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IN THE FIELD OF USE OF ATOMIC ENERGY

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NUCLEAR SAFETY RULES FOR NUCLEAR FUEL CYCLE FACILITIES

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NUCLEAR SAFETY RULES FOR NUCLEAR FUEL CYCLE FACILITIES (NP-063-05)

Federal Environmental, Industrial and Nuclear Supervision Service
Moscow, 2005

These Federal Standards and Rules in the Field of Use of Atomic Energy *The Nuclear Safety Rules for Nuclear Fuel Cycle Facilities* establish nuclear safety requirements for the use, processing, storage and transportation of nuclear fissile materials at nuclear fuel cycle facilities and the nuclear safety requirements for the processes and equipment in use and to designing of nuclear fuel cycle facilities.

This is the first issue of these Rules[1*].

The Rules have been developed on the basis of the legislative acts of the Russian Federation, federal standards and rules in the field of use of atomic energy, as well as recommendations of the IAEA (Safety Series No 110 "Safety of Nuclear Installations"), recommendations of the OECD/NEA ("Safety of Nuclear Fuel Cycle").

This document has passed the legal review by the Ministry of Justice of the Russian Federation (Letter No 01/1498-EZ of 28 February 2006).

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LIST OF ABBREVIATIONS

FA	- Fuel Assembly
FR	- Fuel Rod
NA	- Nuclear Accident
NFC	- Nuclear Fuel Cycle
NFCF	- Nuclear Fuel Cycle Facility
NHA	- Nuclear Hazardous Area
NFM (S,N)	- Nuclear Fissile Material (Substance, Nuclide)
NHS	- Nuclear Hazardous Section
SAR	- Safety Analysis Report
SCR	- Self-sustained Chain Reaction
SCR EAS	- Self-sustained Chain Reaction Emergency Alarm System

CONVENTIONAL SYMBOLS

- Cc - Threshold concentration of fissile nuclide
- D - Diameter of nuclear fissile material sphere, cylinder
- K_{eff} - Effective neutron multiplicity coefficient
- Ma - Threshold accumulation of NFM
- Ml - Threshold load of NFM
- N - Margin coefficient of a certain nuclear safety parameter
- Nf - Threshold fill of NFM
- T - Layer thickness of NFM
- V - Volume of NFM
- K - Neutron multiplicity coefficient
- K_{∞} - Neutron multiplicity coefficient for the infinite medium or infinitely repeated lattice
- M - Mass of NFM
- C - Concentration of fissile nuclide

Indexes determining a type of the nuclear safety parameter (C, D, M, T, V) values

cr – critical value of a nuclear safety parameter

p – permissible value of a nuclear safety parameter

s – safe value of a nuclear safety parameter

th – index of the threshold parameter

BASIC TERMS AND DEFINITIONS

For the purposes of this document the terms and definitions listed below are used.

Conservative approach is the approach where during a safety analysis of NFCF's process systems, components and processes for the parameters and their characteristics the values are assumed that knowingly lead to more unfavorable results.

Critical parameter (critical value of a nuclear safety parameter): critical mass (quantity) - M_{cr}; critical concentration - C_{cr}; critical volume - V_{cr}; critical diameter - D_{cr}; critical layer thickness - T_{cr} is the parameter value of a NFM (S,N)-containing system which equals to the effective multiplicity coefficient of this system, $K_{eff} = 1$.

Emergency alarm system is a combination of engineered features designed to detect SCR and send the alarm signal to evacuate personnel from a nuclear hazardous area.

Group of packagings is the number packagings permitted for storage or transportation without limitation to mutual arrangement of packagings or with such limitation provided by engineered features included in the package.

Higher margin coefficient equipment ("HMC" type equipment) is the unsafe equipment which design features, while processing the given NFM (S,N), provide for the minimum critical mass value exceeding at least 5 times the minimum critical mass of the same NFM (S,N) but within the spherical system with full reflector for which higher margin coefficients are established.

Initiating event is the single mode failure in NFC facility systems (components), a deviation of one nuclear safety parameter, external event or employee (personnel) error which lead to the operational event and may lead to a violation of safe operation limits and/or conditions. The initiating event includes all dependent failures resulted from it.

Lattice spacing is the distance between axes of neighboring packagings, FRs, and FAs located in the nodes of the plane regular lattice or between centers of components located in the nodes of 3D regular lattices.

Limiting parameter value (limiting parameter) is the value of a nuclear safety parameter within its possible range of changes at which (with the given values of other nuclear safety parameters of the system and the given events envisaged by the design) the multiplication of the system or equipment approaches the maximum value.

Margin coefficient is the preset minimal value of the coefficient n (see definitions of "Safe parameter" and "Permissible parameter") used for determining a safe or permissible parameter.

Mass fraction of a nuclide in the material is the value, which is determined as the ratio of nuclide mass to the mass of material.

Mass fraction of neutron moderator in the material is the value, which is determined as a ratio of mass of the neutron moderating nuclides to the mass of material.

Material mass humidity (%) is the ratio of mass of water contained in the unit of volume of the material to the total mass of material within the given unit of volume multiplied by 100.

For the material containing various hydrogen compounds it is permitted to apply the notion of "equivalent humidity", which is equal to the hydrogen mass fraction expressed in percents and multiplied by 9.

Minimal critical parameter is the least value out of the critical parameter values of the system in question over the whole range of its changes.

Multiplicity coefficient is the ratio of full number of neutrons generated by fission of nuclei in the preset composition of materials within the given time interval to the number of neutrons leaving this composition due to absorption and leak within the same time interval. When this value (K) is determined for the infinite medium or infinitely repeated lattice it is called the multiplication factor in the infinite medium K_{∞}, and the effective multiplicity coefficient K_{eff} when it is determined for a medium of finite sizes.

Neutron absorber is the non-fissionable material, which absorbs neutrons.

Neutron isolated system is the system for which the effects of neutron interaction with any surroundings to the value of the effective neutron multiplication coefficient can be neglected.

Neutron moderator is the material effectively delaying high-energy neutrons.

Neutron reflector (reflector) is a part of the system where there are no NFM (S,N) but which is capable of returning neutrons to the part of the system containing NFM (S,N).

Nuclear fissile material (substance) is the material (substance) containing nuclear hazardous fissile nuclides of NFM (N) during handling of which a possibility of SCR initiation cannot be excluded.

Nuclear hazardous fissile nuclide is the fissile nuclide which presence in the material being handled does not exclude a possibility of SCR initiation in this material.

Nuclear hazardous area is the industrial area containing NFM (S) within which the absorbed dose of combined prompt neutron and gamma radiation from SCR with fission rate of 10^{18} may exceed 0.1 Gy.

Nuclear hazardous section is the structural unit of a NFC facility (shop, bay, unit, division, laboratory, storage area) where any handling of the following NFM (S,N) is carried out: plutonium, uranium-233, uranium-235 enriched to greater than 1% (mass), if the total mass of plutonium nuclides and uranium-233, uranium-235 nuclides present in this section at any point of time exceeds 300 grams. The nuclear hazardous section includes all process premises of the structural unit and separate buildings of the structural unit where NFM (S,N) is present or can be present.

The nuclear hazardous section where NFM (S,N) is handled in quantities in excess of 300 grams is not treated as a NHS if it has been deleted from the list of NHS as per the Nuclear Safety Statement.

Nuclear safety parameter: volume, diameter, thickness of layer limited by inner surfaces of a nuclear installation equipment; NFM (S) mass loaded into or present in a nuclear installation; concentrations of NFM (N) in NFM (S) and content of neutron moderators and absorbers in it; uranium enrichment, NFM (S) nuclide composition; NFM (S) humidity (hydrogen concentration); characteristics of the equipment and environs of the nuclear installation, which determine conditions for neutron reflection (layout, geometry, structural materials used, presence of absorbing inserts, etc.); distance between equipment items is the physical value (parameter), which is imposed with a limitation to ensure nuclear safety.

For nuclear installations and packages having repeated design elements (for example, cells and tubes for individual nuclear fuel assemblies for their storage and transportation within a packaging, piles of nuclear material packagings, etc.) nuclear safety parameters also include: **a number of such repeated elements; a distance (lattice spacing) between the neighboring elements' axes**.

Nuclear Safety Statement is the technical document which establishes nuclear safety conditions and parameters for specific equipment and/or process, transportation conditions, storage facilities to ensure nuclear safety in cases where these conditions and parameters for the given equipment and/or process are not defined by regulatory documents.

Nuclide mass concentration is the nuclide mass in the unit of volume of a solution or mixture.

Overload is the conditions where permissible nuclear safety parameter values are exceeded:

- the safe or permissible mass of NFM (S,N) is exceeded more than 1.4 times;
- the safe concentration of NFM (S,N) is exceeded more than 1.1 times.

Package (transportation package) is the set (combination) of packaging elements intended for transportation and/or storage of NFM (S), which includes, as necessary, one or several vessels, absorbers, spacing structures, radiation shielding, cooling and heat insulation devices, shock absorbers etc., required to bring the package in conformance with the safety requirements.

Packaging (NFM (S,N) packaging) is the package with NFM (S,N) placed in it.

Permissible number of packagings is the maximum number of packagings which is permitted to place in a group or pile arrangement.

Permissible parameter (permissible nuclear safety parameter value): permissible mass (quantity) M_p; permissible volume V_p; permissible diameter D_p; permissible layer thickness - T_p is the nuclear safety parameter value of the NFM (S,N)-containing system in question which is n times less than the corresponding critical parameter of the same system. Permissible parameters should provide for K_{eff} of the system to be not more than 0.95.

Pile of packagings is the set of packagings permitted for joint storage provided the established limitations imposed on mutual arrangement of packagings are met through the use of engineered means other than the package constituents (racks, fixing devices, marking, etc.).

Pre-emergency is the NFCF state which is characterized by a violation of safe operation limits and/or conditions which has not changed into a nuclear accident.

Protecting container is the package which design and loading limits provide the reduction of neutron interaction between NFM (S) or products thereof contained in such packages to such a degree that the value of K_{eff} of the system consisting of any number of such packagings does not exceed 0.95 during normal operation.

Safe equipment (type "B" equipment) is the equipment which layout, geometry features and structural materials exclude a possibility of self-sustained chain fission reaction (SCR) initiation during normal operation and under any initiating conditions considered in the design of the nuclear fuel cycle facility.

Safe parameter (safe value of a nuclear safety parameter): safe mass (quantity) M_s; safe concentration S_s; safe volume V_s; safe diameter D_s; safe layer thickness T_s is the nuclear safety parameter of the NFM (S,N)-containing system in question which value is n times less than the corresponding minimal critical parameter of the same system. The safe parameter should provide for K_{eff} of the system not more than 0.95.

Self-sustained chain fission reaction (SCR) is the nuclide nuclei fission process where a number of neutrons generated in the course of the nuclei fission process during any time interval is equal or exceeds the number of neutrons departing the system due to a leak and absorption within the same time interval.

Single mode failure is the failure of a single component.

System (for the purposes of this document) is a combination of NFM (S,N)-containing components which geometry, material and nuclide composition are considered in nuclear safety justification.

System with distant reflector is the system which design features or engineered means or positioning excludes a possibility for the reflectors to approach it at a distance which is less than the established value.

System with full radiation shielding is the system which shielding and isolating components mitigate prompt neutron and gamma radiation from SCR with a number of fissions 10^{18} occurred within it down to less than 0.1 Gy and which shielding components prevent ingress of radioactive aerosols to the attended premises down to levels at which a received dose is less than 0.01 Sv during one hour after the SCR has occurred.

System with full reflector is the system with a closely attached water reflector with a thickness of 25 cm. The system where the reflectors' effects to critical parameter values are equivalent in terms of its reflecting capacity to the closely attached water reflector of more than 25 mm thickness should be considered as the system with the full reflector. Systems with reflectors which reflecting capacities exceed the full reflector should be especially specified while preparing nuclear safety documentation.

System with nominal reflector is the system with the closely attached 25 mm-thick water reflector. The system where the reflectors' effects to critical parameter values are equivalent in terms of its reflecting capacity to the closely attached water reflector with a thickness of more than 3 mm and not more than 25 mm should be considered as the system with the nominal reflector.

System without reflector is the system where the reflector's effects to critical parameter values are equivalent in terms of its reflecting capacity to a closely attached steel or water reflector having a thickness of not more than 3 mm.

Threshold accumulation is the mass of NFM (S,N) which is permitted to accumulate in the auxiliary equipment (filters, lines, traps, etc.), i.e. in the equipment where NFM should not be loaded in accordance with the process but may ingress during operation of this equipment.

Threshold concentration is the mass concentration of NFM (S,N) at which NFM (S,N) is permitted to process in the equipment as well as store or transport in packagings.

Threshold fill is the mass of NFM (S,N) which is permitted to accumulate in the process equipment in excess of the established threshold load, threshold concentration, retained amounts, precipitation, deposits on the equipment surfaces.

Threshold load (complete set) is the mass of NFM (S,N) which is permitted to load into the equipment, individual vessel, package, etc.

Threshold value of a nuclear safety parameter (threshold parameter value, threshold parameter) is the upper/lower limit of a nuclear safety parameter value, which should not be violated during normal operation.

Unsafe equipment ("O" type equipment) is the equipment which is not safe equipment (see the definition of "Safe equipment" ("B" type equipment)).

1. PURPOSE AND SCOPE

1.1. These federal standards and rules "Nuclear Safety Rules for Nuclear Fuel Cycle Facilities" (hereinafter referred to as the Rules) establish:

- basic provisions and general requirements for nuclear safety ensurance as well terms and definitions regarding the use, processing, storage and transportation of NFM (S,N) within the NFCF site;
- nuclear safety ensurance requirements to be met in the course of design, construction, commissioning, operation and decommissioning of nuclear installations and nuclear material storage facilities;
- requirements for methods and means of monitoring of nuclear safety parameters.

1.2. These Rules are applicable to:

- nuclear fuel cycle facilities (NFC) which are under design, construction, operation and decommissioning, including:
  - structures, complexes and installations intended for the use, processing and transportation of NFM (S,N) (including sublimate production, uranium isotope separation, fuel fabrication, chemical metallurgy productions, radiochemical reprocessing, NFM (S) storage facilities located at a nuclear installation and envisaged by its design);
  - as well as stationary facilities and structures intended for storage of NFM (S) including facilities and structures located within the territory of a nuclear installation which are not envisaged by its design; stationary facilities and structures intended for storage of radioactive waste which contains NFM (S);
- research organizations (institutes, laboratories) which use NFM (S) in research and development;
- design, engineering and other organizations (except for construction organizations), which include individual structural units involved in development of technologies; design of equipment, vehicles and packages for the NFM (S) use, processing, storage and transportation; development of methods and means of monitoring of nuclear safety parameters, NFCF process control systems, SCR emergency alarm systems; design of nuclear installations and nuclear material storage facilities of NFCF.

1.4. These Rules are not applicable to:

- structures and complexes with nuclear reactors including nuclear power plants, ships and other vessels, space and aircraft, and other transport and transportable facilities; structures and complexes with commercial, experimental and research nuclear reactors, critical and subcritical nuclear assemblies; installations and devices with nuclear charges for peaceful uses and other nuclear installations equipped with control and protection systems; fresh and spent nuclear fuel storage facilities of nuclear power plants, experimental and research reactors;
- organizations and their structural units, which use, process, store and transport uranium and plutonium where the total mass of uranium-233, uranium-235 and plutonium does not exceed 300 grams at any point of time;
- organizations and their structural units handling uranium which enrichment regarding uranium-235 isotope does not exceed 1% (mass), except for the cases where NFM (S) is in the form of fuel assemblies, fuel rods, pellets;

- structural divisions of a separate NFCF, NFCF operating organization or organization which performs work and renders services for the NFCF operating organization, which have been removed from the NHS list in accordance with the established procedure
- transportation of NFM (S) beyond NFCF site boundaries.

2. GENERAL NUCLEAR SAFETY REQUIREMENTS FOR NUCLEAR FUEL CYCLE FACILITIES

2.1. Nuclear safety of NFCF during NFM (S) use, processing, storage and transportation shall be the creation and maintaining conditions for:

- prevention of NA (SCR initiation);
- mitigation of NA consequences severity as maximum as possible.

2.2. The development of technologies, design of equipment, engineering, construction, commissioning, operation and decommissioning of NFCF shall be carried out in accordance with the main nuclear safety requirements listed below:

- SCR prevention both in normal conditions and in case of any initiating event considered in the safety justification (for cases where there is more than one initiating event the measures aimed at mitigating the NA consequences shall be envisaged);
- prevention of uncontrolled and unauthorized cases of processing, accumulation, movement, transfer, and transportation of NFM (S);
- prevention of violations of nuclear safety conditions and requirements established by the design, engineering and process documentation, nuclear safety regulatory documents (rules, procedures, process regulations) both in normal operation and accident initiating events (an exemplary list of initiating events is given in Appendix 1);
- predominant use of the safe equipment (type "B" equipment), engineered features and automation;
- monitoring (predominantly automated) of nuclear safety parameters and in combination with interlocks.
- use of the conservative approach in the nuclear safety justification.

2.3. The effective neutron multiplication coefficient – K_{eff} – both of any individual equipment piece containing NFM (S,N) and any neutronically isolated system as a whole shall be maintained as low as practicable and shall not exceed $K_{eff} = 0.95$ in normal operation and $K_{eff} = 0.98$ in an operational event (single failure or personnel error).

2.4. During handling of NFM (S,N) the SCR initiation prevention shall be achieved through the limitations and measures listed in paras. 2.4.1 through 2.4.9.

2.4.1. Limitations imposed on geometry and sizes of the equipment (including NFM (S,N) storage cells).

2.4.2. Limitation on NFM (S) isotopic and/or nuclide composition.

2.4.3. The use homogeneous/ heterogeneous neutron absorbers.

2.4.4. Limitation on mass of NFM (S) being placed into the equipment taking account of its isotopics.

2.4.5. Limitation on concentration of NFM (S).

2.4.6. Limitations on mass fractions of neutron moderators in NFM (S).

2.4.7. Limitations on neutron reflectors and mutual arrangement of the NFCF equipment.

2.4.8. Organizational and technical measures to reduce a SCR probability.

2.4.9. A combination of limitations and measures listed in paras. 2.4.1 through 2.4.8 of these Rules.

2.5. Should the equipment be intended for reprocessing of NFM (S) with different isotopic and(or) nuclide composition, the nuclear safety limitations shall be set with regard to the most hazardous composition.

2.6. During storage and transportation of NFM (S,N) the SCR initiation prevention (except for limitations and measures of paras. 2.4.1 through 2.4.9 of these Rules) shall be ensured by:

- design of the storage facility and packages, as well as limitations on the number and arrangement of packages and fire extinguishing equipment in use;
- testing of packagings and packages for conformance to the normal operation conditions;
- measures being taken to provide the necessary cooling of NFM (S) or spent fuel assemblies to prevent changes in NFM (S) phase state, FR damage or damages to storage facility and packages structural elements.

2.7. To ensure nuclear safety it is sufficient to set one of the safe parameters (mass of NFM (N) or NFM (S) being placed into the equipment or a storage item; concentration of NFM (N) or NFM (S); diameter, thickness, volume, as limited by the inner surfaces of the equipment) for individual equipment items or storage items.

2.8. The threshold load, accumulation, fill, geometry of the equipment can be set basing on the permissible parameters only when the production conditions ensure meeting the imposed limitations (mass fraction of neutron moderators, density, isotopic and nuclide composition, neutron absorber concentration). Predominantly, technical means of monitoring of how the additional limitations are met during operation of the equipment including instrumentation for measuring the controlled parameters and actuators (interlocks, dispensers, breakers, etc.) shall be identified.

Otherwise, the equipment characteristics and parameters and the said thresholds shall be set basing on safe values of nuclear safety parameters.

2.9. Safe and permissible parameters of individual equipment items shall be determined proceeding from K_{eff} being not more than 0.95. At this, the margin coefficient *n* shall be not less than the values given below.

	Parameter	Margin coefficient *n*
1.	Safe (permissible) mass	2.1
2.	Safe concentration	1.3
3.	Safe (permissible) volume	1.3
4.	Safe (permissible) diameter	1.1
5.	Safe (permissible) layer thickness	1.1

2.10. For the calculation of safe masses for the HMC equipment the minimal margin coefficient shall be 3.3; for the calculation of safe concentrations it shall be 2.0.

2.11. During storage and transportation of NFM (S) the meeting of nuclear safety requirements for an individual packaging shall be ensured through establishing a safe or

permissible value of one of the nuclear safety parameters (NFM (S,N) mass, NFM (S) concentration, diameter, layer thickness, and volume).

2.12. If the packages other than protective containers are used for storage and transportation of NFM (S) it shall be ensured, additionally to para 2.11, that the nuclear safety requirements with regard to the multiplication coefficient of a group (pile) of packagings are met by setting up a limitation on the number of packagings in a group (pile), minimal distance between packagings, groups (piles) of packagings and establishing requirements for storage conditions, loading and transportation procedure.

2.13. In all cases, when possible, the safe equipment (type "B" equipment) shall be used. In cases where it is impossible or inexpedient, the unsafe equipment with the higher margin coefficient (type "HMC" equipment) shall be used.

The type "O" equipment may be used only when the type "B" equipment or "HMC" equipment is not applicable due to their components being out of order and(or) due to features of adopted technologies, and only in combination with the limitations imposed on the nuclear safety parameter values and control over how such limitations are followed.

The use of unsafe equipment of "HMC" and "O" types shall be justified in the design and approved in accordance with the established procedure.

2.14. To ensure nuclear safety of the type "O" equipment the nuclear safety parameter values shall be selected considering errors of their determining in accordance with Appendix 2.

2.15. The following shall be ensured during NFCF operation:

- prevention of misuse of the equipment;
- incoming inspection (as necessary) of process media and materials in use at NFCF;
- maintaining of the process and auxiliary equipment conditions as designed;
- prevention of exceeding the NFM (S) threshold accumulation for the auxiliary equipment (pipelines, etc.), which is designed as unsafe equipment.

2.16. Operation of the unsafe equipment of "HMC" and "O" types shall be permitted only when one of the nuclear safety requirements listed in paras. 2.16.1 through 2.16.4 of these Rules are met along with requirements of para 2.15 of these Rules.

2.16.1. Limitation of NFM (S) mass being loaded and(or) accumulated in the equipment (through establishing threshold load, accumulation and fill) without limiting other nuclear safety parameters, provided these threshold load, accumulation and fill have been set basing on the safe mass values.

2.16.2. Limitation of the concentration of NFM (N) in NFM (S) being loaded into the process equipment (through establishing threshold concentration and fill of NFM (N)) with an additional condition that:

- threshold fill for such equipment shall not exceed 5% of minimal critical mass established for this equipment;
- threshold concentration of NFM (N) is established basing on the safe concentration.

At this, mass of NFM (S) is not limited.

2.16.3. Limitation (through establishing threshold load and fill and threshold accumulation) of NFM (S) mass being loaded and(or) accumulated in the process equipment with simultaneous setting the threshold values of one or several nuclear safety parameters of the given NFM (S,N) (concentration, mass fraction of fissile nuclides in NFM (N) in NFM (S), density, humidity, etc.), if the threshold load and fill have been established basing on the

permissible mass values determined for limiting values of NFM (S,N) parameters being restrained.

2.16.4. Limitation of volume, diameter and layer thickness with simultaneous setting the threshold values of one or several nuclear safety parameters for the given NFM (S) (mass fraction of NFM (N), neutron moderator, density, NFM (S) humidity, etc.). The permissible geometry sizes of the equipment shall be set basing on the limiting values of the NFM (S,N) parameters. Threshold load, accumulation, concentration and fill are not established for such equipment.

2.17. If during a continuous process NFM (S,N) is transferred from one type of the equipment to the other:

- when NFM (S,N) is transferred to the unsafe equipment from the safe one the limits for nuclear safety parameters shall be also established for the given safe equipment;
- when NFM (S,N) is transferred from the unsafe equipment to the other unsafe equipment the permissible (safe) parameters shall be established basing on the lower values.

Limitations on the nuclear safety parameters shall ensure nuclear safety of the system as a whole.

2.18. The NFCF nuclear safety shall be justified in the design in accordance with the existing regulatory documents and considered in development of the technology and design of individual equipment items.

2.19. At the stages of the development of technologies, design of the equipment as well as at all life stages of NFCF (design, construction, commissioning, operation and decommissioning) required quality of all nuclear safety relevant works shall be ensured in accordance with the existing regulatory documentation.

2.20. The SCR EAS shall be provided at NHS. It shall meet the requirements of paras. 2.201.1 through 2.20.6.

2.20.1. Requirements for EAS design, operation, and technical characteristics are established by regulatory documents.

2.20.2. During NFCF operation SCR EAS shall be continuously available.

If it is guaranteed that the personnel is absent and NFM (S,N) handling operations are terminated in NHS during off hours it is permitted to switch off SCR EAS for such periods of time.

Should troubles be detected in SCR EAS, which lead to its malfunction, NFM (S,N) operations shall be terminated. The work shall be resumed only after SCR EAS troubles have been done with and the system put in working order.

While the system is being restored it is permitted to proceed with the continuous process, provided the radiation monitoring instrumentation is in place and functions in accordance with the requirements of para 2.21 of these Rules.

2.20.3. The visible and audible alarms shall actuate automatically.

2.20.4. After SCR having initiated and SCR EAS actuated, the alarm signal shall continue also after the point of time when the magnitude of the recorded radiation level becomes lower the EAS actuation threshold. Access to the manual controls to switch off the SCR EAS alarm signal shall be restricted and the controls shall be located outside NHA.

2.20.5. The evacuation alarm signal shall be of sufficient sound volume and range. If necessary, the design shall provide for several sources of signal placed so that the signal is audible in all NHA locations subject to evacuation.

2.20.6. A number of SCR EAS false actuations shall not exceed two times a year.

2.21. The personnel are permitted to perform single-time operations with NFM (S,N) at a working area which is not equipped with SCR EAS only under work permits.

When the said operations are performed the instruments shall be used to measure gamma radiation dose rate, which will signal that the established actuation threshold is exceeded. In this connection, the personnel shall be prepared to evacuate immediately at the emergency signal.

2.22. A waiver criterion to install SCR EAS shall be the absence of nuclear safety limitations for nuclear installations and NFM (S,N) storage facilities, as established by these Rules. If there are such limitations, a decision concerning the waiver to install SCR EAS shall be justified in the design on the basis of the Nuclear Safety Statement.

2.23. It is permitted not to install SCR EAS at NHS with full radiation shielding.

2.24. In case of SCR initiation all operations at NHS shall be terminated. A decision to resume operations shall be made after SCR causes and its consequences have been eliminated, as established in the regulatory documentation.

3. ORGANIZATIONAL REQUIREMENTS TO ENSURE NUCLEAR SAFETY

3.1. Structural units required to ensure nuclear safety at NFCF shall be set up at all tiers of NFC management.

3.2. The NFCE operating organization or an organization which performs work and renders services related to the NFCF operation to the operating organization shall set up a nuclear safety unit independent from structural units directly responsible for productions.

It is permitted not to set up a nuclear safety unit in research organizations provided the individuals responsible for nuclear safety are designated.

3.3. The NFCE operating organization or an organization which performs work and renders services related to the NFCF operation to the operating organization shall designate officials with necessary authorities who shall be made responsible by the operating organization or an organization which performs work and renders services related to the NFCF operation to the operating organization for overall work management and responsibility for nuclear safety ensurance and an individual who directly organizes the nuclear safety ensurance activities and controls how nuclear safety is ensured.

Duties and responsibilities of officials of the NFCF nuclear safety units shall be reflected in relevant statutes of the structural units, divisions and in the job descriptions.

3.4. The NFCE operating organization or an organization which performs work and renders services related to the NFCF operation to the operating organization shall draft the Provisions (institutional standard) on Organization of Nuclear Safety Ensurance Activities. These Provisions shall be subject to approval by the official responsible for nuclear safety ensurance.

3.5. The operating organization and organizations which perform work and render services related to the NFCF operation to the operating organization shall have a list of NHSs of each NFCF compiled in accordance with the design documentation. The NHS list and changes to its contents shall be reflected in SAR.

3.6. Process regulations and separate NFM (S) handling operations shall contain a section describing nuclear safety issues (it is permitted to make references to the corresponding section of the “Nuclear Safety Procedures”) and containing:

- data on threshold values of concentrations, masses considering possible deviations from normal operation of the process;
- a description of possible emergency deviations which may lead to SCR;
- personnel actions in the event of a deviation from safe conduct of the process and in the event of accidents;
- hardware and process flow diagrams.

3.7. On the basis of the Provisions on Organization of Nuclear Safety Ensurance Activities, process regulations and regulatory documentation the nuclear safety procedures shall be developed. A Nuclear Safety Procedure shall contain the following sections:

- technical and organizational measures to ensure nuclear safety with the use of genuine name of NFM (S,N) throughout the text;
- a list of the equipment where NFM (S,N) is loaded into or ingresses during operation with a reference to the equipment item (installation) registry number, drawing number, type of equipment ("B", "HMC", "O"), threshold load (threshold accumulation) or threshold concentration, basis for setting such thresholds, errors of determining such parameters, a method to meet these thresholds;
- thresholds of fill, equipment clean-up and washing procedures and frequency and that of its inspection with monitoring instrumentation; frequency of inspections and replacement of filters;
- frequency and procedures of inspections of the equipment geometry and working order of the absorbing inserts;
- procedures for the use of the monitoring equipment used for nuclear safety ensurance;
- conditions of storage, arrangement and transportation of NFM (S,N), a list of packages;
- procedures and permitted means of fire extinguishing in NFM (S,N) premises;
- responsibilities of the personnel for following nuclear safety requirements.

It is permitted to issue separate sections of the Procedure as a stand-alone document which is formatted, formalized and approved similarly to the Nuclear Safety Procedure.

3.8. The NFCF operating organization and(or) or an organization which performs work and renders services related to the NFCF operation to the operating organization and at each NFCF at all tiers shall organize and continuously carry out activities to improve safety culture of workers, technicians and engineers who are directly involved in NFM (S,N) operations or control the conduct thereof, including as relates to meeting the nuclear safety requirements.

3.8.1. The NFCF or its structural units' management shall familiarize the employees in full with the nature of nuclear hazard of a given process, sources of this hazard (possible SCR causes) and SCR initiation consequences.

3.8.2. The employees shall have an opportunity to get from competent specialists explanations on issues of their interest related to nuclear safety and, should they wish, to get additional information and methodological materials.

3.8.3. At work places there shall be memo booklets written on the basis of the Nuclear Safety Procedure and which contain NFM (S,N) threshold fill (load).

3.9. The NFCE operating organization or an organization which performs work and renders services related to the NFCF operation to the operating organization shall develop Provisions on NFM Handling Work Permits for the Personnel in accordance with the existing legislation and regulatory documents.

4. NUCLEAR SAFETY ENSURANCE IN DEVELOPMENT OF PROCESSES, DESIGN OF EQUIPMENT AND NUCLEAR FUEL CYCLE FACILITIES

4.1. The development of processes for the use, processing, storage and transportation of NFM (S) for new and existing (being modernized and upgraded) NFCF shall exclude or minimize a possibility of processes leading to accumulation of NFM (S) in the equipment components (excluding components designed for that), to thermal or corrosion destruction of the equipment components including the absorbing inserts (provided by the design documentation), as well as exclude or minimize the use of explosive and fire hazardous process media and materials.

4.2. Allowances for manufacturing of equipment, corrosion, installation and assembly sizes shall be established conservatively when nuclear safety standards and thresholds are determined.

4.3. The design of a package for NFM (S) storage and transportation shall prevent ingress of water into it during normal operation, operational events and design basis accidents if such ingress leads to exceeding K_{eff} equal to 0.98, as established by these Rules.

4.4. The design shall envisage technical and organizational measures to prevent SCR initiation and limitation of its potential consequences. The predominant use of type "B" equipment shall be envisaged during the design process.

4.5. Safe and permissible parameters of the equipment and NFM (S,N) shall be selected in accordance with the existing regulatory documents. In case they are not present in the regulatory documents, they shall be justified in the design and confirmed by the Nuclear Safety Statement.

4.6. While designing new NFCF and carrying out modernization and upgrading of the existing NFCF it is necessary to:

- limit at maximum the necessity of the personnel presence in NHA through automation or mechanical features of processes in use, relevant locating of the equipment, work places, storage locations, the use of biological shielding and other protection features;
- provide for (where it is possible and expedient) automatic process controls and automatic monitoring of nuclear safety parameters;
- ensure compliance with the requirements of Section 2 of these Rules;
- locate process media which are neutron moderators so as to reduce as much as possible a possibility for these media to get into the close environs of the equipment, storage locations under events anticipated by the design;
- locate the equipment so as to exclude or reduce down to the acceptable levels a possibility of a neutron interaction between individual equipment items containing NFM (S);
- exclude SCR due to neutron interaction between the transported packagings and equipment containing NFM (S) during transportation;
- exclude an ingress of unsafe quantities of hydrogen-containing substances into the equipment, storage facility where such substances shall not be present as established by the nuclear safety requirements;
- arrange the equipment in such a way that will exclude obstacles on the evacuation routes from NHA in case of NA at NFCF and minimize evacuation time;

- for each work place, determine the space within which NFM (S,N) can be moved during process operations without limitations on quantities which do not exceed the established standards and beyond which boundaries NFM (S) shall not be present.

4.7. For NHA measures shall be developed to ensure (in the event of SCR) the immediate evacuation of the employees from their work places and process premises to pre-determined locations the employees are aware of; such evacuation shall be carried out via routes which are pre-determined and well-known by the employees and in such a manner that reduces to minimum the exposure of employees.

At this, the risk associated with the employees leaving their work places and process premises shall be minimized.

4.8. To ensure nuclear safety, the NFCF design shall provide for:

- lists of interlocks and technical requirements for their actuation conditions;
- technical and(or) organizational measures preventing unauthorized access to interlocks, measurement instrumentation and controls;
- means of measurement of nuclear safety parameters. If the measurement taking methodology and nuclear safety parameter measuring equipment include operations involving the employees, to implement them there shall be such procedures for acquisition and processing of data, checking schemes and operating patterns that reduce down to acceptable levels a probability of gross errors of measurement end results, as well as a probability of an overrun of limits of systematic measurement errors, as established by the metrological qualification process;
- frequency and procedures for the inspection of the equipment geometry, working order of absorbing inserts;
- shortest routes of the employees evacuation in the event of NA.

4.9. All NFCF electricity consumers shall be categorized by power supply reliability groups depending on their nuclear safety significance. The categorization of electricity consumers at NFCF by power supply reliability groups and selection of emergency power supply sources shall be justified in the design.

4.10. NFM (S) shall be stored in the designated storage locations.

4.11. The location of the NFM (S) storage facility (except for spent nuclear fuel storage facilities), equipment and engineered features envisaged by the design shall prevent water and other hydrogen-containing liquids from getting into the storage facility.

4.12. When nuclear safety is justified for similar values subject to limitation with regard to nuclear safety, the same units of measure shall be used both in different sections of the same one document and in different documents.

4.13. In the course of designing the NFCF, including the implementing nuclear safety requirements during operation, maintenance and repair (including the repair of equipment after possible accidents associated with NFM (S,N) release from the equipment into the NFCF work premises) the necessity of nuclear safety ensurance in NFCF decommissioning shall be considered.

4.14. At the stages of the NFCF design, development of equipment, development of technologies, construction of buildings, manufacturing and assembling of equipment of NFCF the quality assurance programs shall be in place for the operations related to nuclear safety. The implementation of the said quality assurance programs shall result in compliance of all

design solutions, all individual equipment items and NFCF as a whole to the nuclear safety requirements established by these Rules.

The operating organization shall check on how the said quality assurance programs are implemented and how the requirements for certification of new equipment being procured to NFCF are met.

4.15. The design document packages for nuclear installations, storage facilities and transportation packages under development shall contain the "Nuclear Safety Ensurance" section which is to contain subsections:

- a list of design documentation which includes sections on nuclear safety;
- a list of rooms, installations, storage facilities where NFM (S,N) can be present;
- a description and safety justification of process operations for processing, moving NFM (S) with indication of its state of aggregation, density, isotopic, nuclide and chemical compositions of NFM (S), presence and composition of neutron moderators, reflectors, absorbers, etc, in the scope required for physical calculations of systems;
- a list of the equipment where the NFM (S) is loaded or can get into, including packages, with indication of the equipment item number, drawing number, type of equipment ("B", "HMC", "O"), safe (permissible) parameters and thresholds of nuclear safety, measurement errors of regulated values, methods of meeting nuclear safety standards and requirements, references to paragraphs of rules, nuclear safety statements which are the bases for setting the nuclear safety parameters and thresholds;
- a description and justification of selected methods and means of parameter monitoring and nuclear safety limitations;
- a description of fire extinguishing equipment;
- a list of considered initiating events which could lead to exceeding of safe (permissible) parameters as well as to SCR initiation; result of the analysis of consequences of the situations considered (for each equipment item).
- a description of SCR emergency alarm system.
- results of the consequences analysis for SCR initiated in the equipment and measures to mitigate these consequences (for each equipment item).

5. NUCLEAR SAFETY PARAMETER MONITORING METHODS AND MEANS

5.1. The NFCF design shall identify required engineered features and organizational measures to monitor the following nuclear safety parameters:

- isotopic or nuclide composition of NFM (S);
- mass of NFM (S) being loaded into the equipment;
- concentration, content of NFM (N) in NFM (S);
- mass of NFM (S) present in the equipment before loading;
- mass of NFM (S,N) being accumulated in the auxiliary equipment (filters, lines, traps, etc.);
- mass fraction of the neutron moderator;
- NFM (S) humidity (hydrogen content);
- spent nuclear fuel burnup;
- concentration of homogeneous neutron absorbers;

- equipment geometry.

5.2. Means of monitoring of the nuclear safety parameters shall provide for measuring these parameter values and, if required, triggering actuators and devices (breakers, interlocks) before the actual parameter values run beyond the imposed limits.

5.3. Monitoring devices including automatic and automated measurement equipment shall be qualified in accordance with established procedure.

The automatic and automated measurement equipment shall be furnished with devices allowing for check of their performance or it shall be inspected for stability of its main characteristics with frequency established in the measurement equipment technical documentation.

5.4. The nuclear safety parameter continuous monitoring equipment shall be furnished with external alarms both for overrun of the controlled parameter threshold values and failures of monitoring equipment.

5.5. The equipment for measuring the nuclear safety parameters shall have such regulated metrological characteristics that the regulated value (threshold value) will stay within the operating range of a device measuring this value.

5.6. Should the nuclear safety parameter continuous monitoring equipment, as well as actuators (interlocks, valves, etc.) ensuring that the established limits are met, fail, the process and operations shall be immediately stopped or additional means sufficient for monitoring and actuation shall be introduced until the above equipment operability is restored.

6. NUCLEAR SAFETY DURING COMMISSIONING, OPERATION AND DECOMMISSIONING OF THE EQUIPMENT AND PROCESS SYSTEMS OF NUCLEAR FUEL CYCLE FACILITIES

6.1. During commissioning of the NFCF equipment and process systems it shall be confirmed that quality of work, manufactured equipment, process systems, components of structures important to nuclear safety comply with quality assurance requirements established in the design.

6.2. The operating organization shall develop and implement commissioning programs for the NFCF equipment and process systems.

The scope and sequence of pre-commissioning and aligning operations for all nuclear safety relevant NFCF individual equipment items and process systems shall be established in the design.

6.2.1. Before the first loading of the equipment with NFM (S) in quantities envisaged by the operating regulations the following shall be carried out:

- integrated testing of the major and auxiliary process equipment (without NFM (S));
- tests of envisaged nuclear safety parameter monitoring systems;
- tests of SCR EAS (using radioisotope sources or radiation generators of corresponding types and intensity);
- training and qualification of the NFCF employees to perform all process operations and equipment and process system maintenance operations both in normal operation and in operational events, as well as to act in case of SCR.

The failures of equipment and process systems and their deviations from design limits revealed in the course of testing shall be eliminated.

Results of tests of the equipment and process systems as well as results of checks of the employees' knowledge shall be documented.

6.2.2. Before the first loading of the equipment with NFM (S) in quantities envisaged by the operating regulations SCR EAS shall be rendered operable.

6.2.3. The commissioning (the first loading of NFM (S)) and operation shall be carried out only after the permit has been obtained in accordance with the established procedure.

6.3. The operating organization shall develop and approve process regulations and safety related documents in accordance with the design.

6.4. The commissioning of individual installations, equipment items, hardware of the existing facilities shall be carried out on the basis of the production availability inspection record. The operating organization or an organization which performs work and renders services related to the NFCF operation to operating organization shall report on commissioning of such individual installations and hardware after they have been commissioned to the state body for control over the uses of atomic energy and the state safety regulatory authority; it shall be also reflected in the NFCF's annual nuclear safety status report.

6.5. The documents that regulate pre-commissioning and aligning operations, integrated testing of the process systems (components) shall include operations with NFM (S) during which SCR is possible and measures to mitigate its consequences.

6.6. During operation, the deviations of actual dimensions of the equipment from nominal values as conditioned by allowances for manufacturing of the equipment, corrosion, as well as deviations due to deformation, shall not lead to excess of safe, permissible and pre-set sizes, volumes and to changes in distances envisaged by the operating regulations.

6.7. The information required for nuclear safety ensurance in NFCF decommissioning shall be accumulated and stored during operation, maintenance and repair of NFCF equipment and systems (including the repair of equipment after possible accidents associated with NFM release from the equipment into the NFCF work premises).

6.8. Before the NFCF (its structural unit, equipment item) decommissioning a relevant decommissioning program (project) shall be developed and duly approved. Such program shall include a justification of nuclear safety.

Appendix 1. EXEMPLARY LIST OF INITIATING EVENTS WHICH MAY LEAD TO SELF-SUSTAINED CHAIN FISSION REACTION

1. External events:

- seismic and other phenomena, processes and factors of natural and man-induced origin pertaining to the given geographic region (floods, hurricanes; explosions, etc.) and selected for the input into the design bases in accordance with the requirements of federal standards and rules regarding accounting of external impacts;
- loss of electric power supply (NFCF blackout).

2. Internal events:

- drop of loads during NFCF on-site transportation of NFM (S);
- fire within premises;
- pipeline breaks, damage to hot air systems, etc.;
- accidents resulting in flooding of premises with water due to ruptures of vessels, pipelines, etc.;
- loss of pressurized air supply, depressurization;
- explosions due to chemical reactions;
- degrading of inert medium composition;
- blackout of separate NHA.

3. Corrosion of equipment elements resulting in thinning of pipeline and equipment walls, formation of through holes, leak of solutions, degrading of absorbing properties of the heterogeneous neutron absorbers, failures of anchoring and fixing elements, etc., which foster transformation of the type "B" equipment (vessels and installations) into type "O" equipment (vessels and installations).

4. Ingress of NFM (S) solutions into the unsafe equipment (installations and vessels) where it should not be present due to the process conditions.

5. Collapse of racks, suspensions, equipment, and loss of integrity of an individual NFM (S) packaging, disruption of packagings arrangement, damage to FRs, FAs, and absorbers; changes in the equipment geometry (sizes).

6. A change in the aggregate state, other properties of NFM (S) due to unanticipated supply of agents, sorption, extraction, deposition.

7. An increase in concentration of NFM (N) up to the values exceeding safe concentration due to unanticipated ingress of extractants, sorbents into the equipment (vessels and installations).

8. Transformation of NFM (S) from liquid state into the solid one (deposition, crystallization).

9. An increase in the material humidity due to an unanticipated ingress of vapor, moisture into NFM (S) equipment or packaging and, as a result, an increase in the moderating capacity of the equipment and(or) packaging.

10. Employee's errors during the process and violations of the process regulations:

- incorrect equipment arrangement during start-up and aligning and(or) repair operations;
- repeated NFM (S) loading into the type "O" equipment;
- non-observance of the time interval between loads;
- misloading of NFM (S) (into another equipment, other materials, etc.);
- misswitching of valves;
- sampling errors;

- errors made during measurements and sample analyses;
- non-observance of frequency of equipment cleaning, washing, replacing, as established in the design.

11. Temperature changes of agents, neutron moderators, NFM (S) (due to a fire, failure of the hot air system, heaters, coolers, etc.) leading to changes in the equipment geometry, heat shocks, condensing, boiling, freezing, evaporation of agents, NFM (S), neutron moderators, neutron absorbers, etc.

12. An increase in the neutron moderating efficiency in a NFM (S) containing equipment, reduction in absorbing properties of the neutron absorbers.

13. Changes in NFM (S) density, special distribution and isotopic composition.

14. Overfill of the equipment (vessel, installation) which contains a NFM (S) solution.

Appendix 2. RULES AND METHODS FOR CALCULATION OF NUCLEAR SAFETY PARAMETERS AND CHARACTERISTICS

1. Threshold load, fill, concentration, and accumulation

1.1. Values of threshold load (Ml) and fill (Nf) shall be determined through the following ratios:

$(M\text{l} + \Delta M) + (N\text{f} + \Delta N) \leq M\text{s}\ (M\text{p})$ or

$M\text{l}\ (1 + \delta\text{m}/100) + N\text{f}\ (1 + \delta\text{n}/100) \leq M\text{s}\ (M\text{p})$,

where: ΔM and ΔN are the limits of absolute permissible measurement errors of NFM (S) being loaded and contained in the equipment before loading; they are determined basing on 0.95 confidence probability at $M = M\text{l}$ and $N = N\text{f}$; δm and δn are the limits of relative permissible errors determined by formulae:

$\delta\text{m} = 100\ \Delta M/M\text{l}$ (%); $\delta\text{n} = 100\ \Delta N/N\text{f}$ (%).

While determining Ml and Nf values it is permitted not to take account of fissile nuclides absorbed by structural elements of the installation.

1.2. Threshold concentration value (Cc) shall be determined through the following ratio:

$C\text{c} + \Delta\text{c} \leq C\text{s}$ or $C\text{c} \leq C\text{s}\ (1 + \delta\text{c}/100)$,

where: Δc is the limit of absolute permissible measurement error of concentration at $C = C\text{c}$ determined basing on 0.95 confidence probability;

δc is the limit of relative permissible error determined through the formula:

$\delta\text{c} = 100\Delta\text{c}/C\text{c}$ (%).

1.3. Threshold accumulation value (Ma) shall be determined through the ratio:

$M\text{a} + \Delta \leq M\text{s}\ (M\text{p})$ or $M\text{a} \leq M\text{s}\ (M\text{p}) / (1 + \delta/100)$,

where: Δ is the limit of absolute permissible measurement error of mass of fissile nuclides and NFM being accumulated in the equipment at $M = M\text{a}$ determined basing on 0.95 confidence probability;

δ is the limit of relative permissible error determined through the formula:

$\delta = 100\ \Delta/M\text{a}$ (%).

2. Threshold values of nuclear safety parameters

2.1. To ensure safe operation the threshold values of the corresponding nuclear safety parameters shall be established in addition to safe and permissible parameters.

2.2. The threshold nuclear safety parameter values (threshold parameters) are established for all nuclear safety parameters controlled during operation to reliably restrain their possible actual values by the permissible (safe) values established during design. The threshold parameter values are determined on the basis of the conservatively determined values of:

- corresponding permissible (safe) parameter values;
- measurement errors of these parameters made by measurement instrumentation envisaged by the design;
- uncertainties in actual parameter values related to the end time of actuators' response of the parameter limitation systems (interlocks, dispensers, breakers, etc.).

The threshold parameter values shall be determined as per para 2.2.3.

2.3. If a threshold value of parameter X is established basing on the upper limiting parameter value equal to Xl, it is marked Xn and determined through the following ratios:

$X_n + \Delta x \le X_l$ or $X_n \le X_l/(1 + \delta x/100)$,

where: Δx is the limit of absolute permissible measurement error of parameter X at $X = X_n$; and $\delta x = 100\Delta x/X_n$.

2.4. If a threshold value of parameter Y is established basing on the lower limiting parameter value equal to Y_l, it is marked Y_n and determined through the following ratios:

$Y_l - \Delta y \ge Y_n$ or $Y_n \ge Y_l/(1 - \delta y/100)$,

where: Δy is the limit of absolute permissible measurement error of parameter Y at $Y = Y_n$; and $\delta y = 100\Delta y/Y_n$.

Measurement errors of Δx and Δy shall be determined for 0.95 confident probability.

If the limit value of a relative permissible measurement error of the controlled value does not exceed 2%, it is permitted not to consider it during determining standards and thresholds.