REGULATORY APPROACH TO SAFETY OF LONG TIME OPERATING RESEARCH REACTORS IN RUSSIA

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ABSTRACT

In the Russian Federation more than 60% of operating Nuclear Research Facilities (NRFs)[1] are of age over 30 years old or their usage exceeds originally conceived continuous operation. In this regard, important areas of regulatory body activity are: 1) a systematic assessment of the actual state of structures, systems and components (SSCs) important to safety, 2) control of implementation of organizational and technical measures to mitigate ageing impact on the basis of programmes to manage reliability (service life) of SSCs, and 3) issues of facility modification/reconstruction in line with up-to-day safety requirements. The practice of licensing NRFs with long operating times shows that the national regulations are generally in compliance with IAEA recommendations for ageing management of research reactors. In operating organizations, the ageing management is being effectively provided as a part of the integrated management system for NRFs, including the monitoring of the reliability of SSCs, a methodology to detect their ageing, reporting and investigation of events, analysis of their root causes, and measures to prevent and mitigate ageing effects to safety. The report outlines a good practice of safety regulation of NRFs with long operating times and based on lessons learned from experience, including challenges for future improvement of ageing management.

1. Introduction

An effective ageing management programme (AMP)[2] of structures, systems and components (SSCs) important to safety is one of the aspects for ensuring safety at NRFs. The strategy of an effective AMP based on a proactive approach intended to prevent failures of SSCs due to physical ageing and obsolescence[3] is provided.

In the Russian Federation, the legislative framework for nuclear energy requires the development of an effective AMP for NRFs. Available lessons learned summarize the experience of the integrated management system [1] at 17 organizations operating 58 NRFs including 23 research reactors (RRs), 26 critical assemblies (CAs), and 9 subcritical assemblies (SCAs). The survey of NRFs' ageing shows that 56 % of facilities have physical ageing and 23 % obsolescence. For new facilities under construction/ refurbishment, for example research reactor “PIK” (IAEA code RU0016), the AMP has been established at the design stage and is being supported at the following stages of lifetime[4].

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1 NRFs – nuclear facility including research nuclear reactors (RR), critical nuclear assembles (CA) and subcritical (SCA) nuclear assembles, and related complex of premises, structures, systems, elements, experimental facilities, and personnel that are in boundary of territory (NRF site) defined by the design for utilization of neutrons and ionizing radiation for research purposes.

2 ageing management programme (AMP) – engineering and organizational strategy and actions aimed at the reliability of SSCs during qualified life and/or complementary life time of NRF. In practice, the AMP is accomplished by coordinating existing programmes, including maintenance, periodic testing, and inspection programmes.

3 The characteristics of SSCs gradually change with time or use because of two types of ageing phenomena:

- due to physical degradation of equipment (physical ageing effect) which demand improvement of maintenance and replacement of worn-out components;
- obsolescence of SSCs due to lack of safety design, manufacture or mounting of equipment (non-physical ageing effect) which occurs when SSCs become out of date in comparison with current technology, standards and regulations or when documentation becomes out of date.

4 Stages of lifetime of NRF – design, fabrication and construction, commissioning (shipment, storage, mounting, starting-up and adjustment work, putting in operation), operation (utilization, maintenance, repairing, modification, refurbishment), decommissioning.

According to the national legislation, the operating organization elaborates and carries out measures to maintain the safety of the nuclear installation, radiation source or storage facility, establishing, if it's necessary, special safety monitoring services, and submits information on the safety level of the nuclear installation, radiation source or storage facility to the State safety regulatory authorities. In line with licence conditions issued by the Rostechnadsor[5] for activities at the NRFs, the operating organization should:

- Elaborate measures to update licensing activity in compliance with new safety requirements or realize compensatory measures with accompanied safety justification in the cause if it's unavailable to eliminate existing non-compliances;

- Correct in proper time the Safety Assessment Report (SAR) and NRF's operating documentation taking into account the current state of the NRF and the compensatory measures taken for compliance with new safety requirements or regulations.

According to requirements of the national safety norms the operating organization for the AMP should provide systematic monitoring of SSCs important to safety that are in operation, detecting potential deficiencies in safety; implementing countermeasures for prevention and mitigation of ageing degradation, and maintaining defence in depth of the NRF.

The Rostechnadzor publishes in its annual report [2] the major results of safety review of objects that use nuclear energy, including NRFs. More than 70% of operating NRFs are more than 30 years old. Based on licensing of activities at NRFs, peer review NRFs (expert reviews of safety documentation), inspections, and documented compliance with the licence conditions, Rostechnadzor estimates the current status of safety and security at supervised NRFs as satisfactory. Nevertheless, the methodology of the current safety assessments at NRFs, including ageing phenomena, is a subject for further improvement.

Below the experience is shown for assessment/reassessment of the current safety of NRFs that have operated long time and their AMP.

2. Normative regulation of ageing management programme of NRFs in Russia

According to IAEA recommendation [3], the operating organization should establish a data collection and record keeping system for ageing phenomena review of SSCs in the AMP. The set of Federal Rules and Regulations in the sphere of the use of nuclear energy of the Russian Federation (FRRs)[6] does not include a special standard for AMP of NRFs, but major requirements to AMP are distributed in different FRRs on the safety of objects that use nuclear energy [4].

Based on lessons learned, the draft of the new specific safety guide "Requirements to the Ageing Management Program for Structures, Systems and Components of Research Nuclear Facilities" is planned. It will summarize the national experience of AMP for NPPs and NRFs and

5 The Federal Environmental, Industrial and Nuclear Supervision Service of Russia (Rostechnadzor) is a federal executive body, which exercises the functions on state policy formulation and legal regulation of safety in the field of atomic energy use (except of the activities on development, production, testing, operation and decommissioning of nuclear weapons and military nuclear power installations). Rostechnadzor is the authority within the regulatory framework for safety of the use of nuclear energy in the Russian Federation, e.g. authorized body for state safety regulation in atomic energy uses (federal supervisory body in the field of atomic energy uses).

6 According to the Federal Law on the Use of Nuclear Energy, the Federal Rules and Regulations for the use of Nuclear Energy (FRRs) are legislative acts that lay down requirements on the safe use of nuclear energy, including safety requirements for nuclear objects, safety requirements for the use of nuclear energy, including fundamental principles and criteria of safety compliance, which is obligatory in the carrying out of any type of activity in the use of nuclear energy. FRRs are developed and agreed on by the Government of the Russian Federation. The state regulatory bodies develop, approve and issue safety guides that should assist in compliance with the requirements of an FRRs.

the current IAEA recommendations to the AMP [3]. The following considerations on the AMP of national FRRs are taken into account in the aforementioned draft of the new document:

- Ageing management should be included as a separate topic in the general design criteria for NRFs. At the design stage of NRFs, an appropriate safety margin shall be adopted, conditions for SSCs' operation shall be defined and the NRF service life time shall be justified. Provisions shall be made for necessary monitoring, testing, sampling and inspection for the detection, assessment, prevention, and mitigation of ageing effects and potential ageing related degradation of materials. Particular consideration should be given to elements of SSCs that are difficult to inspect or maintain.

- At the stage of fabrication and construction, relevant information on factors affecting ageing management, including service conditions, should be provided to SSC manufacturers, and, through the manufacturers' management system, this information is properly taken into account in the fabrication and construction of SSCs. Reference (baseline) data, including manufacturing and inspection records, as well as records on shipment and storage conditions, should be collected and documented. Surveillance specimens for specific ageing monitoring programmes for materials should be made available and installed in accordance with design specifications. Fabrication of equipment should be based on certified technology, and justified by previous experience or testing, and be in compliance with requirements of FRRs and other normative documents used by Rostechnadzor. New technology and materials should be used only after justification of their advantages in the reliability of SSCs, service life, and safety indicators enhancement as compared with current technologies and materials.

- At the stage of commissioning, during shipment, storage, mounting, starting-up and adjustment work, manufacturers of equipment shall provide the operating organization with relevant baseline data that may potentially affect the AMP of SSCs. Before the NRF start-up, the operating organization should establish a database on SSCs' reliability and maintenance histories and a systematic programme for measuring and recording baseline data relevant to ageing management and assessment of residual service life for SSCs important to safety. All parameters that can influence ageing degradation should be identified during commissioning and should be tracked throughout the NRFs lifetime. Acceptable criteria for these parameters should be established.

- At the stage of NRF operation, the service life of replaceable equipment of SSCs should be controlled, supported and, if necessary, renewed through valid maintenance, in-service inspection and repairing. Ageing management of non-replaceable equipment of SSCs should be performed using special programmes. Methods for analysis of baseline data should provide detection of ageing effects for assessment of residual service life for SSCs and following operation, if needed. The operating organization should identify and justify possible changes in operational conditions that could cause acceleration or premature ageing and failure of some SSCs. The operating organization should provide ongoing training on operational systems and AMP for personnel at all levels. The operating organization should take into account that NRFs are frequently modified to incorporate new experimental devices or to improve normal operation. In case of NRF extended shutdown, the operating organization shall take appropriate measures to ensure that materials and components do not seriously degrade.

- Before the decommissioning stage, the operating organization shall carry out a comprehensive survey of the NRF to determine the current technical state of the SSC equipment and what necessary changes should be incorporated in the AMP. The activity on the AMP in the decommissioning stage should be continued in compliance

with Principal Decommissioning Plan for NRF developed by the operating organization and approved by the executive body that manages the NRF.

The effective FRRs "Requirements for Justification of Possible Extension of Assigned Operational Life of Objects Using Nuclear Energy" (NP-024-2000)[7] establishes the main criteria and requirement for safe operation of the nuclear object over the service life as defined in the design, and identifies any new procedures to be approved by the Rostechnadzor for further safe operation of the object. In line with established requirements, the operating organization shall incorporate the management of reliability (service life) of SSCs based on the development of supplementary programmes. The efficiency of methods and means for monitoring of the SSCs should be valid for the assessment of their current state and to identify and prevent design initial events.

When design service life of the object (or justified later through expertise) has been reached (or the operating time has reached 30 years), the operating organization should perform the following activities to additional assess the possibility to continue operation:

- Carry out comprehensive survey of the nuclear object;
- Define and justify the residual service life of the SSCs and potential deficiencies in safety;
- Prepare the nuclear object for operation during extra service time including:
  - additional research to define residual service life of the SSCs and potential deficiencies in safety,
  - replacement of equipment with spent service time (and, if necessary, its modernization/modification),
  - testing of systems (elements) to validate design requirements,
  - updating of safety documents and operational instructions.

If the operating time of the object did not reach the design service life (or justified later through expertise) or has operated less than 30 years, the effectiveness of the AMP is reviewed by the Rostechnadzor within the licensing activities at the nuclear object. And, in practice, the licence for the activity is issued by the Rostechnadzor for a period of 5 years. When the licence is expired, the operating organization shall obtain a new licence for the activity and a proper safety evaluation including an assessment of the effectiveness of the AMP shall be performed during the licensing process. Also, the evaluation shall be carried out in the case of changing the licence conditions.To get a new licence for a NRF operation or to approve changing of licensing conditions the operating organization shall submit a set of safety justification documents according to the requirements of the "Administrative Regulation to Perform the State Function of Licensing Activity in the Field of Nuclear Energy Use by the Federal Environmental, Industrial and Nuclear Supervision Service", approved by the government of the Russian Federation from 29.03.2013 № 280, to confirm that the SSCs satisfy the criteria of resistance to ageing phenomena, stability to external impact and functional availability during the specified future time period, but not less than the effective time period of the new licence.

Moreover, the efficiency of the AMP SSCs, based on up-to-date knowledge, regulations, and revisions to the safety analysis, included in the SAR of the NRF, should be reviewed in periodic safety assessments (PSA) of the NRF. Taking into account the recommendations of the IAEA Integrated Regulatory Review Service Mission to the Russian Federation in 2009 [5], the proper amendments have been introduced into Federal Law on the Use of Nuclear Energy according to which the PSA of a nuclear facility and the storage of nuclear fuel shall be performed, if the operating licence has been issued for a time period of more than 10 years, and the PSA shall be repeated every 10 years. At present, the FRRs "Periodic Safety Assessment of Nuclear Research Facilities" is developed and will be become effective in 2014. Moreover, the

7 The document NP-024-2000 applies to all nuclear objects of the use of nuclear energy excluding Nuclear Power Plants and military objects

Rostechnadzor has determined the procedures for submittal of the documents by the operating organizations, with the results of the safety assessment/reassessment of the nuclear facility/storage of nuclear materials for their review and the requirements pertaining to the set of documents and their contents (Order from 14 December, 2012, № 728).

3. Monitoring of safety at NRFs

The Rostechnadzor carries out the systematic analysis of the following sources of information to identify issues and trends of safety conditions at NRFs:

- Incident reports;
- Annual reports of operating organizations on the assessment of nuclear and radiation safety at NRF;
- Outcomes of the activities of services in the structure of the operating organizations on nuclear and radiation control and the implementation of the quality assurance programme (QAP).

To confirm the validity of the submitted data on the safety status of NRFs and to control the efficiency of the management system of operating organizations, the Rostechnadzor organizes and performs inspections on the compliance to safety requirements of the FRRs and the licence conditions.

In ageing management, a proactive approach is being implemented. To this goal, an evaluation of the cumulative effects of both the physical ageing of equipment and the obsolescence of SSCs at an NRF is periodically assessed by different experts at the following levels of safety control:

- Services of the operating organization for control activities on quality assurance programmes (concerning planned measures) and services for nuclear and radiation safety (one per year);
- During review of the annual reports on the assessment of nuclear and radiation safety at NRF (one time per year);
- During the expertise of licensed activities (one time per 5 years);
- During the periodic reassessment of NRF safety (one time per 10 years, if the licence has been issued for a period more than ten years).

3.1. Incident reports

In line with FRRs “Provisions on Investigation and Reporting of the Operational Violations at Nuclear Research Facilities” (NP-027-10), the operating organization shall gather, process, analyze, record, and store the information related to events/incidents at NRFs during their life time. The operating organization should analyze all operational events at NRFs to identify potential deficiencies in safety to incorporate outcomes in the AMP. The reports on the investigation of “the most significant to safety events” shall be submitted to the Rostechnadzor. The categories of these events, including the circumstances and the consequences are in the table of the regulations NP-027-10. Investigation of the events at NRF caused by failures and malfunctions of SSCs, including failures of actuators in the control and protection system, as well as failures of equipment and personnel errors that are not accompanied by circumstances and consequences listed in the table of NP-027-10, shall be investigated according to procedures established by the operating organization in their operational instructions. Analysis of events shows that the most important root causes of the incidents reported to Rostechnadzor are the ageing of SSCs and human errors. The information on event investigation included in the report allows analyzing ageing effects and performing categorization of ageing mechanism. However, the necessity to add requirements into FRRs NP-027-10 for data structuring is being discussed now.

3.2. Annual reports of operating organizations on assessment of nuclear and radiation safety at NRF

In compliance with recommendations in safety guide “Contents of Operating Organization Annual Report on Assessment of Safety Status of Nuclear and Radiation Safety of Nuclear Research Facilities” (RB-025-03), data on the main aspects (directions) of safety insurance shall be included in the annual report of the operating organization, taking into account the specific NRF design and its operation.

Safety indicators (quantitative or qualitative) may be determined for each direction of safety insurance. The boundary values of these safety indicators should be defined by requirements in the FRRs, design documents, operating instructions, and licence conditions. They may include administrative values, operational limits and conditions, safety limits, and values and limits authorized in licence conditions. For obviousness, the state of the safety indicator may be graded on a color scale:

- S (satisfactory for safety, green color) – an indicator does not exceed the administrative values or determined operational limit, licensing conditions are satisfied, and actions to eliminate existing non-compliances with safety requirements are in progress;
- A (acceptable for safety and compensatory technical measures are not needed, white color) - an indicator does not exceed the authorized limit or safety limit, licensing conditions are satisfied, and organizational issues are the only non-compliances with safety requirements;
- L (low safety level and operation is acceptable only with extra compensatory measures, yellow color) - an indicator may reach boundary safety limits, deviations from licensing conditions and safety requirements exist;
- I (inadmissible for safety, red color) - rough violations of safety requirements and licensing conditions take place that lead to licence suspension[8].
- U (data for indicator assessment is absent or indicator cannot be applied, grey color).

The directions for insuring safety and the possible results of their review using the color scale are given in Table 1 below that might be used as a sample form for safety assessment.

№	MAIN DIRECTION OF NRF SAFETY INSURANCE	Experts’ assessment			
		S	A	L	I
1.	*Generic aspects of safety ensuring*				
2.	*Current state of safety barriers on the way of ionizing radiation and radioactive substances to the environment*				
3.	*Incidents review*				
4.	*Nuclear safety*				
5.	*Safety of handling with spent nuclear fuel*				
6.	*Radiation safety of the personnel*				
7.	*Radiation safety of the population and environment*				
8.	*Safety of treatment with radioactive waste*				
9.	*Accounting and control of nuclear materials, radioactive substances and radioactive waste*				
10.	*Industrial safety*				
11.	*Fire and exposure safety*				
12.	*Emergency preparedness*				

Table 1. The main directions for ensuring safety and the possible results of their review using the color scale

8 According to Russian Federation Code of Administrative Violations from 30 December 2001 № 195-FZ the rough violation of safety requirements in the use of nuclear energy is recognized violation that is direct threat for people’s lives life or health and environment.

An example of safety indicators for direction "*Incidents review*" for reported period is given in Table 2.

1. Number of reportable events at NRF that are accompanied by circumstances and consequences listed in the table of NP-027-10 (obligatory report to Rostechnadzor)			
Satisfactory	Acceptable	Low	Inadmissible
No event was reported or one event in the external electricity lines has happened that is beyond the operating organization's responsibility	One event was reported that has no radiation impact to personnel or two events in the external electricity lines has happened that is beyond the operating organization's responsibility	One event was reported that has radiation impact on personnel or more than one event was reported that has no radiation impact to personnel or more than two events in the external electricity lines has happened that is beyond the operating organization's responsibility	An accident has happened
2. Number of unplanned shutdowns of the NRF related to a fault of the SSCs, including malfunctions of actuators in control and protection systems, failures of equipment that are not accompanied by circumstances and consequences listed in the table of NP-027-10 for reportable events (events are investigated according to operating organization instruction only).			
Satisfactory	Acceptable	Low	
No more than one indicated above events have happened	No more than two indicated above events have happened	Three or more indicated above events have happened	
3. Number of facility's scrams when there were no causes and characteristics for action (faulty actuation), excluding a scram associated with work programmes			
Satisfactory	Acceptable	Low	
No more than one indicated above events have happened	No more than two indicated above events have happened	Three or more indicated above events have happened	
4. Number of unplanned shutdowns of NRF because of personnel errors			
Satisfactory	Acceptable	Low	
No more than one indicated above events have happened	No more than two indicated above events have happened	Three or more indicated above events have happened	
5. State of SSCs' service life (qualitative safety indicator)			
Satisfactory	Acceptable		
The service life of SSCs is not exhausted or the defined service life was reached and a safety extension of NRF operation has been justified	The service life of SSCs has been exhausted but the necessary safety justification to extend the NRF operation is absent during more than one reportable period		
6. Quality of maintenance and repairing of SSCs, number of SSCs' malfunctions due to deficiency in maintenance and repairing of SSCs			
Satisfactory	Acceptable	Low	
In reportable period, there was no event because of deficiency in maintenance and repairing of SSCs	In reportable period, there was no more than one event because of deficiency in maintenance and repairing of SSCs	In reportable period, there was more than one event because of deficiency in maintenance and repairing of SSCs	

Table 2. Safety indicators for direction "*Incidents review*"

The IAEA Research Reactors Ageing Database [6] includes examples of ageing phenomena at Russian NRFs.

- WWR-M, 1959, 18MW, tank, light water moderated/cooled, beryllium reflected, HEU fuel;
- IBR-2, 1977, 2 MW (1500 MW in pulse), 5Hz-pulsed fast reactor, liquid sodium cooled, PuO2 fueled (modification was completed in 2010).

As experience shows, the management system of organizations operating NRFs is effective to control the ageing process of SSCs and timely update safety documents and operating documentation of the NRF.

3.3. Outcomes of activities of services in the structure of operating organizations on nuclear and radiation control and implementation of quality assurance programme (QAP).

In line with the requirements of FRRs “General Provisions on the Safety of Nuclear Research Facilities” (NP-033-11), services on nuclear and radiation safety in the structure of the operating organization should be established independently from the management of the NRF to control the safety state, including their safety assessments and inspections.

According to the requirements of FRRs “Nuclear Safety Regulations for Research Reactors” (NP-009-04), the operating organization must provide constant control of compliance with nuclear safety requirements and conduct annual inspections of RR safety by their own nuclear commission. The outcomes of the inspections should be submitted to Rostechnadzor.

Concerning FRRs “Requirements for Quality Assurance Programme (QAP) for Objects that Use Nuclear Energy” (NP-090-11), the operating organization should establish a QAP, develop a quality policy, and implement a management system for QAP, including personnel management, documentation management, and other aspects of QAP.

3.4. State supervision and monitoring of licensed activities at NRF

“Provision on Performance of Federal State Supervision on the Use of Nuclear Energy” № 1044 was approved on 15.10.2012 by the Government of the Russian Federation. It includes subject, grounds, duration, and types of inspections concerning the use of nuclear energy. The planned inspections are carried out according to Rostechnadzor’s plan with the following frequency:

- not less than annually for activities related to nuclear and radiation hazardous work;
- not more than annually for activities that are not related to nuclear and radiation hazardous work.

“Provision on Constant State Supervision Regime on Objects that Use Nuclear Energy”, № 373 was approved on 23.04.2012 by the Government of the Russian Federation. In this document, the Interregional Territorial Departments for Nuclear and Radiation Safety Supervision of Rostechnadzor is assigned the responsibility to carry out monitoring of compliance with the requirements of the FRRs and licence conditions.

4. Conclusion

- The safety regulation of NRFs in Russia pertains to NRFs having a power rating of up 200 MW, including specialized reactors (e.g. fast spectrum reactors, homogeneous reactors, boiling reactors, pulse reactors, and reactors with specialized facilities - hot or cold neutron sources, high pressure and high temperature test loops).
- The legislative and normative framework of the Russian Federation covers all important to safety NRFs aspects of the integrated management system of an operating organization, including services and processes, methods and means of establishing control over ageing management activities.
- Requirements to AMP are distributed in different FRRs and safety guides for objects that use nuclear energy.
- From a regulatory approach to safety, lessons learned from long time operating NRFs in Russia confirm expedience to generalize and structuring the existing practice in a specific safety guide on ageing management for NRFs that should assist compliance with the requirements of the FRRs.

5. References

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