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Safety of Uranium Fuel Fabrication Facilities (Revision of SSG-6)

DS 517

DRAFT SPECIFIC SAFETY GUIDE

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide supersedes the Safety Guide on the Safety of Uranium Fuel Fabrication Facilities that was issued as IAEA Safety Standards Series No. SSG-6 in 2010.~~makes recommendations on how to meet~~ It supplements and elaborates upon the requirements established in the Safety Requirements publication on the Safety of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. SSR-4 [1]~~, and supplements and elaborates on those requirements~~.

~~1.2. The safety of uranium fuel fabrication 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 uranium fuel fabrication facility, with emphasis placed on the safety of their design and operation.~~

~~1.3.~~1.2. Uranium and the waste generated in uranium fuel fabrication facilities are handled, processed, treated and stored ~~throughout~~ at the ~~entire~~ facility. Uranium fuel fabrication facilities may process or use large amounts of hazardous chemicals, which can be toxic, corrosive, combustible and/or explosive. The fuel fabrication processes 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. The potential for a release of energy in the event of an accident at a uranium fuel fabrication facility is associated with nuclear criticality or chemical reactions. The potential for release of energy is small in comparison with that of a nuclear power plant, with generally limited environmental consequences.

~~1.4.~~1.3. The safety of uranium fuel fabrication facilities is addressed by means of their proper siting, design, construction, commissioning, operation including management for safety and decommissioning.

OBJECTIVE

~~1.5.~~1.4. The objective of this Safety Guide is to provide operating organizations, regulatory bodies, designers and other relevant organizations with recommendations and guidance on meeting the requirements established in SSR-4 [1] applicable to ~~that, in the light of experience in States and the present state of technology, should be followed to ensure safety at all stages in the lifetime of~~ a uranium fuel fabrication facility. ~~These recommendations specify actions, conditions or procedures necessary for meeting the requirements established in Ref. [1]. This Safety Guide is intended to be of use to designers, operating organizations and regulators for ensuring the safety of uranium fuel fabrication facilities.~~

SCOPE

~~1.6.~~1.5. The safety requirements applicable to fuel cycle facilities (i.e. facilities for uranium ore processing and refining, conversion, enrichment, reconversion, interim 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 SSR-4Ref. [1]. The requirements applicable specifically to uranium fuel fabrication facilities are established in Appendix I of Ref. [1]. This Safety Guide provides recommendations on meeting thethese requirements for uranium fuel fabrication facilities during their siting, design, commissioning, operation and preparation for decommissioningestablished in Sections 5–10 and in Appendix I of Ref. [1].

1.7.1.6. This Safety Guide deals specifically with the handling, processing, material transfer and storage of natural uranium and low enriched uranium (LEU) that has a ^{235}U concentration of no more than 6%, derived from natural, high enriched or reprocessed uranium; it does not cover facilities that handle uranium metal fuels. Recommendations are also provided for auxiliary activities such as sampling, homogenization and blending. Completed fuel assemblies (e.g. fuel assemblies for pressurized water reactors, boiling water reactors, heavy water reactors, CANDU reactors and advanced gas cooled reactors) are usually stored at the fuel fabrication facility before being transported to the nuclear power plant. Such a storage facility is considered to be part of the fuel fabrication facility. This Safety Guide is limited to the safety of uranium fuel fabrication facilities; it does not deal with any impact that the manufactured fuel assemblies may have on safety for the reactors in which they are going to be used.

1.7. This publication includes specific recommendation of ensuring criticality safety in uranium fuel fabrication facilities. The recommendations supplement more detailed guidance provided in the IAEA Safety Standards Series No. SSG-27, Criticality Safety in the Handling of Fissile Material [2].

1.8. 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 IAEA Safety Standards Series No. GSR Part 1 (Rev.1), Governmental, Legal and Regulatory Framework for Safety Ref. [23] and those on the management system and the verification of safety (e.g. requirements for the management system and for safety culture) as established in Ref. [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].

1.8.1.9. This Safety Guide does not include nuclear security recommendations for a uranium fuel fabrication facility as established 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 in IAEA Nuclear Security Series No. 27-G, (Implementation of INFCIRC/225/Revision 5) [5].

1.9. Sections 3–8 of this publication include 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].

1.10. The typical dry and wet process routes of uranium fuel fabrication facilities are shown in a schematic diagram in Annex 1 (see also Ref. [7]).

STRUCTURE

1.11.1.10. This Safety Guide consists of eight nine sections and three annexes. Section 2 provides general safety recommendations for a uranium fuel fabrication facility. Section 3 of this publication provides guidance on the development of a management system for such facility and the activities associated with it. Section 3 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 5 deals with safety in the design stage: it provides recommendations on safety analysis for operational states and accident conditions and discusses the safety aspects of radioactive waste management in the uranium fuel fabrication facility and other design considerations. Section 5 6 addresses safety aspects in the construction stage. Section 6 7 discusses safety considerations in commissioning. Section 7 8 deals with safety in the stage of operation of the facility: it 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 8 9 provides recommendations on meeting the safety requirements for the preparation for decommissioning of a uranium fuel fabrication facility. Annex I shows the typical process routes for a uranium fuel fabrication facility. Annex II provides examples of structures, systems and components important to safety in uranium fuel fabrication facilities, grouped in accordance with process areas. Annex III provides examples of parameters for defining the operational limits and conditions for a uranium fuel fabrication facility.

2. GENERAL SAFETY RECOMMENDATIONS

2.1. In uranium fuel fabrication facilities, significant amounts of radioactive materialuranium compounds (in gaseous, liquid or solid state) are present some of which could be in a dispersible form,. This is particularly so in the early stages of the fuel fabrication process. In addition, the uranium compoundsradioactive material encountered exists in diverse chemical and physical forms and areis used in conjunction with flammable or chemically reactive substances as part of the process. Thus, in these facilities, the main hazards are potential criticality and releases of uranium hexafluoride (UF_6) and uranium dioxide (UO_2), from which workers, the public and the environment must be protected by means of adequate design and construction and by safe operation.

2.2. The chemical toxicity hazards of LEU or depleted uranium in a soluble form such as UF_6 is more significant than its radiotoxicity hazards. Along with UF_6, large significant quantities of hazardous chemicals such as hydrogen fluoride (HF) are also present. In addition, when UF_6 is released it reacts with the moisture in the air to produce HF and soluble uranyl fluoride (UO_2F_2), which present additional safety hazards. Therefore, comprehensive safety analyses for uranium fuel fabrication facilities should also address the potential hazards resulting from these chemicals.

2.3. In uranium fuel fabrication facilities, only low enriched uranium (LEU) is processed. The radiotoxicity of LEU is low, and thus 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 therefore should be taken into accountconsidered in the safety assessment if the licence held by the facility permits the processing of such uranium.

2.4. Uranium fuel fabrication 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 with an activity of the order of thousands of terabecquerels). However, deviations in processes may develop rapidly into dangerous situations certain accident conditions involving hazardous chemicals or criticality accidents can potentially result in adverse off-site consequences.

2.5. For application of the requirement that the concept of defence in depth be applied at the facility (see Concept of defence in depth in Section 2 in SSR-4of Ref. [1]), the first two levels of defence in depth are the most important, as risks can be reduced to insignificant levels by means of design and appropriate operating procedures (see Sections 4 5 and 78).

3. MANAGEMENT SYSTEM FOR URANIUM FUEL FABRICATION FACILITIES

MANAGEMENT SYSTEM

3.1. The following recommendations provide a means of meeting the requirements 4 and 5 of SSR-4 [1] for the management for and verification of safety for uranium fuel fabrication facilities. The following recommendations are supplementary to, and should be read in conjunction with, the recommendations provided in the IAEA Safety Standards Series No. GS-G-3.1, Application of the Management System for Facilities and Activities [6] and No. GS-G-3.5, The Management System for Nuclear Installations [7].

3.2. A documented management system that integrates the safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements of the operating organization is required to be in place in accordance with IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [8] and Requirement 4 of SSR-4 [1].

3.3. The integrated management system should be established and put into effect by the operating organization, in a timely manner before transitions between major stages in the lifetime of a fuel fabrication facility, to ensure that safety measures are specified, implemented, monitored, audited, documented and periodically reviewed throughout the lifetime of the facility or the duration of the activity.

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

3.5. In determining how the requirements of the management system for safety of uranium fuel fabrication facilities are to be applied, a graded approach based on the relative importance to safety of each item or process should be used.

3.6. The management system should provide structure and direction to the organization in a way that permits and promotes the development of a strong safety culture together with the achievement of high levels of safety performance.

3.7. The management system should address the following four functional areas: management responsibility; resource management; process implementation; and measurement, assessment, evaluation and improvement. In general:

– Management responsibility includes the support and commitment of management necessary to achieve the safety objectives of the operating organization in such a manner that safety is not compromised by other priorities.
– Resource management includes the measures necessary to ensure that the resources essential to the implementation of safety strategy and the achievement of the safety objectives of the operating organization are identified and made available.
– Process implementation includes the activities and tasks necessary to achieve the safety goals of the organization.
– Measurement, assessment, evaluation and improvement provides an indication of the effectiveness of management processes and work performance compared with objectives or benchmarks; it is through measurement and assessment that opportunities for improvement can be identified.

MANAGEMENT RESPONSIBILITY

3.8. The prime responsibility for nuclear and radiation safety, including criticality safety, rests with the operating organization. The documentation of the management system of uranium fuel fabrication facilities should include description of the organizational structure, functional responsibilities and levels of authority. Provisions for ensuring effective communication and clear assignment of responsibilities should be provided to ensure that processes and activities which are important to safety are controlled and performed in a manner that ensures that safety objectives are achieved.

3.9. The management of the operating organization should ensure that all aspects of safety, including monitoring the performance of activities and processes are developed and documented. The management should also ensure that all personnel are adequately trained to perform assigned roles and should establish a system for keeping records that ensures control of performance and verification of activities that are important to safety. The records keeping system should provide for their identification, approval, review, filing, retrieval, and disposal.

3.10. There should be clear, written assignment of responsibilities for key safety functions, as for example criticality safety officer and radiation protection officer.

RESOURCE MANAGEMENT

3.11. The operating organization should provide adequate resources (both human and financial) for the safe operation of the facility or activity as well as resources for mitigation of the consequences of accidents. The management of operating organization should:

– Participate in the activities by determining the required personnel competence and providing initial and periodic training, as necessary;
– Prepare and issue specifications and procedures on safety related activities and operations;
– Support and participate in safety assessment of modifications;
– Make provisions for adequate interfaces and frequent contact between operating personnel and plant managers, including observation of work in progress.

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

3.13. The management system should include procurement activities and should be extended to include vendors and sub-contractors. The operating organization should ensure, through audits, that suppliers of items important to safety have management systems that are adequate for ensuring safety of fuel fabrication facilities.

PROCESS IMPLEMENTATION

3.14. All activities should be performed in accordance with approved procedures and instructions. The operating procedures should cover all facility states (see Definitions in SSR-4 [1]). The procedures should specify all parameters which are intended to control and the criteria to be fulfilled.

3.15. The management system of uranium fuel fabrication facilities should include also management for criticality safety. Further guidance on the management system for criticality safety is provided in SSG-27 [2].

3.16. Any proposed modification to existing facilities or activities, or proposals for introduction of new activities, should be assessed for their implications on existing safety measures and appropriately approved prior to implementation. Modifications of safety significance should be subjected to safety assessment and regulatory review and appropriately approved before they are implemented. The modification process should also apply to procedures for design, fabrication, construction, commissioning and operation. The facility or activity documentation should be updated to reflect modifications, and the operating personnel, including supervisors, should receive adequate training on the modifications.

3.17. The activities for ensuring safety throughout the facility lifetime or activity duration involve different groups and interface with other areas such as those related to nuclear security and to the system for accounting for, and control of nuclear material. These activities should be identified, coordinated, planned, and conducted to ensure effective communication and clear assignment of responsibilities.

MEASUREMENT, ASSESSMENT, EVALUATION AND IMPROVEMENT

3.18. Audits performed by the operating organization as well as proper control of modifications to facilities and activities are particularly important for ensuring safety of fuel fabrication facilities (para. 4.23 of SSR-4 [1]). In addition, independent audits should be also implemented. These audits should also cover measures for emergency preparedness and response. These audits should be carried out regularly and the results should be evaluated by the operating organization and corrective actions should be taken to implement recommendations and suggestions for safety improvements.

3.19. Deviation from operational procedures and unforeseen changes in operations or in operating conditions should be reported and authorized by the management. Such events should be promptly investigated by the operating organization to analyse the causes of the deviation, to identify lessons to be learned, and to determine and implement corrective actions to prevent recurrences. There is also a danger that conditions may change slowly over time in response to factors such as ageing of the facility or owing to increased production pressures.

3.20. The management system should include a means of incorporating lessons learned from operating experience and accidents at facilities in the State and in other States, to ensure continuous improvement in operational practices and assessment methodology. Guidance on and recommendations for establishing a system for the feedback of operating experience are provided in IAEA Safety Standards Series No. SSG-

50, Operating Experience Feedback for Nuclear Installations Ref. [9].

3.4. SITE EVALUATION

3.1.4.1. The site evaluation process for a uranium fuel fabrication facility will depend on a large number of criteriavariables, some of which are more important than others. At the earliest stage of planning a facility, a list of these criteria 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 Risks posed by possible safety significant external initiating eventshazards (e.g. earthquakes, accidental aircraft crashes, hazards arising from nearby industries and transport routes, fires and extreme weather conditions) will probably dominate in the site evaluation process and need to be incorporated into the design of the facility. However, as the potential nuclear hazard posed by a uranium fuel fabrication facility is inherently limited, the risks posed by possible external events should be compensated for by means of adequate design provisions and constraints on processes and operations. Requirements for site evaluation for uranium fuel fabrication facilities are provided in IAEA Safety Standards Series No. SSR-1, Site Evaluation for Nuclear Installations [10] and further guidance is provided in SSG-35, Site Survey and Site Selection for Nuclear Installations [11].

3.2.4.2. The scope of the site evaluation for a uranium fuel fabrication facility are established by Requirement 3 of SSR-1 [10], Requirement 11 and paras. 5.1 to 5.14 of SSR-4 [1] and should reflect the specific hazards listed in Section 2 of this Safety Guide.

4.3. The density and distribution of population in the vicinity of the uranium fuel fabrication facility and the direction of the prevailing wind at the site should be considered in the site evaluation process to minimize any possible health consequences for people in the event of a release of radioactive material and hazardous chemicals.

4.4. Site selection should include assessment of safety risks related to external natural and human induced events.

4.5. To prevent potential conflicts interface between safety and security aspects should be considered systematically in the site evaluation and site selection process (requirement 75 of SSR-4 [1]).

3.3.4.6. 4.6. Site evaluation and selection should be facilitated by experts from both safety and security disciplines. The selection of a site should take into account both safety and security aspects.

4.7. A full record should be kept of the decisions taken on the selection of a site for a uranium fuel fabrication facility and the reasons behind those decisions.

3.4.4.8. The adequacy of the site evaluation should be reviewed periodically during the lifetime of the facility including in case of an increase of a production capacity beyond the original envelope (para 5.14 of SSR-4 [1]).

~~4.~~5. DESIGN

~~GENERAL~~

~~Safety functions for uranium fuel fabrication facilities~~

~~4.1. Safety functions (see Ref. [1], Appendix I, para. I.1), that is 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:~~

~~(1) Prevention of criticality;~~

~~(2) Confinement for the prevention of releases that might lead to internal exposure and for the prevention of chemical releases;~~

~~(3) Protection against external exposure.~~

Specific engineering design ~~requirements~~guidance

~~4.2. The following requirements apply:~~

~~4.3.~~5.1. The requirements on ~~prevention of criticality~~maintaining subcriticality are ~~as~~ established in Requirement 38 and subsequent paras ~~6.43–6.51 and I.3–I.7 of Appendix I~~ of SSR-4~~Ref.~~ [1]. Further guidance on the maintaining of subcriticality of uranium fuel fabrication facilities is provided in Section 3 of SSG-27 [2]

~~4.4.~~5.2. The requirements on confinement for the prevention of releases that might lead to internal exposure and chemical hazards ~~as~~ are established in Requirements 34 and 35 and the following paras. of SSR-4~~paras 6.37–6.39, 6.54–6.55 and paras I.8 and I.9 of Appendix I of Ref.~~ [1].

~~4.5.~~5.3. The requirements on protection against external exposure ~~as~~ are established in Requirement 36 and following paras ~~6.40–6.42 of Ref.~~ SSR-4 [1]. For a facility ~~licensed to use LEU from sources of~~ using uranium from sources other than natural uranium, ~~because of the different,~~ particular care should be taken to minimize contamination due to the different isotopic composition of uranium. The need for shielding should be considered for the protection of personnel ~~workers~~ from the associated higher dose rates of gamma radiation.

Design basis ~~accidents~~ and safety analysis

~~4.6.~~5.4. The definition of a design basis accident in the context of fuel cycle facilities can be found in Definitions ~~para. III-10~~ of ~~Annex III of Ref.~~SSR-4 [1]. The safety requirements relating to design basis ~~accidents~~ are established in ~~paras 6.4–6.9 of Ref.~~ Requirements 14 and 20 of SSR-4 [1].

~~4.7.~~5.5. The specification of a design basis ~~accident~~ (or equivalent) will depend on the facility design, its siting and on ~~national criteria~~regulatory requirements. However, particular consideration should be given to the following hazards in the specification of design basis accidents safety analysis at uranium fuel fabrication facilities:

(a) A nuclear criticality accident;

(b) A release of uranium such as from an(e.g. in the explosion ofin a reaction vessel during the conversion process);

(c) A release of UF_6 such as due to the rupture of a hot cylinder;

(d) A release of HF such as due to the rupture of a storage tank;

(e) A large fire;

(f) loss of electrical power;

(g) Natural phenomena such as earthquakes, flooding, or tornadoes[1]; Internal and external events, including:

i. Internal and external explosions (in particular hydrogen explosions);

ii. Internal and external fire;

iii. Dropped loads and associated handling events;

iv. Natural phenomena (including earthquakes, flooding and tornadoes);

i.v. Aircraft crashes.

(f) An aircraft crash[2].

4.8.5.6. The first two types of events ((a) and (b)) 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 five types of events ((c)–(g)) would lead to chemical releases having All of the above events may have both on-site and off- site consequences. Only the (d) type can have a purely chemical impact.

4.9.5.7. The events listed in para. 4.45.6 may occur as a consequence of a postulated initiating event (PIE). Selected PIEs are listed in Annex Appendix I of Ref.SSR-4 [1].

Structures, systems and components important to safety

4.10.5.8. The likelihood of design basis accidents (or equivalent) should be minimized, and any radiological and associated chemical consequences should be controlled by means of structures, systems and components important to safety (see Requirement 13 of SSR-4 [1]), operational limits and conditions (see Requirement 57 of SSR-4 [1]) and appropriate administrative measures (see paras 6.5–6.9 and Annex III of Ref. [1])). Annex II of this Safety Guide presents examples of structures, systems and components important to safety and representative events that may challenge the associated safety functions.

SAFETY FUNCTIONS

[1] For some facilities of older designs, natural phenomena were not considered. These phenomena should be taken into account in the design of new uranium fuel fabrication facilities.

[2] The consequences of an aircraft crash should be considered even if such an accident is not formally established as a design basis accident.

Prevention of criticality

5.9. The following paragraphs highlight some of the main elements that are specific for uranium fuel fabrication facilities. There are other topics related to criticality safety that are relevant for enrichment facilities and are not adequately covered by this Safety Guide. The principal guidance is obtained in SSG-27 [2].

5.10. If a fuel fabrication facility processes natural uranium, depleted uranium, or uranium with less than 1% ^{235}U enrichment criticality safety would not need to be taken into consideration. In such cases it should be demonstrated that there is no credible fault sequence in which uranium with higher ^{235}U enrichment is fed to the process (see para. 6.138 of SSR-4 [1]). For further guidance see the exemption criteria in para 2.8 of SSG-27 [2].

4.11.5.11. Paras 6.138 - 6.148 of SSR-4 [1] list the requirements for the prevention of criticality by design. For the prevention of criticality in a fuel fabrication facility"For the prevention of criticality by means of design, the double contingency principle shall be the preferred approach" (Ref. [1], para. 6.45). Paragraphs I.3 and I.4 of Appendix I of Ref. [1] establish general requirements for the prevention of criticality in uranium fuel fabrication facilities. Paragraph I.5 of Appendix I of Ref. [1] establishes requirements for the control of systemthe following parameters should be for the prevention of criticality. Some examples of the parameters subject to control are the following:

(a) Mass and degree of enrichment of fissile material present in a process and in storage between processes, e.g. powder in rooms and vessel scrubbers and pellets in storage;
(b) Geometry (limitation of the dimensions or shape) of processing equipment, e.g. by means of safe diameters for storage vessels, control of slabs and appropriate separation distances between containers in storage. The loss of confinement/geometry due to leaks or breaks should also be accounted for;
(c) Concentration of fissile material in solutions, e.g. in the wet process for recycling uranium;
(d) Presence of reflectors or appropriate neutron absorbers, e.g. in the construction of storage areas, drums for powder and fuel shipment containers;
(e) Degree of moderation, e.g. by means of control of moisture levels and of the amount of additives in powder.

5.12. Para. 6.138 of SSR-4 Ref. [1] requires that preference be given to achieving criticality safety by design rather than by means of administrative measures. As an example, to the extent practicable, vessels which could contain fissile material should be made geometrically safe and. should be designed for the maximum authorized enrichment level.

4.12.5.13. The aim of the criticality safety analysis, as required in para. I.6 of Appendix I of Ref. [1], is to demonstrate that the design of equipment together with the related safety measures areis such that the values of controlled parameters are always maintained in the subcritical range. This is generally achieved by determining the effective multiplication factor (keff), which depends on the mass, the distribution and the nuclear properties of the fissionable material and all other materials with which it is associated. The calculated value of keff (including all uncertainties and biases) is then 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]).

4.13.5.14. Several methods 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. For more extensive guidance on performing a criticality safety assessment, including guidance on validation of computer codes see section 4 of SSG-27 [2].

4.14.5.15. 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:

– The useUse of a conservative approach (with account taken of uncertainties in physical parameters and of the physical possibility of worst caseworst-case moderation conditions, etc.).
– The useUse of appropriate and qualified computer codes that are validated within their applicable range and oftogether with the appropriate data libraries of nuclear reaction cross-sections, for the normal and credible abnormal conditions being analysed, while taking into account any bias. (see 4.20-4.25 of SSG-27 [2]).

4.15.5.16. The following parameters should be included in the scope of are recommendations for conducting a criticality safety analysis for a uranium fuel fabrication facility to meet the safety requirements established in Ref. [1], Appendix I, paras I.6 and I.7:

(a) *Mass.* The mass margin should be around more than 100%twice of the maximum mass value attained in normal operation (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. (see also para. 3.17 of SSG-27 [2])
(b) *Geometry of processing equipment.* The analysis should cover possible changes in dimensions due to operation (e.g. bulging of slab tanks or slab hoppers).
(c) *Concentration and density.* The analysis should cover a range of: (i) uranium concentrations for solutions; and (ii) powder and pellet densities plus moderators for solids, to determine the most reactive conditions that could occur.
(d) *Moderation.* The analysis should cover the presence of moderators that are commonly present in uranium fuel fabrication facilities, such as water, oil and other hydrogenous substances (e.g. additives for UO_2 powder), or that may be present in accident conditions (e.g. water from firefighting). Special consideration should be given to cases of inhomogeneous moderation, in particular when transfers of fissile material take place.
(e) *Reflection.* The most conservative margin should be retained of those resulting from different assumptions such as: (i) a hypothetical thickness of water around the processing unit; and (ii)

consideration of the neutron reflection effect due to the presence of human beingsbodies, organic materials, wood, concrete, steel of the container, etc., around the processing unit. 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 (para. 3.22 of SSG-27 [2]).

(f) *Neutron interaction.* Consideration should be given to neutron interaction between all facility parts. This includes the minimum distance of mobile units containing uranium (such as drums), the engineered means for ensuring the minimal distance between equipment containing uranium, and the presence and proper use of the isotopic neutron sources.

(f)(g) *Neutron absorbers.* The neutron absorbers that may be used in uranium fuel fabrication facilities include cadmium, boron, gadolinium and polyvinyl chloride (PVC) used in 'spiders' inside powder drums, plates in the storage areas for pellets or fuel assemblies and borosilicate glass rings ('Raschig' rings) in tanks for liquids. The effects of the inadvertent removal of the neutron absorbers should be considered in the analysis. Presence (and effectiveness) of absorbers should be verified on a periodic basis and before batching of containers or vessels relying on those absorbers.

Confinement to protect against internal exposure and chemical hazards

5.17. To meet the requirementRequirements 34 and 42 of SSR-4 [1] on protection against internal radiation exposure and against toxic chemicalof workers, the public and the environment against releases of hazardous material as established in para. 6.37 of Ref. [1], the use of and the inventory of liquid UF_6 in the facility should be kept to a minimum.

4.16.5.18. As such a uraniumUranium fuel fabrication facility should be designed to minimize, to the extent practicable, contamination of the facility and the environment, and to include provisions to facilitate decontamination and the eventual decommissioning of the facility.

4.17.5.19. The use of an appropriate containment system(s) should be the primary method for protection against the spreading of dust contamination from areas where significant amounts of either uranium powders or hazardous substances in gaseous dispersible form are heldhandled. When practicable, and to improve the effectiveness of the static containment system (physical barriers), a dynamic containment system should be used to create pressure gradients to cause a flow of air towards parts of equipment or areas that are more contaminated. A cascade of reducing absolute pressures can thus be established between the environment outside the building and the hazardous material inside.

4.18.5.20. In the design of the ventilation and containment systems for the uranium fuel fabrication facility, 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. face velocity at the opening of enclosuresthe acceptable range of air speeds at the opening of a hood); and (vi) the dose rate at the filters. In addition, generation of smoke in case of fire should be considered which could pose different requirements to the ventilation system (see para 5.46).

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

Protection of workerspersonnel

4.20.5.22. The ventilation system should be used as one of the means of minimizing the radiation exposure of personnel workers and exposure to hazardous material that could become airborne and so could be inhaled by personnelworkers. Uranium fuel fabrication 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 (Requirement 8 of SSR-4 [1]).

4.21.5.23. Where possible, The the need for the use of protective respiratory equipment should be avoidedminimized through careful design of the containment and ventilation systems (fixed and portable).

4.22.5.24. 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 particulates in the ducts. Multiple filters in series should be used to avoid reliance on a single barrier. In addition, duty and standby filters and/or fans should be provided to ensure the continuous functioning of the ventilation systems. If this is not the case, it should be ensured that failure of the duty fan or filters will result in the safe shutdown of equipment in the affected area.

4.23.5.25. 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 concentrations or gas concentrations in ventilation systems should be installed as necessary.

4.24.5.26. Alarm systems should be installed to alert operators to of fan failures and of high or low differential pressures across filters. At the design stage, provision should also be made for the installation of equipment for monitoring airborne uranium concentration and/or gas concentration. Monitoring points should be chosen that would correspond most accurately to the exposure of personnel workers and would minimize the time for detection of any leakage (see para. 6.1216.39 of Ref.SSR-4 [1]).

4.25.5.27. 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 fireproof dampers and should be constructed from non-flammable and non-corrosive materials.

4.26.5.28. To facilitate decontamination and eventual decommissioning of the facility, the walls, floors and ceilings in areas of the uranium fuel fabrication facility where contamination is likely should be made non-porous and easy to clean. This may be done by applying special coatings, such as epoxy, to surfaces. 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

5.29. The design should provide for the minimization of releases to environment during normal operation by application of best available technology.

5.30. The number of physical barriers for containment should be adapted to the safety significance of the hazard. The minimum number of barriers is generally two (e.g. ventilation system and the building structure). , in accordance with the principle of redundancy (see para. II-1 of Annex II of Ref. [1]). The optimum preferred number of barriers is often three. However, in some cases, only one barrier is sufficient (e.g. cylinder containing solid UF_6)

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

5.32. Uncontrolled dispersion of radioactive 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, or the room or the building itself.

4.28.5.33. In addition, vVentilation of the containment systems, by the discharge of exhaust gases through a stack via gas cleaning equipment such as a filter, reduces the normal environmental discharges of radioactive material to very low levels. In such cases, the ventilation system may also be regarded as a containment barrier.

Protection against external exposure

4.29.5.34. Relevant requirements on design provisions for protection against external radiation exposure are listed in Requirement 36 and the subsequent paras. of SSR-4 [1]. External exposure can should be controlled by means of an appropriate combination of requirements on distance, time and shielding. The installation of shielding or the setting of restrictions on occupancy should be considered for areas used for storing cylinders, in particular empty cylinders that have contained reprocessed uranium since some by-products of irradiation will remain in the cylinder. Similar precautions should be taken in areas of the facility where the uranium has a high specific density and significant amounts of uranium are present (e.g. in storage areas for pellets and fuels).

4.30.5.35. When the UO_2 is of low density (as is the case in conversion or blending units for instance), the shielding provided by the vessels and pipework of the uranium fuel fabrication facility will normally be sufficient to control exposure. In cases where reprocessed uranium is used, specific precautions should be taken to limit the exposure of personnel workers to the decay products (208Tl and 212Bi) of 232U. Such precautions may include administrative arrangements to limit the period of time for which uranium is stored on the site or the installation of shielding.

POSTULATED INITIATING EVENTS

Internal initiating eventshazards

Fire and explosions

4.31.5.36. Uranium fuel fabrication facilities, like all industrial facilities, have to be designed to control fire hazards in order to protect personnelworkers, the public and the environment. Fire in uranium fuel fabrication facilities may lead to the dispersion of radioactive material and/or toxic material by breaching the containment barriers, or may cause a criticality accident by affecting the system or the parameters used for the control of criticality (e.g. the moderation control system or the dimensions of processing equipment).

4.32.5.37. The fire hazards that are specifically encountered in a uranium fuel fabrication facility, such as hazards due to solvents and hydrocarbon diluents, H_2O_2, anhydrous ammonia (NH_3, which is explosive and flammable), sulphuric acid or nitric acid (which pose a danger of ignition by reaction with organic materials), zirconium (a combustible metal, especially in powder or chip forms) and hydrogen, should be given due consideration at the design stage for the facility. Specialized equipment to detect hydrogen fires, should be considered and the design of hydrogen piping should avoid joints prone for failures. For the purpose of suppressing metallic fires appropriate firefighting equipment should be considered.

Fire hazard analysis

4.33.5.38. As an important aspect of fire hazard analysis for a uranium fuel fabrication facility, areas of the facility that require special consideration should be identified (see Requirement 22 of SSR-4 [1]). Special fire hazard analyses should be carried out forFire hazard analyses of the facility should give particular consideration for the following:

(a) Processes involving hydrogen, such as conversion, sintering and reduction of uranium oxide;
(b) Processes involving zirconium in powder form or the mechanical treatment of zirconium metal;
(c) Workshops such as the recycling shop and laboratories where flammable liquids and/or combustible liquids are used in processes such as solvent extraction;
(d) The storage of reactive chemicals (e.g. NH_3, H_2SO_4, HNO_3, H_2O_2, pore formers and lubricants);
(e) Areas with high fire loads, such as waste storage areas;
(f) Waste treatment areas, especially those where incineration is carried out;
(g) Rooms housing safety related equipment, e.g. items such as air filtering systems, whose degradation

damage may lead to radiological consequences that are considered to be unacceptable;

(h) Control rooms;

(h)(i) Impact of a fire on a solid UF_6 cylinder.

4.34.5.39. Fire hazard analysis involves 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. Fire hazard analysis is 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.

4.35.5.40. 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 may seem low, a fire might have significant consequences for safety and, as such, certain protective measures should be undertaken, such as delineating small fire areas, to prevent or curtail the fire from spreading.

5.41. 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

4.36.5.42. 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. Measures for mitigation should be put in place to minimize the consequences of a fire in the event that a fire breaks out despite preventive measures.

4.37.5.43. To accomplish the two-fold aim of fire prevention and mitigation, a number of general and specific measures should be taken, including the following:

– Separation of the areas where non-radioactive hazardous material is stored from the process areas.
– Minimization of the fire load of individual rooms.
– 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.
– 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 and smoke to spread beyond the fire zone in which it breaks out. The higher the fire risk, the greater the number of fire zones a building should have.
– Suppression or limitation of the number of possible ignition sources such as open flames or electrical sparks.

4.38.5.44. Fire extinguishing devices, automatic or manually operated, with adequate extinguishing agent, should be installed in zones where the outbreak of a fire is possible (see Ref.SSR-4 [1], Appendix

~~I,~~ para. 6.79~~I.10~~). In particular, ~~“The~~ the installation of automatic devices with water sprays ~~shall~~ should be carefully assessed for areas where uranium may be present, with account taken of the risk of criticality~~” (Ref. [1], Appendix I, para. I.11)~~. Consideration should be given to collection and treatment ~~minimizing the environmental impact~~ of the water used to extinguish fires.

~~4.39.~~5.45. The design of ventilation systems should be given particular consideration with regard to fire prevention. Dynamic containment comprises ventilation ducts and filter units which may 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. The fire dampers 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.

~~4.40.~~5.46. Lines that cross the boundaries between fire zones (e.g. electricity, gases and process lines) should be designed to ensure that fire does not spread.

Explosions

~~4.41.~~5.47. An explosion can be induced by a fire or it can be the initiating event that results in a fire. Explosions could breach the barriers providing containment and/or could affect the safety measures that are in place for preventing a criticality accident.

~~4.42.~~5.48. In uranium fuel fabrication facilities, the possible sources of explosions include:

(a) Gases (e.g. hydrogen used in the conversion process and sintering furnaces, heating gas, cracked ammonia gas containing a mixture of hydrogen and nitrogen);

(b) Chemical compounds such as ammonium nitrate used in recycling workshops;

~~(b)~~(c) By-products such as red oil, which might be produced in solvent extraction process.

~~4.43.~~5.49. In such situations, consideration should be given to the use of an inert gas atmosphere or dilution systems and to the ability of the components of the system to withstand explosions (e.g. explosions in sintering furnaces). Recycling systems should be regularly monitored to prevent the deposition of ammonium nitrate. ~~“~~In areas with potentially explosive atmospheres, the electrical network and equipment ~~shall~~ should be protected in accordance with national requirements~~the industrial safety regulations” (Ref. [1], Appendix I, para. I.12)~~.

Flooding

~~4.44.~~5.50. Flooding in a uranium fuel fabrication facility may lead to the dispersion of radioactive material and to changes in the conditions for neutron moderation.

~~4.45.~~5.51. In facilities where vessels and/or pipes containing water are present, the criticality analyses should be taken into account concerning 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.

~~4.46.~~5.52. 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.

Leaks and spills

~~4.47.~~5.53. Leaks from equipment and components such as pumps, valves and pipes can lead to the dispersion of radioactive material (e.g. UO_2, U_3O_8 powder and UF_6) and toxic chemicals (e.g. HF), and to the unnecessary generation of waste. Leaks of hydrogenous fluids (water, oil, etc.) can alter the neutron moderation in fissile material and thereby reduce criticality safety. Leaks of flammable gases (H_2, natural gas, propane) or liquids can lead to explosions and/or fires. Leak detection systems should be deployed where leaks could occur.

~~4.48.~~5.54. Vessels containing significant amounts of nuclear material in liquid form should be equipped with level detectors and alarms to prevent overfilling and with secondary containment features such as bunds or drip trays of appropriate capacity and configuration to ensure criticality safety.

5.55. Where it is possible for uranium powder to spill in quantities that could be significant from the standpoint of criticality safety, consideration should be given to installing design features to prevent water or moderator intrusion. Installation of humidity detectors and drainage systems should also be considered.

~~4.49.~~5.56. 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 services~~support systems~~

~~4.50.~~5.57. To fulfil the requirement established in para. ~~6.28~~6.89 of SSR-4~~Ref.~~ [1], an emergency power supply should be provided at least for:

(a) Criticality accident detection and alarm systems;
(b) Ventilation ~~fans~~systems, if necessary for ~~the~~ confinement purposes~~of fissile material~~;
(c) Detection and alarm systems for leaks of hazardous materials; including explosive gases;
(d) Some process control components (e.g. heating elements and valves);
(e) Fire detection and alarm systems;
(f) Monitoring systems for radiation protection and environmental protection;
(g) Fire water pumps, if ~~fire water is~~these are dependent on off-site electric power;

~~4.51.~~5.58. The loss of general supplies such as compressed gas for instrumentation and control, cooling water for process equipment and ventilation systems, heating water, breathing air and compressed air may also have some consequences for safety. For example:

(a) Loss of compressed gas control for safety valves and dampers. In accordance with the safety analysis, valves should be used that are designed to fail to a safe position.

(b) Loss of cooling or heating water. Adequate backup capacity or a redundant supply should be provided in the design.
(c) Loss of breathing air. Backup capacity or a redundant supply should be provided to allow work in areas with airborne radioactive material to continue to be carried out.

Loss or excess of process media

~~4.52.~~5.59. The loss of process media such as hydrogen, nitrogen or steam or any excess of these media may have consequences for safety. Some examples are:

(a) Incomplete chemical reactions, potentially leading to a release of UF_6 into the off-gas treatment system;
(b) Loss of leaktightness of equipment used for transporting uranium powder if a nitrogen flow is used for sealing;
(c) Loss of criticality safety due to loss of safe geometry or loss of moderation control by excess of process gases;
(d) Increase of levels of airborne contamination and/or concentration of hazardous material in the work areas of the facility because of overpressure in the equipment;
(e) Reduction of oxygen concentration in breathing air in the work areas of the facility due to a release of large amounts of nitrogen.

~~4.53.~~5.60. The flow and pressure of process gases should be controlled continuously. In the event of deviations in the flow or pressure, shutdown and/or lock up sequences should start automatically.

Facility and equipment~~Mechanical~~ failures

~~4.54.~~5.61. Particular consideration should be given to the containment for the highly corrosive HF (in vessels, pipes and pumps) and to powder transfer lines where abrasive powder will cause erosion.

~~4.55.~~5.62. 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.

~~4.56.~~5.63. 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.

External ~~initiating events~~hazards

General

5.64. A uranium fuel fabrication facility should be designed 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 [10] and its associated Safety Guides. Examples of specific external hazards for a fuel fabrication facility are provided in the following paragraphs under appropriate headings.

Earthquakes

5.65. To ensure that the design of a uranium fuel fabrication facility provides the required degree of robustness, a detailed seismic assessment (see SSR-1 [10] and IAEA Safety Standards Series No. SSG-9, Seismic Hazards in Site Evaluation for Nuclear Installations [12]) should be made including the following seismically induced events:

(a) Loss of support services, including utilities;

(b) Loss of confinement functions (static and dynamic);

(c) 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 and flooding);

~~(a)~~ The effect on criticality safety functions such as geometry and/or moderation and reflection of the following: i) deformation (geometry control); ii) displacement (geometry control, fixed neutron absorbers, neutron interaction); iii) loss of material (geometry control, soluble neutron absorbers).~~A uranium fuel fabrication facility should be designed for the design basis earthquake to ensure that an earthquake motion at the site would not induce a loss of confinement capability (especially for confinement of UF6 and HF) or a criticality accident (i.e. a seismically induced loss of criticality safety functions, such as geometry and moderation) with possible significant consequences for site personnel or members of the public.~~

~~(b) 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.~~

~~(c) 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.~~

(d) ~~An adequately conservative spectrum should be used for calculating the structural response to guarantee the stability of buildings and to ensure the integrity of the ultimate means of confinement~~

in the event of an earthquake. Certain structures, systems and components important to safety will require seismic qualification. This will apply mainly to equipment used for storage and vessels that will contain significant amounts of fissile or toxic chemical materials. Design calculations for the buildings and equipment should be made to verify that, in the event of an earthquake, no unacceptable release of fissile or toxic material to the environment would occur and the risk of a criticality accident would be very low.

External fires and explosions and external toxic hazards

4.57.5.66. Hazards from external fires and explosions could arise from various sources in the vicinity of uranium fuel fabrication 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.

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

Extreme weather conditions

4.59. Typically, the extreme weather conditions assumed in the design and in the evaluation of the response of a uranium fuel fabrication facility are wind loading, tornadoes, tsunamis, extreme rainfall, extreme snowfall, extreme temperatures and flooding.

4.60. 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.

4.61. 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.

4.62.5.68. A uranium fuel fabrication facility should be protected against extreme weather 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;
(c) The safe shutdown of the facility in accordance with the operational limits and conditions.

Tornadoes

4.63.5.69. Measures for the protection of the facility against tornadoes will depend on the meteorological conditions in the area in which the facility is located. The design of buildings and ventilation systems should be in compliance with specific national regulations relating to hazards from tornadoes.

4.64.5.70. 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 secondary fragments arising from collisions with and spallation of concrete walls or from other types of transfer of momentum.

Extreme temperatures

4.65.5.71. The potential duration of extreme low or high temperatures should be taken into account in the design of support system equipment to prevent unacceptable effects such as the freezing of cooling circuits or adverse effects on venting and cooling systems.

4.66.5.72. If safety limits for humidity and/or the 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.

Snowfall and ice storms

4.67.5.73. The occurrence of Snowfall snowfall and ice storms and its effects should be taken into account in the design and safety analysis. Snow and ice areis generally taken into account as an additional load on the roofs of buildings. The neutron reflecting effect or the interspersed moderation effect of the snow, if relevant, should be considered.

FloodsFlooding

4.68. Flooding should be taken into account in the design of a facility. Two approaches to dealing with flooding hazards have been put forward:

~~In some states the highest flood levels recorded over the period of historical record are taken into account and nuclear facilities are sited at specific locations above the flood level or at a sufficient elevation to avoid major damage from flooding.~~

5.74. ~~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 consideration. The buildings of the facility are designed to withstand the water wave arising from the breach of the dam. In such cases the equipment — especially that used for the storage of fissile material — should be designed to prevent any criticality accident.~~For flooding events, attention should be focused on potential leak paths (containment breaks) into active cells and structures, systems and components important to safety at risk of damage. In all cases, equipment containing fissile material should be designed to prevent any criticality accident. Electrical systems, instrumentation and control systems, emergency power systems (batteries and power generation systems) and control rooms should be protected by design.

~~4.69.~~5.75. 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 level historically recorded and to siting the facility above this flood level, at sufficient elevation and with sufficient margin to account for uncertainties (e.g. in postulated effects of global warming), to avoid major damage from flooding.

Accidental aircraft crashes

~~4.70.~~5.76. ~~The likelihood and possible consequences of impacts onto the 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 (bullet (h)) of Ref. [1].~~ In accordance with the risks identified in the site evaluation (see Section 4), uranium fuel fabrication facility should be designed to withstand the design basis impact.

~~4.71.~~5.77. For evaluating the consequences of impacts or the adequacy of the design to resist aircraft impacts, only realistic crash scenarios should be considered, which may require knowledge of such factors as the possible angle of impact 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 specific requirements for fire protection and for emergency preparedness and response will be necessary.

INSTRUMENTATION AND CONTROL (I&C)

~~**Instrumentation**~~

~~4.72.~~5.78. Instrumentation should be provided to monitor the relevant ~~variables~~ 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~~ accident~~s~~ 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 operating procedures~~ or automatic systems~~.

~~4.73.~~5.79. Instrumentation should be provided for measuring all the main ~~variables~~ parameters whose variation may 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 criticality safety related parameters, radiation levels~~doses due to internal and external exposure~~, releases of effluents and ventilation conditions), and for obtaining any other information about the facility necessary for its reliable and safe operation (such as presence of personnel and environmental conditions).~~ Provision should be made for the automatic measurement and recording of values of parameters that are important to safety.~~

~~Control systems~~

~~4.74.~~5.80. Passive and active engineering controls are more reliable than administrative controls 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, which is generally the shutdown state.

~~4.75.~~5.81. 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 impression of the status and performance of the facility. 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.

Control rooms and panels

~~4.76.~~5.82. Control rooms and Human-Machine-Interface panels should be provided to centralize the availability of information and monitoring of actions. The need for and location of control rooms and panels in different areas should be evaluated taking into account occupational exposure, safety of personnel and emergency response. 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 personnel. Particular consideration should be paid to identifying those events, both internal and external to the control rooms, that may pose a direct threat to the operation of control rooms. Human Ergonomic factors should be taken into account in the design of control rooms and the design of control room displays and systems.~~main data displays, controls and alarms for general conditions at the facility. Occupational exposure should be minimized by locating the control rooms in parts of the facility where the levels of radiation are low. For specific processes (e.g. conversion), it may be useful to have dedicated control rooms to allow the remote monitoring of operations, thereby reducing exposures and risks to operators.~~

~~Particular consideration should be paid to identifying those events, both internal and external to the control rooms, that may 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.~~

Safety related I&C systems ~~for normal operation~~

~~4.77.~~5.83. Safety related I&C systems ~~for normal operation~~ of a uranium fuel fabrication facility should include systems for the following:

(1) I&C relating to criticality detection and alarm:

– 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 present – see para. 6.173 of SSR-4 [1];

(2) Fire detection:

– All rooms with fire loads or significant amounts of fissile and/or toxic chemical material should be equipped with fire alarms.

– Gas detectors should be used in areas where a leakage of gases (e.g. H_2) could conceivably produce an explosive atmosphere.

~~(2)~~(3) Process control ~~instrumentation~~:

– Indicating temperatures, pressures, flow rates, concentrations of chemicals and/or radioactive material, tank levels, ~~etc.~~cylinder weights.

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

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

~~(3)~~(4) Control and monitoring of ventilation. Mainly of differential pressures across high efficiency particulate air (HEPA) filters, prefilters, enclosure exhausts and air flows into hot cells, gloveboxes and hoods~~, as necessary~~.

(5) Control of gaseous and liquid effluents. Real time measurements should be provided if there is a risk of exceeding regulatory limits; otherwise, retrospective measurements on continuously sampled filters and/or probes will generally be sufficient.

~~(4)~~(6) Control of occupational radiation exposure~~Radiation dosimetry~~.

– Sensitive films and/or dosimeters with real time displays and/or alarms, especially in areas with inspection equipment such as X ray generators and active sources (for monitoring external exposure).

– Continuous sampling of filters for retrospective measurement and/or real time measurement with alarms for the detection of releases of radioactive material (for monitoring internal exposure).

(7) Control of Gaseous gaseous and liquid effluents. Real time measurements are necessary if there is a risk of authorized limits being exceeded; otherwise retrospective measurements on continuously sampled filters or probes should be sufficient.

(5)(8) Control of chemical releases. Real time detection and alarm systems should be used in the process areas and/or laboratories where UF_6 is present.

Safety related I&C systems for anticipated operational occurrences

In addition to the listing provided in para. 4.77, safety related I&C systems for use in anticipated operational occurrences should include the following provisions:

All rooms with fissile and/or toxic chemical material should be equipped with fire alarms (except where the permanent presence of operators is sufficient).

Gas detectors should be used in areas where a leakage of gases (e.g. H2 or heating gas) could produce an explosive atmosphere.

Safety related I&C systems for design basis accident conditions

The safety related I&C systems for design basis accident conditions should include provisions in addition to the previous listings to address the following situations:

Criticality. The requirement on I&C systems relating to criticality control is established in para. I.13 of Appendix I of Ref. [1].

Chemical release. The requirement on I&C systems relating to monitoring for chemical releases is established in para. I.14 of Appendix I of Ref. [1].

Release of effluents. The devices used for measuring releases of gaseous and liquid effluents in operational states should also be capable of measuring such releases in the case of a design basis accident. If the measurement devices used in operational states become saturated in accident conditions, resulting in unmonitored releases of effluents, environment sampling should be used to estimate the releases of gaseous and liquid effluents.

HUMAN FACTOR CONSIDERATIONS

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

4.79.5.85. Human factors in operation, inspection, periodic testing and maintenance should be considered at the design stage. Human factors to be considered for uranium fuel fabrication facility should include:

- Possible effects on safety of unauthorized human actions (with account taken of ease of intervention by the operator and tolerance of human error);
- The potential for occupational exposure.

4.80.5.86. 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:

(a) Design of working conditions to ergonomic principles:
   - The operator–process interface, e.g. electronic control panels displaying all necessary information and no more.
   - The working environment, e.g. good accessibility of 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) Operational experience feedback relevant to human factors

SAFETY ANALYSIS

4.81. Safety analysis forThe safety assessment of uranium fuel fabrication facilities should include the safety analysis of the variety of hazards for the whole facility and all activities. The IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [13] requires that all credible postulated initiating events shall be assessed.be performed in two major steps:

4.82. The assessment of occupational exposure and public exposure for operational states of the facility and comparison with authorized limits for operational states;

4.83.5.87. 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.

4.84.5.88. The list of postulated initiating events identified should take into account all the internal and external hazards and the resulting event scenarios and should be carried out considering all the structures, systems and components important to safety that might be affectedThe results of these two steps should be reviewed for identification of the possible need for additional operational limits and conditions.

Safety analysis for operational states

Occupational exposure and exposure of the public

4.85.5.89. A facility specific, realistic, enveloping and robust (i.e. conservative) assessment of internal and external occupational exposure and public exposure 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 an 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 approach plus uncertainties 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 and should account for maintenance activities. 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 facility) 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

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

4.86.5.90. The acceptance criteria associated with the accident analysis should be defined in accordance with GSR Part 4 (Rev. 1), Requirement 16 [13], and with respect to any national regulations and relevant criteria.For uranium fuel fabrication 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.

4.87.5.91. The consequences of design basis accidents for a uranium fuel fabrication facility 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 or 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.

4.88.5.92. To estimate the on-site and off-site consequences of an accident, the wide 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 enveloping cases encompassing the worst consequences should be determined.

4.89.5.93. The following two approaches or an equivalent approach should be considered in the safety assessment of a uranium fuel fabrication facility:

(a) An One approach involves the identification of structures, systems and components important to safety and administrative measures which either reduce the consequences and/or the likelihoods of potential accidents below established criteriausing 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).

(b) An Another approach involves the identification of structures, systems and components important to safety which by design, along with administrative measures, ensure that the consequences of enveloping accident cases with predetermined initiating events are within established criteria.using the enveloping case (the worst case approach), with no account taken of any safety feature that may reduce the consequences or the likelihood of accidents. This assessment is followed by an assessment of the possible accident sequences, with account taken of the emergency procedures and the means planned for mitigating the consequences of the accident. Unlike the first approach, for this approach, only accident consequences and not likelihoods are considered for demonstrating safety. For example, for this approach, the facility designers would ensure that by design the criticality dose contour from an assumed reference criticality excursion (to be defined and justified by the operator) would not impact the public. However, if this is not possible, then a justification should be provided by the operator as to why this cannot be achieved.

Analysis of Design Extension Conditions

5.94. The safety analysis should also identify design extension conditions followed by an analysis of their progression and consequences in accordance with Requirement 21 of SSR-4 [1]. The objective is to analyse additional accident scenarios to be addressed in the design of a uranium fuel fabrication 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 shall be sufficient for the protection of the public, and sufficient time shall be available to take such actions. Moreover, the possibility of conditions arising that could lead to early releases of radioactive material or to large releases of radioactive material is practically eliminated. Design extension conditions include events more severe than design basis accidents that 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 Appendix of SSR-4 [1] should 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 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.

5.95. 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.

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

5.97. Examples of design extension conditions that are applicable to uranium fuel fabrication facilities can be found in the IAEA Safety Report Series No. 90, Safety Reassessment for Nuclear Fuel Cycle Facilities in Light of the Accident at the Fukushima Daiichi Nuclear Power Plant [14].

~~4.90.~~5.98. Analysis of design extension conditions should also demonstrate that the uranium fuel fabrication facility can be brought into the state where the confinement function and sub-criticality can be maintained in the long-term (see also Ref. [2]).

Assessment of possible radiological or associated chemical consequences

~~4.91.~~5.99. ~~Safety assessments should address the consequences associated with possible accidents.~~ The main steps in the ~~development and~~safety analysis ~~of accident scenarios~~ should include the following:

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

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

~~(b)~~(c) Identification of individuals and population groups (for facility personnel ~~workers~~ and members of the public) who could possibly be affected by radiation risks and associated chemical risks arising from the operation of the facility~~accidents, i.e. a ‘critical group’ of people living in the vicinity of the facility~~.

~~(c) Specification of the accident configurations, with the corresponding operating procedures and administrative controls for operations.~~

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

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

~~(e)~~(f) Identification and specification~~Specification~~ of the structures, systems and components important to safety that are credited to reduce the likelihood and/or to mitigate the consequences of accidents.

These structures, systems and components important to safety that are credited in the safety assessment should be qualified to perform their functions in the accident conditions.

(f)(g) Characterization of the source term (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 for the individuals identified in the safety assessment. Considerations for interface between safety and security.

4.92.5.100. The Analysis analysis of the actual site conditions at the site and the conditions expected in the future involves a review of the meteorological, geological and hydrological conditions at the site that may influence facility operations or may play a part in transporting material or transferring energy that is might be released from the facility (see Section 5 of Ref. [1]).

4.93.5.101. Environmental transport 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.

5.102. The identification of workers personnel and members of the public (the critical group of maximally exposed off-site individuals) who may potentially be affected by an accident involves a review of descriptions of the facility and of demographic information.

5.103. In assessment of consequences of design extension conditions, less conservative assumptions compared to design basis analysis may be used (for example prevailing wind directions on the site).

5.104. The magnitude and severity of conditions considered in design extension conditions as well as the acceptance criteria used for acceptability of consequences of design extension conditions should be accepted by the national regulatory body.

Assessment of possible associated chemical consequences

5.105. Useful guideline for assessing the acute and chronic toxic effects of chemicals used in fuel fabrication facilities is provided Ref. [15].

MANAGEMENT OF RADIOACTIVE WASTE AND EFFLUENTS

5.106. The general requirements for predisposal waste management are established in the IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [16] with additional guidance provided in the IAEA Safety Standards Series No. GSG-3, The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste [17], IAEA Safety Standards Series No. GSG-1, Classification of Radioactive Waste [18], IAEA Safety Standards Series No. SSG-41, Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities [19] and IAEA Safety

Standards Series No. GS-G-3.3, The Management System for the Processing, Handling and Storage of Radioactive Waste [20]. Recommendations are provided in the following paragraphs on aspects that are particularly relevant or specific to uranium fuel fabrication facilities.

4.94.5.107. Uranium fuel fabrication facilities should be designed to minimize the generation of radioactive waste both in operation and in decommissioning. For economic and environmental reasons, the recovery of nuclear material and the reuse of chemicals are common practices in uranium fuel fabrication facilities. These practices help to minimize the generation of waste in both solid and liquid forms [8, 9].

4.95.5.108. It is a good practice to reduce the volume and to minimize the reactivity of the radioactive waste in a waste treatment centre on the site. Some important elements of a waste treatment centre are:

- A dedicated workshop for waste treatment;
- Equipment for decontamination;
- The means for conditioning waste;
- Devices for measuring activity;
- A system for ensuring the identification and traceability of and record keeping for waste products;
- Sufficient capacity for storage of waste.

4.96.5.109. In the case of uranium fuel fabrication facilities, the nuclear material to be recovered is uranium both from scraps (i.e. products that are out of specification and that are not directly recycled in the fuel fabrication process) 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 between the loss of uranium through unrecovered waste and the generation of liquid effluents in the recovery process.

MANAGEMENT OF GASEOUS AND LIQUID RELEASES

4.97.5.110. Liquid effluents to be discharged to the environment should be suitably monitored and treated as necessary to reduce the discharges of radioactive material and hazardous chemicals.

4.98.5.111. Monitoring equipment should be installed as necessary, such as differential pressure gauges for detecting filter failures and devices for measuring activity or gas concentration and for measuring the discharge flow by continuous sampling.

OTHER DESIGN CONSIDERATIONS

4.99.5.112. In meeting Requirement 7 of SSR-4 [1] the design of the facility and equipment, including the selection of materials, the needshould be such as to limit the accumulation of uranium and the ease of cleaning and/or surface decontamination should be taken into account at an early stage.

Considering inadvertent accumulation of uranium in process lines, ventilation systems and containers special consideration should be given also to operational experience feedback (see Ref. [21]).

~~4.100.~~5.113. For specific process areas such as conversion areas and sintering furnaces, consideration should be given to the means by which the facility can be shut down safely in an emergency.

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

5.114. Requirements for control over the transfer of radioactive and hazardous materials are listed in Requirement 28 and para. 6.111 – 6.112 in SSR-4 [1].

5.115. For incoming containers, containing radioactive or hazardous material, sufficient technical provisions for checking the integrity should be considered during the design phase.

5.116. All containers used for transportation of radioactive and hazardous material on site should be considered in the safety analysis.

5.117. For cases where misidentification of containers could impose hazard, provisions for easy identification of the content should be used, if possible (for example unique colours, shapes, valves).

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

5.119. The analyses of handlings should cover:

(a) Transportation routes and intersections;
(b) Technical limits of the transportation vehicles;
(c) Handling failures during transportation.

~~4.101.~~5.120. The design of the facility and the production processes should take into account the number of onsite transfers of radioactive and hazardous materials across different safety related zones (such as contamination and criticality control zones).

AGEING MANAGEMENT CONSIDERATIONS

5.121. In line with Requirement 32 of SSR-4 [1], the design of facility should take into account the ageing effects of systems, structures and components important to safety to ensure their reliability and availability during the lifetime of the facility.

5.122. 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.

~~4.102.~~5.123. An ageing management programme should be implemented at the design stage to allow timely maintenance or anticipating equipment replacements.

5.124. Effectiveness of the ageing management programme should be reviewed and assessed periodically.

5.6. CONSTRUCTION

6.1. Requirements for construction of fuel fabrication facilities are listed in Requirement 53 and para. 7.1–7.7 of SSR-4 [1]. General guidance on the construction and construction management of nuclear installations is provided in the IAEA Safety Standards Series No. SSG-38, Construction for Nuclear Installations [22].

5.1.6.2. For uranium fuel fabrication 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).

5.2.6.3. The extent of regulatory involvement in construction should be commensurate with the hazards posed by the facility over its lifetime. 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 prevent future operational problems.

5.3.6.4. Current good practices should be used for building construction and for the fabrication and installation of facility equipment.

5.4.6.5. The construction and commissioning phases may overlap. Construction work in an environment in which nuclear material is present owing to commissioning may be significantly more difficult and time consuming than when no radioactive material is present. Preferably, construction work should be completed prior to commissioning of the facility or its parts. In cases when the construction and commissioning or operational phases overlap, the 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.

6.6. All structures and components after their installation should be properly cleaned and painted with suitable primer followed by appropriate surface treatment. Effect of nearby activities handling corrosive substances should also be considered.

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

~~6.~~7. COMMISSIONING

7.1. The requirements for commissioning are listed in Requirement 54 of SSR-4 [1] and subsequent paragraphs. 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 behaviours and attitudes, throughout the entire organization.

~~6.1.~~7.2. For a uranium fuel fabrication facility, the commissioning should be divided into two main phases:

(1) Inactive or 'cold' commissioning (i.e. commissioning prior to the introduction of uranium into the facility). In this phase, the facility's systems are systematically tested (both individual items of equipment and the systems in their entirety). As much verification and testing as possible should be carried out because of the relative ease of taking corrective actions in this phase. However, given the low radiation levels in a uranium fuel fabrication facility, it would also be acceptable to carry out some of these activities in the subsequent phase. The operating organization should take the opportunity to finalize the set of operational documents.

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

7.3. 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 processes for the removal of uranium.

~~6.2.~~7.4. During inactive 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 phase.

~~6.3. 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.~~

7.5. During commissioning and later during operation of the facility, the estimated doses to personnel ~~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~~analysis report) or adding or changing safety features or work practices.

6.4.7.6. Where possible, lessons from the commissioning and operation of similar uranium fuel fabrication facility should be sought out and applied.

7.8. OPERATION

CHARACTERISTICS ORGANIZATION OF OPERATION OF URANIUM FUEL FABRICATION FACILITIES

7.1.8.1. The distinctive features of a uranium fuel fabrication facility described in para. 2.1that should be taken into account in meeting the safety requirements established in Ref. [1] areSSR-4 [1] for operation.:

The relatively low radiotoxicity of leu, which is processed, handled and stored in large inventories in finely divided and dispersible forms.

The potential for chemical and toxicological impacts on workers, the public and the environment due mainly to hydrogen fluoride, uranium hexafluoride, hydrogen, nitric acid and ammonia).

The potential for fire and explosions resulting in a release of radioactive material (e.g. A hydrogen explosion in a conversion process or a sintering furnace).

7.2.8.2. In a uranium fuel fabrication facility, recent developments have made full automation of individual processes which helps mainly to improve productivity and reduce human interaction with radioactive material. Because of this, automation serves mainly to improve productivity and is used less than in other types of fuel cycle facilities; more emphasis is placed on administrative measures, monitoring and preventative maintenance to ensure safe operation.

8.3. In this section, specific recommendations on good practices and additional considerations in meeting the safety requirements for a uranium fuel fabrication facility are presented.

7.3.8.4. The safety committee in a fuel fabrication facility, as defined in SSR-4 [1], para. 4.29, should be created from the safety committee established for commissioning. Its function should be specified in the management system, it should be adequately staffed, and it should include diverse expertise and have appropriate independence from the direct line management of the operating organization.

QUALIFICATION AND TRAINING OF PERSONNEL

8.5. The safety requirements relating to the qualification and training of facility personnel are established in paras 9.8–9.13 and in paras I.15–I.16 of Appendix I of Ref. Requirements 56 and 58 of SSR-4 [1]. Further Recommendations recommendations are provided in paras 4.6–4.25 of Ref. GS-G-3.1

[6]. In addition, personnel should be provided periodically with basic training in radiation safety.

8.6. Personnel should be provided periodically with basic training in radiation safety and emphasis should be made on protection from radiation exposure, chemical hazards and emergency preparedness and response.

7.4.8.7. 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 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 most effectively.

GENERAL RECOMMENDATIONS FOR FACILITY OPERATIONOPERATIONAL DOCUMENTATION

7.5.8.8. To ensure that the uranium fuel fabrication facility operates well within the operational limits and conditions under normal circumstances, a set of lower level sublimits and conditions should be defined. Such sublimits and conditions should be clear and should be made available to and well understood by the personnel operating the facility.Requirement 57 of SSR-4 [1] and subsequent paragraphs require that operational limits and conditions are developed for a uranium fuel fabrication facility. The safety significance of the operational limits and conditions as well as of the action levels and conditions should be well understood by the personnel operating the facility. The set of action levels should be defined and maintained by the operator.

7.6.8.9. Operating documents should be prepared that list all the operational limits and conditions under which the facility is operated. Annex III gives examples of parameters that can be used for defining the operational limits and conditions in the various processing areas of the facility.

7.7.8.10. Generic limits should also be set for the facility. Examples of limits on operating parameters (SSR-4 [1], para. 9.31) for a uranium fuel fabrication facilitysuch limits are:

– The maximum enrichment of uranium allowed at the facility;
– The specification for UF_6 cylinders and the maximum inventory of UF_6 cylinders allowed in the storage area;
– The maximum allowed throughputs and inventories for the facility.
– Minimum staffing requirements and availability of specific expertise (criticality expert).

7.8.8.11. Consideration should be given to ensuring that uranium, especially uranium powder or pellets, is present only in areas designed for the storage or handling of uranium. Programmes should be put in place for routine monitoring for surface contamination and airborne radioactive material, and more generally for ensuring an adequate level of housekeeping.

7.9.8.12. Operating procedures to directly control process operations directly should be developed. The procedures should include directions for attaining a safe state of the facility from all anticipated operational occurrences and accident conditions. In a uranium fuel fabrication facility, the safe operational state attained after any anticipated operational occurrence is often the shutdown state. Nevertheless, specific operating procedures should be used for the shutdown of certain equipment such as UF_6 vaporizers, rotary kilns for uranium dioxide and sintering furnaces. Procedures of this type should include the actions required to ensure criticality safety, fire protection, emergency planning and environmental protection.

7.10.8.13. 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

8.14. All maintenance activities should be pre-authorised on the basis of a safety assessment.

8.15. For maintenance performed in areas containing or near enriched uranium, criticality safety staff should be consulted before the work commences (see also para. 5.46 of SSG-27 [2]).

8.16. Maintenance activities using radioactive sources or X-ray generators should be coordinated with radiation protection personnel especially when performed by sub-contractors.

7.11.8.17. When carrying out maintenance in a uranium fuel fabrication 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 hydrogen fluoride, ammonia, hydrogen and nitric acid.

7.12.8.18. Maintenance should follow good practices, with particular consideration given to:

(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 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 personal protective equipment and ensuring its use, and emergency response procedures.
(e) Reinstallation of equipment, e.g. reassembly, reconnection of pipes and cables, testing, cleaning the job site and monitoring after recommissioning.

8.19. Additional precautions may also be necessary for the prevention of a criticality accident (see paras 7.20–7.23). Equipment configurations during maintenance can be changed to abnormal settings and hence unexpected operational modes with no prior safety analysis or operational limits and conditions could be reached. When maintenance is performed on installation that may contain enriched uranium or near a storage location of enriched uranium, criticality safety staff should be consulted before the work commences.

7.13.8.20. All temporary changes to the facility configuration during maintenance activities should be coordinated between safety and security specialists to avoid potential conflicts (e.g. cut of electrical power supply on some safety systems, opening of barriers and doors). Compensatory measures should be implemented as necessary.

7.14.8.21. The operating organization should have a system in place which ensures that the information and experience gained through maintenance activities is collected, recorded, analysed and utilized in operating experience feedback programme.

7.15.8.22. Compliance of the operational performance of the ventilation system with the fire protection requirements (see para 4.365.44) should be verified on a regular basis.

8.23. A programme Programme of for calibration and periodic inspections of the facility should be established., whose Its purpose is to verify that the facility and its structures, systems and components areis operating in accordance with the operational limits and conditions. Suitably qualified and experienced persons personnel should carry out calibrations and inspections. Particular consideration should be given to fatigue affecting equipment and to the ageing of structures structures, systems and components.

7.16.8.24. Places in the process line, identified by the operating organization as those with potential for accumulation of uranium compounds, should be periodically inspected.

AGEING MANAGEMENT

8.25. The operating organization should take into account following issues in implementing a systematic ageing management programme in line with requirement 60 of SSR-4 [1]:

(a) Support for the ageing management programme by the management of the operating organization;

(b) Early implementation of an ageing management programme;

(c) A proactive approach based on an adequate understanding of structures, systems and components ageing, rather than a reactive approach responding to structures, systems and components failures;

(d) Optimal operation of structures, systems and components to slow down the rate of ageing degradation;

(e) 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) Minimization of human performance factors that may lead to premature degradation, through enhancement of personnel motivation, sense of ownership and awareness, and understanding of the basic concepts of ageing management;

(g) Availability and use of correct operating procedures, tools and materials, and of a sufficient number of qualified personnel for a given task;

(h) Feedback of operating experience to learn from relevant ageing related events.

8.26. The aging management programme should consider the technical as well as the non-technical aspects of ageing and its effectiveness should be regularly assessed and reviewed (see also para. 5.124). The periodic tests and inspections should be completed by regular checks performed by operating personnel, such as:

(a) Monitoring of deterioration;

(b) Regular visual inspections of uranium powder pipes;

(c) Monitoring of operating conditions (taking heat images of electrical cabinets; check of temperatures of ventilator bearings).

CONTROL OF MODIFICATIONS

~~7.17.~~8.27. ~~A standard process for any modification should be applied in a uranium fuel fabrication facility.~~ The management system for a uranium fuel fabrication facility should include a standard process for all modifications (see para. 3.15). This process should use a modification control form or equivalent management tool. The modification control form should contain a description of what the modification is and why it is being made. The main purpose of the modification control form is to provide the basis for a safety assessment of the modification. The modification control form should be used to identify all the aspects of safety that may be affected by the modification, and to demonstrate that adequate and sufficient safety provisions are in place to control the potential hazards.

~~7.18.~~8.28. 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.

~~7.19.~~8.29. Modification control forms 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 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.

~~7.20.~~8.30. 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 and 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.

~~7.21.~~8.31. The modification control form should specify the functional checks that are required before the modified system may be declared fully operational again.

8.32. Modifications performed on design, layout or procedures of the facility might negatively affect security equipment and vice versa. For example, malfunction of safety equipment may damage nearby security equipment. Therefore, before approval and implementation, any proposed changes to the facility or management arrangements should be reviewed, assessed and endorsed from the safety objective view. In addition, its interface with security should be evaluated to verify that they do not compromise each other.

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

~~7.22.~~8.34. The modification control documentation should be retained at the facility in accordance with national requirements.

CRITICALITY CONTROL

~~7.23.~~8.35. The requirements for criticality safety in uranium fuel fabrication facilities are established in SSR-4 [1], para. 9.83 – 9.85 and 9.86, and general recommendations are provided in SSG-27 [2]. In a uranium fuel fabrication facility, it is particularly important that the procedures for controlling criticality hazard are strictly applied ~~(paras 9.49 and 9.50 of Ref. [1])~~.

~~7.24.~~8.36. Operational aspects of the control of criticality hazards in uranium fuel fabrication 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 powder (e.g. in ventilation ducting), inadvertent precipitation of material containing uranium in storage vessels or loss of neutron absorbers.

(b) Management of ~~the~~ moderating materials, particularly water; for example, decontamination of gloveboxes and ventilation hoods, or in laboratories, and leakages of oils from gear boxes or use of a water or CO_2 based firefighting system (e.g. automatic sprinklers).

(c) Management of mass in transfer of uranium (procedures, mass measurement, systems and records) for which safe mass control is used.
(d) Auxiliary activities such as sampling, homogenization and blending.
(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.

7.25.8.37. The tools used for the purposes of accounting for and control of nuclear material, such as the instruments used to carry out measurements of mass, volume or isotopic composition and software used for accounting these purposes, may also have application in the area of criticality safety. However, if there is any uncertainty about the characteristics of material containing uranium, conservative values should be used for parameters such as the level of enrichment and the density. This arises in particular in connection with floor sweepings and similar waste material.

7.26.8.38. Criticality hazards may be encountered when carrying out maintenance work. Waste and residues arising from decontamination activities should be collected in containers with a favourable geometry (see para. I.20 of Appendix I of Ref. [1]).

7.27.8.39. 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

8.40. 8.26. The requirements for radiation protection in operation are established in SSR-4 [1], para. 9.90-9.101 and in the IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [23]; recommendations are provided in the IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [24]. 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 (SSR-4 [1], para. 9.91).

7.28.8.41. In a uranium fuel fabrication facility, the main radiological hazard for both the workforce personnel and members of the public is from the inhalation of airborne material containing uranium compounds. Insoluble compounds of uranium such as the uranium oxides UO_2 and U_3O_8 pose a particular hazard because of their long biological half-lives (and therefore effective half-lives)[3] and their typically relatively small particle size (typically a few micrometres in diameter) when encountered in uranium fuel fabrication facilities (see para. I.22 of Appendix I of Ref. [1]).

7.29.8.42. Interventions for maintenance and/or modifications are activities that require justification

[3] The biological half-life is the time taken for the amount of a material in a specified tissue, organ or region of the body 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.

and optimization of protective actions as specified in Ref. GSR Part 3 [23]. The procedures for intervention should include:

(a) Estimation of the external exposure prior to the intervention.

(b) Preparatory activities to minimize the doses due to occupational exposure, including:

— Identifying specifically the risks associated with the intervention.

— Specifying in the work permit the procedures protective 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.

7.30.8.43. The risks of exposure of members of the public should be controlled minimized 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.

7.31.8.44. "The monitoring results from the radiation protection programme shall should be compared with the operational limits and conditions, and corrective actions shall be taken if necessary" (para. 9.43 of Ref. [1]). Furthermore, these monitoring results should be used to verify the dose calculations made in the initial environmental impact assessment.

Control of internal exposure

7.32.8.45. 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 at ventilation hoods and entrances to containment areas. Pressure drops across air filter banks should be checked and recorded regularly.

(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 to confirm the adequacy of cleaning programmes.

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

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

(g) Mobile air samplers should be used at possible sources of contamination as necessary.

(h) An investigation should be carried out promptly in response to readings 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 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 causing contamination by airborne radioactive material; (e.g. during periodic testing, inspection or maintenance).

(k) Personal protective equipment (e.g. respirators, gloves and clothes) should be made available for dealing with releases of chemicals or radioactive material from the normal means of confinement in specific operational circumstances (e.g. during maintenance or the cleaning of process equipment before changing enrichment levels).

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

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

7.33.8.46. In vivo monitoring and biological sampling should be made available as necessary for monitoring doses due to occupational exposure.

7.34.8.47. The extent and type of theworkplace monitoring should be commensurate with the expected levels of airborne activityradioactive material and the contamination and radiation type, and the potential for these to changelevels of workplaces.

7.35.8.48. For exposures which are expected to be low, The 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 personnel worker occupancy data. This method should be assessed, and should be reviewed as appropriate by the regulatory body.

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

7.37.8.50. 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 inside the vessel to determine whether any restrictions on the allowed time period for working are required.

7.38.8.51. Estimates should be regularly made, by means of monitoring data on effluents, of radiation doses due to internal exposure received by members of the public who live in the vicinity of the site.

~~Control of external exposure~~

~~7.39.~~8.52. There are only limited areas in a uranium fuel fabrication facility where specific measures for controlling external exposure are required. Typically these will be areas where uranium is stored in bulk. However, it should be noted that the processing of recycled uranium will require much more extensive measures for controlling external exposure.

8.53. 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 from Alfa-n reactions). In addition, newly emptied UF_6 cylinders may also result in external gamma radiation doses that need to be controlled.

~~7.40.~~8.54. Radioactive sources are also used ~~and radiation is generated~~ in a uranium fuel fabrication facility for specific purposes, for example:

(a) Radioactive sources are used for checking uranium enrichment (e.g. ^{252}Cf for rod scanning).
(b) Gamma rays are generated in the checking of uranium enrichment.
(c) X ray generators are used for inspecting fuel rods

~~7.41.~~8.55. External exposure should be controlled by:

(a) Ensuring that locations containing significant amounts of uranium are remote from areas of high occupancy;
(b) Removing uranium from vessels adjacent to work areas in use for extended maintenance work;
(c) Ensuring that radioactive sources are changed by suitably qualified and experienced persons;
(d) Performing routine surveys of radiation dose rates.

~~7.42.~~8.56. Additional controls should be considered if uranium from other than natural sources 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 before the first introduction of uranium from other than natural sources.

INDUSTRIAL AND CHEMICAL SAFETY

~~7.43.~~8.57. ~~See also para. 7.4.~~The requirements relating to industrial and chemical safety are established in Requirement 70 of SSR-4 [1].

~~7.44.~~8.58. The chemical hazards found in uranium fuel fabrication facilities may be summarized as follows:

(a) Chemical hazards due to the presence of hydrogen fluoride (e.g. from uranium hexafluoride), ammonia, nitric acid, sulphuric acid, potassium hydroxide, sodium hydroxide and uranium compounds.

(b) Explosion hazards due to hydrogen (H$_2$), ammonium nitrate, ammonia (NH$_3$), methanol and solvents and liquefied petroleum gas (LPG).

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

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

~~7.45.~~8.60. Fire hazard analyses should be ~~repeated~~ conducted periodically to incorporate changes that may adversely affect the potential for and spread of fires (see para. ~~4.30~~5.51). Specific fire protection equipment to handle metallic fires should be present

8.61. A health surveillance programme should be set up, in accordance with national regulations, for routinely monitoring the health of ~~workers~~ personnel who may 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.

~~7.46.~~8.62. During emergencies, special considerations should be given to the presence of combination of both chemical and radiological hazards.

MANAGEMENT OF RADIOACTIVE WASTE AND EFFLUENTS

~~7.47.~~8.63. The requirements relating to the management of radioactive waste and effluents in operation are established in paras ~~9.54–9.57 of Ref.~~9.102-9.108 of SSR-4 [1].

~~7.48.~~8.64. Gaseous radioactive and chemical discharges should be treated, where appropriate, by means of HEPA filters and chemical scrubbing systems. Performance standards should be set that specify performance levels at which filters or scrubber media are to be changed. After filter changes, tests should be carried out to ensure that new filters are correctly seated.

~~7.49.~~8.65. Chemicals should be recovered and reused where possible. This is particularly important for hydrofluoric acid. Care should be taken to ensure that hydrofluoric acid is suitable for reuse.

~~7.50.~~8.66. One easy way to minimize the generation of solid radioactive waste is to remove as much outer packing as possible before material is transferred to contaminated areas. Processes such as incineration, metal melting and compaction can be used to reduce the volume of waste. As far as reasonably practicable and in accordance with national regulations, waste material should be treated to allow its further use. Cleaning methods should be adopted at the facility that minimize waste generation.

~~7.51.~~8.67. Quality control regimes should be applied to the treatment and disposal of waste from all streams to ensure compliance with authorizations for disposal.

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

EMERGENCY PLANNING AND PREPAREDNESS AND RESPONSE

7.53.8.68. The requirements for emergency planning and preparedness and response specific to uranium fuel fabrication facilities are established in paras 9.62–9.67 and paras I.23 and I.24 of Appendix I of Ref.Requirement 72 and paras. 9.120-9.132 of SSR-4 [1], in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [25], and recommendations are provided in GS-G-2.1 [26] and in IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [27]. The conditions for declaration of an off-site emergency at a uranium fuel fabrication facility may include large releases of UF_6, and also depending on national requirements and facility specific considerations, criticality accidents, large fires or explosions.

8.69. For a uranium fuel fabrication facility, special consideration should be given to the use of water sprays for dealing with a release of hazardous chemicals such as ammonia or hydrofluoric acid.

8.70. The emergency preparedness should include how and when an interface with local and national emergency response organizations should be established. This arrangement should be tested periodically to ensure effective operation during an emergency. Clear communication and authorization protocols should be established with local authorities to ensure proper functioning of the emergency response organization.

8.71. The operator should ensure availability of personnel with specific expertise on the type of hazards present in facility as well as specific environmental sampling equipment for local authorities to support appropriate decision-making.

8.72. Emergency plans and contingency plans should be developed in a coordinated manner, considering all of the responsibilities of the facility personnel and security forces, to ensure that in the event of a simultaneous response of both groups to an event, all critical functions can be performed in a timely manner. Emergency response plans should consider nuclear security events as possible emergency initiators and their implications on emergency situations and 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 including the roles and actions of security forces and emergency response personnel. These situations should be jointly exercised and evaluated. From this, lessons should be identified and recommendations should be made to improve the overall response.

7.54.8.73. For establishing access control procedures during emergencies, when there is a necessity for rapid access and egress of personnel, safety and security specialists should cooperate closely. Both safety and security objectives should be sought for during emergencies as much as possible, in accordance with regulatory requirements. When it is not possible, the best solution taking into account both objectives should be pursued.

FEEDBACK OF OPERATING EXPERIENCE

7.55.8.74. Requirements on feedback of operating experience are listed in SSR-4 [1], paras. 9.133 – 9.137. Further guidance on operational experience program is provided in SSG-50 [9].

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

8.9. PREPARATION FOR DECOMMISSIONING

8.1.9.1. Requirements for the preparation of safe decommissioning of a uranium fuel fabrication facility are established in Section 10 of Ref.SSR-4 [1], paras. 10.1-10.13, and in the IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [28], Sections 2 to 7. Recommendations on decommissioning of nuclear fuel cycle facilities, including uranium fuel fabrication facilities, are provided in Ref. [10].

8.2.9.2. The decommissioning of uranium fuel fabrication facilities is less difficult than that of some other fuel cycle facilities because of the low specific activity of the LEU that is processed in the operational lifetime of such facilities. Consequently, the vast majority of the solid radioactive waste arising from the facility will be low and intermediate level waste or exempt waste.

PREPARATORY STEPS

9.3. Special measures should be implemented during the preparatory works for decommissioning to ensure that criticality control is maintained when handling equipment containing nuclear material which criticality safety is controlled by geometry.

8.3.9.4. In addition to the general preparations for decommissioning described in the IAEA Safety Standards Series No. SSG-47, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities [29] the following preparatory steps specific to uranium fuel fabrication facilities should be performedThe preparatory steps for the decommissioning process should include:

(a) A Postpost-operational cleanout to remove all bulk amounts of uranium and other hazardous materials.

(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.

— 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.

— Risk assessments and method statements for the licensing of the decommissioning process.DECOMMISSIONING PROCESS

— It should be ensured that personnel deployed for 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.

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

— Preventing the spread of contamination by means of appropriate techniques and procedures. In particular, the amount of liquids (water and chemicals) used for decontamination should be minimized to reduce the generation of waste.

— The appropriate handling and packaging of waste as well as planning for the appropriate disposal of radioactive waste.

(c) Safe storage of contaminated material and radioactive waste that cannot be decontaminated or disposed of immediately.

9.5. The decommissioning plan for uranium fuel fabrication facilities should be developed following the guidance provided in SSG-47 [29]. Specific consideration should be given to the following elements:

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

(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;

(n)(d) Preparations for the dismantling of process equipment.

9.6. The developed decommissioning plan and the safety assessment should be periodically reviewed and updated throughout the facility's commissioning and operation stages (see GSR Part 6 [28], Requirements 8 and 10) to take account of new information and emerging technologies to ensure that:

(a) The (updated) decommissioning plan is realistic and can be carried out safely;

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

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

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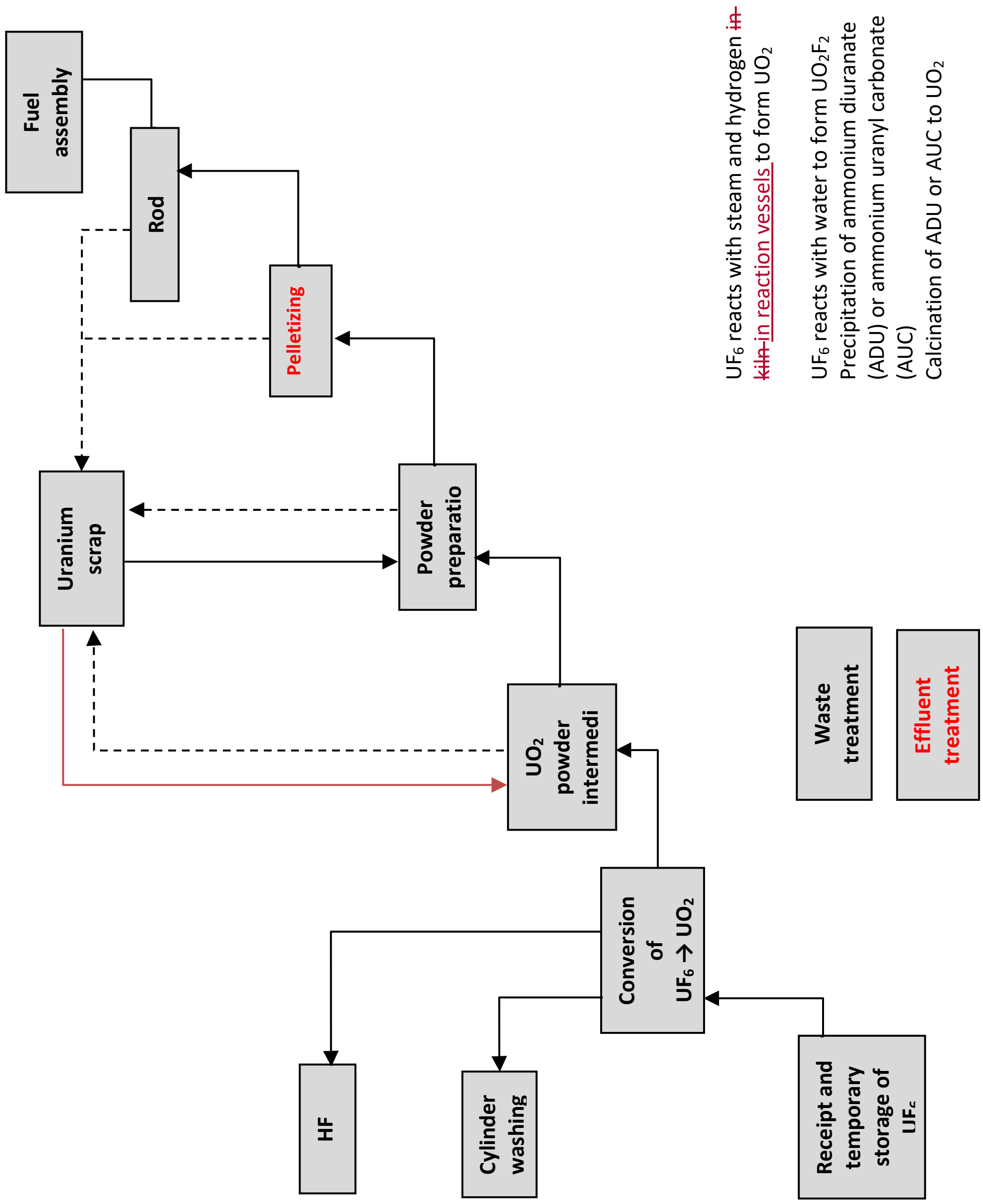
ANNEX I

TYPICAL PROCESS ROUTES IN A URANIUM FUEL FABRICATION FACILITY



ANNEX II

EXAMPLES OF STRUCTURES, SYSTEMS AND COMPONENTS IMPORTANT TO SAFETY AND POSSIBLE CHALLENGES TO SAFETY FUNCTIONS FOR URANIUM FUEL FABRICATION FACILITIES

Safety function: (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
Receipt and temporary storage of UF_6 cylinders	Means of transport	Rupture of cylinder	(2)
	Device for measuring enrichment of ^{235}U	Processing of uranium beyond safety limits	(1)
	Cylinder weighing scale	Rupture of cylinder	(1), (2)
	Shielding	Increase in dose rate	(3)
Conversion area	Vaporization furnace	Rupture of cylinder	(1), (2)
	Cylinder leak detection device	Release of uranium or HF	(1), (2)
	Heating device Cylinder high temperature detection device	Rupture of cylinder	(1), (2)
	Reaction vessel and rotary kiln	Release of uranium, HF and process gases; Degradation of criticality margin (moderationmoisture, geometry)	(1), (2)
	Kiln low temperature detection device	Water condensation in the kiln	(1)
	H_2 pipe work H_2 detection device	Explosion	(2)
	Measurement device to determine the humidity of the powder	Degradation of criticality safety margin (moisturemoderation)	(1)
	Tanks for HF	Release of HF	(2)

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged
	Facilities for treatment of off-gases	Release of HF to the environment	(2)
Intermediate storage of uranium oxide powder	Powder containers	Release of uranium Degradation of criticality safety margin (neutron absorber)	(1), (2), (3)
	Scales	Degradation of criticality safety margin (mass)	(1)
	Shelves	Release of uranium Degradation of criticality safety margin (geometry)	(1), (2)
	Shielding	Increase in dose rate	(3)
Powder preparation	Storage areas, blenders, granulators, pipes	Release of uranium Bulging of vessel	(2), (3) (1)
	Device to control the amount of additives	Degradation of criticality safety margin (moisture)	(1)
	High moisture detection device in uranium powder hoppers	Degradation of criticality safety margin (moisture)	(1)
Pelleting shop	Presses	Release of uranium	(2), (3)
	Sintering furnaces	Explosion	(2)
	H2 pipe work H2 detection device	Explosion	(2)
	Grinding machines	Release of uranium	(2), (3)
	Sludge recovery from wet grinding	Degradation of criticality safety margin (geometry, moderation, mass)	(1)
	Pellet storage	Release of uranium Degradation of criticality safety margin (geometry, neutron absorber)	(2), (3) (1)
Laboratory	Press, sintering furnace, grinding machine	See other process areas above	(1), 2)

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged
	Storage shielding	Increase in dose rate	(3)
Fuel rod manufacturing	Rod loader	Release of uranium	(2)
	Welding machines	Release of uranium Fire due to zirconium particles	(2)
	Rod scanner	External exposure	(3)
	Fuel rod storage	Degradation of criticality safety margin (geometry, neutron absorber, moderation, moisture)	(1)
	Storage shielding	Increase in dose rate	(3)
Fuel assembly manufacturing	Assembling lines	Degradation of criticality safety margin (geometry, neutron absorber) Fire due to zirconium particles	(1) (2)
	Cranes	Dropped assembly	(1), (2)
	Washing facilities	Degradation of criticality safety margin (geometry, neutron absorber)	(1)
	Fuel assembly storage	Degradation of criticality safety margin (geometry, moisture)	(1), 3)
	Storage shielding	Increase in dose rate	(3
Uranium scrap recovery	Furnaces, vessels, pipes	Release of uranium Degradation of criticality safety margin (geometry, mass) Explosion (H_2, chemicals) Fire	(1), (2)
Radioactive waste treatment	Treatment facilities	Release of uranium Release of chemicals Fire	(1), (2)

Process area	Structures, systems and components important to safety	Events	Safety function initially challenged
	Devices for measuring uranium content	Degradation of criticality safety margin (mass)	(1)
	Radioactive waste storage	Fire	(1), (2)
Building	Areas for nuclear and chemical activities	Loss of integrityconfinement	(2)
Ventilation system	Fan and filters for input air	Fire	(2)
	Ventilation control system	Uncontrolled Release release of uranium	(2)
	Filters inside the process areas	Fire Degradation of criticality safety margin (mass)	(1, (2)
	Ducts for air and process gas	Degradation of criticality safety margin (mass)	(1)
	Final filter stage for exhaust air	Fire	(2)
	Fan for exhaust air, stack	Uncontrolled release of uranium	(2)
	Measurement devices for radioactivity in exhaust air	Uncontrolled Release release of uranium	(2, (3)
Treatment and release of water	Tank	Uncontrolled Release release of uranium	(1, (2)
	Treatment facilities	Uncontrolled Release release of uranium	(2)
	Measurement devices for radioactivity in water	Uncontrolled Release release of uranium	(1, (2)
Cylinder washing	Shielding	Increase in dose rate	(3)
Power supply system	Emergency power supply system	Release of uranium under loss of ventilation due to loss of electric power	(2)

ANNEX III
EXAMPLES OF PARAMETERS FOR DEFINING OPERATIONAL LIMITS AND CONDITIONS FOR URANIUM FUEL FABRICATION FACILITIES

Process area (including storage areas)	Parameters for defining operational limits and conditions
Area for receipt and temporary storage of UF_6 cylinders	~~Limited~~ Level of moderation Enrichment Mass UF_6 composition Surface contamination
Building	Leaktightness
Conversion area	~~Limited~~ Level of moderation Pressure in process equipment Temperature in process equipment Composition of the process gas HF content in the process off-gas Uranium content in by-products Surface contamination of process equipment
Intermediate storage of uranium oxide powder	~~Limited~~ Level of moderation Mass in buckets Mass of absorber in drums Geometry of shelves ~~Levels of s~~Surface contamination of process equipment
Powder preparation	Relative humidity in the process area Geometry of slab hopper Integrity of powder lines and powder containers Amount of the additives (moderator) ~~Limited~~ Level of moderation Mass in buckets Mass of absorber in drums Humidity of powder
Pelleting shop	Humidity of powder Mass in buckets Mass of absorber in drums Geometry of shelves Height of green pellets in sintering boats Temperature of sintering furnace Composition of atmosphere in sintering furnace Height of pellet tray stacks Geometry of shelves ~~Levels of surface~~Surface contamination of radioactive sources and process equipment

Process area (including storage areas)	Parameters for defining operational limits and conditions
Laboratory	Mass of uranium Uranium content in waste Levels of surface contamination of radioactive sources and process equipment
Manufacturing and storage area for fuel rods	Height of pellet tray stacks Geometry of shelves Contamination of rods Geometry of rod transfer Geometry of rod cases Levels of surface contamination of radioactive sources
Manufacturing and storage area for fuel assemblies	~~Assembling scheme~~ Position of neutron absorbers Geometry of storage
Uranium scrap recovery	Geometry of vessels Mass of uranium Uranium content in waste
Treatment of radioactive waste	Mass of uranium Uranium content in waste
Ventilation system	Stages of pressure in the building Mass of uranium (e.g. in prefiltering filters) Vacuum in the sampling lines Uranium content in exhaust air
Treatment and release of water	Uranium concentration Uranium content in released water

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