campaign, the values of control parameters shall be based on the fuel and fuel solution characteristics derived from the actual fuel feed programme for that campaign, as required by the safety assessment.

C.5.4.3 The operating organization shall ensure control of, and be able to account for, all nuclear material on the facility at all times.

C.5.5 Operating documentation

C.5.5.1 Operating procedures shall include the action(s) to be taken in the event that operational limits and conditions are exceeded.

C.5.5.2 Particular attention shall be paid to the arrangements for the efficient and accurate transfer of information and records between shift teams (shift handovers) and between shift and day teams.

C.5.5.3 The operator shall document the following:

- a) all incident/accidents/events and associated radionuclide releases;
- b) all environmental monitoring data as required by regulations or license conditions;
- c) radioactive waste inventory including those disposed or stored onsite;
- d) all inspection records and corrective actions.

C.5.5.4 Special provisions

The operating organization shall take actions to minimize the risks associated with maintenance during shutdowns (inter-campaign periods).

C.5.6 Criticality prevention

C.5.6.1 Relevant facility personnel shall be trained in the general principles of criticality control, including the requirements of the emergency response plan.

C.5.6.2 Procedures for the transfer or movement of fissionable material during operational states (including maintenance) shall be defined and submitted for approval from criticality safety staff that are, to the extent necessary, independent of the operations management.

C.5.6.3 Fissionable material, in particular waste materials that have not been monitored for fissile content, shall not be collected or placed in containers unless they have been specifically designed and approved for that purpose.

C.5.6.4 Prior to modifying the location, or neutron reflectors or connections of process equipment installed in inaccessible cells, the criticality assessment shall be updated to determine whether such change is acceptable.

C.5.6.5 Specific provisions shall be provided to reduce the risk of accumulation of organic phase in tanks which handle aqueous solutions containing fissionable materials.

C.5.6.6 All transfers of fissionable material including waste and residues shall be in accordance with the criticality safety requirements of both the sending area and the receiving area and shall be subject to certification by the sending plant and acceptance by the receiving plant prior to sending.

C.5.6.7 The inadvertent addition of water or neutralizing chemicals (often used for decontamination) to fissionable solutions, which can cause precipitation with a criticality risk, shall be minimized. Such liquid feed lines shall be isolated or shall be subject to appropriate administrative controls.

C.5.6.8 The lack of accumulation of fissionable material in tanks, for which subcriticality is not guaranteed only by the geometry shall be periodically reviewed by appropriate means after draining and rinsing, if any.

C.5.6.9 Adequate arrangements for responding to a criticality accident shall be established and maintained. These arrangements shall include the development of an emergency plan, definition of responsibilities and provision of equipment and shall include emergency operating procedures.

C.5.7 Radiation protection

Appropriate equipment, either stationary or mobile, shall be provided at the reprocessing facility to ensure that there is adequate radiation monitoring in operational states and, as far as is practicable, in accident conditions.

C.5.8 Prevention of internal and external exposure

During operation (including maintenance interventions), the prevention of internal and external exposure shall be controlled by both physical and administrative means, in order to limit the need to use personnel protective equipment as far as reasonably practicable.

C.5.9 Fire, chemical & industrial safety management

C.5.9.1 The potential for fire or explosion and the control of ignition sources and potential combustible materials, including hazardous and toxic process chemicals, shall be carefully considered, including during maintenance operations.

C.5.9.2Each handling device used for transferring loads containing radioactive substances or loads in line of equipment containing radioactive materials or participating in safety functions shall be subjected to appropriate check and operating instructions.

C.5.10 Waste management

C.5.10.1 Waste generation, treatment and storage shall be organized according to preestablished criteria and shall take into consideration both on-site storage capacity and disposal.

C.5.10.2 Heat generating high level waste shall be stored in facilities that address the need to maintain suitably reliable cooling.

C.5.10.3 Liquid waste shall be transferred into a solid and neutralized to enhance safety.

C.6 Decommission

Special procedures shall be implemented to ensure that criticality control is maintained in dismantling equipment whose criticality is controlled by geometry.

ANNEX D (NORMATIVE ANNEX) Requirements specific to mixed oxide fuel fabrication facilities

D.1 Scope

The following requirements apply to mixed oxide (MOX) fuel manufacturers that operate, process, and store plutonium oxide, depleted uranium, natural uranium, or reprocessed uranium oxides and use the mixed oxide produced from the above materials as feed for the manufacture of MOX fuel rods and assemblies. These requirements do not apply to preprocessing, or polishing, of oxide powders.

D.2 Design

D.2.1 Safety functions

The facility shall be designed to prevent a criticality accident and the accidental release of hazardous materials. The design shall keep radiation exposures from normal operations as low as reasonably achievable.

D.2.2 Engineering design

By design, occupational radiation exposure shall be solely external exposure and there shall be no measurable internal doses to workers in normal operation. To avoid internal doses in normal operation, the design objective shall be to contain radioactive material, to minimize its spread to work areas and to detect very low levels of airborne contamination.

D.2.3 Criticality prevention

D.2.3.1 Criticality safety shall be ensured by means of preventive measures.

D.2.3.2 Preference shall be given to achieving criticality safety by design, to the extent practicable, rather than by means of administrative measures.

D.2.3.3 Criticality safety shall be achieved by keeping one or more of the following parameters of the system within subcritical limits in normal operations, for anticipated operational occurrences and for design basis accident conditions:

a) PuO₂ (input):

1) Mass and geometry in accordance with the safety specification of PuO_2 isotopic composition and moderation;

2) Presence of appropriate neutron absorbers.

b) UO₂ (input):

1)Mass and geometry in accordance with the safety specification of UO_2 isotopic composition and moderation;

2)MOX powder is formed in the fuel fabrication process, and the associated criticality hazard shall be assessed in accordance with the isotopic specification and the PuO_2 content at each stage of the process. Mass, geometry and moderation shall be considered.

D.2.3.4 For laboratories and, if necessary, for solid plutonium waste, the safe mass and geometry (for storage) of plutonium shall be assessed with the isotopic composition as determined in (a) or (c) above.

D.2.3.5 The safety of the design for a MOX fuel fabrication facility shall be demonstrated by means of a specific criticality analysis in which the following important factors are considered both singly and in combination:

- a) Plutonium isotopic composition, PuO_2 content and uranium enrichment (if $^{235}U > 1\%$): the maximum authorized compositions in any part of the process shall be used in all assessments unless the impossibility of reaching this Pu composition or content (and uranium enrichment if needed) is demonstrated in accordance with the double contingency principle;
- b) Mass: criticality safety shall be assessed with significant margins;
- c) Geometry: the analysis shall include the layout of the facility (storages), and the dimensions of pipes, vessels and other process units;

- d) Density and form of materials: a conservative approach shall be taken;
- e) Concentration and density (in analytical laboratories and liquid effluent units): a conservative approach shall be taken;
- f) Moderation: the analysis shall consider a range of degrees of moderation to determine the most reactive conditions that could occur;
- g) Reflection: a conservative assumption concerning reflection shall be made in the criticality analysis;
- h) Neutron interaction: consideration shall be given to neutron interaction between all facility units that may contain fissile materials.

D.2.3.6 In accordance with national regulations, criticality safety shall be demonstrated for MOX fuel fabrication facilities in areas where the mass of the fissile material exceeds a threshold amount. SSCs important to safety and operational limits and conditions relating to criticality safety shall be derived from such analysis.

D.2.4 Confinement of nuclear material

D.2.4.1 Containment shall be the primary method for confinement against the spreading of powder contamination. Containment shall be provided by two complementary containment systems — static and dynamic:

- a) The static containment system shall consist of at least two static barriers between radioactive material and the environment;
- b) The dynamic containment system shall be used to create airflow towards equipment with higher levels of contamination.

D.2.4.2 The MOX fuel fabrication facility shall be specifically designed to ensure that, in normal operations, radioactive material is confined inside the first static barrier. The second static barrier shall be designed with features for the control of airborne contamination to minimize the radiation exposures of workers in operational states and to limit contamination within the facility to the extent practicable.

D.2.4.3 In the design of a MO fuel fabrication facility, account shall be taken of the performance criteria for ventilation and containment systems, including the pressure difference between zones, the types of filter to be used, the differential pressure across filters and the appropriate flow velocity for operational states.

D.2.4.4 The efficiency of filters and their resistance to chemicals, high temperatures of the exhaust gases and fire conditions shall be taken into consideration.

D.2.5 Occupational protection

MOX fuel fabrication facilities shall be designed with an appropriately sized ventilation system in areas of the facility that have been identified as having significant potential for concentrations of airborne hazardous material.

D.2.6 Environmental protection

If there is a likelihood that leakage may occur at, or may bypass, the filter connection, the design shall accommodate the testing to the last filter (in accordance with accepted standards) to ensure that they correspond to the removal efficiency used in the design.

D.2.7 Postulated initiating events

D.2.7.1Protection against internal fires and explosions

D.2.7.1.1A detection and/or suppression system shall be installed that is commensurate with the risks of fires and is in compliance with national requirements.

D.2.7.1.2Extinguishing devices, automatically or manually operated, with the use of an adequate extinguishing material shall be installed in areas where a fire is possible and where the consequences of a fire could lead to the wide dispersion of contamination outside the first static barrier. The installation of automatic devices with water sprays shall be carefully assessed for areas where uranium, plutonium and/or MOX powder may be present, with account taken of the risk of criticality.

D.2.7.1.3In areas with potentially explosive atmospheres, the electrical network and equipment shall be protected in accordance with industrial safety regulations.

D.2.7.2 Leaks and spills

D.2.7.2.1 In process areas where a moderation mode is used for criticality control, unless account is taken of the presence of liquids or the possible leakage of liquids in criticality assessments, liquid pipes shall be excluded or a minimum of two physical barriers shall be used in normal conditions and in other facility conditions, or the amount of liquid shall be limited and controlled by design (e.g. oil for the pellet press).

D.2.7.2.2 Liquids may be used in laboratories. Their use shall be limited and controlled if necessary by means of detection systems to detect spillage.

D.2.7.2.3 Spillages of radioactive material (powder) from process vessels shall be contained in glove boxes, but such spillages may still lead to criticality hazards. The possibility of such events shall be considered in the safety analysis.

D.2.7.3 Loss of decay heat removal

The cooling systems shall be assessed in accordance with the safety functions of the MOX fuel fabrication facility.

D.2.7.4 Load drops

Handling systems shall be designed to reduce the frequency of occurrence of load drops. The consequences of possible load drops shall be minimized.

D.2.7.5 Mechanical failure

Measures for the industrial safety of non-nuclear-designed equipment installed in gloveboxes (e.g. mechanical guards) shall be adapted to the nuclear environment.

D.2.8 Instrumentation and control systems

D.2.8.1 Safety related instrumentation and control systems in normal operations

D.2.8.1.1 In normal operations, a number of parameters shall be measured and controlled to prevent a criticality. These parameters shall be of high integrity and shall be calibrated against known standards. Changes to computer codes and data shall be controlled to a high standard by means of the management system.

D.2.8.1.2 Gloveboxes shall be equipped with instrumentation and control systems for fulfilling the requirements for a negative pressure.

D.2.8.1.3 Equipment shall be installed to continuously sample air in the breathing zone of workers for the retrospective assessment of doses due to internal exposure. Portable and installed equipment shall be able to detect surface contamination on people, equipment, products and other objects to verify the effective confinement of radioactive material.

D.2.8.1.4 Real time measurements shall be made to confirm that filtration systems are working effectively. Discharges shall be measured continuously.

D.2.8.2 Safety related instrumentation and control systems for accident conditions

Radiation detectors (gamma and/or neutron detectors), with audible and, where necessary, visible alarms for initiating immediate evacuation from the affected area, shall cover all the areas where a significant quantity of fissile material is present, unless it can be demonstrated that a criticality accident is highly unlikely to occur.

D.2.9 Radioactive waste management

D.2.9.1 All situations in which waste may be generated shall be considered in order to ensure that the potential impact of the waste on the safety of the facility is considered, that its generation is minimized, and that a means is available for its handling, collection and disposition.

D.2.9.2 Waste shall be first bagged in the glovebox and then removed from the glovebox using bagging ports in which a bag is attached to the glovebox and the waste is inserted and then removed after sealing to maintain confinement. The size of the port shall be such as to accommodate the expected waste, which may include

equipment that has been replaced. Filters from the gloveboxes and the ventilation system shall have engineered features. In all cases, the arrangements shall ensure confinement, criticality control (if necessary) and control of operator doses.

D.2.9.3 Design features shall be provided for the collection and transport of waste in containers to provide an additional level of confinement. Consideration shall be given to criticality control, if necessary, and radiation exposure of the operator when a number of bags of waste are collected.

D.2.9.4 Stores shall be designed to ensure control of criticality, if necessary, control of confinement and control of the radiation exposure of operators.

D.2.9.5 Discharges shall be measured continuously.

D.2.10 Other design considerations

D.2.10.1 In the design of intermediate MOX and PuO₂ storages for MOX fuel fabrication facilities, consideration shall be given to:

- a) Criticality;
- b) Fire;
- c) Confinement;
- d) Heat removal (if appropriate);
- e) Exposure of operators due to entering the store and handling the material;
- f) Access to respond to anticipated operational occurrences such as dropped trays of pellets;
- g) Maintenance of the in-store handling, lifting and transfer equipment;

D.2.10.2 The maintenance policies shall be determined before the design is established.

D.3 Construction

The construction of MOX fuel fabrication facilities tends to take a number of years as they are complex facilities, and construction workers, including engineers and architects, may move away to other work and be replaced. Knowledge and experience relating to construction shall be maintained during the construction period.

D.4 Commissioning

Plutonium or 'hot processing' commissioning requires major changes in personnel and equipment, containment, criticality and radiation control arrangements:

- a) For the workforce, the safety culture shall be enhanced so as to ensure safe operation with plutonium;
- b) The management shall ensure that both the facility and the workforce are fully ready for the change before it is implemented.

D.5 Operation

D.5.1 Qualification and training of personnel

Special attention shall be paid to training workers in glovebox operations, including actions to be taken if contamination occurs.

Specific attention shall be paid to the qualification and training of personnel for dealing with the radiological hazards (e.g. criticality, external exposure, contamination) and specific conventional hazards (e.g. fire), security and emergency drills.

An inappropriate response to a fire or explosion at the facility could increase the consequences of the event (e.g. radiological hazards including criticality, chemical hazards). Specific training of external firefighters and rescue staff shall be organized by the operating organization.

D.5.2 Criticality prevention

If PuO₂ or MOX powder has to be removed from equipment, only approved containers shall be used.

D.5.3 Radiation protection

Close attention shall be paid to the confinement of PuO_2 and MOX powders and the control of contamination in the workplace.

Dose measuring equipment shall be adapted to ensure that it correctly measures gamma and neutron radiation doses.

D.5.4 Emergency planning and preparedness

Emergency arrangements shall be put in place for criticality accidents, the release of radioactive material and the spread of fires and explosions.

In dealing with a fire, a firefighting medium shall be used that does not itself create a criticality hazard.

D.6 Decommissioning

Criticality safety shall be ensured for the temporary storage of waste contaminated with plutonium that is generated by the dismantling of glove boxes and their contents.

ANNEX E (NORMATIVE ANNEX) Requirements Specific to Fuel Cycle Reseach and Development Facilities

E.1 Scope

E.1.1 The following requirements are specific to fuel cycle research and development facilities at laboratories and at pilot and demonstration scales that receive, handle, process, examine and store a large variety of radioactive materials with very different physical characteristics (e.g. uranium, thorium, plutonium), other actinides (e.g. Americium, Neptunium, Curium), separated isotopes (fissionable and non-fissionable),fission products, activated materials and irradiated fuel. Furthermore, a wide range of other materials are used in such facilities, for example graphite, boron, gadolinium, hafnium, zirconium, aluminum, heavy water and various metal alloys.

E.1.2 Fuel cycle research and development facilities are generally characterized by the need for high flexibility in their operations and processes, but typically have low inventories of fissionable materials and can include both hands-on and remote handling operations. Fuel cycle research and development facilities can be used to investigate various fuel manufacturing techniques, reprocessing and waste handling techniques and processes, as well as to investigate material properties of fuel before and after irradiation in the reactor, and to develop equipment, the use of which is envisaged later at an industrial scale.

E.1.3 Some safety issues specific to fuel cycle research and development facilities are:

- a) the manipulation of small amounts of radioactive material;
- b) the diversity of the experiments carried out and the associated safety assessment, which might be covering several different experiments;
- c) the potential manipulation of unusual radionuclides, such as "exotic" actinides, with the associated risks;
- d) the organizational and human factors as the operations are mainly manual and require the cooperation between the operating personnel of the facility and R&D personnel.

E.2 Design

E.2.1 Safety functions

The facility shall be designed to prevent a criticality accident and the accidental release of hazardous (including radioactive) materials. The design shall keep radiation exposures during normal operation and accident conditions as low as reasonably achievable.

E.2.2 Engineering design

The design shall, as far as reasonably practicable, prevent hazardous concentrations of gases and other explosive or flammable materials.

E.2.3 Criticality prevention

E.2.3.1 Criticality safety shall be ensured by means of preventive measures.

E.2.3.2 Criticality safety shall be ensured by means of preventive measures. Preference shall be given to achieving criticality safety by design, to the extent practicable, rather than by means of administrative measures.

E.2.4 Confinement of nuclear material

Containment shall be the primary method for ensuring confinement against the spreading of contamination. Containment can be provided by two complementary containment systems — static (e.g. physical barriers) and/or dynamic (e.g. ventilation). In view of the large range of potential radiological hazards presented by fuel cycle research and development facilities, a graded approach shall be used in the design of the containment systems with respect to the nature and number of the barriers and their performance, in accordance with the severity of the potential radiological consequences of their failure.

E.2.5 Protection against exposure to radiations

The activities involved in fuel cycle research and development facilities generally rely on analytical data from samples. Sampling devices, sample transfer methods, sample storage and the analytical laboratories shall be designed to minimize doses to workers.

E.2.6 Postulated initiating events

E.2.6.1 A fire detection system shall be installed that is commensurate with the risks of fires and is in compliance with national requirements.

E.2.6.2 In areas with potentially explosive atmospheres, the electrical network and equipment shall be protected in accordance with industrial safety regulations.

E.3 Operation

E.3.1 Management system

E.3.1.1 Procedures shall be developed to ensure that radioactive material received at the facility is appropriately characterized and acceptable before it is allowed to be stored or used within the facility.

E.3.1.2 An inappropriate response to a fire or explosion at the facility could increase the consequences of the event (e.g. radiological hazards including criticality, chemical hazards). Specific training and drills for personnel and external fire and rescue staff shall be organized by the operating organization.

E.3.2 Criticality prevention

E.3.2.1 Criticality hazards may be encountered during any research and development activity, including maintenance work. If fissile material has to be removed from equipment, only approved containers shall be used. E.3.2.2 In the criticality safety assessment, the choice and safety of the use of fire extinguishing media, e.g. water

or powder, shall be addressed.

E.3.2.3 Any wastes and residues arising from experiments or pilot processes, decontamination, or maintenance activities that contain fissile material shall be collected in containers with a favorable geometry and shall be stored in dedicated criticality safe areas.

E.3.2.4 An emergency plan shall be prepared and shall focus on the following aspects for immediate response:

- a) Fire and explosion;
- b) Criticality accidents;
- c) Release of hazardous materials, both radioactive and chemical.

E.3.2.5 In dealing with a fire or a release of hazardous materials (e.g. UF6), the actions taken or the medium used to respond to the emergency shall not create criticality hazard or add to the chemical hazard.

E.4 Decommission

E.4.1 Special procedures shall be implemented to ensure that criticality control is maintained in dismantling equipment whose criticality is controlled by geometry.

E.4.2 Criticality safety shall be ensured for the temporary storage of radioactive waste contaminated with plutonium that is generated by the dismantling of gloveboxes and their contents.

ANNEX F (informative annex) Selected Postulated Initiating Events

F.1 External postulated initiating events

F.1.1 Natural phenomena would include:

- a) Extreme weather conditions: precipitation including rain, hail, snow, ice; frazil ice; wind including tornadoes, hurricanes, cyclones, dust storms or sand storms; lightning; extreme high or low temperatures; extreme humidity;
- b) Flooding;
- c) Earthquakes and eruptions of volcanoes;
- d) Natural fires;
- e) Effects of terrestrial and aquatic flora and fauna (leading to blockages of inlets and outlets and damage to structures).
- F.1.2 Human induced phenomena include:
 - a) Fires, explosions or releases of corrosive or hazardous substances (from surrounding industrial or military installations or transport infrastructures);
 - b) Aircraft crashes;
 - c) Missile strikes (arising from structural and/or mechanical failure in surrounding installations);
 - d) Flooding (e.g. failure of a dam, blockage of a river);
 - e) Loss of power supply;
 - f) Civil strife (leading to infrastructure failure, strikes and blockades).
- F.2 Internal postulated events

Internal events would include:

- a) Loss of energy and fluids (e.g. loss of electrical power supplies, air and compressed air, vacuum, superheated water and steam, coolant, chemical reagents and ventilation);
- b) Failures in use of electricity or chemicals;
- c) Mechanical failure, including drop loads, rupture (of pressure retaining vessels or pipes), leaks (due to corrosion), plugging;
- d) Failures of, and human errors with, instrumentation and control systems;
- e) Internal fires and explosions (due to gas generation and process hazards);
- f) Flooding (e.g. vessel overflows).

ANNEX G (INFORMATIVE ANNEX) Availability and Reliability Principles Used in Fuel Cycle Facility Safety

G.1 Redundancy

G.1.1 The principle of redundancy will need to be applied as a design principle for improving the reliability of systems important to safety. The design will need to ensure that no single failure can result in a loss of capability of SSCs important to safety to perform their intended safety functions. Multiple sets of equipment that cannot be tested individually cannot be considered redundant.

G.1.2 The degree of redundancy adopted will also need to reflect the potential for undetected failures that could degrade reliability.

G.2 Independence

The principle of independence (as functional isolation, or as physical separation by means of distance, barriers or layout of process equipment or components) will need to be applied, as appropriate, to enhance the reliability of systems, in particular with regard to common cause failures.

G.3 Diversity

The principle of diversity can enhance reliability and reduce the potential for common cause failures. It will need to be adopted for safety significant systems wherever appropriate and reasonably practicable.

G.4 Double contingency

Process designs will need to incorporate sufficient safety factors to require at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible.

G.5 Fail-safe design

Where practicable, the fail-safe principle will need to be applied to components important to safety, i.e. if a system or component shall fail, the fuel cycle facility will pass into a safe state without the need to initiate any protective or mitigatory actions.

G.6 Testability

All SSCs important to safety will need to be designed and arranged so that their safety functions can be adequately inspected and tested, and the SSCs important to safety can be maintained, as appropriate, before commissioning and at suitable and regular intervals thereafter in accordance with their importance to safety. If it is not practicable to provide adequate testability of a component, the safety analysis will need to take into account the possibility of undetected failures of such equipment.

ANNEX H (INFORMATIVE ANNEX) Safety in the Design of a Fuel Cycle Facility

H.1 Scope

This annex gives an overview of the approach to safety in the design of a fuel cycle facility, including five steps: input data, identification of hazards, hazard evaluation, establishment of operating limits and conditions, and justification of safety measures.

H.2 Input data

H.2.1 Input data consist of:

- a) Specification of data for the facility design basis on the basis of the product to be used, the processes to be performed, the production capability, etc.;
- b) Safety objectives of the facility;
- c) Definition of the safety functions to be fulfilled by the facility.

H.2.2 A safety function is a function the loss of which may lead to radiological or chemical consequences for the workforce, the public or the environment. In the context of fuel cycle facilities, they consist of:

- Confinement against dispersion of radioactive material and chemical hazards; and associated secondary safety functions: structural integrity, cooling (evacuation of decay heat) and prevention of radiolysis;
- b) Protection against external irradiation;
- c) Prevention of criticality.

H.3 Identification of hazards

H.3.1 Identification of all external and internal hazards (radiological and chemical hazards):

- a) External hazards, from an established list;
- b) Radiological and chemical internal hazards (facility specific or from an established list, e.g. H.3.2). Chemical hazards are taken into account only when they may lead to radiological consequences.
- H.3.2 The following is a list of the main non-nuclear internal hazards:
 - a) Loss of energy and fluids (e.g. loss of electrical power supplies, air and pressurized air, vacuum, superheated water and steam, coolant, chemical reagents and ventilation);
 - b) Failures in use of electricity or chemicals;
 - c) Mechanical failure, including drop loads, rupture (of pressure retaining vessels or pipes), leaks (due to corrosion), plugging;
 - d) Failures of, and human errors with, instrumentation and control systems;
 - e) Internal fires and explosions (due to gas generation and process hazards);
 - f) Flooding (e.g. vessel overflows).

H.4 Hazard evaluation

H.4.1 Development of event scenarios and identification of the postulated initiating events

H.4.1.1 In this step, the hazards identified during the hazard identification step are linked with the postulated initiating events to produce event scenarios. These event scenarios may be grouped by event and hazard type (e.g. loss of confinement, criticality, and fire).

H.4.1.2 A postulated initiating event (PIE) is an event identified in design as capable of leading to anticipated operational occurrences or accident conditions. Postulated initiating events could lead to a release of significant amounts of radiation and/or radioactive material and associated chemical materials depending on the hazards.

H.4.2 Evaluation of the consequences of event scenarios

For each event scenario or group of event scenarios, the consequences to workers, the public and the environment are estimated.

H.4.3 Identification of structures, systems and components important to safety and their safety requirements

H.4.3.1 For those scenarios potentially leading to unacceptable consequences, SSCs important to safety that fulfill the necessary safety functions are identified.

H.4.3.2 A structure, system or component (SSC) important to safety is a barrier specifically for preventing the occurrence of initiating events and for mitigating the consequences of accidents is.

H.4.3.3 A design basis accident (DBA) is an accident against which a facility is designed according to established design criteria such that the consequences are kept within defined limits. These accidents are events against which design measures are taken when designing the facility. The design measures are intended to prevent an accident or to mitigate its consequences if it does occur. Accidents may be grouped together with one representative bounding case if they are related to the same identified hazard and therefore have a common set of SSCs important to safety. For criticality accidents, specific preventive measures are implemented (e.g. double contingency principle). Mitigatory measures for and assessment of the consequences of a criticality accident are regulated by national legislation. Therefore, mitigatory measures for and consequence assessments of criticality accidents are not necessarily part of the DBA approach.

H.4.3.4 Facility states are set out in table H.1.DBAs and anticipated operational occurrences are specified and their possible consequences are assessed. Safe design is achieved by ensuring that the possible consequences of all DBAs and anticipated operational occurrences are acceptable.

Table H.1 Facility states

Operational states		Accident	conditions		
Normal operation1	Anticipated	operational	Beyond d	design	basis
	occurrence		Design basis accident	accident	

Normal operation is operation within specified operational limits and conditions;

An anticipated operational occurrence is an operational process deviating from normal operation which is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions.

H.4.3.5 The emergency preparedness and response plan is determined; this defines the mitigatory measures that will need to be taken to ensure that any off-site consequences are acceptable.

H.4.3.6 To perform the safety analysis, DBAs are postulated, using bounding assumptions.

H.4.4 Evaluation of the mitigated consequences and likelihood

If the consequences of an event after mitigatory measures have been taken and/or the likelihood of occurrence of the event make the event still not acceptable (see Fig. 2 of this publication), the evaluation (step 3.B) is iterated and the SSCs important to safety (step 3.C) are modified until the results become acceptable.

H.5 Establishment of operational limits and conditions

The operational limits and conditions are defined clearly.

Operational limits and conditions (OLCs) are a set of rules setting forth parameter limits, the functional capability and the performance levels of equipment and personnel approved by the regulatory body for safe operation of an authorized facility.

H.6 Justification of safety measures

In this step, the licensing documentation of the facility is prepared.