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Safety of Conversion Facilities and Uranium Enrichment Facilities (

DS 517A

Revision of IAEA Safety Standards Series No. SSG-5)

DRAFT SPECIFIC SAFETY GUIDE

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. ~~This Safety Guide on~~ Requirements for all the ~~Safety~~important areas of ~~Conversion Facilities and Uranium Enrichment Facilities makes recommendations on how to meet the requirements~~ safety in all stages of the lifetime of a nuclear fuel cycle facility are established in ~~the~~IAEA Safety ~~Requirements publication on the~~Standards Series No. SSR-4, Safety of Nuclear Fuel Cycle Facilities [1~~], and supplements and elaborates on those requirements.~~].

~~1.1. The~~This Safety Guide provides specific recommendations on the safety of conversion facilities and uranium enrichment facilities~~ is ensured by means of their proper siting, design, construction, commissioning, operation including management, and decommissioning. This Safety Guide addresses all these stages in the lifetime of a conversion facility or an enrichment facility, with emphasis placed on design and operation.~~

1.2. . Uranium and the waste generated in conversion facilities and uranium enrichment facilities are handled, processed, treated and stored ~~throughout~~at the ~~entire~~ facility. Conversion facilities and uranium enrichment facilities may process or use large amounts of hazardous chemicals, which can be toxic, corrosive, combustible and/or explosive.

~~1.2.~~1.3. The conversion process and the enrichment process can rely to a large extent on operator intervention and administrative controls to ensure safety, in addition to ~~active and~~ passive and active engineered safety measures. ~~A significant~~The potential hazard associated with these facilities ~~is~~includes a loss of the means of confinement resulting in a release of uranium hexafluoride (UF_6) and hazardous chemicals such as ~~hydrofluoric acid (HF)~~hydrogen fluoride and fluorine~~ (F_2).~~. In addition, for uranium enrichment facilities and conversion facilities that process uranium with a ^{235}U ~~concentration~~enrichment of more than 1%, criticality can also be a ~~significant~~potential hazard.

~~1.2.~~

1.4. This Safety Guide supersedes IAEA Safety Standards Series No. SSG-5, Safety of Conversion Facilities and Uranium Enrichment

Facilities[1].

OBJECTIVE

1.5. The objective of this Safety Guide is to provide recommendations that, in the light of experience in Stateson site evaluation, design, construction, commissioning, operation and the present state of technology, should be followed to ensure safetypreparation for all stages in the lifetime of adecommissioning for conversion facility or afacilities and uranium enrichment facility. These recommendations specify actions, conditions or procedures necessary for meeting thefacilities to meet the applicable requirements established in Ref.SSR-4 [1]. This

1.3.1.6. The recommendations in this Safety Guide is intended to be of use to designers,are aimed primarily at operating organizations and regulators for ensuring the safety of conversion facilities and uranium enrichment facilities, regulatory bodies, designers and other relevant organizations.

SCOPE

1.4.1.7. The safety requirements applicable to fuel cycle facilities (i.e. facilities for uranium ore processing and refining, conversion, enrichment, reconversion[2], storage of fissile material, fabrication of fuel including uranium and plutonium mixed oxide fuel, storage and reprocessing of spent fuel, associated conditioning and storage of waste, and facilities for the fuel cycle related research and development) are established in Ref.SSR-4 [1]. TheThis Safety Guide provides recommendations on meeting these requirements applicable specifically tofor conversion facilities andor uranium enrichment facilities are established in Appendix III of Ref. [1]. This Safety Guide provides recommendations on meeting the requirements established in Sections 5–10 and in Appendix III of Ref. [1]..

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Conversion Facilities and Uranium Enrichment Facilities, IAEA Safety Standards Series No. SSG-5, IAEA, Vienna (2010).

[2] Also called 'deconversion'.

1.5.1.8. This Safety Guide deals specifically with the handling, processing, material transfer and storage of depleted, natural and low enriched uranium (LEU) that has a ^{235}U concentration^{235}U enrichment of no more than 6%, which could be derived from natural, high enriched, depleted or reprocessed uranium. In conversion facilities for the conversion of uranium concentrate to UF_6, several different conversion processes are currently used throughout the world on a large industrial scale. At present enrichment facilities use either the gaseous diffusion process or the gas centrifuge process.Recommendations are also provided for auxiliary activities such as laboratory services. This Safety Guide deals also with the generation and management of radioactive wastes and effluents arising from the handling and processing of these materials.

1.9. The provisions for the conversion of uranium concentrate to UF_6 in this publication are applicable to several different conversion processes which are currently used throughout the world on a large industrial scale. The provisions of this Safety Guide are applicable to the gas centrifuge enrichment process which is currently the only process used for uranium enrichment on an industrial scale. This publication includes specific recommendations for ensuring criticality safety in a conversion facility or a uranium enrichment facility. It supplements more detailed recommendations on criticality safety provided in IAEA Safety Standards Series No. SSG-27, Criticality Safety in the Handling of Fissile Material [2].

1.6.1.10. The implementation of other safety requirements, such as those on the legal and governmental framework and regulatory supervision (e.g. requirements for the authorization process, regulatory inspection and regulatory enforcement) as established in Ref. [2]IAEA Safety Standards Series No. GSR Part 1 (Rev.1), Governmental, Legal and those on the management system and the verification of safety (e.g. requirementsRegulatory Framework for the management system and for safety culture) as established in Ref.Safety [3],] is not addressed in this Safety Guide. Recommendations on meeting the requirements for the management system and for the verification of safety are provided in Ref. [4].

1.3. Sections 3–8 of this publication provide recommendations on radiation protection measures for meeting the safety requirements established in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (Ref. [5]). The recommendations in the present Safety Guide supplement the recommendations on occupational radiation protection provided in Ref. [6].The typical process routes of conversion facilities and enrichment facilities are shown in schematic diagrams in Annexes I and II (see also Ref. [7]).

1.11. This Safety Guide does not include recommendations on nuclear security. Recommendations on nuclear security for a conversion facility or uranium enrichment facility are provided in IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5) [4] and guidance is provided in IAEA Nuclear Security Series No. 27-G, Physical Protection of Nuclear Material and Nuclear Facilities (Implementation of INFCIRC/225/Revision 5) [5]. However, this Safety Guide includes recommendations on managing interfaces between safety, nuclear security and the State system for nuclear material accounting and control.

STRUCTURE

1.7.1.12. This Safety Guide consists of eight sections and four annexes. Section 2 provides the general safety recommendations for aan overview of hazards in conversion facility or ana uranium enrichment facility. Section 3 provides recommendations on the development of a management system for such facilities and the activities associated with it. Section 4 describes the safety aspects to be considered in the evaluation and selection of a site to avoid or minimize any environmental impact of operations. Section 4 deals with5 addresses safety in the design stage; it provides recommendations on the conduct of the safety analysis for operational states and accident conditions and discussesprovides details on the safety aspects of radioactive waste management in thea conversion facility or a uranium enrichment facility and on other design considerations. Section 56 addresses the safety aspects in the construction stage. Section 6 discusses7 addresses safety considerations in commissioning. Section 78 deals with safety in the stage of operation of the facility: it and provides recommendations on the management of operation, maintenance and periodic testing, control of modifications, criticality control, radiation protection, industrial safety, the management of waste and effluents, and emergency planning and preparedness. and response. Section 89 provides recommendations on meeting the safety requirements for the preparation for decommissioning of a conversion facility or ana uranium enrichment facility. Annexes I and II showillustrate the typical process routes for a conversion facility and ana uranium enrichment facility, respectively. Annexes III and IV provide examples of structures, systems and components important to safety and operational limits and conditions grouped in accordance with process areas, for conversion facilities and uranium enrichment facilities, respectively.

2 GENERAL SAFETY RECOMMENDATIONS

2. HAZARDS IN CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

2.1. In conversion facilities and uranium enrichment facilities, large amounts of uranium compounds arecan be present in a dispersible form:

— . In conversion facilities, the raw uranium mining product is processed to UF_6, and uranium exists in diverse chemical and physical forms (gaseous, liquid, dissolved or solid) and is used in conjunction with flammable or chemically reactive substances as part of the process.

— In uranium enrichment facilities, most of the uranium is in the chemical form UF6.

1.8.2.1. The physical form of UF_6 could be the gaseous, liquid or solid state.

2.2. In For conversion facilities andthe main hazards are the following:

— Potential release of chemicals, especially hydrogen fluoride, fluorine and UF_6;
— External exposure from the handling of residues containing thorium and its daughter products produced in fluorination reactors.
— External exposure from the handling of recently emptied cylinders, especially those used as containers for reprocessed uranium, where

there is a buildup of ^{232}U.

2.3. For uranium enrichment facilities, the main hazards are HF and UF6. In addition, where uranium is processed that has a 235U concentration of more than 1%,:

— Potential release of UF_6;
— Potential criticality may be a significant hazard. Workers, the public and the environment must be protected from these hazards during commissioning, operationevent since the enrichment of ^{235}U present in uranium enrichment facilities is greater than 1%;
— External exposure from the handling of recently emptied cylinders, and decommissioningcylinders used as containers for reprocessed uranium, with buildup of ^{232}U.

1.9.2.4. Generally, in a conversion facility or ana uranium enrichment facility, only natural uranium or LEU that has a ^{235}U concentrationenrichment of no more than 6% is processed. The radiotoxicity of this uranium is low, and any potential off-site radiological consequences following an accident would be expected to be limited. However, the radiological consequences of an accidental release of reprocessed uranium would be likely to be greater, and this should be taken into account in the safety assessment if the licence held by the facility permits the processing of reprocessed uranium.

1.10.2.5. The For enrichment levels below 6% and for non-reprocessed uranium, the chemical toxicity of uranium in a soluble form such as UF_6 is more significant than its radiotoxicity. Along with UF_6, large quantities of hydrogen fluoride is also present, which is a hazardous chemicals such as HF are present. Also, whenchemical substance. When UF_6 is released, it reacts with the moisturewater in the air to produce HF and mainly producing hydrogen fluoride and water-soluble uranyl fluoride (UO_2F_2), which present additional safety hazards. Therefore, comprehensive safety analyses for conversion facilities and uranium enrichment facilities should also address the potential non-radiological hazards resulting from these chemicals.

1.11.2.6. ConversionIn general, conversion facilities and uranium enrichment facilities do not pose a potential radiation hazard with the capacity to cause an accident with a significant off-site release of radioactive material (in amounts equivalent to a release to the atmosphere of ^{131}I from a nuclear power plant with an activity of the order of thousands of terabecquerels). However, deviations in processes may develop rapidly into dangerous situationscertain accident conditions involving hazardous chemicals (for example, large release of hydrogen fluoride) can potentially result in adverse off-site consequences.

1.12.2.7. For the application of the requirement that the concept of defence in depth be applied at the facility (see Section 2 of Ref.SSR-4 [1]), the first two levels of defence in depth are, if applied correctly to conversion facilities and uranium enrichment facilities, would be able to reduce the most important, as risks can be reduced to insignificantto appropriately low levels by means of design and appropriate operating procedures (see Sections 4 and 7).5 and 8). Nevertheless, the remaining levels of defence in depth should still be applied in accordance with a graded approach.

2.2.

2.3.

3. MANAGEMENT AND VERIFICATION OF SAFETY FOR CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

3.1. A documented management system that integrates safety, health, environmental, security, quality, and human and organizational factors of the operating organization is required to be established and implemented with adequate resources, in accordance with Requirement 4 of SSR-4 [1]. The integrated management system should be established and put into effect by the operating organization, early in the design stage of a conversion facility or a uranium enrichment facility, to ensure that safety measures are specified, documented, implemented, monitored, audited and periodically reviewed throughout the lifetime of the facility or the duration of the activity.

3.2. Requirements for the management system are established in GSR Part 2 [6]. Associated recommendations are provided in IAEA Safety Standards Series Nos GS-G-3.1, Application of the Management

System for Facilities and Activities [7], GS-G-3.5, The Management System for Nuclear Installations [8], GSG-16, Leadership, Management and Culture for Safety in Radioactive Waste Management [9], and TS-G-1.4, The Management System for the Safe Transport of Radioactive Material [10].

3.3. Coordination of the nuclear safety and security interface in the establishment of the integrated management system should be ensured. The management system should consider the specific concerns of each discipline regarding the management of information. Potential conflicts between the need for transparency of information relating to safety matters and the need for protection of the information for security reasons should be addressed.

3.4. In determining how the management system for the safety of conversion facilities and uranium enrichment facilities is to be developed and applied, a graded approach is required to be used (see Requirement 7 and para. 4.15 of GSR Part 2 [6]). This approach should be based on the relative importance to safety of each item or process.

3.5. The management system is required to support the development and maintenance of a strong safety culture, including in all aspects of criticality safety: see Requirement 12 of GSR Part 2 [6].

3.6. In accordance with paras 4.15–4.23 of SSR-4 [1], the management system is required to address the following functional areas:

(a) Management responsibility, which includes the necessary support and commitment of the management to achieve the objectives of the operating organization.
(b) Resource management, which includes the measures necessary to ensure that the resources essential to the implementation of safety policy and the enhancement of safety and the achievement of the objectives of the operating organization are identified and made available.
(c) Process implementation, which includes the actions and tasks necessary to achieve the goals of the operating organization.
(d) Measurement, assessment, evaluation and improvement, which provide an indication of the effectiveness of management processes and work performance compared with objectives or

benchmarks. It is through measurement, assessment and evaluation that opportunities for improvement are identified.

MANAGEMENT RESPONSIBILITY

3.7. The prime responsibility for safety, including criticality safety, rests with the operating organization. In accordance with para. 4.11 of GSR Part 2 [6], the management system for conversion facilities and uranium enrichment facilities is required to clearly specify the following:

(a) A description of the organizational structure;
(b) Functional responsibilities;
(c) Levels of authority.

3.8. The documentation of the management system should describe the interactions among the individuals managing, performing and assessing the adequacy of the processes and activities important to safety. The documentation should also cover other management measures, including planning, scheduling and resource allocation (see para. 9.9 of SSR-4 [1]).

3.9. Paragraph 4.15 of SSR-4 [1] states:

> "The management system shall include provisions for ensuring effective communication and clear assignment of responsibilities, in which accountabilities are unambiguously assigned to individual roles within the organization and to suppliers, to ensure that processes and activities important to safety are controlled and performed in a manner that ensures that safety objectives are achieved."

The management system should include arrangements for empowering relevant personnel to stop unsafe operations at the conversion facility or uranium enrichment facility.

3.10. The operating organization is required to ensure that safety assessments and analyses are conducted, documented and updated: see Requirement 24 and para. 4.65 of IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [11] and Requirement 5 of SSR-4 [1].

3.11. In accordance with para. 4.2(d) of SSR-4 [1], the operating organization is required to audit all safety related matters on a regular basis. This should include the examination of arrangements for emergency preparedness and response, such as emergency communications, evacuation routes and signage. Checks should be performed by the nuclear criticality safety staff who performed the safety assessments to confirm that the data used and the implementation of criticality safety measures are correct. Audits should be performed by personnel who are independent of those that performed the safety assessments or conducted the activities important for safety. The data from audits should be documented and submitted for management review and for action, if necessary.

RESOURCE MANAGEMENT

3.12. The operating organization is required to provide adequate resources (both human and financial) for the safe operation of a conversion facility or uranium enrichment facility (see Requirement 9 of GSR Part 2 [6]), including resources for mitigating the consequences of accidents.

3.13. The management of the operating organization should undertake the following:

(a) Determine the necessary competence of personnel and provide training, as necessary;
(b) Prepare and issue specifications and procedures on safety related activities and operations;
(c) Support and perform safety assessments including modifications;
(d) Have frequent personal contact with personnel, including observing work in progress;
(e) Make provisions for adequate staffing[3], succession planning and retention of corporate knowledge.

3.14. Requirement 58 of SSR-4 [1] states that:

> **"The operating organization shall ensure that all activities that may affect safety are performed by suitably qualified**

[3] Including for situations where a large number of personnel might be unavailable, such as during an epidemic or a pandemic affecting an area where personnel live.

and competent persons”.

3.15. In accordance with Requirement 58 and paras 9.39–9.47 of SSR-4 [1], the operating organization is required to ensure that these personnel receive training and refresher training at suitable intervals, appropriate to their level of responsibility. In particular, personnel involved in activities with fissile material, radioactive material, including waste, and chemicals should understand the nature of the hazard posed by these materials and how the risks are controlled by the established safety measures, operational limits and conditions, and operating procedures.

3.16. Requirement 11 of GSR Part 2 [6] states that:

> **“The organization shall put in place arrangements with vendors, contractors and suppliers for specifying, monitoring and managing the supply to it of items, products and services that may influence safety”**

In accordance with paras 4.33–4.36 of GSR Part 2 [6], the management system for a conversion facility or a uranium enrichment facility is required to include arrangements for procurement.

3.17. In accordance with para. 4.16(b) of SSR-4 [1], the operating organization is required to ensure that suppliers of items and resources important to safety have an effective management system in place. To meet these requirements, the operating organization should conduct audits of the management systems of the suppliers.

PROCESS IMPLEMENTATION

3.18. Requirement 63 of SSR-4 [1] states:

> **“Operating procedures shall be developed that apply comprehensively for normal operation, anticipated operational occurrences and accident conditions, in accordance with the policy of the operating organization and the requirements of the regulatory body.”**

Paragraph 9.66 of SSR-4 states that:

“Operating procedures shall be developed for all safety related operations that may be conducted over the entire lifetime of the facility.”

3.19. The management system for a conversion facility (if applicable: see para. 5.38) or for a uranium enrichment facility should include management for criticality safety. Further recommendations on the management system for criticality safety are provided in SSG-27 [2].

3.20. Any proposed modification to existing facilities or activities, or proposals for introduction of new activities, are required to be assessed for their implications on existing safety measures and appropriately approved before implementation: see para. 9.57(b) –(c) of SSR-4 [1]. Modifications of safety significance are required to be subjected to safety assessment and regulatory review, and, where necessary, they are required to be authorized by the regulatory body before they are implemented: see paras 9.57(h) and 9.59 of SSR-4 [1]. The facility or activity documentation is required to be updated to reflect modifications (see paras. 9.57 (f)–(g) of SSR-4 [1]). The operating personnel, including supervisors, should receive adequate training on the modifications.

3.21. Requirement 75 of SSR-4 [1] states:

“The interfaces between safety, security and the State system of accounting for, and control of, nuclear material shall be managed appropriately throughout the lifetime of the nuclear fuel cycle facility. Safety measures and security measures shall be established and implemented in a coordinated manner so that they do not compromise one another.”

The activities for ensuring safety throughout the lifetime of the facility or duration of the activity involve different groups and interface with other areas such as those relating to nuclear security and to the system for nuclear material accounting and control. The activities with such interfaces should be identified in the management system, and should be coordinated, planned and conducted to ensure effective communication and clear assignment of responsibilities. Communications regarding safety and security should ensure that confidentiality of information is maintained. This includes the system of nuclear material accounting and control, for which information security should be coordinated in a manner ensuring that subcriticality is not compromised.

MEASUREMENT, ASSESSMENT, EVALUATION AND IMPROVEMENT

3.22. The audits performed by the operating organization (see para. 3.11), as well as proper control of modifications to facilities and activities (see para. 3.18) are particularly important for ensuring subcriticality. The results of audits are required to be evaluated by the operating organization and corrective actions to be taken where necessary: see para. 4.2(d) of SSR-4 [1].

3.23. Deviation from operational limits or conditions, deviations from operating procedures and unforeseen changes in process conditions that could affect nuclear criticality safety are required to be reported and promptly investigated by the operating organization and the operating organization is required to inform the regulatory body: see paras 9.34, 9.35 and 9.84 of SSR-4 [1]. The depth and extent of the investigation should be proportionate to the safety significance of the event, in accordance with a graded approach. The investigation should cover the following:

(a) An analysis of the root causes of the deviation to identify lessons and to determine and implement corrective actions to prevent a recurrence;
(b) An analysis of the operation of the facility or conduct of the activity including an analysis of human factors;
(c) A review of the safety assessment and analyses that were previously performed, including the safety measures that were originally established.

3.24. Requirement 73 of SSR-4 [1] states that: **"The operating organization shall establish a programme to learn from events at the facility and events at other nuclear fuel cycle facilities and in the nuclear industry worldwide."** Recommendations on operating experience programmes are provided in IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations [12].

VERIFICATION OF SAFETY

3.25. In accordance with Requirement 5 of SSR-4 [1], the safety of a conversion facility or a uranium enrichment facility is required to be assessed in the safety analysis and verified by periodic safety reviews. The operating organization should ensure that these periodic safety reviews of the facility form an integral part of the organization's management system.

3.26. Requirement 6 of SSR-4 [1] states, that: **"An independent safety committee (or an advisory group) shall be established to advise the management of the operating organization on all safety aspects of the nuclear fuel cycle facility."**

The safety committee of a conversion facility or a uranium enrichment facility should have members or access to experts in areas of protection against toxic chemical hazards, criticality safety and radiation protection. Such experts should be available to the facility at all times during operation.

2.4. SITE EVALUATION FOR CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

2.1.4.1. The site evaluation process for a conversion facility or ana uranium enrichment facility will depend on a large number of criteria, some of which are more important than others.variables. At the earliest stage of planning a facility, a list of these criteriavariables should be prepared and considered in accordance with their safety significance. In most cases, it is unlikely that all the desirable criteria can be met, and the risks The risks posed by possible safety significant external initiating events hazards (e.g. earthquakes, accidental aircraft crashes, fires and, nearby explosions, floods, extreme weather conditions) will probably dominate in the site evaluation process. These risks should be compensated for by means of adequate design provisions and constraints on processes and operations as well as possible economic arrangements. and should be taken into account into the design of the facility. Requirements for site evaluation for a conversion facility or a uranium enrichment facility are provided in IAEA Safety Standards

Series No. SSR-1, Site Evaluation for Nuclear Installations [13] and further recommendations are provided in IAEA Safety Standards Series No. SSG-35, Site Survey and Site Selection for Nuclear Installations [14].

4.2. The density of The scope of the site evaluation for a conversion facility or a uranium enrichment facility is established in Requirement 3 of SSR-1 [13], Requirement 11 and paras. 5.1–5.14 of SSR-4 [1] and should reflect the specific hazards listed in Section 2 of this Safety Guide.

2.2.4.3. The population density and population distribution in the vicinity of a conversion facility or ana uranium enrichment facility and the direction of the prevailing wind at the site shouldare required to be considered in the site evaluation process to minimize any possible health consequences for people in the event of a release of hazardous chemicalsradioactive material and hazardous chemicals: see Requirements 4 and 12 of SSR-1 [13]. Also, in accordance with Requirement 25 and paras 6.1–6.2 of SSR-1 [13], the dispersion in air and water of radioactive material released from the conversion facility or uranium enrichment facility are required to be assessed taking into account the orography, land cover and meteorological features of the region. The environmental impact from the facility under all facility states is required to be evaluated (see para. 5.3 of SSR-4 [1]) and should meet the applicable criteria established in national regulations.

4.4. A Security advice is required to be taken into account in the selection of a site for a conversion facility or uranium enrichment facility: see para. 11.4 of SSR-4 [1]. The selection of a site should take into account both safety and security aspects and should be facilitated by experts from both safety and security

2.3.4.5. The operating organization should maintain a full record should be kept of the decisions taken on the selection of a site for a conversion facility or ana uranium enrichment facility and the reasons behind those decisions.

4.6. The site characteristics should be reviewed periodically for their adequacy and persistent applicability during the lifetime of a conversion facility and uranium enrichment facility. Any changes to these characteristics which might require safety reassessment should be identified and evaluated (see para 5.14 of SSR-4 [1]). This includes the case of an increase of a production capacity beyond the original envelope.

5. DESIGN OF CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

3 SAFETY FUNCTIONSDESIGN

GENERAL

SAFETY

5.1. Requirement 7 of SSR-4 [1] states:

> **"The design shall be such that the following main safety functions for are met for all facility states of the nuclear fuel cycle facility:**
>
> **(a) Confinement and cooling of radioactive material and associated harmful materials;**
> **(b) Protection against radiation exposure;**
> **(c) Maintaining subcriticality of fissile material."**

Cooling of radioactive material is not applicable to conversion facilities and uranium enrichment facilities. Maintaining subcriticality is applicable for facilities that process uranium with a ^{235}U enrichment of more than 1%.

3.1. Safety functions (see Ref. [1], Appendix III, para. III.1), i.e. the functions the loss of which may lead to releases of radioactive material or chemical releases having possible radiological consequences for workers, the public or the environment, are those designed for:

(2) Prevention of criticality;
(3) Confinement for the prevention of releases that might lead to internal exposure and for the prevention of chemical releases;
(4) Protection against external exposure.

3.2. For conversion facilities:

— The main hazard is the potential release of chemicals, especially HF and UF_6. Controls to address this hazard will adequately protect also against The requirements on protection against internal radiation exposure.

— A criticality hazard exists only if the conversion facility processes uranium with a ^{235}U concentration greater than 1%.

3.3. External exposure is a concern for the handling of residues containing thorium and its daughter products produced in fluorination reactors. External exposure is also a concern in the handling of recently emptied cylinders, especially those used as containers for reprocessed uranium, where there is a buildup of ^{232}U.For enrichment facilities:

— The main hazard is a potential release of UF_6;

— A criticality hazard exists since the concentration of ^{235}U present in enrichment facilities is greater than 1%;

— External exposure is a concern in the handling of recently emptied cylinders, especially those used as containers for reprocessed uranium, with buildup of ^{232}U.

Specific engineering design requirements

3.4. The following requirements apply:

2.4.5.2. The requirements on prevention of criticalityby design are established in Requirement 34 and paras 6.43120–6.51 and III.3–III.7122 of Appendix III of Ref.SSR-4 [1];].

2.5.5.3. The requirements on the confinement for the prevention of releases that might lead to internal exposure and chemical hazardsof radioactive material and associated hazardous materials are established in Requirement 35 and paras 6.37–6.39, 6.54–6.55 and paras III.8 and III.9 of Appendix III of Ref.123–6.128 of SSR-4 [1];].

2.6.5.4. The requirements on protection against external radiation exposure are established in Requirement 36 and paras 6.40129–6.42134 of Ref.SSR-4 [1]. ShieldingProtective measures should be considered for processes or areas in conversion facilities and uranium enrichment facilities that could involve sources ofemitting high levels of external gamma radiation, such as reprocessed uranium or newly emptied cylinders (e.g. exposure to daughter products of ^{232}U and ^{238}U).

5.5. The requirements on maintaining subcriticality are established in

Requirement 38 and paras 6.138–6.156 of SSR-4 [1]. Further recommendations on the design of conversion facilities and uranium enrichment facilities to ensure subcriticality are provided in Section 3 of SSG-27 [2].

Design basis accidents and safety analysis

5.6. The definition of aA design basis accident in the context of fuel cycle facilities can be found in para. III-10 of Annex IIIis a postulated accident leading to accident conditions for which a facility is designed in accordance with established design criteria and conservative methodology, and for which releases of Ref. [1]. radioactive material are kept within acceptable limits [1].

2.7.5.7. The safety requirements relating to design basis accidentsfor items important to safety and for the design basis analysis for a nuclear fuel cycle facility are established in paras 6.4–6.9Requirements 14 and 20 of Ref.SSR-4 [1].] respectively.

Conversion facilities

2.8.5.8. The specification of a design basis accident (or equivalent) will depend on the design of the facility design, its siting and national criteriaon regulatory requirements. However, particular consideration should be given to the following hazards in the specification of the design basis accidents for conversion facilitiessafety analysis:

(a) A releaseHazards for conversion facilities:

(i) Release of HFhydrogen fluoride or ammonia (NH_3) due to the rupture of a storage tank or piping;

(ii) A releaseRelease of UF6 due to the rupture of a storage tank, piping or a hot cylinder;

(i) A large fire originatingFires resulting from H_2 or exothermic reactions involving substances such as hydrogen and solvents;

(b) An explosion of a reduction furnace (release of H_2);

(c) NaturalInternal and external hazards, including internal and external explosions (in particular hydrogen explosions), internal and external fires, dropped loads and handling errors, extreme meteorological phenomena such as (in particular earthquakes, flooding orand tornadoes;

(ii) An), accidental aircraft crash;crashes.

(d) Nuclear criticality accidents, e.g. in a wet process area with a ^{235}U content of more than 1% (reprocessed uranium or unirradiated LEU).

(b) The first four types of events ((a)–(d)) are of major safety significance as they might result in chemicalHazards for uranium enrichment facilities:

(i) Release of UF6 due to the rupture of a storage tank, piping or a hot cylinder;

(ii) Internal and external hazards, including internal and external explosions (in particular hydrogen explosions), internal and external fires, dropped loads and handling errors, extreme meteorological phenomena (in particular earthquakes, flooding and tornadoes), accidental aircraft crashes.

2.9.5.9. These hazards would result primarily in chemico-toxic and radiological consequences for on the site workers and maypersonnel. However, they might also result in some adverse off-site consequences for peoplethe public or the environment. The last type of accident on the list would generally be expected to result in few or no off-site consequences unless the facility is very close to occupied areas.

3.5. The hazards listed in para. 4.6 may5.8 might occur as a consequence of a postulated initiating event (PIE).. Selected PIEspostulated initiating events for nuclear fuel cycle facilities are listed in Annex Ithe Appendix of Ref. [1].

3.6. The potential occurrence of a criticality accident should be considered for facilities that process uranium with a ^{235}U concentration of more than 1%. Particular consideration should be given to the potential occurrence of a criticality accident for facilities treating various feed products including reprocessed uranium.

Enrichment facilities

3.7. The specification of a design basis accident (or equivalent) will depend on the facility design and national criteria. However, particular consideration should be given to the following hazards in the specification of design basis accidents for enrichment facilities:

(a) The rupture of an overfilled cylinder during heating (input area);

(b) The rupture of a cylinder containing liquid UF_6 or the rupture of

piping containing liquid UF_6 (depending on the facility design for product take-off);
(c) A large fire, especially for diffusion facilities;
(d) Natural phenomena such as earthquakes, flooding or tornadoes (see footnote 1);
(e) An aircraft crash;
(f) A nuclear criticality accident.

3.8. These hazards would result primarily in radiological consequences for on-site workers, but might also result in some adverse off-site consequences for people or the environment. The last type of hazard on the list would generally be expected to result in few or no off-site consequences unless the facility is very close to populated areas.

2.10.5.10. The hazards listed in para. SSR-4.10 may occur as a consequence of a PIE. Selected PIEs are listed in Annex I of Ref. [1].

Structures, systems and components important to safety

5.11. The likelihoodParagraph 6.21 of SSR-4 [1] states that:

"The design basis accidents (or equivalent) should be minimized, and any radiological and associated chemical consequences should be controlled by means of of the nuclear fuel cycle facility: […]

(e) Shall provide for structures, systems and components important to and procedures to control the course of and, as far as practicable, to limit the consequences of failures and deviations from normal operation that exceed the capability of safety and appropriate administrative measures (operational limits and conditions). systems."

Annexes III and IV contain of this Safety Guide present examples of structures, systems and components and representative events that maymight challenge the associated safety functions. in conversion facilities and uranium enrichment facilities.SAFETY FUNCTIONS

Confinement of radioactive material and toxic chemical material

5.12. To meet Requirements 34 and 42 of SSR-4 [1] on protection against internal radiation exposure and against toxic chemical hazards, the risk of releasing nuclear material from the conversion or enrichment process should be decreased by minimizing the following parameters as far as possible:

- (i) The amount of liquid UF_6 in process areas, e.g. by limiting the size of crystallization (desublimation) vessels in both conversion facilities and uranium enrichment facilities;
- (ii) The amount of nuclear material unaccounted for in the process vessels;
- (iii) The duration of operation when UF_6 is at a pressure above atmospheric pressure;
- (iv) The capacity for storage of hydrogen fluoride, ammonia and hydrogen.

5.13. Conversion facilities and uranium enrichment facilities are required to be designed to minimize, to the extent practicable, contamination of the facility and releases of radioactive material to the environment, and to facilitate decontamination and eventual decommissioning of the facility: see Requirements 24, 25 and 33 of SSR-4 [1].

5.14. To meet Requirement 10 and para. 6.21(a) of SSR-4 [1], in the working areas where liquid UF_6 is processed or where there is a potential for significant airborne particulates, two static barriers and preferably a third barrier for the prevention of uncontrolled releases to the environment should be installed. Particular consideration should also be given to minimizing the use of flexible hoses and to ensuring their maintenance and periodic checking.

5.15. The use of an appropriate containment system should be the primary method for protection against the spreading of contamination from areas where significant quantities of either powder of uranium compounds or hazardous substances in a gaseous form are held (Requirement 35 of SSR-4 [1]). To improve the effectiveness of static containment, a dynamic containment system providing negative pressure should be used when practicable, through the creation of airflow towards the more contaminated parts of equipment or an area. The speed of the airflow should be sufficient to prevent the migration of radioactive material back to areas that are less contaminated. A cascade of reducing absolute pressures can thus be established between the environment outside the building and the hazardous material inside.

5.16. In the design of the ventilation and containment systems for areas that might contain elevated levels of airborne radioactive material during operation, account should be taken of criteria such as: (i) the desired pressure difference between different parts of the premises; (ii) the air replacement ratio in the facility; (iii) the types of filters to be used; (iv) the maximum differential pressure across filters; (v) the appropriate flow velocity at the openings in the ventilation and containment systems (e.g. the acceptable range of air speeds at the opening of a hood); (vi) the dose rate at the filters; (vii) the potential accumulation of nuclear fissile materials in ventilation elements (filters, ventilation ducts); and (vii) the humidity and potential for moisture within the ventilation system; (viii) predictive and preventive maintenance strategies.

5.17. To prevent the propagation of a fire through ventilation ducts and to maintain the integrity of firewalls, and as practicable in view of the potential of corrosion by HF, ventilation systems should be equipped with fire dampers and should be constructed from non-flammable and non-corrosive materials.

5.18. Protection against chemical hazards should include the control of any route for chemicals into the workplace and to the environment.

Protection of workers

5.19. Requirements on the design of uranium fuel fabrications facilities to ensure radiation protection of workers are established in Requirement 8 of SSR-4 [1].

5.20. Conversion facilities and uranium enrichment facilities are required to be designed with appropriately sized ventilation and containment systems in areas of the facility identified as having potential for giving rise to significant concentrations of airborne radioactive material and other hazardous material: see para 6.126 of SSR-4 [1]. The ventilation system should be used as one of the means of minimizing the radiation exposure of workers and exposure to hazardous material that could become airborne and so could be inhaled by workers. Where possible, the layout of ventilation equipment should be such that the flow of air is away from the personnel workplaces and from personnel evacuation routes.

5.21. For normal operation, the need for the use of protective respiratory equipment is required to be avoided through careful design of the containment and ventilation systems: see para 9.100 of SSR-4 [1]. For example, a glovebox, hood or special device should be used to ensure the continuity of the first confinement barrier rather than reliance on the need for respiratory protection.

5.22. In areas that might contain airborne uranium in particulate form, primary filters should be located as close to the source of contamination as practicable. In designing ventilation systems, consideration should be given to preventing the potential for unwanted deposition of uranium due to insufficient air velocity or accumulation areas within the ducts. Means for periodical surveillance in areas where accumulation of airborne contamination could occur should be provided. Multiple filters in series should be used to avoid reliance on a single filter. In addition, duty and standby filters and/or fans should be provided to ensure the continuous functioning of the ventilation systems. If such filters and/or fans are not provided, it should be ensured that failure of the duty fan or filter will result in the safe shutdown of equipment in the affected area. Where possible, the reliance on a single filter (e.g. during other filter maintenance or replacement) should only occur during shutdown of main processes within the facility.

5.23. Monitoring equipment such as differential pressure gauges (on filters, between rooms or between a glovebox and the room in which it is located) and devices for measuring uranium or concentrations of hazardous substances in gaseous form in ventilation systems should be installed as necessary.

5.24. Audible alarm systems should be installed to alert operators to fan failure or high or low differential pressures. At the design stage, provision is also required to be made for the installation of equipment for monitoring airborne radioactive material and/or gas monitoring equipment: see para 6.120 of SSR-4 [1]. Monitoring points should be chosen that would correspond most accurately to the exposure of personnel and would minimize the time for detection of any leakage: see para. 6.121 of SSR-4 [1].

5.25. If fume hoods and gloveboxes are used (e.g. in laboratories), their design should be commensurate with the specific local hazards in the conversion facility or the uranium enrichment facility.

5.26. To facilitate decontamination and the decommissioning of the facility, the walls, floors and ceilings in areas of the conversion facilities and uranium enrichment facilities where contamination could exist during normal operations should be made non-porous and easy to clean. This may be done by applying special coatings, such as epoxy, to such surfaces and ensuring that no areas are difficult to access. In addition, all surfaces that could become contaminated should be made readily accessible to allow for periodic decontamination as necessary.

Protection of the public and the environment

5.27. Paragraph 3.9 of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [15] states that:

"Any person or organization applying for authorization: […]

> e) Shall, as required by the regulatory body, have an appropriate prospective assessment made for radiological environmental impacts, commensurate with the radiation risks associated with the facility or activity.

Further recommendations for performing environmental impact assessment of conversion facilities and uranium enrichment facilities are provided in IAEA Safety Standards Series No. GSG-10, Prospective Radiological Environmental Impact Assessment for Facilities and Activities [16].

5.28. The design should provide for adequate monitoring of the source of releases (gaseous emissions and liquid effluents) as well as for the monitoring of the receiving environment around the facility. The design should also provide for the identification of breaches to confirm there is no breach of confinement barriers and the impact to the environment and the public complies with authorized limits.

5.29. The efficiency of filters and their resistance to chemicals (hydrogen fluoride and ammonia), moisture in the ventilation system, and high temperatures of the exhaust gases and fire conditions should be taken into consideration for assessment of releases to the environment.

5.30. The uncontrolled dispersion of radioactive or chemical substances to the environment as a result of an accident can occur if all the confinement barriers are impaired. Barriers may comprise the process equipment itself, or the room or building structure. The number of physical barriers for confinement should be adapted to the safety significance of the hazard. The minimum number of barriers is two, in accordance with Requirement 23 of SSR-4 [1]. The preferred number of barriers is often three.

5.31. Ventilation of the containment systems, by the discharge of exhaust gases through a stack via gas cleaning mechanisms such as wet scrubbers in conversion facilities, or cold traps and dry chemical absorbers in uranium enrichment facilities, reduces the normal environmental discharges of radioactive or chemical (mainly hydrogen fluoride) material to very low levels. In such cases, the ventilation system may also be regarded as a confinement barrier.

Protection against external exposure

5.32. Relevant requirements on design provisions for protection against external radiation exposure are established in Requirement 36 and paras 6.129–6.134 of SSR-4 [1].

5.33. External exposure of workers should be controlled by means of an appropriate combination of requirements on distance, time and shielding. Owing to the low specific activity of naturally sourced material, the shielding provided by the vessels and pipe work of a conversion facility or a uranium enrichment facility will normally be sufficient to control adequately occupational exposure. However, in areas that are in close proximity to newly emptied UF_6 cylinders or bulk storage areas, installation of shielding or restrictions on occupancy should be considered.

5.34. When reprocessed uranium is processed, additional protective measures should be considered for protection of personnel, because of the higher gamma dose rates from ^{232}U daughters and fission products (^{208}Tl and ^{212}Bi).

5.35. In selecting the areas for storage of tailings, requirements on distance, occupancy time and shielding should be considered to minimize the direct exposure of personnel to gamma and neutron radiation. In estimating the exposure, 'sky shine' (scattered gamma radiation in air) should also be taken into account.

Prevention of nuclear criticality

5.36. "For the prevention Prevention of nuclear criticality by means of design, the double contingency principle shall be the preferred approach" (Ref. [1], para 6.45). Paragraph III.is an important topic with various aspects to be considered during the design of a conversion facility or uranium enrichment facility (see Requirement 38 of SSR-4 [1]). Paragraphs 5 of Appendix III of Ref. [1] establishes requirements for the control of system parameters .37–5.43 provide recommendations on some of the main elements of criticality safety that are specific for conversion facilities or uranium enrichment facilities. Detailed recommendations on criticality safety are provided in SSG-27 [2].

5.37. If a conversion facility processes natural uranium, depleted uranium, or uranium with less than 1% ^{235}U enrichment, a full criticality safety assessment is not necessary (see para. 6.138 of SSR-4 [1]). In such cases it should be demonstrated that there is no credible fault sequence in which uranium with higher than 1% ^{235}U enrichment is fed to the process as, for example, the use of recycled uranium. For further recommendations see para 2.8 of SSG-27 [2].

2.11.5.38. Paragraphs 6.138 - 6.148 of SSR-4 [1] establish requirements for the prevention of criticality by means of design. For the prevention of criticality in conversion facilities and uranium enrichment facilities. Some examples of the following parameters should be subject to control are listed in the following:

(a) The massMass and degree of enrichment level(s) of fissile material present in a process: for conversion facilities, in vessels or mobile transfer tanks, or analytical laboratories; for enrichment facilities, in effluent treatment units or analytical laboratories;.

(b) Geometry and/or interaction (of processing equipment. Control can be achieved by limitation of the dimensions or shape) of processing equipment, (e.g. by means of safe diameters for storage vessels, control of slabs~~ and~~, appropriate distances in and between storage vessels~~;~~). The loss of confinement or changes in the geometry due to leaks or breaks should also be taken into consideration.

(c) Concentration of fissile material in solutions~~, –~~ (e.g. in the wet process for recovering uranium or decontamination~~;~~).

(d) Presence of reflectors or appropriate ~~neutron absorbers, e.g.~~ neutron ~~poisoning of cooling water in gaseous diffusion enrichment facilities;~~absorbers.

(e) Degree of moderation~~, e.g.~~. For example, this can be achieved by means of control of the ratio of hydrogen to ^{235}U in UF_6 cylinders and in ~~diffusion~~centrifuge cascades, taking into account the hydrolysis products of UF_6 (uranyl fluoride in particular) whose H/U ratio can be higher than the maximum retained for UF_6.

5.39. Paragraph ~~III.4 of Appendix III~~6.138 of ~~Ref.~~SSR-4 [1] ~~requires~~states that ~~preference be given to achieving~~(footnote omitted):

> "In areas of the facility where the quantity of fissile material involved is so low or the isotopic composition is such that it meets exemption criteria specified by, or agreed with, the regulatory body, then a full criticality safety ~~by design rather than~~ assessment is not necessary. In all other cases, criticality safety shall be ensured by means of ~~administrative~~preventive measures~~. As~~ that are, as far as reasonably achievable, established in the design. In this context the area subject to criticality control may be an ~~example~~entire enrichment cascade, a building or the entire site."

~~2.12.~~5.40. For conversion facilities or uranium enrichment facilities, to the extent practicable, vessels which could contain fissile material should be made geometrically ~~safe~~favorable and should be designed for the maximum authorized enrichment level including a reasonable safety margin.

5.41. The criticality safety analysis should demonstrate that the design of equipment and the related safety measures are such that the values of controlled parameters are always maintained in the subcritical range. This should be achieved by determining the effective multiplication factor (k_{eff}), which depends on the mass, the geometry, the distribution and the nuclear properties of uranium and all other materials with which it is associated, including low temperature effects (in the parts of the process operating at temperatures far below 0°C). The calculated value of k_{eff} (including all uncertainties and biases) should then be compared with the value specified by the design limit (which should be set in accordance with paras 2.4–2.7 of SSG-27 [2]).

2.13.5.42. Several methods that vary widely in basis and form can be used to perform the criticality safety analysis, such as the use of experimental data, reference books or consensus standards, hand calculations and calculations by means of deterministic or probabilistic computer codes. Calculations should be suitably verified and validated and performed under a quality management system. For more extensive recommendations on performing a criticality safety assessment, including recommendations on validation of computer codes, see Section 4 of SSG-27 [2].

3.9. The aim of the criticality analysis is to demonstrate that the design of equipment is such that the values of controlled parameters are always maintained in the subcritical range. This is generally achieved by determining the effective multiplication factor (k_{eff}), which depends on the mass, the distribution and the nuclear properties of uranium and all other materials with which it is associated. The calculated value of k_{eff} is then compared with the value specified by the design limit .

3.10. The methods of calculation vary widely in basis and form, and each has its place in the broad range of situations encountered in the field of nuclear criticality safety. The criticality analysis should involve:

5.43. The criticality safety analysis should include the following:

(a) The use of a conservative approach (withtaking into account taken of uncertainties :

(i) Uncertainties in physical parameters and of, the physical possibility of worst-case moderation conditions);, and the potential of non-homogeneous distributions of moderators;

(ii) Optimal geometry configuration of a system with fissile material;

(iii) Plausible operational occurrences and their combinations if they cannot be shown to be independent;

(iv) Operational states that might result from external hazards.

—The use of appropriate verified and qualifiedvalidated computer codes that are validated within their applicable range and of together with the appropriate data libraries of nuclear reaction cross-sections.

(b) The following are recommendations, for conductingthe normal and credible abnormal conditions being analysed, while taking into account any bias and its uncertainties (see paras 4.20–4.25 of SSG-27 [2]).

2.14.5.44. The following parameters should be included in the scope of a criticality safety analysis for a conversion facility or ana uranium enrichment facility to meet the safety requirements established in(see para. III.6.144 of Appendix III of Ref.SSR-4 [1].:]):

(a) *Enrichment*. The potential for errors in the uranium enrichment of a fissile material should be considered if the maximum authorized enrichment level is not used in the criticality safety analysis (see para. 5.40).

(a)(b) *Mass. Mass.* The mass margin should be 100% of the maximum value attained in normal operation (to sufficient to compensate for possible 'double batching', i.e. the transfer of two batches of fissile material instead of one batch in a fuel fabrication process) or equal to the maximum physical mass that could be present in the equipment.over-batching of uranium in normal operation (see also para. 3.17 of SSG-27 [2]).

(b)(c) *Geometry of processing equipment*. "The potential for changes in dimensions during operation shallis required be considered" (e.g. bulging of slab tanks or slab hoppers).) in accordance with para. 6.144 of SSR-4 [1].

(c)(a) *Neutron interaction*. Preference should be given to engineered spacing over spacing achieved by administrative means.

(d) *Moderation*. Hydrogenous substances (e.g. water— and, oil) are common moderators that are present in conversion facilities and uranium enrichment facilities or that may be present in accident conditions (e.g. water from firefighting); the). The subcriticality of a UF_6 cylinder should not rely only on moderation control.

(e) *Reflection*. Full water reflection should be assumed in the criticality safety analysis unless it is demonstrated that the worst case conditions relating to neutron reflection (e.g. by human beingsbodies, organic materials, wood, concrete, steel of the container) result in a lower degree of reflection. The degree of reflection in interacting arrays should be carefully considered since the assumption of full water reflection maymight provide a degree of neutronic isolation from interacting items. Consideration should be given to situations where material may be present that could lead to a greater increase of the neutron multiplication factor than in a full water reflection system (see para. 3.22 of SSG-27 [2]). Moderation control should ensure criticality safety for an individual UF_6 cylinder or an array of UF_6 cylinders for any conditions of reflection.

(f) *Neutron interaction.* Preference should be given to engineered spacing over spacing achieved by administrative means.

(f)(g) *Neutron absorbers.* Paragraph 6.144(i) states that "When taken into account in the safety analysis, and if there is a risk offor degradation, or if they could become broken or dislodged, the presence and the integrity of neutron absorbers shall be verifiable during periodic testing. Uncertainties." In accordance with para. 6.114(j), uncertainties in absorber parameters shallare required to be considered in the criticality calculations.". The neutron absorbers that may be used in conversion facilities and uranium enrichment facilities include cadmium, gadolinium or boron in annular storage vessels or transfer vessels for liquids. Absorber parameters include thickness, density and isotopic concentrationnuclide composition.

Confinement to protect against internal exposure and chemical hazards

3.11. As far as possible, the following parameters should be minimized:

PROVISIONS FOR HEAT REMOVAL

5.45. To meet Requirement 39 of SSR-4 [1], where the potential for exothermic reactions with large heat releases exists (as for example the fluorination process in conversion facilities), facility design should consider appropriate cooling systems to remove heat from the chemical reactions and to ensure safe operation for all facility states.

5.46. Continuous monitoring of cooling systems should be ensured to prevent uncontrolled release of radioactive material.

5.47. Cooling water systems design should have provisions for periodic inspections and maintenance to address corrosion and ageing management.

- The amount of liquid UF_6 in process areas, e.g. by limiting the size of crystallization (desublimation) vessels in both conversion and enrichment facilities;
  - (i) The amount of nuclear material unaccounted for in the process vessels;
  - (ii)(i) The duration of operation when UF_6 is at a pressure above atmospheric pressure;
- The capacity for storage of HF, NH_3 and H_2.

3.12. Conversion facilities and enrichment facilities should be designed to minimize, to the extent practicable, contamination of the facility and releases of radioactive material to the environment, and to facilitate decontamination and eventual decommissioning.

3.13. Especially in the working areas where liquid UF_6 is processed, two static barriersshould be installed. Particular consideration shouldalso be given to minimizing the use of flexible hoses and to ensuring their maintenance and periodic checking.

2.15.1.1. Use of an appropriate containment system should be the primary method for protection against the spreading of dust contamination from areas where significant quantities of either powder of uranium compounds or hazardous substances in a gaseous form are held. To improve the effectiveness of static containment, a dynamic containment system providing negative pressure should be used when practicable, through the creation of airflow towards the more contaminated parts of equipment or an area. The speed of the airflow should be sufficient to prevent the migration of radioactive material back to areas that are less contaminated. A cascade of reducing absolute pressures can thus be established between the environment outside the building and the hazardous material inside.

3.14. In the design of the ventilation and containment systems for areas that may contain elevated levels of airborne radioactive material during operation, account should be taken of criteria such as: (i) the desired pressure difference between different parts of the premises; (ii) the air replacement ratio in the facility; (iii) the types of filters to be used; (iv) the maximum differential pressure across filters; (v) the appropriate flow velocity at the openings in the ventilation and containment systems (e.g. the acceptable range of air speeds at the opening of a hood); and (vi) the dose rate at the filters.

Protection of workers

3.15. The ventilation system should be used as one of the means of minimizing the radiation exposure of workers and exposure to hazardous material that could become airborne and so could be inhaled by workers. Conversion facilities and enrichment facilities should be designed with appropriately sized ventilation and containment systems in areas of the facility identified as having potential for giving rise to significant concentrations of airborne radioactive material and other hazardous material. Wherever possible, the layout of ventilation equipment should be such that the flow of air is from the operation gallery towards the equipment.

3.16. The need for the use of protective respiratory equipment should be minimized through careful design of the containment and ventilation systems. For example, a glovebox, hood or special device should be used to ensure the continuity of the first containment barrier when changing a valve to remove theneed for respiratory protection.

3.17. In areas that may contain airborne uranium in particulate form, primary filters should be located as close to the source of contamination as practicable unless it can be shown that the design of the ventilation ducts and the air velocity are sufficient to prevent unwanted deposition of uranium powder in the ducts. Multiple filters in series should be used to avoid reliance on a single filter. In addition, duty and standby filters and/or fans should be provided to ensure the continuous functioning of ventilation systems. If this is not the case, it should be ensured that failure of the duty fan or filter will result in the safe shutdown of equipment in the affected area.

3.18. Monitoring equipment such as differential pressure gauges (on filters, between rooms or between a glovebox and the room in which it is located) and devices for measuring uranium or gas concentrations in ventilation systems should be installed as necessary. Alarm systems should be installed to alert operators to fan failure or high or low differential pressures. At the design stage, provision should also be made for the installation of equipment for monitoring airborne radioactive material and/or gas monitoring equipment. Monitoring points should be chosen that would correspond most accurately to the exposure of workers and would minimize the time for detection of any leakage (see para. 6.39 of Ref. [1]).

3.19. To prevent the propagation of a fire through ventilation ducts and to maintain the integrity of firewalls, and as practicable in view of the potential of corrosion by HF, ventilation systems should be equipped with fire dampers and should be constructed from non-flammable materials.

3.20. If fume hoods and gloveboxes are used (e.g. in laboratories), their design should be commensurate with the specific local hazards in the conversion facility or enrichment facility.

2.16.1.1. To facilitate decontamination and the eventual decommissioning of the facility, the walls, floors and ceilings in areas of the conversion facilities and enrichment facilities where contamination is likely to exist should be made non-porous and easy to clean. This may be done by applying special coatings, such as epoxy, to such surfaces and ensuring that no areas are difficult to access. In addition, all surfaces that could become contaminated should be made readily accessible to allow for periodic decontamination as necessary.

Protection of the environment

3.21. The uncontrolled dispersion of radioactive or chemical substances to the environment as a result of an accident can occur if all the containment barriers are impaired. Barriers may comprise the process equipment itself, or the room or building structure. The number of physical barriers for containment should be adapted to the safety significance of the hazard. The minimum number of barriers is two, in accordance with the principle of redundancy (see para. II-1 of Annex II of Ref. [1]). The optimum number of barriers is often three. In addition, ventilation of the containment systems, by the discharge of exhaust gases through a stack via gas cleaning mechanisms such as wet scrubbers in conversion facilities, or cold traps and dry chemical absorbers in enrichment facilities, reduces the normal environmental discharges of radioactive or chemical (mainly HF) material to very low levels. In such cases, the ventilation system may also be regarded as a containment barrier. The design should also provide for the monitoring of the environment around the facility and the identification of breaches to the containment barriers.

Protection against external exposure

2.17.1.1. External exposure can be controlled by means of an appropriate combination of requirements on distance, time and shielding. Owing to the low specific activity of naturally sourced material, the shielding provided by the vessels and pipe work of a conversion facility or an enrichment facility will normally be sufficient to control adequately occupational exposure. However, in areas that are in close proximity to newly emptied UF_6 cylinders or bulk storage areas, installation of shielding or restrictions on occupancy should be considered.

3.22. Additional shielding or automation may also be required for the handling of reprocessed uranium.

3.23. When reprocessed uranium is processed, shielding should be strengthened for protection of the workers, because of the higher gamma dose rates from 232U daughters and fission products.

2.18.1.1. In selecting the areas for storage of tailings, requirements on distance, occupancy time and shielding should be considered to minimize the direct exposure of members of the public to gamma and neutron radiation. In estimating the exposure, 'sky shine' (scattered gamma radiation in air) should also be taken into account.

3.24.

POSTULATED INITIATING EVENTS

Internal initiating events

5.48. Paragraph 6.60 of SSR-4[1] states that "The list of internal and external hazards, including human induced hazards (see Requirements 15 and 16), shall be used to select initiating events for detailed further analysis." Paragraphs 5.49–5.95 provide recommendations on foreseeable internal and external hazards for conversion facilities and uranium enrichment facilities.

Internal hazards

Fire and explosion

5.49. Conversion facilities An analysis of fire and explosion is required to be conducted for conversion facilities and uranium enrichment facilities~~, like all industrial facilities, have to be designed~~ to ~~control fire hazards in order to protect workers,~~ meet Requirement 22 and the ~~public and the environment.~~ requirements established in paras 6.77–6.79 of SSR-4 [1].

~~2.19.~~5.50. Fire in conversion facilities and uranium enrichment facilities ~~can~~could lead to the dispersion of radioactive material ~~and/~~or toxic material by breaching the ~~containment~~confinement barriers or ~~may~~could cause a criticality accident by affecting the system ~~of~~or the parameters used for the control of criticality (e.g. the moderation control system or the dimensions of ~~processing equipment).~~the processing equipment). Special consideration should be given to the fire extinguishing media deployed, and their potential moderation effect. In accordance with para. 6.146 of SRS-4 [1], the choice of fire extinguishing media (e.g. water or powder) and the safety of their use is required to be addressed with regard to criticality safety.

~~2.20.~~5.51. The fire hazards that are specifically encountered in a conversion facility such as from anhydrous ammonia (explosive and flammable), nitric acid (ignition if organic materials) and hydrogen should be given due consideration.

Fire hazard analysis

~~2.21.~~5.52. As an important aspect of fire hazard analysis, areas of the facility that ~~require~~need special consideration should be identified. ~~Special fire~~Fire hazard analyses of the facility should be ~~carried out~~performed for all areas with high-risk fire sources such as ~~follows~~areas where diffusers are located, areas with combustible materials (including low voltage cables), and premises where safety equipment is installed. Particular consideration during the fire hazard analysis should be given to the following:

(1) For conversion facilities:

~~(g)~~(b) Processes involving ~~H_2~~hydrogen, such as reduction of uranium oxide;

~~(h)~~(c) Workshops using flammable liquids (e.g. dodecane), such as purification units and laboratories;

~~(i)~~(d) The storage of reactive chemicals (e.g. ~~NH_3, H_2, HNO_3~~ammonia, hydrogen, nitric acid, dodecane);

(j)(e) Areas with high fire loads, such as waste storage areas;
(k)(f) Waste storage and treatment areas, especially those where incineration is carried out;
(l)(g) Rooms housing safety related equipment, e.g. items, such as air filtering systems, whose degradation maymight lead to radiological consequences that are considered to be unacceptable;
(m)(h) Transformers and rooms housing battery chargers;
(n)(i) Control rooms.;
(j) Vehicles such as UF_6 cylinder transporters and forklifts that use hydrocarbon fuel.

(2) For gaseous diffusionuranium enrichment facilities:

(a) Areas with high fire loads, such as areas containing lubricating oil tanks and vessels containing degreasing or decontamination solvents;
(b) The storage areas for reactive chemicals (e.g. ClF_3, F_2);
(c) Diesel storage tanks;
(d) Transformers and rooms housing battery chargers;
(e) Areas storing combustible waste prior to its conditioning;
(f) Control rooms.
(5) For gas centrifuge enrichment facilities:
(g)(b) Diesel storage tanks;
(h)(c) Transformers and rooms housing battery chargers;
(i)(d) The storage of solvents (e.g. methylene chloride CH_2Cl_2);;
(j)(e) Areas storing combustible waste prior tobefore its conditioning;
(k)(f) Control rooms.;
(g) Vehicles such as UF_6 cylinder transporters and forklifts that use hydrocarbon fuel.

2.22.5.53. Fire hazard analysis involvesfor conversion facilities and uranium enrichment facilities should involve identification of the causes of fires, assessment of the potential consequences of a fire and, where appropriate, estimation of the frequency or probability of occurrence of fires. It isshould be used to assess the inventory of fuels and initiation sources, and to determine the appropriateness and adequacy of measures for fire protection. Computer modelling of fires may sometimes be used in support of the fire hazard analysis.

~~2.23.~~5.54. The estimation of the likelihood of fires can be used as a basis for making decisions or for identifying weaknesses that might otherwise go undetected. Even if the estimated likelihood of fire may seem low, a fire might have significant consequences for safety and, as such, certain protective measures should be taken such as delineating small fire areas, to prevent or curtail the fire from spreading.

~~2.24.~~5.55. The analysis of fire hazards should also involve a review of the provisions made at the design stage for preventing, detecting and ~~fighting~~mitigating fires.

Fire prevention, detection and mitigation

~~2.25.~~5.56. Prevention is the most important aspect of fire protection. Facilities should be designed to limit fire risks by the incorporation of measures to ensure that fires do not break out. Mitigation measures should be put in place to minimize the consequences of a fire in the event that a fire breaks out despite preventive measures.

~~2.26.~~5.57. To accomplish the twofold aim of fire prevention and mitigation of the consequences of a fire, a number of general and specific measures should be taken, including the following:

(a) Separation of the areas where non-radioactive hazardous material is stored from the process areas;
(b) Minimization of the fire load of individual rooms~~;~~.
(c) Selection of materials, including those for civil structures and compartment walls, penetrations and cables associated with structures, systems and components important to safety, in accordance with functional criteria and fire resistance ratings~~;~~.
(d) Compartmentalization of buildings and ventilation ducts as far as possible to prevent the spreading of fires. Buildings should be divided into fire zones. Measures should be put in place to prevent or severely curtail the capability of a fire to spread beyond the fire zone in which ~~it~~the fire breaks out. The higher the fire risk, the greater the number of fire zones a building should have~~;~~.
(e) Suppression or limitation of the number of possible ignition sources such as open flames or electrical sparks.

~~2.27.~~5.58. Paragraph 6.79 of SSR-4 [1] establishes requirements for the analysis with regard to fire extinguishing systems. Fire extinguishing devices, automatic or manually operated, with adequate extinguishing agent, should be installed in the areaszones where the outbreak of a fire is possible (see Ref. [1], Appendix III, para. III.10). In particular, "the. The installation of automatic firefighting devices with water sprays shallshould be assessed with care for areas where UF_6 is present, with account taken of the potential risk of HFhydrogen fluoride generation and criticality events for enriched material" (Ref. [1], Appendix III, para. III.11).uranium. Consideration should be given to minimizing the environmental impact of the water used to extinguish fires.

2.28.5.59. The design of ventilation systems should be given particular consideration with regard to fire prevention. Dynamic containment comprisessystems comprise ventilation ducts and filter units, which maymight constitute weak points in the fire protection system unless they are of suitable design. Fire dampers should be mounted in the ventilation system unless the likelihood of widespread fires is acceptably low. They should close automatically on receipt of a signal from the fire detection system or by means of temperature sensitive fusible links. Spark arrestors should be used to protect the filters if necessary. The required operational performance of the ventilation system should be specified so as to comply with fire protection requirements.

2.29.5.60. Lines that cross the boundaries between fire areas or fire zones (e.g. electricity lines, gas and process lines) should be designed to ensure that fire does not spread.

Explosions

2.30.5.61. An explosion can be induced by fire or it can be the initiating event that results in a fire. Explosions could breach the barriers providing confinement and/or could affect the safety measures that are in place for preventing a criticality accident.

2.31.5.62. In conversion facilities and uranium enrichment facilities, the possible sources of explosions include the following:

(a) Gases (in conversion facilities: e.g. H_2hydrogen or NH_3ammonia used in the reduction process; in uranium enrichment facilities:

chemical oxidants such as ~~F_2, ClF_3~~fluorine, chlorine trifluoride or UF_6). Design provisions should be implemented to prevent an explosive mixture of the above chemical oxidants and of hydrocarbons or halo-hydrocarbons. Where the prevention of such an explosive mixture cannot be ensured, consideration should be given to the use of an inert gas atmosphere or dilution systems.

~~(b)~~ Solid chemical compounds (in conversion facilities only: ammonium nitrate when in a high temperature environment~~);~~

~~(c)~~(b)). Monitoring of possible deposits should be implemented to prevent any accumulation of ammonium nitrate.

Flooding

~~2.32.~~5.63. Flooding in a conversion facility or ~~an~~a uranium enrichment facility ~~may~~might lead to the dispersion of radioactive material if the radioactive material were not kept in a confined state (e.g. yellow cake, ammonium diuranate (ADU) in conversion). For UF_6, which is always kept in a confined state, flooding would only result in a release of hazardous materials if there were a simultaneous loss of confinement. Flooding can potentially result in buoyancy induced failure of vessels, pipes and equipment causing a loss of confinement.

~~2.33.~~5.64. In any case, flooding ~~may~~might lead to a change in criticality safety parameters such as reflection and/or moderation.

~~2.34.~~5.65. In facilities where vessels and/or pipes containing water are present~~,~~ (including any installed firefighting systems), the criticality safety analyses should take into account the presence of the maximum amount of water that could be contained within the room under consideration as well as the maximum amount of water in any connected rooms. Such rooms or premises should be clearly identified and the personnel should be informed.

~~2.35.~~5.66. Walls (and floors if necessary) of rooms where flooding could occur should be capable of withstanding the water load ~~to avoid any 'domino effect' due to their failure~~and safety related equipment should not be affected by flooding.

Leaks and spills

2.36.5.67. LeaksIn addition to the loss of raw materials and their environmental impact, leaks from containment systems such as vessels, cylinders, pumps, valves and pipes can lead to the dispersion of radioactive material (e.g. uranium solutions and powders, gaseous or liquid UF_6) and toxic chemicals (e.g. HF, F_2, NH_3, ClF_3hydrogen fluoride, fluorine, ammonia, chlorine trifluoride) and to the unnecessary generation of waste. Leaks of hydrogenous fluids (e.g. water, oil, etc.)) can adversely affectalter the neutron moderation and/or reflection and thereby reduce criticality safety. Leaks of flammable gases (e.g. H_2hydrogen) or liquids can lead to explosions and/or fires. Leak detection systems should be deployed where leaks could occur.

2.37.5.68. For conversion andfacilities, uranium recovery locations ofand uranium enrichment facilities, vessels containing significant amounts of nuclear material, or hazardous chemicals, in solution form should be equipped with level detectors and alarms to prevent overfilling and with secondary containmentconfinement features such as bunds or drip trays of appropriate capacity and. For fissile material the configuration is required to ensure criticality safety.: see para. 6.143 of SSR-4 [1].

2.38.5.69. The surfaces of floors and walls should be chosen to facilitate their cleaning, in particular in wet process areas. This will also facilitate the minimization of waste from decommissioning.

Loss of support systemsservices

2.39.5.70. To fulfilmeet the requirement established in para. 6.2889 of Ref.SSR-4 [1], an emergency back-up power supply, that can be deployed in a timely manner to provide backup power, should be provided at least for the following systems and components:

(a) Criticality accident detection and alarm systems;
(b) Ventilation systems, if necessary, for the confinement of hazardous material;
(c) Detection and alarm systems for leaks of hazardous materials, including explosive gases;
(d) Some process control components (e.g. heating elements, valves);
(e) Fire detection and suppression systems;
(a)(f) Monitoring systems for radiation protection and environmental protection;

— Detection and alarm systems for leaks of hazardous materials;
— Fire detection and alarm systems;
— Criticality accident detection and alarm systems;
— Ventilation systems, if necessary forLighting within the confinement of hazardous material;

(b)(g) Some process control components (e.g. heating elements and valves);facility.

— Fire pumps, if fire water is dependent on off-site electrical power.

3.25. For uranium enrichment facilities, a loss of electrical power maymight result in major operational consequences. In addition, there maymight be some safety implications from a loss of electrical power, such as the formation of solid uranium deposits.

2.40.5.71. For the centrifuge process, a A backup electrical power system should be provided for the removal of the UF_6 from the cascade and its transfer to UF_6 cylinders or chemical absorber traps.

— For the diffusion process, the inherent heat is sufficient to keep the UF_6 in its gaseous form for several days in the process equipment. However, solidification of the UF_6 may start beyond this period. A first potential safety issue involves the heating of solidified UF_6 for sublimation within the process equipment and piping, which may lead to local liquefaction of the UF_6 and a subsequent loss of confinement. A second potential safety issue is that a large quantity of solid enriched uranium could accumulate in an unsafe geometry such that a loss of moderation control could cause a criticality event.

2.41.5.72. The licensing documentation (safety case) should address the remedial actions necessary for the facility, including the items identified abovein para 5.70 to return to a safe operational state, unless the likelihood of an extended loss of power can be ruled out on probabilistic grounds.

2.42.5.73. The consequences of the loss of general supplies such as gas for instrumentation and control, cooling water for process equipment and ventilation systems, heating water, breathing air and compressed air may have also some consequences for safety. For example should be analysed at least for the following:

(a) Loss of gas supply to gas controlled safety valves and dampers: In accordance with the safety analysis, valves should be used that are ‘design to fail’ to a safe position;.

(b) Loss of cooling or heating water: Adequate backup capacity or a redundant supply should be provided for in the design.

Loss or excess of process media

Processing errors

2.43.5.74. The following list gives examples of hazards to be considered during the safety assessment as defined in para. 6.29 of Ref. [1]:in relation to the loss or excess of process reagents and diluent gases:

(a) Incomplete chemical reactions in conversion facilities maymight lead to a release of hazardous chemicals.

(b) Overpressure in the equipment maymight cause an increase of the levels of airborne radioactive material and/or concentration of hazardous material in the working areas of the facility.

(c) Excess of F_2fluorine in the fluorination process in conversion facilities maymight result in its release.

(d) Releases of large amounts of nitrogen maymight result in a reduction of the oxygen concentration in breathing air in the work areas of the facility.

(e) Loss of steam or hot water supply maymight result in the solidification of UF_6 in the piping and equipment in a diffusion facility.

(f) Failure of the air supply maymight result in the failure of safety related air operated valves.

Mechanical failure

ParticularFacility failures and equipment failures

2.44.5.75. To meet Requirement 40 of SSR-4 [1], particular consideration should be given to the confinement of highly corrosive and hazardous materials such as UF_6, F2fluorine and HFhydrogen fluoride in vessels, pipes and pumps and to powder transfer lines where abrasive powder will cause erosion.

2.45.5.76. The design should minimize the potential for mechanical impacts to containers of hazardous material caused by moving devices such as vehicles and cranes. The design should ensure that the movement of heavy loads by cranes above vessels and piping containing large amounts of hazardous and/or radioactive material is minimized, as a major release of hazardous or radioactive material could occur if the load were accidentally dropped.

~~2.46.~~5.77. Failure due to fatigue or chemical corrosion or lack of mechanical strength should be considered in the design of containment systems for hazardous and/or radioactive material.

5.78. To prevent failure of equipment containing hazardous materials (for example calciners or furnaces), effective programmes for maintenance, periodic testing and inspection should be established at the design stage.

External ~~initiating events~~hazards

~~*Earthquakes*~~

General

5.79. A conversion facility or a uranium enrichment facility should be designed ~~for the design basis earthquake to~~ in accordance with the nature and severity of the external hazards, either natural or human induced, identified and evaluated in accordance with the provisions of SSR-1 [13] and Requirement 16 of SSR-4 [1]. Detailed recommendations on external hazards are provided in Safety Standards Series Nos SSG-9 (Rev. 1), Seismic Hazards in Site Evaluation for Nuclear Installations [17], SSG-18, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations [18], SSG-21, Volcanic Hazards in Site Evaluation of Nuclear Installations [19], SSG-68, Design of Nuclear Installations Against External Events Excluding Earthquakes [20]. Recommendations for specific external hazards for a conversion facility or a uranium enrichment facility are provided in the paragraphs 5.80–5.95.

Earthquakes

5.80. To ensure that the ground motion during an earthquake at the site would not induce a lossdesign of a conversion facility or a uranium enrichment facility provides the required degree of robustness, a detailed seismic assessment (see SSR-1 [13] and SSG-9 (Rev. 1) [17]) should be made including the following seismically induced events:

(a) Loss of cooling.
(b) Loss of support services, including utilities.
(c) Loss of confinement capability (especially for confinement of UF6 and HF) or a criticality accident (i.e. a seismically induced loss of criticality functions (static and dynamic).
(d) Loss of safety functions, for ensuring the return of the facility to a safe state and maintaining the facility in a safe state after an earthquake, including structural functions and functions for the prevention of other hazards (e.g. fire, explosion, load drop, flooding).
(d)(e) The effect on criticality safety functions such as geometry and/or moderation) with possible significant consequences for site personnel or members of the public. of the following:

3.26. To define the design basis earthquake for the facility, the main characteristics of the disturbance (intensity, magnitude and focal distance) and the distinctive geological features of the local ground should be determined. The approach should ideally evaluate the seismological factors on the basis of historical data for the site. Where historical data are inadequate or yield large uncertainties, an attempt should be made to gather palaeoseismic data to enable the determination of the most intense earthquake affecting the site to have occurred over the period of historical record. The different approaches can be combined since the regulatory body generally takes into account the results of scenarios based on historical data and those based on palaeoseismic data in the approval of the design.

3.27. One means of specifying the design basis earthquake is to consider the historically most intense earthquake, but increased in intensity and magnitude, for the purpose of obtaining the design response spectrum (the relationship between frequencies and ground accelerations) used in designing the facility. Another way of specifying the design basis earthquake is to perform a geological review, to determine the existence of capable faults and to estimate the ground motion that such faults might cause at the location of the facility.

(i) Deformation (geometry control);

(ii) Displacement (geometry control, fixed neutron poisons);

(iii) Loss of material (geometry control, soluble neutron poisons).

5.81. Depending on the site characteristics and the location of the conversion facility or uranium enrichment facility, as evaluated in the site assessment (see Section 4), the effect of a tsunami induced by an earthquake and other extreme flooding events should be addressed in the facility design.

External fires and explosions and external toxic hazards

~~2.47.~~5.82. Hazards from external fires and explosions could arise from various sources in the vicinity of conversion facilities or uranium enrichment facilities, such as petrochemical installations, forests, pipelines ~~and~~, road, rail or sea routes used for the transport of flammable material such as gas or oil, and volcanic hazards.

5.83. To demonstrate that the risks associated with such external hazards are below acceptable levels, the operating organization should first identify all potential sources of hazards and then estimate the associated event sequences affecting the facility. The radiological or associated chemical consequences of any damage should be evaluated and it should be verified that they are within acceptance criteria. Toxic hazards should be assessed to verify that specific gas concentrations meet the acceptance criteria. It should be ensured that external toxic hazards would not adversely affect the control of the facility. The operating organization should ~~carry out~~conduct a survey of potentially hazardous installations and transport operations for hazardous material in the vicinity of the facility. In the case of explosions, risks should be assessed for compliance with overpressure criteria.

~~2.48.~~5.84. To evaluate the possible effects of flammable liquids, toxic spills, volcanic ashes, falling objects (such as chimneys~~)~~), air shock waves and missiles resulting from explosions, their distance from the facility and hence their potential to cause physical damage should be assessed.

Extreme ~~weather conditions~~meteorological phenomena

3.28. Typically, extreme weather conditions assumed in the design and in the evaluation of the response of a conversion facility or an enrichment facility are wind loading, tornadoes, tsunamis, extreme rainfall, extreme snowfall, extreme temperatures and flooding.

3.29. The general approach is to use a deterministic design basis value for the extreme weather condition and to assess the effects of such an event on the safety of the facility. The rules for obtaining the design basis values for use in the assessment may be specified by local regulations.

3.30. The design provisions will vary according to the type of hazard and its effects on the safety of the facility. For example extreme wind loading is associated with rapid structural loading and thus design provisions for an event involving extreme wind loading should be the same as those for other events with potentially rapid structural loading such as earthquakes. However, effects of extreme precipitation or extreme temperatures would take time to develop and hence there would be time for operational actions to be taken to limit the consequences of such events.

2.49.5.85. A conversion facility or ana uranium enrichment facility should be protected against extreme weathermeteorological conditions as identified in the site evaluation (see Section 4) by means of appropriate design provisions. These should generally include the following:

(a) The ability of structures important to safety to withstand extreme weather loads;
(b) The prevention of flooding of the facility including adequate means to evacuate water from the roof in cases of extreme rainfall and to prevent failure of water pipes due to freezing;
(c) The guarantee of safe state for the facility in accordance with the operational limits and conditions.

Tornadoes

2.50.5.86. Measures for the protection of the facility against tornadoes will depend on the meteorological conditions for the area in which the facility is located. The design of buildings and ventilation systems should be in compliancecomply with specific national regulations relating to hazards from tornadoes. If pertinent national regulations do not exist, the design should adhere to international good practices.

~~2.51.~~5.87. High winds are capable of lifting and propelling objects as large as automobiles or telephone poles. The possibility of impacts of tornado missiles such as these should be taken into consideration in the design stage for the facility, as regards both the initial impact and the effects of possible secondary fragments arising from collisions with and spallation ~~of~~from concrete walls or from other types of transfer of momentum.

Extreme temperatures

~~2.52.~~5.88. The potential duration of extreme low or high temperatures should be taken into account in the design of the main process equipment and support system equipment to prevent adverse effects such as the following:

(a) The crystallization of uranium nitrate solutions, or liquid or gaseous UF_6;
(b) The freezing of the cooling system used in desublimers (cold traps) such as those used in off-gas systems;
~~those used in off-gas systems;~~
(c) The freezing of emergency oil used to blanket concentrated ~~HF~~hydrogen fluoride solutions after a breach of a vessel;
(d) The liquefaction of solid UF_6 in piping.

~~2.53.~~5.89. If safety limits for humidity or temperature are specified in a building or a compartment, the air-~~-~~conditioning system should be designed to perform efficiently also under extreme hot or wet weather conditions. For structures without expansion joints, the additional loads due to thermal expansion on structural systems should be considered in the design.

Snowfall and ice storms

~~2.54.~~5.90. The occurrence of snowfall and ~~its~~ice storms and their effects should be taken into account in the design of the facility and the safety analysis. Snow ~~is~~and ice are generally taken into account as an additional load on the roofs of buildings. The neutron reflecting effect and/or the interspersed moderation effect of the snow, if relevant, should be considered (e.g. for product cylinder storage areas).

Floods

Flooding

2.55.5.91. For any flood events such as extreme rainfall (for an inland site) or storm surge (for a coastal site) attention should be taken into account focused on potential leak paths (breaks in the design of a facility. Two approachesconfinement barrier) into structures, systems and components important to dealing with safety when these are vulnerable to damage. Equipment containing fissile material should be designed to prevent any criticality accident in the event of flooding hazards have been put forward:. Electrical systems, instrumentation and control systems, emergency power systems (batteries and power generation systems) and control rooms should be protected by design.

2.56.5.92. In some States For extreme rainfall, attention should be focused on the stability of buildings (e.g. hydrostatic and dynamic effects), the water level and, where relevant, the potential for mudslides. Consideration should be given to the highest flood levels level historically recorded over the period of historical record are taken into account and nuclear facilities are sitedand to siting the facility above this flood level, at specific locations or at a sufficient elevation and with sufficient margin to account for uncertainties, to avoid major damage from flooding.

In other States, in which the use of dams is widespread and where a dam has been built upstream of a potential or existing site for a nuclear facility, the hazard posed by a breach of the dam is taken into account. The buildings of the facility are designed to withstand the water wave released from the breach. In such cases the equipment — especially that used for the storage of fissile material — should be designed to prevent any criticality accident.Accidental aircraft crash hazards

3.31. The likelihood and possible consequences of impacts onto a facility should be calculated by assessing the number of aircraft that come close to the facility and their flight paths, and by evaluating the areas vulnerable to impact, i.e. areas where hazardous material is processed or stored. If the risk is acceptably low, no further evaluations are necessary. See also para. 5.5 (item (h)) of Ref. [1].

5.93. Other effects of combined water levels (such as high tides or tsunamis) should be considered.

Accidental aircraft crashes

5.94. In accordance with the risks identified in the site evaluation (see Section 4), a conversion facility or a uranium enrichment facility should be designed to withstand the design basis impact.

~~2.57.~~5.95. For evaluating the consequences of impacts or the adequacy of the design to resist aircraft impacts, ~~only realistic~~ crash scenarios included in the design basis should be considered, which may ~~require~~demand the knowledge of such factors as the possible angle of impact, velocity of the aircraft or the potential for fire and explosion due to the aviation fuel load. In general, fire cannot be ruled out following an aircraft crash ~~and so the establishment of~~. Therefore, specific requirements for fire protection and for emergency preparedness and response ~~will~~should be ~~necessary.~~established.~~INSTRUMENTATION AND CONTROL (I&C)~~

INSTRUMENTATION AND CONTROL ~~Instrumentation~~

~~2.58.~~5.96. Instrumentation should be provided to monitor the ~~variables~~relevant parameters and systems and general conditions of the facility over their respective ranges for: (1) normal operation; (2) anticipated operational occurrences; and (3) ~~design basis accidents~~accident conditions, to ensure that adequate information can be obtained on the status of operations and the facility, and proper actions can be undertaken in accordance with the operating procedures ~~or in support of automatic systems~~.

~~2.59.~~5.97. Instrumentation should be provided for measuring all the main ~~variables~~parameters whose variation ~~may~~might affect the safety of processes~~,~~ (such as pressure, temperature and flowrate). In addition, instrumentation should be provided for monitoring ~~for safety purposes~~ general conditions at the facility (such as ~~radiation doses due to internal and external exposure~~radioactivity levels, releases of effluents and ventilation conditions), and for obtaining any other information about the facility necessary for its reliable and safe operation~~. Provision should be made for the automatic measurement and recording of values of parameters that are important to~~

safety.Control systems (such as presence of personnel and environmental conditions).

2.60.5.98. Passive and active engineering controls are more reliable than administrative control and should be preferred for control in normal operational states and in accident conditions. Automatic systems should be designed to maintain process parameters within the operational limits and conditions or to bring the process to a predetermined safe state.

2.61.5.99. Appropriate information should be made available to the operator for monitoring the effects of automatic actions. The layout of instrumentation and the manner of presentation of information should provide the operating personnel with an adequate impressionpicture of the status and performance of the facility with consideration given to important parameters that should be recorded for future use. Devices should be installed that provide in an efficient manner visual and, as appropriate, audible indications of operational states that have deviated from normal conditions and that could affect safety. Provision should be made for the automatic measurement and recording of values of parameters that are important to safety and where applicable, manual periodic testing should be used to complement automated continuous testing of conditions.

Control rooms and panels

2.62.5.100. Control rooms and human–machine interface panels should be provided to centralize the main data displays, controls and alarms for general conditions at the facility.availability of information and monitoring of actions. Occupational exposure and safety of personnel should be minimized by locatingconsidered when the location of control rooms in parts of the facility where the levels of radiation are low. For specific processesis selected. Where applicable, it may be useful to have dedicated control rooms to allow for the remote monitoring of operations, thereby reducing exposures and risks to operatorspersonnel. Particular consideration should be paid to identifying those events, both internal and external to the control rooms, that maymight pose a direct threat to the operators and to the operation of control rooms. Ergonomic factors should be taken into account in the design of control rooms and the design of control room displays and systems.

Safety related I&Cinstrumentation and control systems for normal operation

2.63.5.101. Safety related I&C instrumentation and control systems for normal operation of a conversion facility or ana uranium enrichment facility should include systems for the following:

(a) I&C relating to Criticality control and criticality safety.detection and alarm:

(i) ForProcess controls, in particular for uranium enrichment facilities, include in-line devices for enrichment measurement should be used to monitor the enrichment levels of products. For diffusion enrichment facilities, the ratio of hydrogen to uranium should be monitored by an in-line analyser (e.g. an HF infrared analyser). The requirement on I&C systems relating to criticality control

(i)(ii) Radiation detectors (gamma and/or neutron detectors) with audible and, where necessary, visible alarms for initiating immediate evacuation from the affected area, should cover all the areas where a significant quantity of fissile material is established inpresent: see para. III.166.173 of Appendix III of Ref.SSR-4 [1].

(b) Fire detection:

(i) All rooms with both fire loads *and*or significant amounts of fissile and/or toxic chemical material should be equipped with fire alarms(except where the permanent presence of operators is sufficient).;

(ii) Gas detectors should be used in areas where a leakage of gases (e.g. H_2hydrogen) could produce an explosive atmosphere.

(c) Instrumentation and control relating to the process, e.g.indicating temperatures, pressuresProcess control:

(i) Parameters such as temperature, pressure, flow rates, concentrationsrate, concentration of chemicals and/or radioactive material, tank levels, cylinder weights.The corresponding requirements are established in paras III.13 and III.14 of Appendix III of Ref. [1]. In filling should be monitored.

(i)(ii) Before heating a UF_6 cylinderscylinder, the weight of UF_6 should be measured and should be monitored by appropriate and reliable devices to ensure thatconfirmed to be below the fill limit is not exceeded.(e.g. by using a second independent weighing scale).

(6) I&C relating to the chemical purity of UF_6 (for diffusion enrichment facilities).

The corresponding requirement is established in para. III.15 of Appendix III of Ref. [1].

(iii) I&C relating to If the system has the capability of reaching a temperature where hydraulic rupture can occur, the temperature during heating should be limited by means of two independent systems.

(b)(d) Control of ventilation, i.e. mainly: Mainly devices for measuring differential pressures across high efficiency particulate air (HEPA) filters and airflows.

(7) I&C relating toControl of gaseous and liquid effluents.

(c)(e) : Real time measurements should be provided if there is a risk offoreseeable potential for exceeding regulatory limits; otherwise, retrospective measurements on continuously sampled filters and/or probes will generally be sufficient.

(8) I&C relating to the prevention of Control of explosive mixtures.

(d)(f) : Real time measurements, controls and alarms are necessary if there is a risk of foreseeable potential for exceeding regulatory and safety limits, (e.g. devices for measuring the concentration of O_2 in the reduction kiln in conversion facilities.).

(9) Control of chemical releases:Safety related I&C systems for anticipated operational occurrences

— In addition to the listing provided in para. 4.87, I&C systems for use in anticipated operational occurrences should include the following provisions:

(g) All roomsControl of occupational radiation exposure:

— For monitoring external exposure, dosimeters with both fire loads *and* significant amounts of fissilereal time displays and/or toxic chemical material alarms should be equipped with fire alarms (except where the permanent presence of operators is sufficient).

(i) Gas detectors should be usedinstalled in areas where a leakage of gases (e.g. H_2) could produce an explosive atmosphereradioactive releases have the potential to occur, and especially in areas with inspection equipment such as X-ray generators and active sources.

(ii) For monitoring internal exposure continuous sampling of filters for retrospective measurement and/or real time measurement with alarms should be performed for the detection of releases of radioactive material.

(h) Control of asphyxiants: Presence and concentration of asphyxiants (such as nitrogen, ammonia, NO_x) in working areas where it might impact operational safety should be monitored.

(e)(i) Control of chemical releases: Real time detection and alarm systems should be used in the process areas and/or laboratories where HF and hydrogen fluoride, UF_6 and chlorine trifluoride above atmospheric pressure is present.

3.32.

3.33.

3.34.

3.35.

HUMAN FACTOR CONSIDERATIONS

2.64.5.102. The requirements relating to human factor considerationsfactors engineering are established in paras 6.15 and 6.16Requirement 27 of Ref.SSR-4 [1].

2.65.5.103. Human factors in operation, inspection, periodic testing, and maintenance should be considered at the design stage. Human factors to be considered for a conversion facility or a uranium enrichment facility should include the following:

(a) Possible effects on safety of unauthorized human actions (with account taken of ease of intervention by the operator and tolerance of human error);

(b) The potential for occupational exposure.

2.66.5.104. DesignThe design of the facility to take account of human factors is a specialist area. Experts and experienced operators should be involved from the earliest stages of design. Areas that should be considered include the following:

(a) Design of working conditions to ergonomic principles.:

(ii)(iii) The operator–process interface, e.g.for example, electronic control panels displaying all the necessary information and no moresuperfluous information;

(iii)(iv) The working environment, e.g.for example, ensuring good accessibility ofaccess to and adequate space around equipment and suitable finishes to surfaces for ease of cleaning.

(b) Choice of location and clear labelling of equipment so as to facilitate maintenance, testing, cleaning and replacement;.

(c) Provision of fail-safe equipment and automatic control systems for accident sequences for which reliable and rapid protection is required;.

(d) Good task design and job organizationease for implementing operating procedures, particularly during maintenance work, when automated control systems may be disabled;.

(e) Minimization of the need to use additional means of personal radiation protection.

(f) Operating experience feedback relevant to human factors.

SAFETY ANALYSIS

3.36. SafetyGSR Part 4 (Rev. 1) Requirement 14 of GSR Part 4 (Rev. 1) [11] states that: **"The performance of a facility or activity in all operational states and, as necessary, in the post-operational phase be assessed in the safety analysis"**. The safety analysis for conversion facilities and uranium enrichment facilities should be performed in two major steps:

2.67.5.105. The assessment of occupational exposure and public exposure for operational states of the include the analysis of variety of hazards for the whole facility and comparison with authorized limits for operational states;all activities

— Determination of the radiological and associated chemical consequences of

— design basis accidents (or the equivalent) for the public and verification that they are within the acceptable limits specified for accident conditions.

3.37. The results of these two steps should be reviewed for identification of the possible need for additional operational limits and conditions.

5.106. The list of postulated initiating events identified should take into account all the internal and external hazards that can be used to develop the resulting event scenarios for the purpose of establishing the list of structures, systems and components important to safety. The functions of the structures, systems and components being relied upon for safety should not be adversely impacted by the event scenarios.

Safety analysis for operational states

Occupational exposure and exposure of the public

2.68.5.107. A facility specific, and realistic, enveloping and robust (i.e. conservative) assessment of internal and external occupational exposure and exposure of the public during normal operation and anticipated operational occurrences should be performed on the basis of the following assumptions:

(1) Calculations of the source term should use: (i) the material with the highest specific activity for a given isotopic composition; (ii) the licensed inventory of the facility; and (iii) the maximum material throughput that can be processed by the facility. The poorest performances of barriers in normal operation should be used in the calculations. A best estimate approachmethodology with the use of adequate margins may also be used.

(2) Calculations of the estimated doses due to occupational exposure should be made on the basis of the conditions at the most exposed workplaces and should use maximum annual working times. On the basis of data on dose rates collected during commissioning runs and as necessary, the operational limits and conditions may include maximum annual working times for particular workplaces.

(3) Calculations of the estimated doses to the public (i.e. a ‘critical group’ of people living in the vicinity of the facilityto the ‘representative person’) should be made on the basis of maximum estimated releases of radioactive material to the air and to water and, maximum depositions to the ground, and direct exposure. Conservative models and parameters should be used to calculate the estimated doses to the public.

Releases of hazardous chemical material

3.38. Facility specific, realistic, robust (i.e. conservative) estimations of chemical hazards to workers and releases of hazardous chemicals to the environment should be performed in accordance with the standards applied in the chemical industry.

Safety analysis for accident conditions

Methods and assumptions for safety analysis for accident conditions

3.39. For conversion facilities and enrichment facilities, there is no general agreement on the best approach to the safety analysis for design basis accidents and the associated acceptance criteria. However, there is a tendency for the following or similar criteria to be adopted for new advanced facility designs.

5.108. For To estimate the on-site and off-site consequences of an accident, the entire range of physical processes that could lead to a release of radioactive material and any associated hazardous chemicals to the environment should be modelled in the accident analysis and the cases encompassing the worst consequences should be determined.

2.69.5.109. The consequences of design basis accidents for a conversion facility or ana uranium enrichment facility, consequences of design basis accidents would generally be limited to consequences for individuals on the site and close to the location of the accident. The consequences depend on various factors such as the amount and rate of the release of radioactive material and hazardous chemicals, the distance between the individuals exposed or affected and the source of the release, pathways for the transport of material to the individuals and the exposure times.

3.40. To estimate the on-site and off-site consequences of an accident, the wide range of physical processes that could lead to a release of radioactive material to the environment should be modelled in the accident analysis and the enveloping cases encompassing the worst consequences should be determined.

5.110. The following approachesThe acceptance criteria associated with the accident analysis should be defined in accordance with Requirement 16 of GSR Part 4 (Rev. 1) [11], and with respect to national regulations and relevant criteria.

2.70.5.111. To demonstrate the protection of workers, public and the environment from accidents the following two approaches, or another equivalent approach, should be considered in the safety assessment of conversion facilities and uranium enrichment facilities:

(4) An approach using the enveloping case (the worst case approach, e.g. the release of liquid UF_6 from a cylinder filled to the maximum fill limit), with account taken only of those safety features that mitigate the consequences of accidents and/or that reduce their likelihood. If necessary, a more realistic case can be considered that includes the use of some safety features and some non-safety-related features beyond their originally intended range of functions to reduce the consequences of accidents (the best estimate approach).

(1) The worst case approachThe first approach involves the identification of structures, systems and components important to safety based on an analysis of all credible accidents that can exceed pre-established criteria for facility personnel, members of the public and the environment. It also involves demonstrating that these structures, systems and components can reduce the consequences and/or the likelihood of potential accidents below the pre-established criteria. This approach would also provide information for the development of the emergency plans.

(2) The second approach starts with the selection of the limiting accident conditions, referred to as bounding or enveloping scenarios. It should be then demonstrated in a conservative way, with no account taken of any (active) structures, systems and components important to safety ~~feature~~or administrative measures, that ~~may reduce~~ the consequences ~~or the likelihood~~ of ~~accidents~~these limiting accident conditions are within established facility independent acceptance criteria. This assessment is followed by a review of the possible accident sequences~~,~~ to identify provisions of design features and administrative measures, taking into account a graded approach in accordance with ~~account taken~~Requirement 11 of SSR-4 [1], to further reduce the ~~emergency procedures~~consequences and ~~the means planned for mitigating~~/or the likelihoods of potential accidents and to provide information for the development of the emergency plans.

~~2.71.~~5.112. Accident consequences ~~of the accident.~~should be assessed in accordance with the requirements established in GSR Part 4 (Rev. 1) [11] and with relevant parts of its supporting Safety Guides.

~~*Assessment of possible radiological or associated chemical consequences*~~

~~3.41. Safety assessment should address the consequences associated with possible accidents. The main steps in the development and analysis of accident scenarios should include:~~

5.113. Requirement 38 of SSR-4 [1] states:

> **"The design shall ensure an adequate margin of subcriticality, under operational states and conditions that are referred to as credible abnormal conditions, or conditions included in the design basis."**

The potential occurrence of a criticality accident should be considered for uranium enrichment facilities and for conversion facilities that process uranium with a ^{235}U enrichment of more than 1% as part of the safety analysis for accident conditions. Particular consideration should be given to the potential occurrence of a criticality accident for facilities handling and processing various feed products including reprocessed uranium.

5.114. In accordance with paras 6.149 and 6.150 of SSR-4 [1], the need for and suitability of mitigatory measures and the effectiveness of protective actions are required to be assessed for criticality accidents.

Analysis of design extension conditions

5.115. The safety analysis should identify design extension conditions, and their progression and consequences should be analysed in accordance with Requirement 21 of SSR-4 [1]. The objective is to identify and analyse additional accident scenarios to be addressed in the design of a conversion facility or uranium enrichment facility to ensure that the design is such that, for design extension conditions, off-site protective actions that are limited in terms of times and areas of application are sufficient for the protection of the public, and sufficient time would be available to take such actions and moreover that the possibility of conditions arising that could lead to early releases of radioactive material or to large releases of radioactive material is practically eliminated (see para 6.74 of SSR-4 [1]).

5.116. Design extension conditions include events more severe than design basis accidents that could originate from extreme events or combinations of events which could cause damage to structures, systems, and components important to safety or which could challenge the fulfilment of the main safety functions. The postulated initiating events provided in the Appendix of SSR-4 [1] are required to be used including combinations of initiating events as well as events with additional failures. Accidents that have more severe consequences as well as progression of events that could potentially lead to a criticality event, radiological or chemical releases should also be analysed to support emergency preparedness and response and assist in the development of emergency plans to mitigate the consequences of an accident.

5.117. Additional safety features or increased capability of safety systems, identified during the analysis of design extension conditions, should be implemented in the facility where practicable.

5.118. For analysing design extension conditions, best estimate methods with realistic boundary conditions can be applied. Acceptance criteria for this analysis, in accordance with para 6.74 of SSR-4 [1], should be defined by the operating organization and should be reviewed by the national regulatory body.

5.119. Examples of design extension conditions that are applicable to conversion facilities and uranium enrichment facilities can be found in Ref. [21].

5.120. Analysis of design extension conditions should also demonstrate that the conversion facility or uranium enrichment facility can be brought into the state where the confinement function and subcriticality can be maintained in the long-term.

Assessment of possible radiological or chemical consequences

5.121. The main steps for the assessment of possible radiological or chemical consequences in the safety analysis should include the following:

(a) Analysis of the actual site conditions (e.g. meteorological, geological, hydrogeological site conditions) and conditions expected in the future including internal and external initiating events with the potential for adverse effects.

~~(b) Identification of workers and members of the public who could possibly be affected by accidents; i.e. a 'critical group' of people living in the vicinity of the facility.~~

~~(c)~~(b) Specification of facility design information and facility configurations, with the corresponding operating procedures and administrative controls for operations.

(c) Identification of individuals and population groups (for facility personnel and members of the public) who could possibly be affected by radiation risks and/or associated chemical risks arising from the operation of the facility.

(d) Identification and analysis of conditions at the facility, including internal and external initiating events that could lead to a release of material or energy with the potential for adverse effects, the time frame for emissions and the exposure time, in accordance with reasonable scenarios.

(e) ~~Specification~~Quantification of the consequences for the individuals and population groups identified in the safety assessment.

~~(e)~~(f) Identification and specification of the structures, systems and components important to safety that may be credited to reduce the likelihood and to mitigate the consequences of accidents. The structures, systems and components important to safety that are credited in the safety assessment should be qualified to perform their functions in accident conditions.

~~(f)~~(g) Characterization of the source term (e.g. material, mass, release rate, temperature~~, etc.).~~).

~~(g) Identification and analysis of intra-facility transport pathways for material that is released.~~

(h) Identification and analysis of pathways by which material that is released could be dispersed in the environment.

(i) ~~Quantification of the consequences~~Considerations for the ~~individuals identified in the~~interface between safety ~~assessment.~~and nuclear security.

~~2.72.~~5.122. ~~Analysis~~The analysis of the ~~actual~~site conditions ~~at the site and the conditions expected in the future~~ involves a review of the meteorological~~,~~ conditions (such as wind speed, stability class, building wake effects), geological and hydrological conditions at the site (such as surface water flow rate) that ~~may~~might influence facility operations or ~~may~~might play a part in transporting material or transferring energy that ~~is~~might be released from the facility ~~(see Section 5 of Ref. [1]).~~.

~~2.73.~~5.123. Environmental ~~transport~~transfer of material should be calculated with qualified computer codes or by using data derived from qualified codes, with account taken of the meteorological and hydrological conditions at the site that would result in the highest exposure of the public.

~~2.74.~~5.124. The identification of ~~workers~~personnel and members of the public (i.e. the ~~critical group of maximally exposed off-site individuals~~representative person) who ~~may~~might potentially be affected by an accident involves a review of descriptions of the facility and of demographic information.~~MANAGEMENT OF RADIOACTIVE WASTE~~

5.125. ~~Conversion facilities~~Further recommendations on the assessment of potential radiological impact to the public can be found in GSG-10 [16]. Useful guidelines for assessing the acute and chronic toxic effects of chemicals used in conversion facilities and uranium enrichment facilities are provided in Ref. [22].

EMERGENCY PREPAREDNESS AND RESPONSE

5.126. A comprehensive hazard assessment should be performed in accordance with Requirement 4 of IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [23] before commissioning. The results of the hazard assessment should provide a basis for identifying the emergency preparedness category relevant to the facility and the on-site areas and, as relevant, off-site areas where protective actions and other response actions may be warranted in case of a nuclear or radiological emergency. Further recommendations are provided in IAEA Safety Standards Series No. GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [24].

5.127. The operating organization of a facility is required to establish emergency arrangements that take into account the potential hazards at the facility (Requirements 47 and 72 of Ref. SSR-4 [1]). The emergency plan and the necessary equipment and provisions should be determined on the basis of selected scenarios for design extension conditions and beyond design basis accidents (or the equivalent). The conditions under which an off-site emergency is required to be declared for a facility should include criticality accidents, widespread fires in the UF_6 storage area, and earthquakes.

MANAGEMENT OF RADIOACTIVE WASTE~~DESIGNED~~

5.128. The general requirements for optimization of protection and safety for waste and effluent management and the formulation of a waste strategy are established in IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [25] and recommendations are provided in IAEA Safety Standards Series Nos GSG-3, The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste [26], GSG-1, Classification of Radioactive Waste [27], SSG-41, Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities [28] and GSG-16 [9]. Recommendations on aspects that are particularly relevant or specific to conversion facilities and uranium enrichment facilities are provided in paras 5.129–5.132.

~~2.75.~~5.129. In accordance with Requirement 24 of SSR-4 [1], the generation of radioactive waste is required to be kept to the minimum practicable in terms of both activity and volume, by means of appropriate design measures. The operating organization of conversion facilities and uranium enrichment facilities should to the extent practicable recover uranium and reuse chemicals to minimize the generation of waste~~ both in operation and in decommissioning. For economic and environmental reasons, the recovery of uranium and the reuse of chemicals are common practices in conversion facilities and enrichment facilities. These practices minimize the generation of waste in both solid and liquid forms [8, 9].~~.

~~2.76.~~5.130. In the design ~~phase~~stage, including in the design for uranium recovery, a review of various techniques should be undertaken to identify the most appropriate technique to minimize waste generation. Safety related factors should also be taken into account in selecting the most appropriate technique.

~~2.77.~~5.131. In the case of conversion facilities and uranium enrichment facilities, the nuclear material to be recovered is uranium both from scraps and as secondary outputs from ventilation filters or from cleaning of the facility. The process of recovering uranium from scraps may include dissolution and solvent extraction, which generate liquid effluents. An appropriate balance should ~~thus~~ be ~~achieved~~sought between the ~~loss~~benefits of ~~uranium through unrecovered waste~~ recovering useful material, the solid and ~~the generation of~~ liquid ~~effluents in~~waste generated and the ~~recovery process~~environmental impact.

5.132. Appropriate quality controls should be applied throughout the management of waste from all waste streams. Recommendations on the management system for radioactive waste management are established in GSG-16 [9].

MANAGEMENT OF GASEOUS AND LIQUID

RELEASESEFFLUENTS

5.133. Liquid effluents to be discharged to the environment should be suitablyConversion facilities and uranium enrichment facilities should be designed so that the need for discharges is avoided. If discharges cannot be avoided, the operating organization should ensure that discharge limits can be met in normal operation and accidental releases to the environment are prevented.

2.78.5.134. Liquids from operating processes should be monitored, treated and managed as necessary to reduce the discharges of radioactive material and hazardous chemicals.

5.135. MonitoringWhere necessary, equipment should be installed as necessaryto reveal potential failure of treatment systems, such as differential pressure gauges for detecting filter failures and devices for measuringto identify failed filters. If required by the safety analysis or the relevant authorization, discharge monitoring should be provided via continuous sampling of the activity or gas concentration and for measuring, coupled with continuous measurement of the discharge flow measuring devices by continuous samplingrate.

2.79.5.136. In addition to the utilization of the best available techniques to remove suspended solids, residual radionuclides in effluents discharged to the environment should be in soluble form, as far as possible, to allow effective dispersal in the aquatic system without coagulation, deposition and buildup of the radionuclides that could result in the need for environmental cleanup activities.

OTHER DESIGN CONSIDERATIONS

2.80.5.137. In the designTo meet Requirement 7 of SSR-4 [1], at an early stage in the facility and equipment, including thedesign, selection of equipment and materials, the need should be such as to ensure confinement, limit the accumulation of uranium and increase the ease of cleaning and/or surface decontamination should be taken into account at an early stage.. With regard to inadvertent accumulation of uranium in process lines, ventilation systems and containers, special consideration should be given to operating experience feedback (see Ref. [29]).

~~2.81.~~5.138. For specific process areas, consideration should be given to the means by which the facility can be shut down safely in an emergency.

~~2.82.~~5.139. Minimization of the storage of hazardous materials on the site should be considered in the design~~.;;.Design of the storage area for UF_6 cylinders~~.

5.140. Selection of materials for civil structures and equipment should be done with respect to their chemical and thermal compatibility considering the chemicals used in the facility processes.

Design provisions for on-site transfer of radioactive material and hazardous materials

5.141. Requirements for the control over the transfer of radioactive material and other hazardous materials are established in Requirement 28 and paras 6.111–6.112 of SSR-4 [1].

5.142. The design of the facility and the production processes should take into account the number of on-site transfers of radioactive material and other hazardous materials across different safety related zones (such as contamination zones and criticality controlled areas).

5.143. For incoming containers containing radioactive material or other hazardous materials, sufficient technical provisions for checking their integrity should be considered during the design stage.

5.144. All containers used for transfer of radioactive material and other hazardous materials on the site should be considered in the safety analysis.

5.145. For cases where misidentification of containers could pose a hazard, provisions for easy identification of the content should be used (for example, use of unique colours, shapes, valves).

5.146. Technical provisions for inspection and maintenance of containers which are classified as items important to safety should be available. All containers should be controlled by a computer based system (actual status, position, technical conditions).

5.147. The analyses of handling arrangements should cover the following:

(a) Transport routes and intersections within the facility;
(b) Technical limits of the transport vehicles;
(c) Handling failures during transport.

Design of the storage area for UF_6 cylinders

2.83.5.148. Provision should be made for avoiding any deep corrosion of cylinders that wouldcould result in a loss of confinement of UF_6 (especially for the storage of depleted UF_6. over long periods of time).

2.84.5.149. The design of new storage areas should allow easy access to conduct periodic inspections and testing of cylinders and should minimize occupancy (limitation ofto limit occupational exposure).

2.85.5.150. Flammable material should not be stored close to theany storage area for UF_6 cylinders.

2.86.5.151. A large aircraft crash on the storage area for UF_6 cylinders is generally not considered as a design basis accident. However, this scenario may need to be considered in the design extensions conditions analysis. In accordance with specific site considerations, engineered provisions such as drainage or rafts may minimize the potential of a significant pool fire.

5.152. Special consideration should be given to the storage of cylinders with reprocessed uranium (including cylinders with heels) which represent higher radiation risk to personnel.

AGEING MANAGEMENT CONSIDERATIONS

5.153. In accordance with Requirement 32 of SSR-4 [1], the design of facility is required to take into account the ageing effects and the degradation mechanisms of systems, structures and components important to safety to ensure their reliability and availability during the lifetime of the facility.

5.154. The design should allow all systems, structures and components important to safety to be easily inspected in order to detect their ageing (static containment deterioration, corrosion) and to allow their maintenance or replacement if needed.

5.155. An ageing management programme should be implemented at the design stage to ensure that provisions are in place for timely maintenance of systems, structures and components important to safety and for anticipating equipment replacements.

5.156. Effectiveness of the ageing management programme for the facility should be reviewed and assessed periodically.

~~3.~~6. CONSTRUCTION OF CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

6.1. Requirements for the construction of conversion facilities and uranium enrichment facilities are established in Requirement 53 and paras 7.1–7.7 of SSR-4 [1]. General recommendations on the construction and construction management of nuclear installations are provided in IAEA Safety Standards Series No. SSG-38, Construction for Nuclear Installations [30].

~~3.1.~~6.2. For conversion facilities and uranium enrichment facilities, the criteria used for the construction of the building and the fabrication of the process equipment and components used in the facility and for their installation, should be the same as or more stringent than those used for the non-nuclear chemical industry, and should be specified as part of the design (e.g. seismic design).

6.3. The extent of regulatory involvement in construction should be commensurate with the hazards posed by the facility over its lifetime.

~~3.2.~~6.4. In addition to the construction programme (see Requirement 53 of SSR-4 [1]) and the management process by which the operating organization maintains control over construction, frequent visits to the construction site should be used to provide feedback of information to the construction contractor to avoid future operational problems.

3.3.6.5. EnrichmentUranium enrichment facilities are complex mechanical facilities and, as such, modularized components should be used in their construction. This enables equipment to be tested and proven at manufacturers' shops before its installation at the uranium enrichment facility. This will also aid commissioning, maintenance and decommissioning of the facility. Components and cables in ana uranium enrichment facility should be clearly labelled, owing to the complexity of the control systems.

3.42. The construction and commissioning phases may overlap. Construction work in an environment in which nuclear material is present owing to commissioning can be significantly more difficult and time consuming than when no radioactive material is present.

6.6. Preferably, construction work should be completed before commissioning of the facility or its parts. In cases when the construction and commissioning or operational stages overlap, appropriate precautions should be considered to minimize potential adverse impact of construction activities on safety. Consideration should be also given to the protection of equipment which has been already installed.

6.7. All structures and components after their installation should be properly cleaned and painted with suitable primer followed by appropriate surface treatment.

6.8. The effects of nearby activities handling corrosive substances should also be considered.

6.9. Contractors engaged in the construction work should be properly assessed for their integrity and competency in adhering strictly to design requirements and quality requirements to ensure the future safety of the facility.

4.7. COMMISSIONING OF CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

7.1. The requirements for commissioning are established in Requirement 54 and paras 8.1–8.23 of SSR-4 [1].

7.2. The operating organization should make the best use of the commissioning stage to become completely familiar with the facility. It should also be an opportunity to promote and further enhance safety culture, including positive behaviors and attitudes, throughout the entire organization.

~~4.1.~~7.3. For a conversion facility or ~~an~~a uranium enrichment facility, the commissioning should be divided into two main ~~phases~~stages:

~~(5) Inactive or 'cold'~~Cold commissioning (i.e. commissioning ~~prior to~~before the introduction of uranium into the facility).

(1) In this ~~phase~~stage, the facility's systems are systematically tested, ~~from~~ both individual items of equipment and the systems in their entirety. As much verification and testing as possible should be ~~carried out~~performed because of the relative ease of taking corrective actions in this ~~phase~~stage. However, given the low radiation levels in a conversion facility or ~~an~~a uranium enrichment facility, it would also be acceptable to ~~carry out~~conduct some of these activities in the subsequent ~~phase~~stage.
The operating organization should ~~also~~ take the opportunity to finalize the set of operational documents and to train the personnel in the safety requirements, operating procedures (including those for maintenance) and emergency procedures. At the end of this stage, the operating organization should provide evidence of conformity of the facility to design requirements and safety requirements and operational readiness for active commissioning to the regulatory body.

(2) ~~Active or 'hot'~~Hot commissioning (i.e. commissioning with the use of uranium). In this ~~phase~~stage, the safety systems and measures for confinement and for radiation and chemical protection should be tested.
Testing in this ~~phase~~stage should consist of: (i) checks for airborne radioactive material and checks of levels of exposure at the workplace; (ii) smear ~~checks on~~sampling of surfaces; (iii) checks for gaseous and liquid discharges~~ and releases of liquids~~; and (iv) checks for the unexpected accumulation of material.
Testing in this second step should be ~~carried out~~performed with the use of natural or depleted uranium to prevent risks of criticality, to minimize occupational exposure and to reduce the possible need for decontamination.

7.4. During cold commissioning the operating organization should verify (by a ‘smoke test’ or other equivalent method) that the location of key radiological instruments is correctly designed, i.e. that the air flows within the plant are as estimated by the calculations during the design stage.

7.5. During commissioning and later during operation of the facility, the estimated doses to personnel that were calculated should be compared with the actual doses or dose rates. If, in operation, the actual doses are higher than the calculated doses, corrective actions should be taken, including making any necessary changes to the licensing documentation (i.e. the safety analysis report) or adding or changing safety features or work practices.

4.2.7.6. To minimize the contamination of equipment during commissioning, process testing with uranium should be used where necessary to evaluate the performance of instruments for the detection of radiation or to evaluate the processes for the removal of uranium.

3.43. The verification process, defined in para. 8.4 of Ref. [1], should be completed prior to the operation stage. The operating organization should use the commissioning stage to become familiar with the facility. The facility management should use the commissioning stage to develop a strong safety culture and good behavioural attitudes throughout the entire organization.

3.44. During commissioning and later during operation of the facility, the estimated doses to workers that were calculated should be compared with the actual doses or dose rates. If, in operation, the actual doses are higher than the calculated doses, corrective actions should be taken, including making any necessary changes to the licensing documentation (i.e. the safety case) or adding or changing safety features or work practices.

7.7. Sufficient operating personnel, suitably qualified and with the necessary training, should be available at each stage of the commissioning.

7.8. Where possible, lessons identified from the commissioning and operation of similar conversion facilities or uranium enrichment facilities should be sought out and applied.

4 OPERATION

5.8. CHARACTERISTICS OF CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

ORGANIZATION OF OPERATION OF CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

5.1.8.1. The distinctive features of a conversion facility or ana uranium enrichment facility thatdescribed in Section 2 should be taken into account in meeting the safety requirements established in Ref.Section 9 of SSR-4 [1] are:].

4.1. The relatively low radiotoxicity of the radioactive material but with the potential for chemical and toxicological impacts on workers, the public and the environment, mainly due to: (1) large amounts of UF_6 at pressures above atmospheric pressure; (2) reaction products (UO_2F_2, HF) associated with liquid UF_6 operations; and (3) storage and handling of large amounts of solid uranium compounds.

4.2. The potential for fire and explosions resulting in a release of radioactive material (e.g. an H_2 explosion in a reduction furnace in a conversion facility or a lubrication oil fire in a gaseous diffusion facility).

4.3. The potential for criticality accidents that may result from enriched uranium operations.

4.4. Significant chemical hazards, e.g. in conversion facilities, large amounts of anhydrous liquid HF and ammonia may be present; in diffusion enrichment facilities, a potential for a release of ClF_3 may exist.

4.5. In this section, specific recommendations on good practices and additional considerations in meeting the safety requirements for a conversion facility or an enrichment facility are presented.

4.6.

8.2. The internal safety committee in a conversion facility or a uranium enrichment facility, in accordance with para. 4.29 of SSR-4 [1], should be created from the safety committee established for commissioning (see also para 3.26).

STAFFING OF A CONVERSION FACILITY OR URANIUM ENRICHMENT FACILITY

8.3. Requirement 56 of SSR-4 [1] states, that: **"[t]he operating organization shall ensure that the nuclear fuel cycle facility is staffed with competent managers and sufficient qualified personnel for the safe operation of the facility."**

8.4. Para. 9.16 of SSR-4 [1] states, that: "[a] detailed programme for the operation and utilization of the nuclear fuel cycle facility shall be prepared in advance and shall be subject to the approval of senior management."

The programme for the operation and utilization of the conversion facility or uranium enrichment facility should be reviewed and updated periodically to ensure that it is consistent with and supports long term objectives.

8.5. The staffing should address the development of professional and managerial skills and experience, and should take into account losses of personnel and their knowledge due to retirement and other reasons. The long term staffing plan should allow sufficient time for the transfer of responsibilities to new personnel, and thereby facilitate continuity in the conduct of duties.

8.6. The staffing of a conversion facility or uranium enrichment facility should be based on the functions and responsibilities of the operating organization. A detailed analysis of tasks and activities to be performed should be made to determine the staffing and qualification needs at different levels in the organization. This analysis should also be used to determine the recruitment, training and retraining needs for the facility.

8.7. The operating organization should establish the necessary arrangements to ensure the safety of personnel and the safe operation of the conversion facility or uranium enrichment facility during situations in which a large number of personnel might be unavailable, such as during an epidemic or a pandemic affecting areas in which personnel live. Such arrangements should include the following:

(a) Retaining a minimum number of qualified personnel on the site to ensure safe operation of the facility;

(b) Ensuring that a minimum number of qualified back-up personnel remain available off the site;

(c) Establishing additional measures to prevent the spread of an infection on the site, in accordance with national and international guidance (e.g. enabling remote working for non-essential personnel).

QUALIFICATION AND TRAINING OF PERSONNEL

5.2.8.8. The safety requirements relating to the qualification and training of facility personnel are established in paras 9.8–9.13 and III.18–III.21 of Appendix III of Ref. [1]. Recommendations are provided in paras 4.6–4.25 of Ref. [4]. The training on prevention and mitigation of fires and explosions that could result in a release of radioactive material (para. III.20 of Appendix III of Ref. [1]) should cover: (1) an H_2 explosion in a reduction furnace in a conversion facility; and (2) a lubrication oil fire in a gaseous diffusion enrichment facility. In addition, personnel should be provided periodically with basic training in radiation safety.Requirements 56 and 58 of SSR-4 [1]. Detailed recommendations are provided in paras 4.6–4.25 of GS-G-3.1 [7].

8.9. GENERAL RECOMMENDATIONS FOR FACILITY OPERATIONTo ensure that the The operating personnel of a conversion facility or a uranium enrichment facility operatesshould receive specific training in the mitigation of chemical effects and the detection of overexposure: see para. 9.41 of SSR-4 [1].

8.10. In addition to the specific training required in para 9.49 of SSR-4 [1], the training on prevention and mitigation of fires and explosions that could result in a release of radioactive material should be provided. Such training should cover: (1) a H2 explosion in a reduction furnace in a conversion facility; and (2) a lubrication oil fire in a uranium enrichment facility. In addition, personnel should be provided periodically with basic training in nuclear and radiation safety.

8.11. Complementary training of safety and security personnel and their mutual participation in exercises of both types should be part of the training programme to effectively manage the interface between safety and security. In particular, personnel with responsibilities and expertise in safety analysis and safety assessment as well within the as in operational safety, including radiation protection personnel and nuclear criticality safety staff, should be provided with a working knowledge of the security requirements of the facility and security experts should be provided with a working knowledge of the safety considerations of the facility, so that potential conflicts between safety and security can be resolved effectively.

OPERATIONAL DOCUMENTATION

5.3.8.12. Requirement 57 and paras 9.27–9.37 of SSR-4 [1] require that operational limits and conditions under normal circumstances, a set of lower level sublimitsbe developed for a conversion facility or a uranium enrichment facility. The safety significance of the operational limits and conditions, the operating envelope, should be defined. Such sublimits as well as of the action levels and conditions should be clear, published and well understood by the personnel operating the facility. The set of action levels should be defined and maintained by the operating organization.

5.4.8.13. Operating documentsOperational documentation should be prepared that list all the operational limits and conditions under which the facility is operated. Annexes III and IV give examples of parameters that can be used for defining the operational limits and conditions in the various processing areas of the facility.

5.5.8.14. GenericIn accordance with para. 9.31 of SSR-4 [1], limits should alsoon operating parameters are required to be setestablished for thea conversion facility. or a uranium enrichment facility. Examples of such limits are the following:

(a) The maximum enrichment of uranium allowed at the facility;
(b) The feed specification limits;
(c) The maximum allowed inventories for processes and for the facility.;
(d) Minimum staffing requirements and availability of specific expertise (nuclear criticality expert).

5.6.8.15. Consideration should be given to ensuring that uranium is present only in areas designed for the storage or handling of uranium. ProgrammesTo meet the requirements established in para. 6.121 and in Requirement 64 of SSR-4 [1], programmes should be put in place for routine monitoring forof surface contamination and airborne radioactive material, and more generallycontamination, and for ensuring an adequate level of housekeeping.

5.7.8.16. Operating procedures should be developed to control process operations directly should be developed. The procedures should include directions for attaining a safe state of the facility for all anticipated operational occurrences and accident conditions. Procedures of this type should include the actions requiredneeded to ensure criticality safety, fire protection, emergency planning and environmental protection.

5.8.8.17. The operating procedures for the ventilation system should be specified for fire conditions, and periodic testing of the ventilation system should be carried out and fire drills should be performed.

MAINTENANCE, CALIBRATION AND PERIODIC TESTING AND INSPECTION

8.18. When carrying out The safety requirements relating to maintenance, calibration, periodic testing and inspection of conversion facilities and uranium enrichment facilities are established in Requirement 65 and paras 9.74–9.82 of SSR-4 [1].

8.19. Maintenance activities in a conversion facility or ana uranium enrichment facility should be pre-authorized on the basis of a safety assessment.

8.20. Before maintenance is performed in areas where fissile material is located (or near such areas), criticality safety staff should be consulted (see also para. 5.46 of SSG-27 [2]).

8.21. Maintenance activities using radioactive sources or X-ray generators (e.g. those used for the inspection of welds or flow gauges) should be coordinated with radiation protection personnel especially when performed by sub-contractors.

5.9.8.22. When performing maintenance in a conversion facility or a uranium enrichment facility, particular consideration should be given to the potential for surface contamination or airborne radioactive material, and to specific chemical hazards such as hazards due to uranium compounds, hydrogen fluoride, fluorine, hydrogen and nitric acid.

~~5.10.~~8.23. Maintenance should follow good practices with particular consideration given to the following:

(a) Work control~~, —~~ (e.g. handover and handing back of documents, means of communication and visits to job sites, changes to the planned scope of work, suspension of work ~~and~~, ensuring safe access~~.~~);
(b) Equipment isolation~~, —~~ (e.g. disconnection of ~~electrical cabling and~~equipment from power supply, heat and pressure piping ~~and~~, venting and purging of equipment~~.~~);
(c) Testing and monitoring~~, —~~ (e.g. checks before commencing work, monitoring during maintenance ~~and~~, checks for recommissioning~~.~~);
(d) Safety precautions for work~~, —~~ (e.g. specification of safety precautions, ensuring the availability of fully functional personal protective equipment and ensuring its use ~~and~~, emergency ~~procedures.~~plans);
(e) Reinstallation of equipment~~, —~~ (e.g. reassembly, reconnection of pipes and cables, testing, cleaning the job site ~~and~~, monitoring after recommissioning~~.~~);

~~4.7. Attention should also be paid to the handling of radioactive sources and X ray equipment used in a conversion facility or an enrichment facility for specific purposes, e.g. those used for the inspection of welds.~~

~~4.8. Additional precautions may also be necessary for the prevention of a criticality accident (see paras 7.20–7.23).~~

(f) Verifying that after maintenance is performed the work area and equipment have been placed back within normal safe condition.

8.24. Changing equipment configurations during maintenance might result in abnormal settings and potential occurrence of unexpected operational modes with no prior safety analysis or operational limits and conditions. This should be prevented by consulting criticality safety staff before the maintenance is performed on installations that may contain enriched uranium or are located near a storage area of enriched uranium.

8.25. All temporary changes to the facility configuration during maintenance activities should be coordinated between safety and security specialists to avoid potential conflicts (e.g. loss of electrical power supply on some safety systems, opening of barriers and doors). Compensatory measures should be implemented as necessary. Particular attention should be given to changes which could affect the systems or structures required for neutron isolation of adjacent fissile units. When the changes affect temporarily these systems or structures, it should be ensured that these systems or structures continue to deliver their required safety function when reinstated.

5.11.8.26. Compliance of the operational performance of the ventilation systemsystems with the fire protection requirements (see para 4.45) should be verified on a regular basis.

5.12.8.27. A programme offor calibration and periodic inspections of the facility should be established, whose. Its purpose is to verify that the facility isand its structures, systems and components are operating in accordance with the operational limits and conditions. Suitably qualified and experienced personspersonnel should carry outperform calibrations and these inspections.

Inspection of cylinders in storage

8.28. Paragraph III.22 of Appendix III of Ref. [1] establishes the requirements relatingPlaces in the process line, identified by the operating organization as places with potential for accumulation of uranium compounds, should be periodically inspected.

8.29. 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 should be established at long term storage facilities to monitor and record the level of cylinderscorrosion (particularly at plugs and valves and along the skirt welds).

AGEING MANAGEMENT

8.30. The operating organization should take into account the following in storage. Informationimplementing an ageing management programme in accordance with Requirement 60 of SSR-4 [1]:

(a) Ensuring support for the ageing management programme by the management of the operating organization;
(b) Ensuring early implementation of an ageing management programme;
(c) Following a proactive approach based on an adequate understanding of the ageing of structures, systems and components, rather than a reactive approach responding to failures of structures, systems and components;
(d) Ensuring optimal operation of structures, systems and components to slow down the rate of ageing degradation;
(e) Ensuring the proper implementation of maintenance and testing activities in accordance with operational limits and conditions, design requirements and manufacturers' recommendations, and following approved operating procedures;
(f) Minimizing human performance factors that might lead to premature degradation, through enhancement of personnel motivation, sense of ownership and awareness, and understanding of the basic concepts of ageing management;
(g) Ensuring availability and use of correct operating procedures, tools and materials, and of a sufficient number of qualified personnel for a given task;
(h) Collecting operating experience feedback to learn from relevant ageing related events.

8.31. The ageing management programme should consider the technical as well as the non-technical aspects of ageing, and its effectiveness should be regularly assessed and reviewed.

5.13.8.32. The periodic testing of UF_6 cylinders is provided in Sections 4 and 5 of Ref. [7].tests and inspections should be completed by regular checks performed by the operating personnel, such as the following:

(a) Monitoring of deterioration (measurement of metallic impurities in fluoric acid);
(b) Regular visual inspections of uranium powder pipes;
(c) Monitoring of operating conditions (e.g. taking heat images of electrical cabinets, check of temperatures of ventilator bearings).

CONTROL OF MODIFICATIONS

8.33. ~~A standard process for any modification should be applied in~~Requirement 61 of SSR-4 [1] states that "**[t]he operating organization shall establish and implement a programme for the control of modifications to the facility.**" The management system for a conversion facility or ~~an~~a uranium enrichment facility~~. This~~ should include a standard process ~~should use a modification control form or an equivalent management tool.~~for all modifications (see para. 3.18). The ~~modification~~work control ~~form~~system, quality assurance procedures and appropriate testing procedures of the facility should be used for the implementation of modifications.

~~5.14.~~8.34. All proposed modifications should contain a description of the modification is and why it is being made~~. The main purpose of the modification control form is to ensure that a~~ , provide the basis for safety assessment ~~is conducted for~~of the modification~~. The modification control form should be used to~~, and identify all the aspects of safety that ~~may~~might be affected by the modification, and to demonstrate that adequate and sufficient safety provisions are in place to control the potential hazards.

8.35. ~~Modification control forms~~The operating organization should prepare procedural guidelines and provide training to ensure that the responsible personnel have the necessary training and authority to ensure that modification projects are carefully considered: see paras 9.57(e) and 9.58 of SSR-4 [1]. The safety of modifications should be assessed for potential hazards during installation, commissioning and operation.

~~5.15.~~8.36. Proposed modifications should be scrutinized by and be subject to approval by qualified and experienced persons to verify that the arguments used to demonstrate safety are suitably robust. This ~~should be considered~~is particularly important if the modification could have an effect on criticality safety. The depth of the safety arguments and the degree of scrutiny to which they are subjected should be commensurate with the safety significance of the modification~~.~~ (see also para. 9.59 of SSR-4 [1]).

8.37. In accordance with para 4.31(d) of SSR-4 [1], the safety committee is required to review the proposed modifications. Suitable records of their decisions and recommendations should be kept.

5.16.8.38. The modification control form should also specify which documentation will need to be updated as a result of the modification. (e.g. training plans, specifications, safety assessment, notes, drawings, engineering flow diagrams, process instrumentation diagrams, operating procedures). Procedures for the control of documentation should be put in place to ensure that documents are changed within a reasonable time period following the modification. Personnel should be informed and trained accordingly before operation commences.

5.17.8.39. An adequate management process should be used as an overall means of monitoring the progress of modifications through the system and as a means of ensuring that all modification proposals receive an equivalent and sufficient level of scrutiny. The modification control formdocumentation should also specify the functional checks that are requiredshould be performed before the modified system may be declared fully operational again.

8.40. Modifications performed on design, layout or procedures of the facility might adversely affect security equipment and vice versa. For example, malfunction of safety equipment might damage nearby security equipment. Therefore, before approval and implementation, any proposed changes to the facility or to management arrangements should be reviewed, assessed and endorsed to ensure that all applicable safety requirements and criteria are met. In addition, the interface with security should be evaluated to verify that safety measures and security measures do not compromise each other: see Requirement 75 of SSR-4 [1].

5.18.8.41. The modifications made to a facility (including those to the operating organization) should be reviewed on a regular basis to ensure that the combinedcumulative effects of a number of modifications with minor safety significance do not have hitherto unforeseen effects on the overall safety of the facility. This should be part of (or additional to) the periodic safety review or an equivalent review process.RADIATION PROTECTION

8.42. In a conversion facility or an enrichment facility, the main radiological hazard for both the workforceThe modification documentation (see para. 9.57(f) of SSR-4 [1]) should be retained at the facility in accordance with national requirements.

CONTROL OF NUCLEAR CRITICALITY HAZARDS

8.43. The requirements for criticality safety in conversion facilities and uranium enrichment facilities are established in Requirement 66 and paras. 9.83–9.85 and 9.88 of SSR-4 [1], and general recommendations are provided in SSG-27 [2]. In conversion facilities and uranium enrichment facilities that process uranium with a ^{235}U enrichment of more than 1%, it is particularly important that the procedures for controlling criticality hazards are strictly applied.

8.44. Operational aspects of the control of criticality hazards in conversion facilities and uranium enrichment facilities should be taken into consideration, including the following:

(a) Prevention of unexpected changes in conditions that could increase the probability of a criticality accident; for example, unplanned accumulation of uranium compounds (e.g. in ventilation ducting), inadvertent precipitation of material containing uranium in storage vessels or loss of neutron absorbers;
(b) Control of the enrichment level to detect deviations that could lead to enrichment above the maximum enrichment used in criticality safety analysis, both steady state and transients, before a significant amount of material above this limit has accumulated;
(c) Management of moderating materials; for example, undertaking checks before an empty cylinder is used in the facility to receive material enriched by 235U above 1%, to ensure that no hydrogenous material (e.g. water, oil, or plastics) is present in the cylinder;
(d) Management of mass in transfer of uranium (procedures, mass measurement, systems and records) for which safe mass control is used;
(e) Reliable methods for detecting the onset of any of the foregoing conditions;
(f) Periodic calibration or testing of systems for the control of criticality hazards;

(g) Evacuation drills to prepare for the occurrence of a criticality and/or the actuation of an alarm.

8.45. For any wet cleaning process, a safe uranium holdup limit should be defined. It should be verified that the uranium holdup is below this safe limit before the wet cleaning process can be started (see also para. 9.88(b) of SSR-4 [1]).

RADIATION PROTECTION

8.46. The requirements for radiation protection in operation are established in Requirement 67 and paras. 9.90-9.101 of SSR-4 [1] and in GSR Part 3 [15]; recommendations are provided in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [31]. The operating organization should have a policy to optimize protection and safety, and is required to ensure doses are below national dose limits and within any dose constraints set by the operating organization (see para. 9.91 of SSR-4 [1]). The policy should address the minimization of exposure to radiation by all available physical means and by administrative arrangements, including the use of time and distance during operations and maintenance activities.

5.19.8.47. In a conversion facility or a uranium enrichment facility, the main radiological hazard under accident conditions for both the personnel and members of the public is from the inhalation of airborne material containing uranium compounds. In conversion facilities, insoluble compounds of uranium such as the uranium oxides UO_2dioxide and U_3O_8triuranium octoxide pose a particular hazard because of their long biological half-lives (and therefore effective half-lives)[4]. Thus,In accordance with para. 9.99 of SSR-4 [1], close attention shouldis required to be paid to the confinement of uranium powders and the control of contamination in the workplace. In uranium enrichment facilities, most uranium compounds have a short biological half-life. The chemical hazards for the uranium compounds found in conversion facilities and uranium enrichment facilities dominate the radiological

[4] The biological half-life is the time taken for the amount of a material in a specified tissue, organ or region of the body (or any other specified biota) to halve as a result of biological processes. The effective half-life is the time taken for the activity of a radionuclide in a specified place to halve as a result of all relevant processes.

hazards.

5.20.8.48. In conversion facilities and uranium enrichment facilities, in normal operation, the main characteristic that needs to be taken into account in the development of measures for radiation protection is that the external and internal dose rates are relatively low. It is required to put in placeTo meet the requirements established in paras 9.94 and 9.120 of SSR-4 [1] for conversion facilities (if applicable) or for uranium enrichment facilities, emergency arrangements for criticality incidents, which should be put in place, as these are the only events in which a high external dose rate would be encountered.

5.21.8.49. Interventions for maintenance and/or modifications are major activities that require justification and optimization of protective actions, as specified in Ref. [5GSR Part 3 [15]. The procedures for intervention should include the following:

(a) Estimation of the external exposure prior tobefore an intervention in areas such as those for the processing and handling of ashes containing thorium gamma emitters arising from the fluorinefluorination reactor in conversion facilities;.
(b) Preparatory activities to minimize the doses due to occupational exposure, including:
   (i) Identifying specifically the risks associated with the intervention;
   (ii) Specifying in the work permit the proceduresprotective measures for the intervention (such as for the individual and collective means of protection, – (e.g. use of masks, clothing and gloves, and time limitation);).
(c) Measurement of the occupational exposure during the intervention;.
(d) Implementation of feedback of information for identifying possible improvements.

8.50. The risks of exposure of members of the public should be controlledminimized by ensuring that, as far as reasonably practicable, radioactive material is kept away and/or removed from ventilation exhaust gases to prevent its being discharged to the atmosphere. “

~~5.22.~~8.51. The monitoring results from the radiation protection programme ~~shall~~should be compared with the operational limits and conditions and corrective actions ~~shall~~are required to be taken if necessary~~" (~~ (see para. 9.~~43~~34 of ~~Ref.~~SSR-4 [1]). Furthermore, these monitoring results should be used to verify the dose calculations made in the initial environmental impact assessment.

~~**Control of internal exposure**~~

~~5.23.~~8.52. Internal exposure should be controlled by the following means:

(a) Performance targets should be set for all parameters relating to internal exposure, e.g. levels of contamination.

(b) Enclosures and ventilation systems should be routinely inspected, tested and maintained to ensure that they continue to fulfil their design requirements. Regular flow checks should be ~~carried out~~performed at ventilation hoods and entrances to ~~containment~~confinement areas. Pressure drops across air filter banks should be checked and recorded regularly. Surveillance of the ventilation system should be conducted to detect any unwanted accumulation of fissile and radioactive material.

(c) A high standard of housekeeping should be maintained at the facility. Cleaning techniques should be used that do not give rise to airborne radioactive material, e.g. the use of vacuum cleaners with HEPA filters.

(d) Regular contamination surveys of areas of the facility and equipment should be ~~carried out~~performed to confirm the adequacy of cleaning programmes.

(e) Contamination zones should be delineated and clearly indicated.

(f) Continuous air monitoring should be ~~carried out~~performed to alert facility operators if levels of airborne radioactive material exceed predetermined action levels.

(g) Mobile air samplers should be used ~~at~~where there are possible sources of contamination, as necessary.

(h) An investigation should be ~~carried out~~conducted promptly in response to ~~readings~~the detection of high levels of airborne radioactive material.

(i) Personnel and equipment should be checked for contamination and should undergo decontamination if necessary, ~~prior to~~

~~their~~before leaving contamination zones. Entry to and exit from the work area should be controlled to prevent the spread of contamination. In particular, changing rooms and decontamination facilities should be provided.

(j) Temporary means of ventilation and means of confinement should be used when intrusive work increases the ~~risk of~~potential for causing contamination by airborne radioactive material (e.g. activities for vessel connection and/or disconnection, periodic testing, inspection and maintenance).

(k) Personal protective equipment should be made available for dealing with releases of chemicals (e.g. acid gas) or radioactive material from the normal means of confinement in specific operational circumstances (e.g. during disassembly or the cleaning of process equipment).

(l) Personal protective equipment should be maintained in good condition, should be cleaned as necessary, and should be inspected.

(m) Any ~~staff~~personnel having wounds should protect them with an impervious covering for work in contamination zones.

~~5.24.~~8.53. In vivo monitoring and biological sampling should be made available as necessary for monitoring doses due to occupational exposure. Since most of the uranium present in conversion facilities and uranium enrichment facilities is in soluble form, the frequency of sample collection and the sensitivity of analytical laboratory equipment should be appropriate to detect and estimate any uptake of uranium for routine or emergency purposes.

~~5.25.~~8.54. The extent and type of ~~the~~workplace monitoring should be commensurate with the ~~levels~~expected level of airborne ~~radioactive material and the~~activity, contamination ~~levels~~and radiation type, and the potential for any of ~~workplaces~~these parameters to change.

~~5.26.~~8.55. ~~The~~For exposures which are expected to be low, the method for assessing doses due to internal exposure may be based upon the collection of data from air sampling in the workplace, in combination with ~~worker~~personnel occupancy data. This method should be assessed~~,~~ and should be reviewed as appropriate by the regulatory body.

~~5.27.~~8.56. On~~ the~~ completion of maintenance work, the area concerned should be decontaminated if necessary, and air sampling and smear ~~checks~~sampling of surfaces should be ~~carried out~~performed to confirm that the area can be returned to normal use.

~~5.28.~~8.57. In addition to industrial safety requirements for entry into confined spaces, if entry is necessary into vessels that have contained uranium, radiation dose rate surveys should be ~~carried out~~performed inside the vessel to determine whether any restrictions on the allowed ~~time period for~~ working time are required.

~~5.29.~~8.58. Preference should be given to estimating the internal dose received by members of the public using environmental monitoring data. However, internal doses may also be estimated by using qualified dispersion models and dose models in conjunction with reliable data on effluents.

~~**Control of external exposure**~~

~~5.30.~~8.59. There are ~~only~~ limited operations in a conversion facility or ~~an~~a uranium enrichment facility where specific measures for controlling external exposure are required. Typically, these will be areas where the following activities take place:

(a) Operations involving recently emptied cylinders;
(b) Storage of bulk quantities of uranium;
(c) Handling of UF_6 cylinders;
(d) Handling of ashes from fluorination.

~~5.31.~~8.60. ~~Moreover, it should be noted that much~~The control of external exposure should account for the dose from neutrons as necessary, especially in areas where UF_6 is stored in bulk (neutrons are emitted from spontaneous fission and alpha-neutron reactions). In addition, newly emptied UF_6 cylinders might also result in external gamma radiation doses that need to be controlled. Much more extensive controls for limiting external exposure will be required in the processing of reprocessed uranium than in the processing of natural uranium.

~~5.32.~~8.61. Radioactive sources are also used in a conversion facility or ~~an~~a uranium enrichment facility for specific purposes, e.g.

radioactive sources are used for checking uranium enrichment.

~~5.33.~~8.62. External exposure should be controlled by:

(a) Ensuring that significant amounts of uranium and recently emptied cylinders are remote or appropriately shielded from areas of high occupancy;

(b) Ensuring that radioactive sources are changed by suitably qualified and experienced persons;

(c) Performing routine surveys of radiation dose rates.

~~5.34.~~8.63. Additional controls should be considered if reprocessed uranium is used as a feedstock at the facility. Such material has a higher specific activity than uranium from natural sources and thus has the potential to increase substantially both external and internal exposures. It could also introduce additional radionuclides into the waste streams. A comprehensive assessment of doses due to occupational exposure and exposure of the public should be ~~carried out~~conducted before the first introduction of uranium from other than natural sources.

~~CRITICALITY CONTROL~~

~~4.9. In conversion facilities and enrichment facilities that process uranium with a ^{235}U concentration of more than 1%, it is particularly important that the procedures for controlling criticality hazard are strictly applied (paras 9.49 and 9.50 of Ref. [1]).~~

~~4.10. In addition to the requirement established in para. III.23 of Appendix III of Ref. [1], operational aspects of the control of criticality hazards in conversion facilities and enrichment facilities should include:~~

~~(a)~~ ~~Anticipation of unexpected changes in conditions that could increase the risk of a criticality accident; for example, unplanned accumulation of uranium fluorides (e.g. in ventilation ducting), inadvertent precipitation of material containing uranium in storage vessels or loss of neutron absorbers;~~

~~- Management of the moderating materials; for example, before a new product cylinder is used in the facility, checks should be undertaken to ensure that no hydrogenous material is present in the cylinder (e.g. water or oil);~~

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~~(a) Management of mass in transfer of uranium (procedures, mass measurement, systems and records) for which safe mass control is used;~~

~~(a) Reliable methods for detecting the onset of any of the foregoing conditions;~~

~~(a) Periodic calibration or testing of systems for the control of criticality hazards;~~

~~(a) Evacuation drills to prepare for the occurrence of a criticality and/or the actuation of an alarm.~~

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INDUSTRIAL AND CHEMICAL SAFETY

8.64. ~~See also para. 7.3.~~ The requirements relating to industrial and chemical safety are established in Requirement 70 of SSR-4 [1].

~~5.35.~~8.65. The industrial and chemical hazards ~~found~~present in conversion facilities and uranium enrichment facilities may be summarized as follows:

(a) Chemical hazards due to the presence of ~~HF (e.g from~~ UF_6~~), F_2, HNO_3, NH_3~~, hydrogen fluoride (including hydrogen fluoride produced through hydrolysis of UF_6), fluorine, nitric acid, ammonia and uranium compounds;

(b) Chemical hazards due to the presence of UF_6, hydrogen fluoride (including produced through hydrolysis of UF_6 in contact with air moisture), fluorine, nitric acid, ammonia and uranium compounds;

~~(b)~~(c) Explosion hazards due to ~~H_2, NH_3~~hydrogen, ammonia, ammonium nitrate, methanol, solvents and oxidants present in diffusion cascades;

~~(c)~~(d) Asphyxiation hazards due to the presence of nitrogen or carbon dioxide.

8.66. Presence of hydrogen fluoride in conversion facilities represents the main hazard for the protection of personnel, public and the environment. Special consideration should be given to storage, handling and processing of hydrogen fluoride on the site (for example during transfer of large volumes of hydrogen fluoride from storage tanks to the process area). Industry specific national requirements should be applied as appropriate.

~~5.36.~~8.67. The threshold of ~~HF~~hydrogen fluoride that a human can detect by smelling is lower than the occupational exposure level.levels that can result in acute health effects. As a consequence, specific routine occupational measurements for HF hydrogen fluoride do not need notto be implemented. In addition, releases of UF_6, generate colourless gaseous hydrogen fluoride and a visible white cloud of UO_2F_2uranyl fluoride particulates. For release of UF_6 and HFother chemical releases that can easilyresult in visible clouds, periodic training should be seen, leadinggiven to all site personnel to follow the requirement established in para. III.19 of Ref. [1]:procedure “see, evacuate or shelter, and report”.

5.37.8.68. A health surveillance programme should be set up, in accordance with national regulations, for routinely monitoring the health of workerspersonnel who maymight be exposed to uranium and associated chemicals, e.g. HF, F_2hydrofluoric acid, fluorine and HNO_3nitric acid. Both the radiological radiotoxicity and the chemical toxicity effects of uranium should be considered, as necessary, as part of the health surveillance programme.

8.69. The exposure of personnel to chemical hazards should be assessed using a method similar to that for the assessment of radiation doses and should be based upon the collection of data from air sampling in the workplace, in combination with personnel occupancy data. This method should be assessed and reviewed as appropriate by the regulatory body. The acceptable levels of exposure for various chemical hazards in a conversion facility or a uranium enrichment facility can be found in Ref. [20].

8.70. The selection of personal protective equipment should be commensurate to the hazard present (e.g. acid filters for protective equipment for acids, particulate filters for particulates, combination filters where both hazards are present).

5.38.8.71. Fire hazard analyses should be repeatedconducted periodically to incorporate changes that maymight adversely affect the potential for and spread of fires (see para. 4.38paras 5.52–5.55).

8.72. RISK OF A health surveillance programme should be set up, in accordance with national regulations, for routinely monitoring the health of personnel who might be exposed to uranium and associated chemicals (e.g. hydrogen fluoride, beryllium, ammonia, nitric acid, sulphuric acid, potassium hydroxide and sodium hydroxide). Both the radiological and the chemical effects of uranium should be considered, as necessary, as part of the health surveillance programme.

8.73. During an emergency, special consideration should be given to the presence of both chemical and radiological hazards.

OVERFILLING OF CYLINDERS

5.39.8.74. The corresponding requirement is established in para. III.27 of Ref. [1]. Fill limits for cylinders should be established to ensure that, when UF_6 expands (by around 35%) on liquefaction, hydraulic rupture does not occur. Further, heating after liquefaction is required forcould result in hydraulic rupture to occur.

5.40.8.75. In a conversion facility or ana uranium enrichment facility, the weight of a cylinder being filled should be monitored to reduce the potential for overfilling, generally by means of weighing scales.

RISK OF OVERHEATING OF CYLINDERS

5.41.8.76. The requirements on the risk of overheating of cylinders are established in paras III.28 and III.29 of Appendix III of Ref. [1]. "In the event of an overfilled cylinder, UF_6 in excess shallshould be transferred by sublimation only" (e.g. by evacuation to a cooled low pressure receiving vessel).

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

HANDLING OF CYLINDERS CONTAINING LIQUID UF_6

5.42.8.78. Movement of cylinders containing liquid UF_6 should be minimized. Cylinders containing liquid UF_6 should be moved only using appropriately qualified apparatus that has been designated as important to safety. Relevant administrative operational limits and conditions should be established for the movement and storage of cylinders containing liquid UF_6, (e.g. predetermined paths, maximum allowed heights, speeds and distances during movement, dedicated storage areas, minimum cooling times, use of valve protectors and, restrictions on load movement above hot cylinders.).

ON-SITE HANDLING OF SOLID UF_6

5.43.8.79. The length of time requiredneeded for the cooling of a cylinder containing liquid UF_6 should be sufficient to ensure that all of the liquid UF_6 has solidified.

5.44.8.80. Cylinders containing solid UF_6 should be moved only using appropriately qualified apparatus that has been designated as important to safety.

5.45.8.81. Consideration should be given to the impact of a fire on a cylinder containing solid UF_6 (e.g. a fire involving a transporter for UF_6 cylinders). In case a cylinder containing UF_6 is directly affected by a fire, then its cooling should be considered in accordance with facility procedures to reduce the potential for rupture.

STORAGE OF TAILINGS STORAGE

5.46.8.82. Site licences generally define a site limit for the total amount of tailings of UF_6 (depleted uranium hexafluoride) that may be stored. Therefore, a plan for disposition of tailings should be prepared well before this limit is reached, to ensure that future arisingsgeneration of tailings dodoes not exceed the site limit. Tailings of UF_6 maystored for long term should be deconverted to a chemically more stable form of uranium, e.g. an oxide of uranium.

5.47.8.83. A recording and tracking system should be used to make periodic inspections of uranium accounting and ensure cylinder integrity.

5.48.8.84. Periodic inspections of the tailingstailings' storage area should be conducted to check standards of housekeeping and ensure that there is nothe fire load in the storage area does not exceed the load considered in the facility safety assessment.

MANAGEMENT OF RADIOACTIVE WASTE AND EFFLUENTS

5.49.8.85. The requirements relating to the management of radioactive waste and effluents in operation are established in Requirement 68 and paras 9.54102–9.57108 of Ref.SSR-4 [1].

5.50.8.86. Gaseous radioactive and chemical dischargesRadioactive gases and chemicals should be treated, where appropriate, by means of HEPA filters and chemical scrubbing systems. Performance standards should be set thatto specify performance levels at which filters or scrubber media are toshould be changed. After filter changes, tests should be carried outperformed to ensure that new filters are correctly seated and yield a removal efficiency as used in the analyses.

5.51.8.87. Liquid dischargesRadioactive liquids from operating processes should be treated effectively. Chemicals should be recovered and reused where possible. This is particularly important for HFhydrogen fluoride and ammonium nitrate produced in the deconversion process. Care should be taken to ensure that HFthat any radiological contamination in material being recycled is below the national threshold limits so that these chemicals are suitable for reuse externallyin other industrial applications.

5.52.8.88. One easy way to minimize the The generation of solid radioactive waste is to removeshould be minimized by removing as much outer packing as possible before material is transferred to contamination areas. Processes such asThe operating organization should use the best available techniques in minimizing the generation of radioactive waste (including incineration, metal melting and compaction can be used to reduce the volume of wastes.). As far as reasonably practicable and in accordance with national regulations, wasteradioactive material should be treated to allow its further use. Cleaning methods should be adopted at the facility that minimize the generation of waste.

5.53.8.89. In conversion facilities, unburnt ashes resulting from the fluorination of uranium should be treated to recover the uranium content. The remaining material (oxides of ^{234}Th, ^{230}Th and ^{228}Th if reprocessed uranium is used) should be stored safely. To limit exposure, the treatment of ashes should be postponed to benefit from the decay of ^{234}Th and ^{228}Th.

~~4.11. Information on the management of waste and effluents can also be found in Refs [8, 9].~~

EMERGENCY ~~PLANNING AND~~ PREPAREDNESS AND RESPONSE

8.90. The requirements for emergency ~~planning and~~ preparedness and response are established in Requirement 72 and paras ~~9.62–9.67~~, 9.120–9.132 of SSR-4 [1], in GSR Part 7 [23], and ~~paras III.31~~recommendations are provided in GS-G-2.1 [24] and ~~III.~~in IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [32~~–of Appendix III of Ref. [1].~~]. The conditions for declaration of an ~~off-site~~ emergency at a conversion facility or ~~an~~a uranium enrichment facility may include large releases of UF_6, ~~HF, F_2~~hydrofluoric acid, fluorine and ~~NH_3~~ammonia and also, depending on national requirements and facility specific considerations, criticality accidents, large fires (e.g. in the solvent extraction units of a conversion facility) or explosions.

8.91. The emergency preparedness arrangements should address how and when an interface with local and national emergency response organizations should be established. These arrangements should be tested periodically to ensure effective operation during an emergency. Clear communication and authorization protocols should be established with local authorities to ensure that the emergency response organization can respond effectively to an emergency at the facility.

8.92. The operating organization should ensure availability of personnel with specific expertise on the type of hazard present in facility as well as availability of specific environmental sampling equipment to support local authorities in decision making relating to an emergency at the facility.

8.93. Emergency plans and contingency plans should be developed in a coordinated manner, considering all responsibilities of the facility personnel and security forces, to ensure that in the case of an event when simultaneous response of both groups is needed, all crucial functions can be performed in a timely manner. Emergency response plans should consider nuclear security events as possible initiator of an emergency and their implications on emergency situations and should be coordinated with the security response. Strategies for rapidly determining the origin of events and deploying appropriate first responders (safety personnel, security forces or a combination of both) should be developed. These strategies should also include the roles and actions of security forces and emergency response personnel. The response to such events should be jointly exercised and evaluated by security forces and emergency response personnel. From these exercises or evaluations, lessons should be identified and recommendations should be made to improve the overall response to a potential event.

8.94. For establishing access control procedures for an emergency, when there is a necessity for rapid access and egress of personnel, safety specialists and security specialists should cooperate closely. Both safety objectives and security objectives should be met in an emergency, in accordance with regulatory requirements. When this is not possible, the best solution that takes into account both objectives should be pursued.

FEEDBACK OF OPERATING EXPERIENCE

8.95. Requirements on feedback of operating experience are established in paras. 9.133–9.137 of SSR-4 [1]. Further recommendations on the operating experience programme are provided in SSG-50 [12].

8.96. The programme for the feedback of operating experience at conversion facilities and uranium enrichment facilities should cover experience and lessons identified from events and accidents at the facility as well as from other nuclear fuel cycle facilities worldwide and other relevant non-nuclear accidents. It should also include evaluation of trends in operational disturbances, trends in malfunctions, near misses and other incidents that have occurred at conversion facilities and uranium enrichment facilities and, as far as applicable, at other nuclear installations. The programme should include consideration of technical, organizational and human factors.

~~6.~~9. PREPARATION FOR DECOMMISSIONING OF CONVERSION FACILITIES AND URANIUM ENRICHMENT FACILITIES

~~6.1.~~9.1. Requirements for the preparation for safe decommissioning of a conversion facility or ~~an~~a uranium enrichment facility are established in ~~Section 10 and~~ paras ~~III.33–III.35 of Appendix III of Ref. [1]. Recommendations on~~ 10.1–10.13 of SSR-4 [1] and general safety requirements for the decommissioning of ~~nuclear fuel cycle~~ facilities~~, including conversion facilities and enrichment facilities,~~ are ~~provided~~established in ~~Ref. [1].~~IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [33].

9.2. ~~Owing to~~ Special measures should be implemented during the ~~low~~ preparatory works for decommissioning to ensure that criticality control is maintained when handling equipment containing nuclear material whose subcriticality is controlled by geometry, moderation or poisoning. Care should also be taken for possible changes in the fissile material form.

~~6.2.~~9.3. In addition to the general preparations for decommissioning described in IAEA Safety Standards Series No. SSG-47, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities [34], the following preparatory steps specific ~~activity of the depleted, natural and LEU that is processed at~~to conversion facilities and uranium enrichment facilities~~, most of the waste resulting from the decommissioning of such facilities will be in the low level waste category.PREPARATORY STEPS~~ should be followed:

~~9.1. The preparatory steps for the decommissioning process should include the following:~~

(a) A post-operational cleanout should be performed to remove all the ~~gaseous~~ UF6 and the bulk amounts of uranium compounds and other hazardous materials from the process equipment. ~~The corresponding requirement is established in para. III.33 of Appendix III of Ref. [1].~~

(i) In conversion facilities, the first step is to ~~carry out~~perform dry mechanical cleaning, to minimize the generation of liquid waste. The uranium resulting from the dry mechanical cleaning process should be recovered.

- ~~*In diffusion enrichment facilities, ClF_3 or F_2 is used to convert solid uranium fluorides (e.g. UF_4, UF_5, UO_2F_2) into gaseous UF_6. In addition, flushing with a gas (e.g. N_2 or dry air) that does not react with UF_6 and other gases present in the facility should be used to remove the residual UF_6 and HF. The UF_6 and other gases are pumped and recovered in cold traps and chemical traps. If the complete recovery of uranium compounds by the use of ClF_3 or F_2 is not feasible, dry mechanical decontamination should be performed.*~~

(ii) In centrifuge uranium enrichment facilities, gaseous UF_6 is pumped out and recovered in cold traps. In addition, flushing with an inert gas (e.g. ~~N_2~~nitrogen) should be used to remove the residual UF_6 and ~~HF~~hydrogen fluoride.

(b) Any grounds (surface and subsurface), groundwater, parts of buildings and equipment contaminated with radioactive material or chemical material and their levels of contamination should be identified by means of comprehensive site characterization~~;~~.

(c) ~~The facility should be decontaminated to~~Risk assessments and method statements for the licensing of the decommissioning process should be prepared.

9.4. The decommissioning plan for conversion facilities and uranium enrichment facilities should be developed following the recommendations provided in SSG-47 [33]. Specific consideration should be given to the following elements:

(a) Description of the facility status at the beginning of decommissioning, including the list of systems that should be operational;

~~(a)~~(b) Determination of methods of decontamination of the facility to reach the levels required by the regulatory body for cleanup operations or the lowest reasonably achievable level of residual contamination;

(c) Preparation of risk assessments and method statements for the decommissioning process;

(d) Preparations for the dismantling of process equipment.

9.5. The developed decommissioning plan and the safety assessment should be periodically reviewed and updated throughout the commissioning and operation stages of the facility (see Requirements 8 and 10 of GSR Part 6 [33]) to take into account new information and emerging technologies to ensure that:

(a) The (updated) decommissioning plan is realistic and can be implemented safely.

(b) Updated provisions are made for adequate resources and their availability, when needed.

(c) The radioactive waste anticipated remains compatible with available (or planned) storage capacities and disposal considering its transport and treatment.

REFERENCES

(c)(b) INTERNATIONAL Risk assessments and method statements for the licensing of the decommissioning process should be prepared.

DECOMMISSIONING PROCESS

9.2. The decommissioning of the facility should contain the following successive steps: dismantling, dry cleaning and further dismantling (for conversion facilities and diffusion enrichment facilities only) and wet cleaning.

9.3. It should be ensured that personnel carrying out the decommissioning of the facility have the necessary training, qualifications and experience for such work. These personnel should have a clear understanding of the management system under which they are working to maintain acceptable environmental conditions and to implement the relevant environmental, health and safety standards.

9.4. Paragraphs III.34 and III.35 of Appendix III of Ref. [1] establish the requirements for active decommissioning.

9.5. In the decommissioning process, particular consideration should be given to:

- Preventing the spread of contamination by means of appropriate techniques and procedures;
- Appropriate handling and packaging of waste as well as planning for the appropriate disposal of radioactive waste;
- Safe storage of contaminated material and radioactive waste that cannot be decontaminated or disposed of immediately.

(d)

(e)

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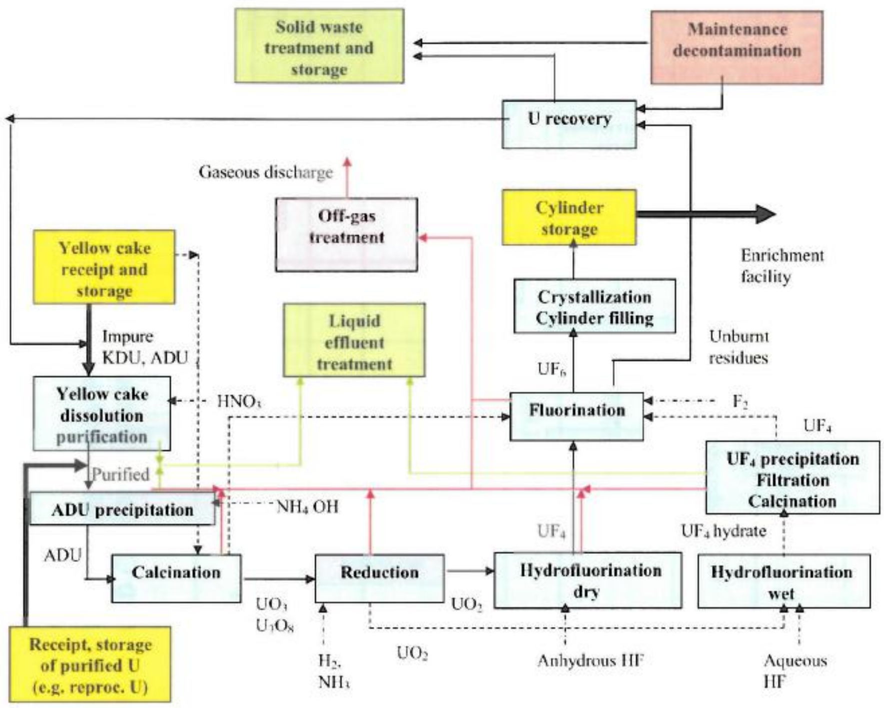
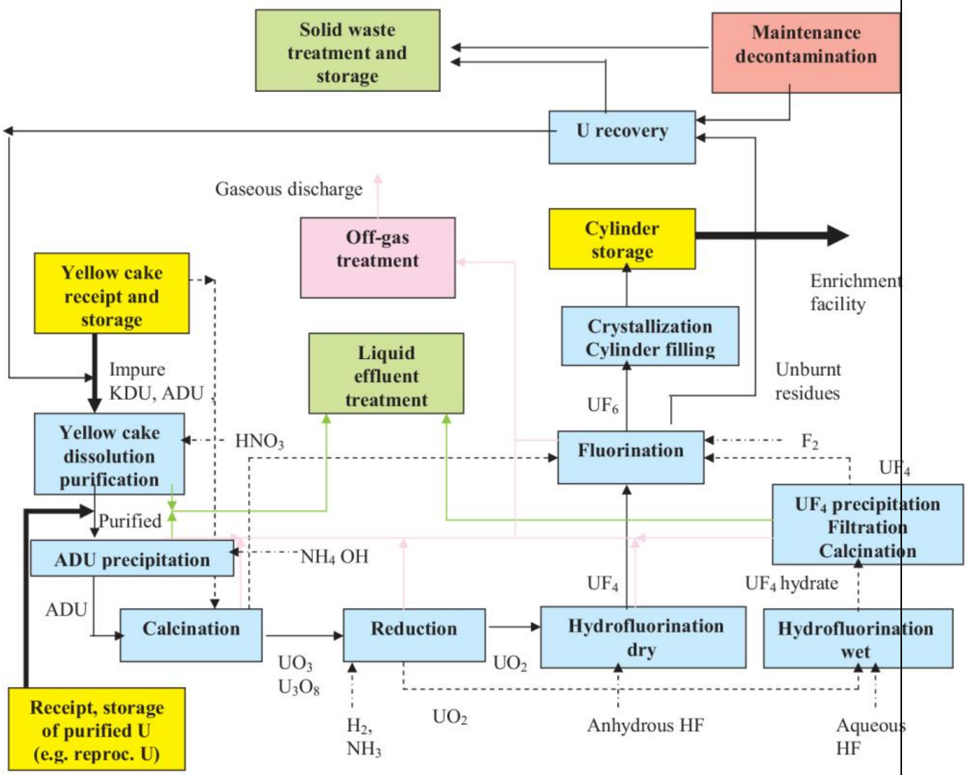
Annex I

TYPICAL PROCESS ROUTES IN A CONVERSION FACILITY



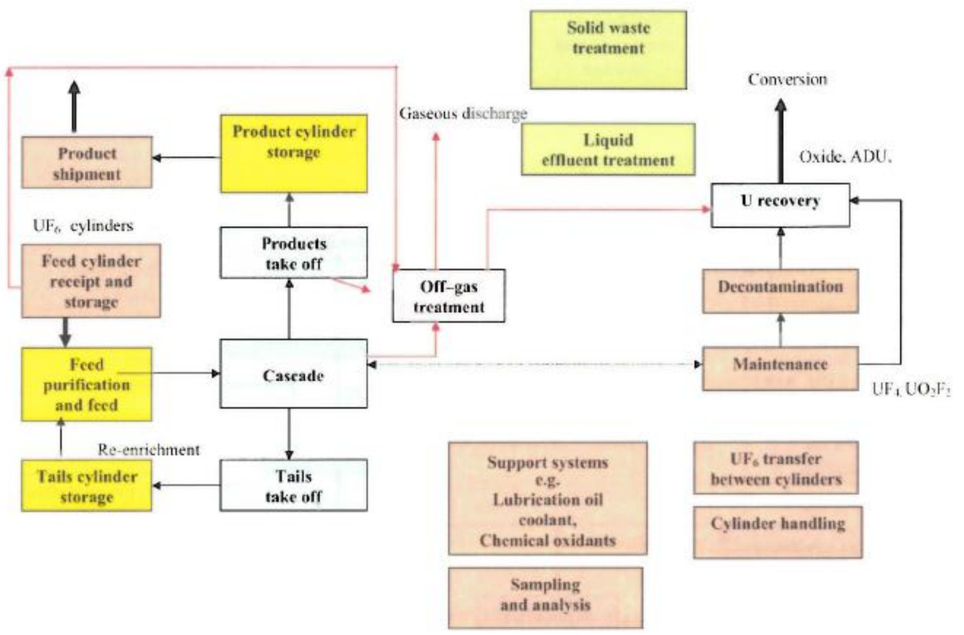


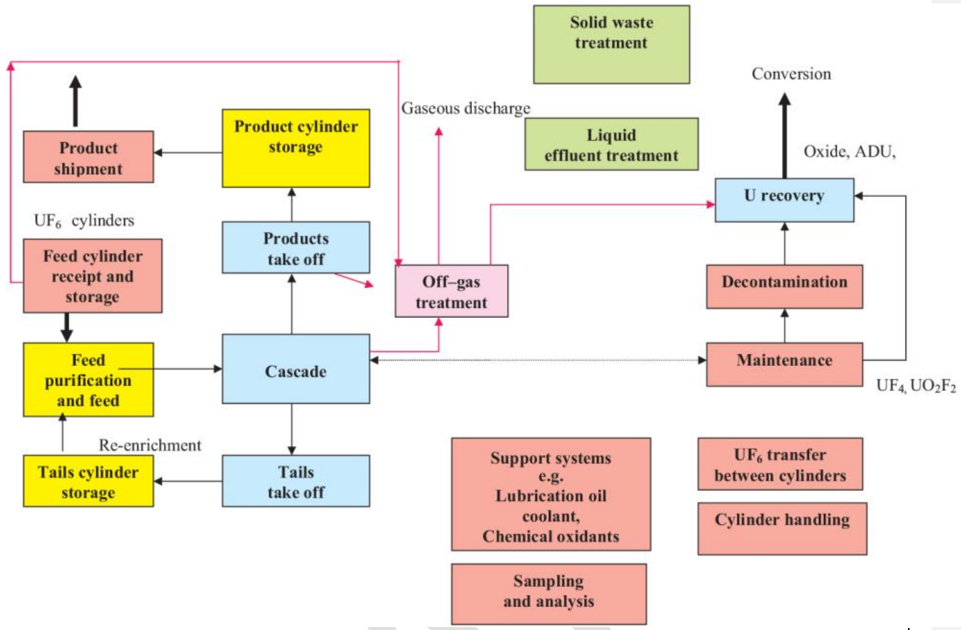
Solid waste treatment and storage
Maintenance decontamination
U recovery
Gaseous discharge
Off-gas treatment
Cylinder storage
Enrichment facility
Yellow cake receipt and storage
Impure KDU, ADU
Liquid effluent treatment
Crystallization Cylinder filling
Unburnt residues
UF_6
Yellow cake dissolution purification
HNO_3
Fluorination
F_2
UF_4
UF_4 precipitation Filtration Calcination
Purified
ADU precipitation
NH_4 OH
UF_4
UF_4 hydrate
ADU
Calcination
Reduction
Hydrofluorination dry
Hydrofluorination wet
UO_3
U_3O_8
UO_2
Receipt, storage of purified U (e.g. reproc. U)
H_2, NH_3
UO_2
Anhydrous HF
Aqueous HF

ADU – ammonium diuranate

Annex II

TYPICAL PROCESS ROUTES IN ~~AN~~A URANIUM ENRICHMENT FACILITY




Solid waste treatment
Conversion
Gaseous discharge
Product shipment
Product cylinder storage
Liquid effluent treatment
Oxide, ADU,
U recovery
UF$_6$ cylinders
Products take off
Feed cylinder receipt and storage
Off–gas treatment
Decontamination
Feed purification and feed
Cascade
Maintenance
UF$_4$, UO$_2$F$_2$
Re-enrichment
Tails cylinder storage
Tails take off
Support systems e.g. Lubrication oil coolant, Chemical oxidants
UF$_6$ transfer between cylinders
Cylinder handling
Sampling and analysis

Annex III

EXAMPLES OF STRUCTURES, SYSTEMS AND COMPONENTS IMPORTANT TO SAFETY, ASSOCIATED EVENTS AND OPERATIONAL LIMITS AND CONDITIONS FOR CONVERSION FACILITIES

Safety function includes: (1) Maintaining subcriticality; (2) Confinement to protect against internal exposure and chemical hazards; (3) Protection against radiation exposure.

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Reagents				
Receipt and storage of anhydrous HF	— Flexible hoses and transfer devices; — Automatic shutoff valves; — Refrigerated storage tanks; — Oil spreader	Release of HF	(2)	Storage room temperature; Oil temperature
HF transfer	Transfer pipes	Release of HF	(2)	
Receipt and storage of NH_3	— Flexible hose and transfer devices; — Automatic shutoff valves; — Storage vessels	Release of NH_3	(2)	
Receipt of H_2	— Flexible hose and transfer devices; — Automatic shutoff valves	Explosion	(2)	
Production of anhydrous F_2	Electrolysis cells; piping; H H_2 detectors	Explosion; release of HF and F_2	(2)	H_2 concentration in air room; F_2 and HF content in gases

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Receipt and storage of yellow cake				
	Powder containers	Release of uranium	(2)	Mass, enrichment, concentration
Dissolution, purification and storage of yellow cake				
Dissolution	Dissolver and facilities for off-gas treatment	Release of uranium and nitrogen oxide (NOx)	(2)	Concentration of nitrogen oxide in gaseous effluent
Purification	— Fire detectors; — Flameproof apparatus	Fire	(2)	
Receipt and storage of purified uranium, (e.g. reprocessed uranium)				
Receipt of uranium nitrate (enriched uranium)	Checking device for ^{235}U content	Processing of uranium beyond safety limits	(1)	Enrichment, concentration

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Intermediate storage of uranium nitrate	Tank, drip tray, leak detector	Breach of tank	(2)	Integrity of tank, valves and lines
ADU precipitation				
	Vessels, filter, drying device	Release of uranium	(2)	Integrity of tank, valves and lines
Calcination				
	Kiln	Release of uranium	(2)	Integrity of kiln; relative pressure of room or kiln; Concentration of nitrogen oxide in gases
Reduction				
	Rotary kiln or flowing bed reactor	Release of uranium	(2)	Relative pressure of kiln versus of room
	Reduction furnace; in-line oxygen monitor H_2 detection devices in rooms	— Explosion — Release of uranium powder	(2)	O_2 amount, H_2 concentration, relative pressure kiln versus room

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
	Off-gas treatment units	Release of uranium powder	(2)	Uranium concentration
Dry hydro fluorination				
	— Hydro fluorination reactor; — Facilities for off-gas treatment	Release of HF	(2)	HF, uranium content in gases
	Shielding	Increase in dose rate	(3)	Thickness
Wet hydro fluorination				
	— Hydro fluorination reactor; — Facilities for off-gas treatment	Release of HF	(2)	HF, uranium content in gases
Fluorination				
	— Fluorination reactor; — Washing column for off-gas treatment	Release of F_2, HF and UF_6	(2)	F_2, uranium content in gases

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Crystallization and cylinder filling				
	High pressure measuring device; Cylinder and valve; Weight measuring device; UF_6 level detector in intermediate product take off tank to confirm transfer into cylinders; Pipes, vessels and valves containing UF_6; UF_6 release detection system	Release of UF_6 (breach of confinement): - Defective cylinder leads to breach; - Overfilling; - UF_6 left in process gas lines leading to a release of UF_6; - Release of liquid UF_6	(2)	Pressure; Visual cylinder inspection; Weight limits
	Vessels, piping	Release of UF_6	(2)	Integrity of tank, valves and lines
	Leak detection	Release of uranium and HF	(2)	HF concentration
Handling and storage of cylinders				
	UF_6 cylinders	Release of uranium and HF	(2)	Thickness

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
	Means of ~~transportation~~transfer, cranes, etc.	Breach of cylinder; Valve wrenching	(2)	Position of valve protector
Recovery of uranium				
Solvent extraction	Vessels and drip trays; Leak detectors	Breach of vessels; Spills of solutions of radioactive material	(2)	Integrity of vessels and valves
Solvent extraction	Mixer settlers or extraction columns	Fire; Releases	(2)	Temperature
Intermediate storage of unburnt residues	Shielding	Increase in dose rate	(3)	Thickness
Off-gas treatment				
	Aerosol and gas measuring devices	Release of HF, F_2 and uranium	(2)	Uranium content in released air
	Columns, piping	Release of uranium and HF	(2)	HF content in released air

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Treatment of ~~liquid effluents~~radioacti				
	Tank, piping	Release of uranium and other impurities	(2)	Uranium concentration; Uranium content in released water
	Measuring devices for radioactive and chemical impurities	Release of uranium and other impurities	(2)	
	Exhaust pipe	Release of uranium and other impurities	(2)	
Building				
	Areas for nuclear and chemical activities	Loss of integrity	(2)	Leaktightness
Pipes containing water or solutions				

	Piping	Loss of integrity	(1)	Thickness	

~~**Note:** Safety function includes: (1) Criticality prevention; (2) Confinement to protect against internal exposure and chemical hazards; (3) Protection against external exposure.~~

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Annex IV

EXAMPLES OF STRUCTURES, SYSTEMS AND COMPONENTS IMPORTANT TO SAFETY, ASSOCIATED EVENTS AND OPERATIONAL LIMITS AND CONDITIONS FOR URANIUM ENRICHMENT FACILITIES

Note: Safety function includes: (1) Criticality prevention; (2) Confinement to protect against internal exposure and chemical hazards; (3) Protection against external exposure.

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Receipt and storage of feed cylinders				
	Weighing scales; Cylinder and valve; Isotope measuring device	Breach during the heating; Defective cylinder leads to breach; Criticality event in the process	(1,), (2)	Limit on cylinder weight; Visual inspection of cylinders; Limit on feed enrichment

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Feed purification				
	Pressure measuring device for cold cylinders; Temperature measuring device of UF_6; Pressure measuring device of UF_6; UF_6 leak detectors; Shielding (if reprocessed uranium); Feed connector and piping; UF_6 cylinder; UF_6 cylinder; Autoclave isolation valve system	Explosion (F_2); Heating trip, cylinder breach; Heating trip, cylinder breach; Personnel exposure; Personnel exposure; Release into the second containmentconfinement barrier	(1,), (2,), (3)	Pressure and temperature limits; Detection limits for UF_6 detectors; Visual inspection and pressure test of the feed connectors; Pressure check of feed cylinder; Remove light gases to the required level for centrifuge uranium enrichment facilities

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Cascade				
	— Vessels, valves and pipes when UF_6 pressure is above atmospheric pressure; — Leak detectors when UF_6 pressure in the facility is above atmospheric pressure; — Pressure and temperature measuring devices to control mass flows and to detect in leakages or generation of reaction products; — Enrichment measuring device; — Pressure measuring device for product flow; — Isolation; — Process motor trip device; — Neutron poison concentrations in cooler water; — Compressor trip.	Release of uranium and HF; Increase enrichment and in leakages–criticality; Criticality; Criticality; Release of UF_6; Release of UF_6; Criticality; Release of UF_6	(1,), (2)	Detection limits for UF_6 detectors Pressure and temperature limits Specific enrichment limits Poison concentration levels Detection of UF_6

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
	— Heat exchanger tubes in contact with UF_6; — Temperature and pressure measuring devices.	Reaction of UF_6 with water leading to buildup of uranic deposits; Introduction of moderator of the introduction of Freon®halohydrocarbons leading to an explosion	(1,), (2)	— Maintenance of the integrity of the tubes — Pressure and temperature limits
	In-line analysers to monitor for hydrocarbons or Freon®halohydrocarbon and for detecting ingress of oil or Freon®halohydrocarbons	Reaction of UF_6 with oil leading to criticality and/or explosion	(1,), (2)	Limit on hydrocarbon concentrations
Product take-off				
	Low pressure and temperature measuring devices; High pressure measuring device; Cylinder and valve; Weighing scales; UF_6 level detector in intermediate product take off tank to confirm correct transfer into cylinders; Pipes, vessels and valve containing UF_6; UF_6 release detection system;	Moderation control to prevent HF condensation; UF_6 release (breach of confinement); Defective cylinder leads to breach; Overfilling; UF_6 left in process gas lines leading to release of UF_6; Release of liquid UF_6	(1,), (2)	Vapour pressure of HF Pressure Visual empty cylinder inspection Weight limit

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Off-gas treatment				
	Cold traps and/or chemical traps; Temperature measuring device for cold traps; Measuring device for effluents discharged to atmosphere	Release of uranium to secondary ~~containment~~confinement barrier or atmosphere; External radiation dose from any accumulated uranium or uranium daughter isotopes	(1~~,~~), (2~~,~~), (3)	Temperature measuring device of cold traps
Tailings take-off				
	High pressure measuring device; Cylinder and valve; Weighing scales; UF_6 level detector in intermediate product take off tank to confirm adequate transfer into cylinders; Pipes, vessels and valve containing UF_6; UF_6 release detection system.	Release of UF_6 (breach of confinement); Defective cylinder leads to breach; Overfilling; UF_6 left in process gas lines leading to release of UF_6~~;~~; Release of liquid UF_6	(2)	Pressure Visual empty cylinder inspection Weight limit

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Maintenance				
	Geometrically ~~safe~~favourable containers for the collection of residues.	Criticality Operator exposure	(1~~,~~), (2)	~~Safe~~Safely subcritical dimensions of the containers
Decontamination				
	Various criticality controls (e.g. on mass, geometry, concentration); Level controls on tanks	Criticality; Process liquor spill; Operator exposure	(1~~,~~), (2)	Limits on concentration and mass
Uranium recovery				
	Various criticality controls (e.g. on mass, geometry, concentration); Level controls on tanks; Storage of liquors and/or recovered uranium in ~~safe~~favourable geometry tanks or containers	Criticality; Process liquor spill; Operator exposure	(1~~,~~), (2)	Limits on concentration and mass; ~~Safe~~Safely subcritical dimensions of the containers

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Off-gas treatment				
	Differential pressure; Activity measurements and alarms; HF concentration measurements; ~~Safe~~ Favourable geometry scrubbers	Blocked or torn filters: failure of ventilation or discharge to atmosphere	(1,), (2)	High and low pressure alarms ~~Safe~~Safely subcritical dimension of apparatus
Sampling and transfer of liquid UF6				
	Pressure measuring device for the cold cylinder; Temperature measuring device in the cylinder during heating; ~~Pressure measuring device of UF_6;~~ Pressure measuring device of UF_6; UF_6 leak detectors; Pipes, vessels and valve containing UF_6	Explosion (F_2); Cylinder breach; Cylinder breach; Personnel exposure; Release into the second ~~containment~~confinement barrier	(1,), (2,), (3)	Pressure and temperature limits; Detection limits for UF_6 detectors; Visual inspection and pressure test of connectors
Cylinders handling				
	Valve protectors for liquid UF_6; Devices for moving cylinders containing liquid UF_6, such as cranes, carts and transporters	Release of uranium and HF	(2,), (3)	Procedures

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Radioactive waste treatment				
	Treatment facilities	Release of uranium; Release of chemicals; Fire	(1,), (2)	
	Measuring devices for uranium content	Degradation of criticality safety margin (mass)	(1)	
	Radioactive waste storage	Fire	(1,),	
Building				
	Areas for nuclear and chemical activities	Loss of integrity	(2)	Leaktightness
Ventilation system				
	Fan and filters for input air	Fire	(2)	Differential pressure on filters; Flow stages of pressure in the building; Vacuum in the sampling lines
	Ventilation control system	Release of uranium	(2)	Differential pressure on filters

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
	Filters inside the process areas		(1), (2)	Differential pressure on filters
	Ducts for air and process gas	Degradation of criticality safety margin (mass)	(1)	Mass of uranium (e.g. pre-filters)
	Final filter stage for waste air	Fire	(2)	Differential pressure on filters
	Measurement devices for radioactivity in waste air	Release of uranium	(2)	Uranium concentration release
Treatment and release of water				
	Tank	Release of uranium	(1),	Level measuring device
	Measurement devices for radioactivity in water	Release of uranium	(2), (1)	Sampling and analyses before release

~~**Note:** Safety function includes: (1) Criticality prevention; (2) Confinement to protect against internal exposure and chemical hazards; (3) Protection against external exposure.~~

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Process area	Structures, systems and components important to safety	Events	Safety function initially challenged	Parameters for defining operational limits and conditions
Power supply system				
	Emergency power supply system	Loss of criticality safety and radiation protection control	(2)	Maximum time for power supply reconstitution

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