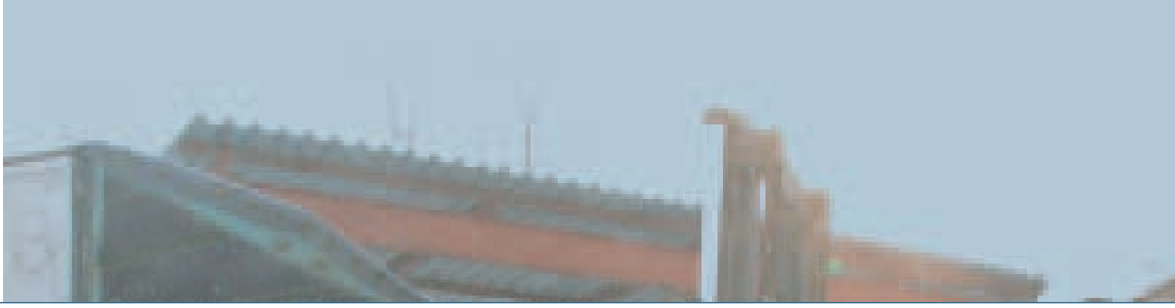

StrålevernRapport ▪ 2007:5

Upgrading the Regulatory Framework of the Russian Federation for the Safe Decommissioning and Disposal of Radioisotope Thermoelectric Generators

Statens strålevern
Norwegian Radiation Protection Authority

References:
Sneve M.K, Reka V. Upgrading the Regulatory Framework of the Russian Federation for the Safe Decommissioning and Disposal of Radioisotope Thermoelectric Generators. StrålevernRapport 2007:5. Østerås: Norwegian Radiation Protection Authority, 2007.

Contributors:
Finne I, Eikelmann I M, Smith G M, Barraclough I, Deregel Ch, Le Mao S, Lizot M T, Maigne J P, Rancillac F, Snihs J O, Zinger I, Brøed R, Shempelev A, Ivanova M.

Key words:
Radiation protection and safety Regulation of RTG. Decommissioning and disposal of RTG. Supervision and control. Threat Assessment of RTG in NW Russia

Abstract:
The overall objective of the collaborative project was to upgrade the existing regulatory framework of the Russian Federation for the safe decommissioning and disposal of RTGs, with a focus on the priority areas: regulatory requirements and regulations; threat/hazard assessment needed in the licensing of the activity and authorisations (permits) for employees of the operating organisations; supervision over the radiological safety; supervision over emergency preparedness; physical protection in RTG decommissioning; and environmental impact assessment review for RTG dismantling, transportation, temporary storage and disposal.

Referanse:
Sneve M K, Reka V. Upgrading the Regulatory Framework of the Russian Federation for the Safe Decommissioning and Disposal of Radioisotope Thermoelectric Generators. StrålevernRapport 2007:5. Østerås: Statens strålevern, 2007. Språk: engelsk.

Bidragsytere:
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Emneord:
Regulerende strålevern og sikkerhet av RTG. Dekomisjonering og sluttdeponering av RTG. Oppsyn og kontrol. Trusselvurdering av RTG i Nordvest Russland.

Resymé:
Formålet med dette samarbeidsprosjektet var å oppgradere eksisterende regelverk i Russland for sikker dekommisjonering og lagring av RTGs, med fokus på følgende områder: myndighetskrav og regelverk; trusselvurdering for lisensiering; overvåking og kontroll av strålevern og sikkerhet; beredskap og fysisk sikring og EIA for transport og lagring av RTG.

Head of project: Malgorzata K. Sneve.
Approved:

Per Strand, Director, Emergency Preparedness and Environmental Protection Department.

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Upgrading the Regulatory Framework of the Russian Federation for the Safe Decommissioning and Disposal of Radioisotope Thermoelectric Generators

A Collaborative Project of the
Norwegian Radiation Protection Authority
and
Rostechnadzor

Final Project Report

Statens strålevern
Norwegian Radiation
Protection Authority
Østerås, 2007

CONTRIBUTORS TO THE PROJECT

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Executive Summary

The Norwegian Government, through a Plan of Action implemented by the Ministry of Foreign Affairs, is promoting improvements in radiation protection and nuclear safety in North-West Russia. Some of this work is directed to the safe decommissioning of radioisotope thermoelectric generators (RTGs), which are mainly used as electric power sources in remote navigation facilities (lighthouses).

At present, there are around 700 RTGs in use in the Russian Federation, about 30% of which have been in use longer than the design operational lifetime. In addition, there have been several cases where the responsible organisation has lost individual RTGs or where RTGs have been tampered with by unauthorised persons. The RTGs represent a very high radiological hazard. They contain radioactive sources with radioactivity levels of tens of thousands of curies, possibly up to 400 000 Ci, or nearly 15 000 TBq, per RTG. Consequently, the government of the Russian Federation has decided that all institutions owning RTGs must make a full inventory of them, take measures to increase their physical protection and carry out the necessary work for their potential decommissioning and disposal.

The Federal Environmental, Industrial and Nuclear Supervision Service of Russia, Rostechnadzor, identified a need for upgrading the regulatory framework for the safe decommissioning and disposal of the RTGs, taking account of the magnitude of the problem and the high hazard associated with the RTGs, the upcoming work on their decommissioning and disposal as well as the lack of experience in this area. This regulatory project was established to address these issues, running in parallel with the ongoing work to remove and safely store the RTGs.

Objective

The overall objective of the collaborative project was to upgrade the existing regulatory framework of the Russian Federation for the safe decommissioning and disposal of RTGs, with a focus on the following priority areas:

- Regulatory requirements and regulations;
- Threat/hazard assessment needed in the licensing of the activity and authorisations (permits) for employees of the operating organisations;
- Supervision over the radiological safety;
- Supervision over emergency preparedness;
- Physical protection in RTG decommissioning; and
- Environmental impact assessment review for RTG dismantling, transportation, temporary storage and disposal.

Project organisation

The Project Leaders were, on the Russian side, **Vladimir Reka, Rostechnadzor**, and on the Western side, **Malgorzata K. Sneve, NRPA, Norway**.

The collaborative project had six tasks, based on the six priority areas listed above, and nine deliverables were prepared under these tasks. This report describes the final results of the project. Appendices A–F contain the nine deliverables, and the main text provides an overview of the main issues identified through the various tasks and the project as a whole.

The hazard

The radiological hazard of interest to this project is the strontium-90 radioisotope heat sources (RHSs) in the RTGs. The hazard is large: RHSs of the type used in RTGs have the potential to cause serious health and environmental impacts if they are not kept under proper control. The purpose of the industrial project is to eliminate the hazard (and hence the risks associated with it) by decommissioning the RTGs and disposing of the RHSs. The processes needed to achieve this long-term reduction in risk may temporarily increase some existing risks or introduce new ones. The purpose of the regulatory project is to ensure that appropriate technical and regulatory measures are in place to ensure that the risks at all stages of the decommissioning process are kept sufficiently low.

The primary hazard associated with RHSs is external radiation, and so is local to the RTGs. The hazard is realised particularly in cases where:

- Untrained and unauthorised individuals come into contact with RTGs, whether or not the shielding is initially undamaged; or
- The shielding has been damaged due to previous events, accidents or malicious events, and so even fully trained and authorised personnel may be subject to high doses rates.

Dispersion of Sr-90 in the environment is possible only in the event of highly unlikely extreme situations, such as:

- Long term immersion in water (probably accidentally, as a result of dropping into the sea during transport by helicopter or sinking of a vessel carrying RTGs);
- Very severe impacts affecting the RHS itself (probably accidentally, for example by dropping from a helicopter onto land or crushing by a vehicle);
- Very severe fire (probably accidental); or
- Explosion (probably intentional, for example as a 'dirty bomb').

Evidence of 'leaking' of Sr-90 in other circumstances is inconclusive. Apparent evidence of leakage of Sr-90 – for example enhanced dose rates some distance from an RTG and radioactive contamination in the surrounding area – may be the result of corrosion of depleted uranium (DU) shielding. The loss of shielding may lead to dramatically increased dose rates from the intact RHS, and the crumbling DU may contaminate surrounding soil. Nevertheless, these reported phenomena should be investigated further.

Control of the hazard

Proper control of the hazard associated with RHSs during RTG decommissioning requires:

- Correct actions by operator, who is primarily responsible for safety and security, complying with laws, regulations and regulatory guidance, but also using 'ALARA' approach; and
- Effective supervision of these actions by regulators.

Such proper control entails establishment and maintenance of:

- Radiation protection measures to control exposure in planned activities;
- Radiation safety measures to prevent accidents;
- Accounting and security measures to prevent misappropriation or malicious acts; and
- Capability to detect and respond to failures in these measures, maintain whatever control is possible in the short term and re-establish proper control as soon as practicable.

This in turn requires:

- Prior assessment of situations and proposed activities;
- Rigorous, documented planning of activities, taking account of the prior assessment;
- Use of properly qualified and trained people;
- Compliance with laws, regulations, and project specifications when performing activities;
- Ongoing review and improvement of work performance (including preventing future accidents by learning lessons from accidents and near misses); and
- Regulatory supervision and inspection to ensure this is all done.

A detailed analysis has been carried out of these requirements and of the existing legislative, regulatory and operational measures for all stages of RTG decommissioning. The analysis identified nine key steps corresponding to optimisation of protection and safety of personnel and the public at each stage in RTG decommissioning and nine key regulatory issues. The resulting 9-by-9 matrix of tasks and issues was analysed to identify a number of priority areas for regulatory action. A number of these priority issues have been taken into account in the various tasks of this project. The priority areas were as follows:

- Systematic and timely definition of decommissioning plans and specification of decommissioning projects, and regulatory approval of these;
- Thorough inspection prior to starting decommissioning operations, including operational inspection of the RTG's condition (as part of the basis for the decommissioning plan) and regulatory inspection of the preparedness of the operator to carry out the decommissioning work;
- Preventing and responding to accidents during the various types of transport;
- Physical protection of RTGs during transport;
- Safety and security of collections of RTGs at temporary storage locations; and
- Ensuring consistency in safety and security arrangements.

Future needs

Some priority issues identified through this analysis were not fully addressed during the current project and may need to be considered for future work.

In general, however, the key need for the future in relation to the regulation of RTG decommissioning is to achieve consistent practical implementation of the framework of regulations and processes already in place and enhanced through this project, through all steps of decommissioning and for all RTGs. Although there may be scope for further improvements in the framework, regulations and procedures are now in place, and the operators and regulators need to be engaged in understanding them and ensuring that they are applied. A significant element of future work will therefore be to raise awareness among the regional inspectors of Rostechnadzor and the operators (and also among the controlling organisations and organisations rendering services) of the regulations and procedures, the reasons behind them, and the importance of applying them. This issue could be addressed, for example, by means of educational workshops for regional inspectors of Rostechnadzor, and possibly also for staff of the operators and organisations rendering services.

Contents

1. Introduction

Background

The Norwegian Government, through a Plan of Action implemented by the Ministry of Foreign Affairs, is promoting improvements in radiation protection and nuclear safety in North-West Russia. Some of this work is directed to the safe decommissioning of radioisotope thermoelectric generators (RTGs), which are mainly used as electric power sources in remote navigation facilities (lighthouses).

At present, there are around 700 RTGs in use in the Russian Federation, about 30% of which have been in use longer than the design operational lifetime. In addition, there have been several cases where the responsible organisation has lost individual RTGs or where RTGs have been tampered with by unauthorised persons (usually with the apparent intent of stealing shielding materials, rather than to use the RTGs themselves for non-sanctioned purposes). In particular, this has happened at military facilities of the Ministry of Defence. The RTGs represent a very high radiological hazard. They contain radioactive sources with radioactivity levels of tens of thousands of curies, possibly up to 400 000 Ci, or nearly 15 000 TBq, per RTG. Hence, according to IAEA[1], they should be classified as "Category 1" radioactive sources, i.e. sources that could give exposures at levels that might lead to death with after a relatively short period of exposure. Consequently, the government of the Russian Federation has decided that all institutions owning RTGs must make a full inventory of them, take measures to increase their physical protection and carry out the necessary work for their potential decommissioning and disposal. Hence, there is an urgent objective to carry out an analysis and make decisions regarding RTG future management as soon as possible.

Western assistance, specifically from Norway and U.S. have been given to support Russia in removal and securing the radioactive sources in the RTGs. From the Norwegian side this project is headed by the County Governor of Finnmark. As a first step in the work for decommissioning and disposal of those RTGs that are located along the coasts of the White and Barents Seas, Norway has provided funding to the All-Union Research Institute of Technical Physics and Automatics of the Russian Federation (VNIITFA) to develop the justification of environmental safety for an industrial project (also supported by Norwegian Government funding) on the decommissioning and disposal of these RTGs. The draft justification document has been submitted to and reviewed by the Federal Environmental, Industrial and Nuclear Supervision Service of Russia, Rostechnadzor, who concluded that some important safety aspects have not been fully addressed, e.g. the assessment of the radiological risks in case of possible accidental situations at each stage of the operational work, including failures in the technological processes, accidents during transportation and security measures against malicious activities.

Rostechnadzor concluded that there was a need for upgrading the regulatory framework for the safe decommissioning and disposal of the RTGs, taking account of the magnitude of the problem and the high hazard associated with the RTGs, the upcoming work on their decommissioning and disposal as well as the lack of experience in this area. This regulatory project was established to address these issues, running in parallel with the ongoing industrial project to remove and safely store the RTGs.

Objective

The overall objective of the collaborative project was to upgrade the existing regulatory framework of the Russian Federation for the safe decommissioning and disposal of RTGs, with a focus on the following priority areas:

- Regulatory requirements and regulations;

[1] IAEA (2005). Categorization of Radioactive Sources. IAEA Safety Standards Series No. RS-G-1.9, International Atomic Energy Agency, Vienna.

- Threat/hazard assessment needed in the licensing of the activity and authorisations (permits) for employees of the operating organisations;
- Supervision over the radiological safety;
- Supervision over emergency preparedness;
- Physical protection in RTG decommissioning; and
- Environmental impact assessment review for RTG dismantling, transportation, temporary storage and disposal.

Project organisation

The Project Leaders were, on the Russian side, **Vladimir Reka, Rostechnadzor**, and on the Western side, **Malgorzata K. Sneve, NRPA, Norway**.

The collaborative project had six tasks, based on the six priority areas listed above. Nine deliverables, D1–D9 (see below), were prepared under these tasks.

Task	Title	Russian Task Leader	Western Task Leader	Deliverables
1	Assessment of current regulatory requirements and regulations for radiation protection and safety	V. Skugarov, Rostechnadzor	G. Smith, * Enviros, UK	D1, D2
2	Review of applications for licensing and authorisations	M. Rylov, RESCenter	R. Avila,* Facilia, Sweden	D3, D4
3	Adaptation of procedures for monitoring of radiological safety	V. Reka, Rostechnadzor	C. Deregel,* IRSN, France	D5
4	Improvement of regulatory activities in the area of emergency preparedness	A. Shulgin / V. Shempelev, SEC NRS	I-M Eikelmann, NRPA, Norway	D6, D7
5	Physical protection in RTG decommissioning	V. Pervin, Rostechnadzor	I. Finne, NRPA, Norway	D8
6	Environmental impact assessment review for RTG dismantling, transportation, temporary storage and disposal	A. Pechkurov, Rostechnadzor	J O Snihs, SSI, Sweden	D9

*In addition to task leaders other Western participants has been very activly involved in the project work: I. Barraclough from Enviros, S. Le Mao, M.T. Lizot, J.P. Maigne and F. Rancillac from IRSN, I. Zinger and R. Brøed from Facilia.

In addition, a threat assessment was prepared during the project, intended to:

- Determine the main radiological threats to workers and the public which require regulatory attention;
- Determine the main requirements for risk assessment, i.e. those issues which will require most urgent and/or detailed analysis;
- Identify any relevant additional regulatory requirements, and the nature of the safety work instructions to be developed by the operator; and
- Identify key issues in the implementation of the regulatory process.

The threat assessment was issued as a separate report, with the aim of helping to focus the ongoing work in the six main tasks on the key regulatory issues.

This report describes the final results of the project. Appendices A–F contain nine reports (Deliverables D1–D9, listed in the table below), prepared by Rostechnadzor for these six tasks, taking account of contributions and comments from the Western experts. Acronyms and abbreviations are listed in Appendix G.

D1 Report on the overview of the current interrelations among the Russian organisations (which operate RTG, render services on RTG design and decommissioning), bodies for control of nuclear energy use, state safety regulatory authorities

D2 Report on the assessment of the current state of the Russian regulatory basis, which provides for the radiation safety requirements for the management of radiation sources, and the possibility of its use to carry out RTG decommissioning and disposal operations taking into account IAEA recommendations and the European experience

(D2a Threat Assessment Report)

D3 Report on the analysis of the Russian methodologies and initial risk assessment

D4 Report on software for performing risk assessments for RTGs decommissioning stages using upgraded software

D5 Handbook for inspections

D6 Report on the safety insurance in RTG decommissioning and preventions of emergency situations involving RTGs during transportation by different modes of transport

D7 Report on the development of the draft requirements to planning and preparedness to mitigate consequences of radiation accidents occurred in transportation of radioactive substances

D8 Report on the physical protection insurance for RTG decommissioning

D9 Report on EIA requirements for RTG decommissioning and disposal

The main text of this report provides an overview of the main issues identified through the various tasks and the project as a whole. This overview was prepared on the basis of the deliverables D1–D9, the Threat Assessment, additional input from the participants and discussion at the final project workshop, which was held in Moscow, 8–9 November 2006.

2. Assessment of current regulatory requirements and regulations for radiation protection and safety (Task 1)

Work performed

Within this Task the following topics were covered:

a. Clarification of the roles and responsibilities of Russian organisations (RTG operators, the organisations rendering services on RTG design and decommissioning), bodies for control of nuclear energy use, which include RTG operators, and state safety regulatory authorities.

b. Analysis of the Russian regulatory basis, which provides for the radiation safety requirements for the management of radiation sources, and the practicability and sufficiency of its use to carry out RTG decommissioning and disposal operations taking into account IAEA recommendations and the European experience.

The following steps were implemented:

a. The overview of the current interrelations among RTG operators, organisations, which render support to the operators on safe RTG management, transport organisations, organisations, which render support during RTG decommissioning and disposal, organisations dealing with RTG storage, their role and responsibility in RTG management. The overview of the current interrelations between RTG operators and the bodies for control of the nuclear energy use and state safety regulatory authorities.

b. Assessment of the current state of the Russian regulatory basis, which provides for the radiation safety requirements for the management of radiation sources, and the practicability and sufficiency of its use to carry out RTG decommissioning and disposal operations taking into account IAEA recommendations and the European experience.

The results of work specified in paras are addressed in Deliverable D1: "Report on the overview of the current interrelations among the Russian organisations (which operate RTG, render services on RTG design and decommissioning), bodies for control of nuclear energy use, state safety regulatory authorities".

The results of work specified in para b) are addressed in Deliverable D2: "Report on the assessment of the current state of the Russian regulatory basis, which provides for the radiation safety requirements for the management of radiation sources, and the possibility of its use to carry out RTG decommissioning and disposal operations taking into account IAEA recommendations and the European experience".

Deliverables D1 and D2 are presented in Appendix A.

Results and conclusions

Task 1 has helped to clarify and document the regulatory basis for decommissioning RTGs in the Russian Federation. A regulatory basis exists for ensuring radiation protection and safety in activities involving radioactive sources, which takes account of and is broadly consistent with international safety principles and practices. Task 1 has helped to identify the ways in which the legislation, regulations and rules specified for radioactive sources in general are applied to the different steps involved in decommissioning RTGs to provide adequate protection of workers, the public and the environment.

The overall primary responsibility for safety in the decommissioning of RTGs rests with the operator (owner) of the RTG. In particular, the operator (owner) is responsible for defining an appropriate decommissioning programme for its RTGs in advance of decommissioning, developing a project specification for the decommissioning programme, providing a safety analysis report justifying the safety of the proposed project, and ensuring that the decommissioning work is carried out in accordance with the specification and relevant regulations. In practice, the organisations undertaking specific tasks in the decommissioning programme take on a degree of responsibility for the safe performance of those tasks. VNIITFA, for example, which carries out or supervises the most hazardous steps in RTG decommissioning for different RTG owners, has developed detailed guidance and procedures for carrying out these tasks.

All RTG decommissioning works, by any operator, require a licence from the regulator Rostechnadzor. To obtain a licence for RTG decommissioning an organisation shall submit to Rostechnadzor documents justifying the safety of the decommissioning activities. The list of these justifying documents is determined by a regulatory document "Requirements to the Package and Contents of Documents Justifying Radiation Safety of the Licensed Activity in the Field of Use of Atomic Energy in the National Economy" (RD-07-08-99).

The package of justifying documents for obtaining a RTG decommissioning licence shall include:

1. RTG Safety Analysis Report which contains:

a) Information on structures (premises) of a facility including the following information about each such structure (premise):

- description of radiation hazardous works (productions, technologies) carried out inside the structure (premise) during decommissioning of the facility with indication of the class of works;
- actual data on types and number of radiation sources (including sealed radionuclide sources) available inside the structure (premise) at the time when operation of the facility has been terminated;
- actual data on activity, radioisotope composition, state of aggregation of radioactive substances (including radioactive substance contained in radionuclide sources) and (or) radioactive waste available inside the structure (premise) at the time when operation of the facility has been terminated;
- description of technical solutions and means used to ensure radiation safety of the facility and declared activity;

b) Information about the organisation of radiation monitoring, structure and staff of the radiation safety service unit for decommissioning of the facility;

c) Description of technical solutions and means used to ensure radiation safety in decommissioning of the facility;

d) Description of the system for collection, reprocessing and disposal of radioactive waste generated during decommissioning of the facility;

e) Information about physical protection of the facility, radioactive substances and (or) radioactive waste during decommissioning of the facility;

f) Information about availability of material and technical means intended to be used in case of a radiation accident and justification whether they are adequate and sufficient;

g) Information about the procedure of training, knowledge examination in radiation safety standards and rules, qualification, briefing and granting of permits to employees for carrying out radiation hazardous works;

h) List of regulatory documents establishing radiation safety and physical protection requirements for the facility of an appropriate category, and information about availability of the mentioned documents in the organisation-applicant;

i) Radiation safety analysis of the facility (at the decommissioning stage).

2. Decommissioning programme for the facility.

3. List of design, engineering, operating and process documentation developed for the decommissioning of the facility.

4. Design, engineering, operating and process documentation in accordance with the list specified in para 3 of the requirements (to be submitted under Rostechnadzor request).

5. Copy(ies) of the radiation safety guide(s) for the decommissioning of the facility.

6. Copies of manuals for prevention of accidents and fires and elimination of their consequences during the decommissioning of the facility.

7. Decision-making criteria in case of initiation of radiation accidents.

8. Copy of the action plan to protect employees (personnel) and population against radiation accident and its consequences during the decommissioning of the facility.

9. Quality assurance programme for the decommissioning of the facility.

10. List of organisations rendering engineering and technical support of the declared activity, as well as carrying out works and rendering services in the field of use of atomic energy during implementation of this activity indicating the scope of works (services).

The Federal standards and rules “General Safety Provisions for Radiation Sources” (NP-038-02) contain requirements to this Programme which shall include a list and sequence of organisational measures and works on RTG dismantling and transportation of the dismantled RTG.

The Programme shall be developed on the basis of the engineering and radiation survey to be conducted by the operating organisation.

It can be concluded from Task 1 that the existing Russian regulatory framework covering the decommissioning of RTGs is generally satisfactory. Consistent implementation of the requirements of this framework by all operators in all RTG decommissioning activities needs to be ensured and demonstrated through effective regulatory inspection and enforcement, which is addressed in Task 3.

3. Review of applications for licensing and authorisations (Task 2)

Work performed

This task addressed the following topics:

a. The overview and analysis of the Russian certified methodologies and software for performing RTG safety assessments and analyses of risks to man and the environment, including potential scenarios when safety requirements are not met with regard to all stages of the transport schemes providing for the delivery of RTGs under decommissioning to the places of their dismantling and disposal;

b. Performing initial risk assessments for all stages of RTGs decommissioning, using methods and software identified at a) and focussing on priorities identified in draft D2a deliverable;
c. Review of the possibilities for upgrading of existing software to assess risks at all stages of RTGs decommissioning based on the results of the above analysis;
d. Risk assessment of RTG using upgraded software.

The results of work specified in paras a) and b) are addressed in Deliverable D3: "Report on the analysis of the Russian methodologies and initial risk assessment".

The results of work specified in para c) and d) are addressed in Deliverable D4: "Report on software for performing risk assessments for RTGs decommissioning stages using upgraded software".

Deliverables D3 and D4 are presented in Appendix B.

Results and conclusions

The methodology used for analysis of risks at different stages of RTG decommissioning is effective, and could be applied to other facilities or activities.

Preliminary assessment of the risks associated with the transport and technological scheme for all stages of RTG decommissioning led to the conclusions that:

- The maximum collective doses to personnel in dismantling, repackaging, loading and delivery of RTG are likely to be associated with the management of damaged RTGs from Roslyakovo and from Golets Island. Individual workers involved in the recovery of these damaged RTGs could receive doses of some tens of mSv per RTG;
- The highest risks are associated with carriage of RTGs as external loads by helicopter. The primary risks arise from the possibility of dropping the RTG onto land (resulting in a need to recover in high dose rates due to likely damage to the shielding) or into the sea (resulting in a need to recover to prevent possible release of Sr-90 in the long term);
- The lowest risks correspond to transport of RTGs from the White Sea by special vessel, for which the risk of failures is estimated to be much lower; and
- Therefore, replacement of helicopter transport of undamaged RTGs from the coast of the Kola Peninsula by two trips using the special vessel is able to reduce the level of additional risk.

On the basis of a detailed comparison of three risk assessment packages (Relex, ASM SZMA and Risk Spectrum) that are certified by the Russian body of state safety regulation, it was concluded that the software complex ASM SZMA was most appropriate for assessing risks at all stages of RTG decommissioning.

4. Adaptation of procedures for monitoring of radiological safety (Task 3)

Work performed

Within this task the following topics were covered:

a. Adaptation of existing inspection procedures to the specific needs of RTG inspections, to be carried out at the various stages of their decommissioning, transport and disposal.

b. Upgrading of systems for follow-up and recording of inspection and development of procedures for monitoring of continuing compliance. The audit trail would ensure compliance with regulation and help identify promptly any irregularities, or potential problems.

The work within this task was organised in the following way:

a. Discussion of plan for adaptation of inspection procedures and develop specifications for the system to follow and record inspection procedures and monitoring of the compliance.
b. Development of a handbook for inspections, Deliverable D5.

Deliverable D5 is presented in Appendix C.

Results and conclusions

An inspection handbook has been developed in Task 3 to assist inspectors in implementing the state supervision and control of safety during RTG decommissioning activities. It describes procedures for monitoring the application of the system of measures being used at all stages of RTG decommissioning to assure ecological and radiation safety. The handbook takes account of the experience gained by the radiation safety inspection divisions in 2004–2005, as well as results of the international cooperation. It received positive responses from the Rostechnadzor territorial offices which supervise organisations in charge of RTG operation and decommissioning. The inspection handbook will be put into effect within the Rostechnadzor system from 1 February 2007.

The inspection handbook provides detailed guidance for four types of inspection that are applied in the course of RTG decommissioning:

- **Inspections of preparedness**, which are targeted to verify that the administrative and technical (preliminary) stage of the work on RTG decommissioning activities is fulfilled. Inspections of preparedness focus upon development, agreement and approval of the administrative and regulatory documents on safety analysis, complete training of the personnel involved in the work, manufacturing (selection) and certification (testing) of the technical facilities intended to be used in the course of decommissioning activities;
- **Inspections of safety**, which are conducted in the course of field stage operations on RTG decommissioning by the operating and/or transport organisation. The inspections of safety are targeted to verify, directly in the course of decommissioning activities, that the requirements of federal and departmental regulatory documents, programmes, design documents are met, and that the restricting conditions of permission documents, quality assurance and radiation protection programmes, as well as safety measures during RTG transportation, are observed;
- **Inspections of compliance**, which are conducted upon completion by the operating organisation of each successive (annual) stage of operations on batch decommissioning of RTGs. These inspections focus on reports on the work carried out inspecting and decommissioning RTGs during the relevant period, results of inspections of preparedness and safety, reports on any investigation of violations, and other information about the achieved level of safety; and
- **Inspections of storage conditions** at radiation hazardous facilities where the decommissioned RTG (RHS) are stored, including inspection of the documents regulating temporary storage of the given products, the level of personnel training, and preparedness for elimination of radiation accident consequences at the facilities.

For each type of inspection, the handbook defines the terms of the inspections, the type of documents justifying safety of the given type of activities and the preparatory procedure for inspections, as well as listing the issues to be verified during the inspection of the given type of activities. The handbook includes a summary of general safety requirements established in regulatory and departmental documents, compliance with which is to be controlled in the course of RTG transportation and decommissioning activities.

The inspection book also contains reference information which relates to RTG decommissioning in operational locations in the Baltic, Northwest, North and Far East regions of Russia, RTG transportation to the temporary storage facilities and temporary storage.

5. Improvement of regulatory activities in the area of emergency preparedness (Task 4)

Work performed

This task addressed the following topics:

a. Evaluation of each step in RTG management to determinate possibility for accidents – accident scenario analysis with special focus on transportation;
b. Assessment of the existing notification schemes and systems in case of a radiological accident involving RTG, or in case of unauthorised actions (overlap with task 5);
c. Development of requirements for planning and preparedness to mitigate consequences of radiation accidents occurred in transportation of radioactive substances followed by development of standards and rules (technical regulations) taking account of these requirements and Development of requirements for the content of the emergency response action plan on personnel protection in case of accident during the transportation of radioactive substances.

Task 4 included the following steps implemented by the Russian specialists:

a. Analysis of the emergency scenarios for RTGs dismantling and decommissioning operations carried out in 2001-2004 as regards safety insurance and prevention of emergency situations during the transportation by different modes of transport.
b. Development of the requirements to planning and preparedness to mitigate consequences of radiation accidents occurred in transportation of radioactive substances and requirements to the content of the action plan on personnel protection in case of accident during the transportation of radioactive substances.

The results of work specified in paras a) and b) are addressed in Deliverable D6: “Report on the safety insurance in RTG decommissioning and preventions of emergency situations involving RTGs during transportation by different modes of transport” and Deliverable D7: “Report on the development of the draft requirements to planning and preparedness to mitigate consequences of radiation accidents occurred in transportation of radioactive substances”.

Deliverables D6 and D7 are presented in Appendix D.

Results and conclusions

The operating organisations and the organisations which perform the works in RTG dismantlement and transportation, and disposal of RHS-90, have developed and are implementing in practice a highly efficient system of measures to assure ecological and radiation safety. This system of organisational and technical measures during the period 2001–2005 has ensured that dose limits for the personnel who perform radiation hazardous works have not been exceeded and no significant radioactivity has been released to the environment.

However, Task 4 has identified some necessary improvements to the system, as well as reinforcing the need to assure strict compliance with the requirements of the developing normative basis for assuring safety, in particular:

- For radioactive sources of the highest categories of potential radiation hazard, the operating organisation should develop a decommissioning programme not later than one year before the end of the designed life of the source;
- On the basis of the decommissioning project specification, the operating organisation should develop a safety justification report for the decommissioning project and submit it in accordance with established routine to the authority for state regulation of safety in the area of uses of atomic energy;
- The RTG decommissioning programme should take account of engineering and radiation examination of the RTGs by the operating organisation, and should include the list and the sequence of organisational measures and works for the dismantlement and transportation of RTGs;
- Dismantlement and transportation of RTGs from their locations should be performed by trained personnel in compliance with the developed manual and in compliance with the requirements of technical documentation for the specific items. Such manuals should be submitted as part of the package of documents justifying the safety of the works.

The programmes for organisations which participate in the works on RTG disposal should provide information on emergency response in accordance with the relevant regulatory requirements. This information may be included in an “Emergency response” section in the programmes in accordance with the established requirements, or reference may be made to a specific separate document which provides this information.

In addition, a review was conducted of the normative-legal acts and requirements that must be taken into account at planning and ensuring of preparedness for elimination of radiation consequences of the accident during transportation of radioactive materials.

Taking account of this review, draft Federal Norms and Rules "Requirements for Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" have been developed. These are currently passing through the approval process and will be issued when approved as Federal Norms and Rules. Recommendations on the structure and content of the standard Plan of Organisation of Actions on Elimination of Accident Consequences during Transport of Radioactive Materials have also been prepared.

The draft regulatory document was reviewed by 12 ministries and agencies, and was published for consideration by the public. It is planned that that this document receives approval and will put into effect the Federal Norms and Regulations in 2007.

6. Physical protection in RTG decommissioning (Task 5)

Work performed

This task addressed the following topics:

a. Analysis of distribution of duties and responsibility among bodies for control of the use of atomic energy, organisations operating RTGs (as regards physical protection) at the stages of RTG operation, decommissioning, transportation, temporary storage and disposal;

b. Analysis of the Russian regulatory basis that establishes physical protection requirements and a possibility to apply this basis to RTG decommissioning and disposal;
c. Assessment for possible improvement of the Russian regulatory basis for RTGs (as regards physical protection) mainly during their transportation and emplacement on special accumulation sites and in temporary storage facilities taking account of IAEA recommendations and European experience.

Task 5 included the following steps implemented by the Russian specialists:

a. Review of the current situation related to distribution of duties and responsibility among bodies for control of the use of atomic energy, organisations operating RTGs (as regards physical protection) at the stages of RTG operation, decommissioning, transportation, temporary storage and disposal;
b. Review of the current state of the Russian regulatory basis that establishes physical protection requirements and a possibility to apply this basis to RTG decommissioning and disposal taking account of IAEA recommendations and European experience;
c. Development of recommendations for possible improvement of the Russian regulatory basis for physical protection of RTGs, mainly during their transportation and emplacement on special accumulation sites and in temporary storage facilities.

The results of work specified in paras a), b) and c) are addressed in Deliverable D8: "Report on the physical protection insurance for RTG decommissioning".

Deliverable D8 is presented in Appendix E.

Results and conclusions

A review was conducted of regulatory requirements and practices for physical protection of radioactive sources in the Russian Federation. Although an effective system is already in place, some improvements were identified, particularly in relation to ensuring that effective physical protection is maintained during transportation of RTGs or RHSs.

To improve the Russian regulatory basis it is reasonable to:

- Finalise (revise) the "Physical Protection Rules for Radiation Sources, Storage Facilities, Radioactive Substances" (NP-034-01) to make the categorisation of radiation sources in terms of their radiation hazard fully consistent with the IAEA recommendations (in particular, on Categorisation of Radioactive Sources).
- Put into effect specific Physical Protection Rules for Radioactive Substances and Radiation Sources during their Transportation; and
- Complete the development and put into effect the regulatory document "Requirements to Planning of Measures to Provide for Preparedness to Eliminate Radiation Consequences of Accidents during Transportation of Nuclear Materials and Radioactive Substances".

7. Environmental impact assessment review for RTG dismantling, transportation, temporary storage and disposal (Task 6)

Work performed

This task addressed the following topics:

a. Review of the Russian Federation application of EIA related requirement to the steps involved in RTG decommissioning and disposal.

b. Review of international recommendations and other national good practice on EIA for decommissioning and disposal of RTGs.

Task 6 included the following steps implemented by the Russian specialists:

a. Analysis of Russian and international EIA requirements for decommissioning and disposal of radiation-hazardous facilities and first of all RTGs;

b. Development of recommendations on EIA for RTG decommissioning and disposal.

The results of work specified in paras a) and b) are addressed in Deliverable D9: "Report on EIA requirements for RTG Decommissioning and Disposal".

Deliverable D9 is presented in Appendix F.

Results and conclusions

Environmental impact assessment principles and methods in Norway, European Union countries and in Russia have much in common. The environmental impact assessment procedures are based everywhere on the principles generally recognised at the international level (for example, prevention, openness, mandatory environmental impact assessment for all projects that are capable of causing significant environmental impact).

Differences between national approaches relate mainly to the level and forms in which these principles are implemented and are conditioned to a great extent by differences in the state structure and institutional specifics of each country. Nevertheless, there is scope for convergence and unification of the regulatory basis, environmental impact assessment procedures and criteria used in Norway, EU countries and the Russian Federation. Further work in this area is required, especially, as regards installations and types of activity that may cause considerable radiation impact on the environment and population.

Strictly, Russian law does not appear to require EIA for the decommissioning of RTGs, as decommissioning is considered to be a continuation of the planned life cycle of an activity that was operating before EIA regulations came into effect. Nevertheless, application of the methodology for health and environmental risk assessment in development of the emergency scenario for different tasks in RTG decommissioning gives a real possibility to make an objective assessment of hypothetical consequences and to adjust processes and minimise a probability of negative consequences in advance. It is planned that this methodology will be a mandatory instrument of the EIA methodology.

It is very important to provide for the close interaction between developers of the projects and state regulatory bodies responsible for the health protection, environmental protection, nuclear and radiation safety at the design stage of the potentially radiation-hazardous operations.

8. Conclusions, General Observations and Future Needs

The hazard

The radiological hazard of interest to this project is the strontium-90 radioisotope heat sources (RHSs) in the RTGs. The hazard is large: RHSs of the type used in RTGs have the potential to cause serious health and environmental impacts if they are not kept under proper control. The purpose of the industrial project is to eliminate the hazard (and hence the risks associated with it) by decommissioning the RTGs and disposing of the RHSs. The processes needed to achieve this long-term reduction in risk may temporarily increase some existing risks or introduce new ones. The purpose of the regulatory project is to ensure that appropriate technical and regulatory measures are in place to ensure that the risks at all stages of the decommissioning process are kept sufficiently low.

The primary hazard associated with RHSs is external radiation, and so is local to the RTGs. The hazard is realised particularly in cases where:

- Untrained and unauthorised individuals come into contact with RTGs, whether or not the shielding is initially undamaged; or
- The shielding has been damaged due to previous events, accidents or malicious events, and so even fully trained and authorised personnel may be subject to high doses rates.

Dispersion of Sr-90 in the environment is possible only in the event of highly unlikely extreme situations, such as:

- Long term immersion in water (probably accidentally, as a result of dropping into the sea during transport by helicopter or sinking of a vessel carrying RTGs);
- Very severe impacts affecting the RHS itself (probably accidentally, for example by dropping from a helicopter onto land or crushing by a vehicle);
- Very severe fire (probably accidental); or
- Explosion (probably intentional, for example as a ‘dirty bomb’).

Evidence of ‘leaking’ of Sr-90 in other circumstances is inconclusive. Apparent evidence of leakage of Sr-90 – for example enhanced dose rates some distance from an RTG and radioactive contamination in the surrounding area – may be the result of corrosion of depleted uranium (DU) shielding. The loss of shielding may lead to dramatically increased dose rates from the intact RHS, and the crumbling DU may contaminate surrounding soil. Nevertheless, these reported phenomena should be investigated further.

Control of the hazard

Proper control of the hazard associated with RHSs during RTG decommissioning requires:

- Correct actions by operator, who is primarily responsible for safety and security, complying with laws, regulations and regulatory guidance, but also using ‘ALARA’ approach; and
- Effective supervision of these actions by regulators.

Such proper control entails establishment and maintenance of:

- Radiation protection measures to control exposure in planned activities;
- Radiation safety measures to prevent accidents;

- Accounting and security measures to prevent misappropriation or malicious acts; and
- Capability to detect and respond to failures in these measures, maintain whatever control is possible in the short term and re-establish proper control as soon as practicable.

This in turn requires:

- Prior assessment of situations and proposed activities;
- Rigorous, documented planning of activities, taking account of the prior assessment;
- Use of properly qualified and trained people;
- Compliance with laws, regulations, and project specifications when performing activities;
- Ongoing review and improvement of work performance (including preventing future accidents by learning lessons from accidents and near misses); and
- Regulatory supervision and inspection to ensure this is all done.

Regulation in the Russian Federation rests upon radiation hazardous facilities being assigned to categories based on the level of hazard. The special case of RTGs highlights an area of possible ambiguity in the categorisation process. Most facilities present a similar level of hazard in terms of both the severity and the extent of possible impacts: an accident resulting in a large release of radionuclides could potentially cause impacts that are very severe locally and also widespread. RTGs are unusual in that they represent a very large local hazard, but the potential for effects beyond the immediate area is low.

Hence, categorisation schemes that emphasise the potential consequences for an individual would classify the RHSs from RTGs in the highest hazard categories; as, for example, in the IAEA categorisation of sources linked to the Code of Conduct. On the other hand, categorisation schemes based on the area that could be affected in the event of an accident will tend to place RTGs in one of the lowest categories. Decommissioning involves transporting RTGs, which substantially increases the range of types of accident that could occur and of locations in which they could occur.

It is important therefore not to place too much emphasis on simple categorisation. In terms of most of the safety and security measures that could be applied to radiation hazardous facilities, RTGs need to be treated as a large radiation hazard. In the event of any discrepancy between categorisation systems, therefore, it would be prudent to place RTGs in the higher hazard category.

One possible exception to this relates to emergency response arrangements: emergency plans for RTGs need to provide robust mechanisms to respond to an emergency situation, but the measures will be essentially local to the immediate vicinity of the RTG, and so will not affect significant numbers of people. These measures will not need to cover large areas, but must be capable of being carried out at any locality within a large area. This requires procedures that are not overly dependent on resources that can not easily be moved and are flexible enough for application in a wide range of environments.

Regulatory priorities

A detailed analysis has been carried out of these requirements and of the existing legislative, regulatory and operational measures for all stages of RTG decommissioning. The analysis identified nine key steps corresponding to optimisation of protection and safety of personnel and the public at each stage in RTG decommissioning (see also Figure 1):

1. Operator's inspection of RTGs in their place of operation;
2. Recovery of RTGs from their operational locations (often by helicopter or barge) and loading onto a ship;

3. Transportation of RTGs by ship (or in some cases by helicopter) to a temporary storage point, short-term storage and transfer to train;
4. Transportation of RTGs by rail to facility for dismantling (FSUE Izotop or FSUE PA Mayak – via FSUE DalRAO for RTGs from Eastern areas);
5. Loading onto trucks and transportation by road to VNIITFA;
6. Removal of RHSs at VNIITFA and loading of RHS packages onto trucks;
7. Transportation of packaged RHSs by road back from VNIITFA to Izotop and loading onto trains;
8. Transportation of packaged RHSs by rail to FSUE PA Mayak; and
9. Processing of RTGs and RHSs at Mayak.

and nine key regulatory issues:

a. Compliance with terms and conditions of licences, permissions and implementation of previous prescriptions;
b. Operator's personnel selection and training;
c. Regulatory inspection of RTGs prior to decommissioning;
d. Measures to prevent accidents and incidents and preparedness to respond effectively to any accidents or incidents that do occur;
e. Transportation of RTGs and RHSs;
f. Compliance with radiation safety requirements;
g. Physical protection of RTGs and RHSs;
h. Accounting and control of RTGs and RHSs; and
i. Investigation of any accidents or incidents.

General observations

The first conclusion from this project is that a satisfactory technical and regulatory framework exists in the Russian Federation for the safe decommissioning of RTGs. A number of necessary or desirable improvements have been identified in the framework, and particularly in its implementation, but the project did not identify fundamental defects that seriously compromised safety. Some of these improvements have been addressed through this project, and others are the subject of recommendations for future work, as described below.

The 9-by-9 matrix of tasks and issues (see Table 1) was analysed to identify a number of priority areas for regulatory action. A number of these priority issues have been taken into account in the various tasks of this project, as indicated below and as described in the previous sections. The priority areas were as follows:

- Systematic and timely definition of decommissioning plans and specification of decommissioning projects, and regulatory approval of these. This has been addressed in depth and emphasised through the specification of requirements for decommissioning programmes (Task 1) and the inspection procedures developed in Task 3;
- Thorough inspection prior to starting decommissioning operations, including operational inspection of the RTG's condition (as part of the basis for the decommissioning plan) and regulatory inspection of the preparedness of the operator to carry out the decommissioning work. This is explicitly set out and emphasised in the inspection procedures developed in Task 3;

- Preventing and responding to accidents during the various types of transport. This has been addressed through emphasis on requirements for safe transport (Task 1), assessment of risks during transport (Task 2), inspection of safety arrangements for transport (Task 3) and emergency preparedness and response arrangements specifically for accidents during transport (Task 4). The response arrangements have been developed using experience from real cases of recovering damaged RTGs. These focus on recovery of a damaged RTG on land, which is apparently considered to be a worst case. However, further consideration may need to be given to the scenario of a (possibly damaged) RTG dropped into the sea from a helicopter. The planned response is evidently to recover such an RTG by providing a marker at the location. However, the procedure for recovering an RTG from the sea has not been described;
- Physical protection of RTGs during transport. This aspect of physical protection has been particularly emphasised in Task 5, and the relevant requirements are being modified to give special attention to transport;
- Safety and security of collections of RTGs at temporary storage locations (where multiple RTGs could present an increased hazard if not properly controlled). Inspection of the safety and security arrangements at storage locations is specifically addressed in the handbook developed in Task 3; and
- Ensuring consistency in safety and security arrangements. Regional offices of Rostechnadzor are responsible for regulating RTG decommissioning in their regions, and the unified norms and guidance developed under this project should help to provide a common basis for regulation in all regions. It is also important that the requirements be clear and consistent for all operating organisations, military and civilian. Licensing of all RTG decommissioning by Rostechnadzor should help to provide this clarity and consistency.

Future needs

Some priority issues identified through this analysis were not fully addressed during the current project and may need to be considered for future work. These include:

- The newly developed Federal Norms and Rules on preparedness and response for radiological emergencies during RTG transportation should be supported by safety guides giving operators, consignors, consignees, carriers and organisations rendering services more detailed guidance on implementation of the Federal Norms and Rules.
- Methodological guidance specifically addressing procedures for inspections of RTG transportation by sea and by rail might usefully be developed;
- A joint emergency exercise involving Rosatom, Rostechnadzor and Western experts could help to improve common understanding of the roles of organisations and procedures to be followed in the event of an accident and facilitate exchange of experience between participants;
- Preventing accidents during hot cell transfer of RHSs from RTGs to transport packages. This is a specific task performed by VNIITFA at its own facility (or, in the future, at Mayak), and appears potentially to represent a significant risk because the RHSs are temporarily vulnerable when they are neither in the RTG nor in a shielded transport package. The risk assessments presented in this project indicate that the associated risks are taken to be negligible, but detailed demonstrated that this is the case has not been presented;
- Long term management of RHSs at Mayak. There remains some uncertainty about the final fate of the RHSs at Mayak, and therefore the long term safety cannot be definitively assessed. As described in Appendix C, the stated plan is to vitrify the RHSs for storage and subsequent disposal underground, but there is no currently operational vitrification facility at Mayak;
- Application of EIA methodology to RTG decommissioning. EIA may not be strictly necessary under Russian law, as the decommissioning of RTGs can be considered to be simply a

continuation of the planned life cycle of facilities that were in operation prior to the introduction of EIA regulations. It might nevertheless be recommended to conduct an assessment of the environmental impacts of RTG decommissioning and their mitigation, and consideration of alternatives.

A further issue identified is systematic follow-up in the aftermath of any incidents or accidents that might occur. It is important that the results from investigations of such events are used as experience feedback to improve procedures and help to prevent future incidents and accidents. To help ensure that operators do this, consideration should be given to extending the regulatory inspection manual to include also outline procedures for 'reactive' inspections following incidents or accidents.

Consideration might also be given to developing regulatory inspection methodologies and programmes that would be appropriate as a basis for licensing life extensions for RTGs that are to remain in service.

In general, however, the key need for the future in relation to the regulation of RTG decommissioning is to achieve consistent practical implementation of the framework of regulations and processes already in place and enhanced through this project, through all steps of decommissioning and for all RTGs. Although there may be scope for further improvements in the framework, regulations and procedures are now in place, and the operators and regulators need to be engaged in understanding them and ensuring that they are applied. A significant element of future work will therefore be to raise awareness among the regional inspectors of Rostechnadzor and the operators (and also among the controlling organisations and organisations rendering services) of the regulations and procedures, the reasons behind them, and the importance of applying them. This issue could be addressed, for example, by means of educational workshops for regional inspectors of Rostechnadzor, and possibly also for staff of the operators and organisations rendering services.

TABLE 1 Grid of regulatory issues and steps in decommissioning

Types of inspection	Decommissioning steps	Regulatory issues								
		a) Compliance with licence conditions etc..	b) Personnel selection and training	c) Regulatory inspection prior to decommissioning	d).Prevention of accidents and emergency preparedness	e) transportation	f) radiation safety	g) physical protection	h) accounting and control	i) Investigation of accidents and incidents
Inspection of preparedness	Review of the decommissioning programme and project, safety analysis report and EIA	★	✓	★	✓	-	-	-	✓	-
Inspection of safety	1. Operator inspection	✓	✓	★	-	-	★	-	✓	✓
	2. Removal from the operation locations (by helicopter, towing, ship)	✓	✓	★	★	✓	★	✓	-	✓
	3. RTG transportation to the railway (by ship or helicopter)	✓	✓	-	-	★	-	★	✓	✓
	4. RTG railway transportation to Izotop or Mayak	✓	✓	-	✓	★	-	✓	-	✓
	5. RTG: from Izotop to VNIITFA by road	★	✓	-	✓	★	★	✓	-	✓
	6. RHS removal	✓	★	-	★	★	★	✓	-	✓
	7. RHS: from VNIITFA to Izotop by road	✓	✓	-	✓	★	★	✓	-	✓
	8. RHS: to Mayak by railway	-	-	-	-	★	-	✓	-	✓
	9. RTG/ RHS reprocessing at Mayak	✓	✓	-	-	-	✓	✓	✓	✓
Inspection of compliance	Operator review of the inspection results, data on the safety level, final documents on safety inspection results	✓	✓	✓	✓	✓	✓	✓	✓	✓
Inspection of storage conditions	Inspection of RTG/RHS storage in the temporary storage facilities	✓	★	-	★	-	-	★	✓	-

KEY: ✓ indicates issue of regulatory importance addressed by existing processes; ★ indicates a priority issue where further regulatory development is needed.

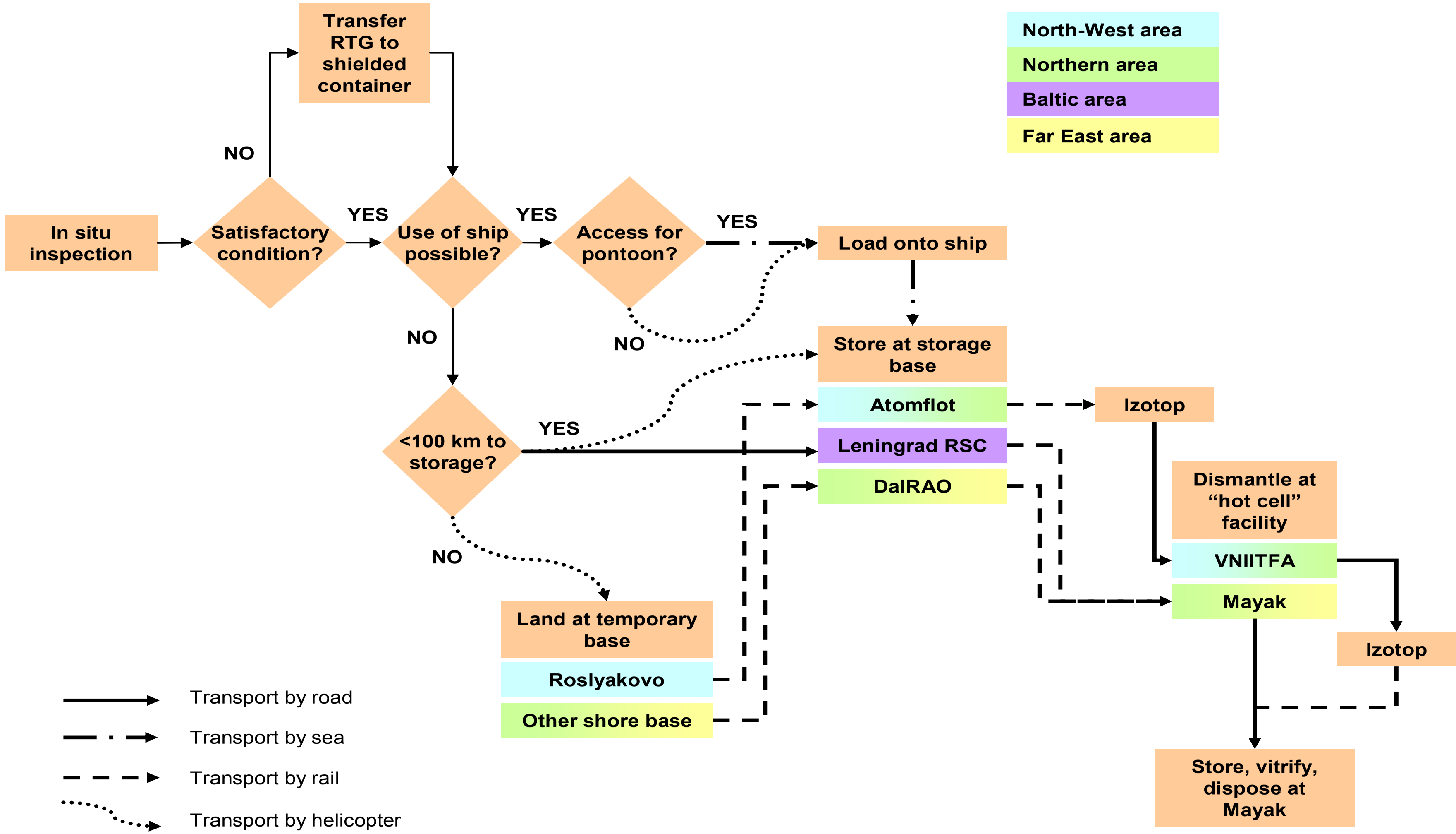


Figure 1 *Flow diagram of RTG decommissioning*

Appendix A
Assessment of current regulatory requirements and regulations for radiation protection and safety
(Task 1)

A-1. Overview of the current interrelations among the Russian organisations (which operate RTG, render services on RTG design and decommissioning), bodies for control of nuclear energy use, state safety regulatory authorities (Deliverable D1)

1. What is an RTG?

RTGs are autonomous power supply sources which provide a dc voltage from 7 to 30 W used for different autonomous apparatus with a capacity from several watts up to 80 W. Different electrical devices providing for accumulation and conversion of electrical energy produced by a generator are used jointly with RTGs.

RTGs are commonly used as a power supply source for navigational lighthouses and light signs, as well as for radio beacons and weather stations.

RTG utilises a heat source based on the radionuclide Strontium-90 (RHS-90).

RHS-90 is a sealed radiation source with a fuel compact, usually, in the form of ceramic strontium titanate ($SrTiO_3$) which is doubly hermetically sealed by argon arc welding inside the capsule. Some RTGs utilise strontium in the form of strontium borosilicate glass. The capsule is protected against external impacts by a thick RTG cladding made from stainless steel, aluminium and lead. Biological shield is fabricated so that the radiation dose on the apparatus surface does not exceed 200 mR/h and the radiation dose at 1m from the apparatus does not exceed 10 mR/h. Variant designs are discussed in the next section.

In accordance with the requirements of the Safety Rules for Transportation of Radioactive Materials (NP-053-04, para 5.3.7) radiation level under routine transportation conditions shall not exceed 2 mSv/h (200 mrem/h) in any point on the outside vehicle surface including hold, compartment, or defined deck area of a vessel, and shall not 0,1 mSv/h (10 mrem/h) at the distance of 2 m from this surface.

In accordance with the IAEA Regulations for Safe Transport of Radioactive Materials (IAEA, 2005 TS-R-1, para. 531) the maximum radiation level in any point on the outside surface of the packaging or transport package shall not exceed 2 mSv/h.

The half-life period of Strontium-90 is 29 years. When RHS-90 is fabricated it contains from 30 to 180 kCi of Strontium-90. The strontium decay produces a daughter isotope - beta-emitter, Yttrium-90 with a half-life of 64 hours. Gamma-irradiation dose rate for RHS-90 itself, without metal shield, amounts to 400— 800 R/h at a distance of 0.5 metres and 100— 200 R/h at a distance of 1 metre from RHS-90.

__Table 1__ Radioactive element – RHS-90

Dimensions of the casing	10 cm x 10 cm
Weight	5 kg
Capacity	240 Watt
Content of Strontium-90	1500 TBq (40000 Curie)
Surface temperature	300-400 Centigrade
Dose rate at a distance of 0.02-0.5 м	2800-1000 R/hour

Note: Data on the gamma-radiation exposure dose rate for RHS-90, and parameters of its radioactive element presented in Table 1 are taken from the technical characteristics for the sealed radiation source RHS-90 as per the relevant technical documentation.

RHS-90 becomes safe in terms of the activity only in 900-1000 years.

2. RTG types

RTGs differ in parameters for the output electric voltage, output electric power, mass, dimensions and components of shielding, etc. The most commonly used RTG type is “Beta-M” – one of the first developed RTG design.

Main RTG parameters are:

- nominal electric dc voltage of a single-channel RTG or nominal electric voltage of each from independent electric channels of multi-channel RTG;
- nominal electric power of a single-channel RTG or nominal electric power of each from independent electric channels of multi-channel RTG;
- RTG service lifetime which is calculated from the date when RHS has been loaded into RTG.

__Table 2__ Technical characteristics of the most commonly used RTG types

Parameters	RTG Type			
	IEU-1	IEU -2	Beta-M	Gorn
Electric power, Вт	80	11	9	60
Range of operating temperatures , ^{0}C	-50 - +40	-40 - +35	-60 - +55	60 - +55
Dimensions: diameter, mm height, mm	Without packaging: 760 1510	975 1675	600 655	Without packaging: 850 1230
Weight, kg	2300	820	565	1050
RTG type	RHS-90-530 (3 pcs.) RHS -90-180 (3 pcs.)	RHS -90-580	RHS -90-230	RHSu-90-352 (2 pcs.) RHSu-90-387 (1 pcs.)
Nominal activity as for the date of production, kCi	340	90	35	170
Dose rate produced by RTG, μSv/s (mrem/h) not higher than: - on the RTG surface, - 1 m from the RTG surface	0,56 (200) 0,028 (10)	0,56 (200) 0,028 (10)	0,56 (200) 0,028 (10)	0,56 (200) 0,028 (10)

It should be noted that the radionuclide heat source (RHS) completely excludes any radionuclide release into the environment within the whole period of its radioactive decay. And it is provided by a range of engineering, chemical and engineering barriers preventing the contact of the radionuclide fuel compact with the environment and chemical interaction with it.

The following barriers should be considered as the most important from them:

- the compact material is a solid non-reactive refractory ceramic pellet practically insoluble in water;
- engineering cladding of each pellet is made from refractory alloy preventing the pellet from damage in case of thermal and mechanical effect;
- outer shield is a solid thick-walled casing hermetically sealed by two sequentially welded end lids.

Overall, RTGs (with their additional shielding containers where relevant) are designed, constructed and certified to meet the requirements for Type B(U) transport containers.

So, in terms of assurance of safe RHS use, its design represents by itself a multi-barrier protection of RHS against a possible thermo-mechanical and chemical (corrosion) effects.

3. Control bodies and operating organisations

In total more than 1000 RTGs were produced in the USSR. Some of them were disposed of after their operational period expired.

Now about 650 RTGs (as of the beginning of 2006) are in operation or shall be decommissioned in the Russian Federation. The design service lifetime of all RTGs will expire in 10-15 years. At present activities on RTG decommissioning and disposal of shall be carried out.

One of the problems related to the safe management of these sources is connected with the fact that organisations operating RTG belong to the Defence Ministry, Sea and Inland Water Transport Agency and Rosgidromet in terms of an interdepartmental subordination. Thus, a problem related to inter-branch co-ordination of their activities emerges. And now Rosatom – a body for control of the use of atomic energy, to which a RTG designer – All-Russia Scientific and Research Institute for Technical Physics and Automation (VNIITFA) - belongs, is solving this problem.

In organisation of RTG decommissioning activities **Rosatom** is responsible for:

- inter-branch co-ordination of activities related to RTG monitoring, physical protection, decommissioning, disposal of, establishment of the infrastructure for the safe temporary storage;
- attraction and providing for consolidation of resources provided by foreign partners to solve issues related to RTG decommissioning within the frames of the international co-operation under Global Partnership against proliferation of the weapons of mass destruction and other international agreements, programs, contracts and projects;
- establishment of the infrastructure for the safe temporary storage and shipment of RTGs, providing for its functioning;
- dismantling and disposal of decommissioned RTGs;
- co-ordination of work on development and maintenance of the uniformed electronic database for RTGs located on the territory of the Russian Federation.

Bodies for control (**the Defence Ministry, Transport Ministry, Rosgidromet**) that include organisations operating RTGs, are responsible for:

- feasibility study, development of the design and plan to equip RTGs with monitoring and physical protection means;
- equipping RTGs with monitoring means and construction (improvement) of RTG physical protection system;
- providing for the functioning of the monitoring, alarm, physical protection and control systems for the operating RTGs;
- RTG decommissioning and delivery to the place of their temporary storage and transshipment;
- RTG replacement by alternative electric power supply sources (if necessary);
- providing for the temporary storage of decommissioned RTGs at subordinate enterprises.

In case of such organisation of RTG decommissioning activities **Rostechnadzor** is entrusted with:

- development of radiation safety requirements for RTG decommissioning and disposal of;
- development of requirements to the package and contents of documents related to RTG operation and decommissioning, and licensing of the mentioned activity;
- supervision of safety in RTG decommissioning and disposal of.

Note: supervision of safety in RTG decommissioning and disposal of assumes control of compliance with the regulatory requirements established in the regulatory documents existing in the field of use of atomic energy.

As it has been mentioned above about 650 RTGs are in operation in the Russian Federation.

RTG owners are the Defence Ministry, Transport Ministry (Federal Sea and Inland Water Transport Agency), Rosgidromet.

The Transport Ministry operates RTGs of "Beta-M", "Efir-MA", "Gorn" and "Gong" type on the lines of the North Sea Route. An operating organisation is FSUE "Hydrographic Enterprise" responsible for safety of RTG operation on the lines of the North Sea Route.

In whole, the diagram for FSUE "Hydrographic Enterprise" subordination is the following:

Transport Ministry

Federal Sea and Inland Water Transport Agency

FSUE "Hydrographic Enterprise"

Hydrographic ships

Hydrographic bases

Arkhangelsk	Tiksi
Dikson	Kolyma
Igarka	Pevek
Khatanga	Provideniya

The Defence Ministry owns RTGs of different types. RTGS of IEU-1, IEU-1M, IEU-2, IEU-2M, "Gong", "Beta-M", "Efir", "Grab" and "Gorn" type used in troops are attributed to the category of stationary power devices operated both inside the indoor areas and in the open air.

The Defence Ministry is responsible for navigational and hydrographic support of sea routes. This task is assigned to the Navy within the Defence Ministry and its direct implementation – to the Hydrographic Service of the Navy - Main Department for Navigation and Oceanography of the Defence Ministry.

4. RTG decommissioning

RTGs with the expired service lifetime and also faulty RTGs shall be decommissioned and transferred either to an enterprise-fabricator or specialised organisation for temporary storage.

RTG decommissioning includes engineering examination to determine if dismantling and transportation are possible, and radiation survey to define gamma-radiation dose rate on the surface of a product and at a given distance from its surface, and to determine presence and level of surface radioactive contamination of a product and within the area around.

Based on the engineering examination and radiation and contamination surveys, the operating organisation shall develop a RTG decommissioning program which shall include a list and sequence of organisational measures and activities related to RTG dismantling and transportation.

Since RTGs belong to different authorities there is a problem related to inter-branch coordination of RTG decommissioning activities carried out by these authorities. Now this problem is being solved by the Federal Atomic Energy Agency (Rosatom), such subordinate organisations as FSUE "VNIITFA", FSUE VO "Isotope", FSUE PA "Mayak", FSUE "Base for Special Shipments" belong to.

But, on the whole, the following organisations are involved in RTG decommissioning activities:

N	Body for control	Operating organisation	Type of activity
1	Federal Atomic Energy Agency (Rosatom)	1. FSUE "VNIITFA"). 2. FSUE "PA"Mayak" 3. FSUE VO "Isotope" 4. FSUE "Base for Special Shipments" 5. FSUE "DalRAO" 6. FSUE "SevRAO"	1. FSUE "VNIITFA"). Rendering services to operating organisation on RTG decommissioning, temporary storage, preparation for disposal and transportation; 2. FSUE "PA"Mayak": RTG disposal (storage); 3. FSUE VO "Isotope": RTG transportation and temporary storage; 4. FSUE "Base for Special Shipments": RTG transportation; 5. FSUE "DalRAO", FSUE "SevRAO": temporary RTG storage.
2	Defence Ministry	1. Hydrographic Service of the North Fleet 2. Hydrographic Service of the Baltic Fleet 3. Hydrographic Service of the Pacific Fleet 4. RHBZ Depot of the North Fleet of the Defence Ministry	RTG operation, temporary RTG storage
3	Ministry for Transport, Sea and Inland Water Transport Agency	1. FSUE "Hydrographic Enterprise"	RTG operation
4		1. JSC "Murmansk Aviation Company" 2. FSUE "Naryan-Marskiy Joint Squadron"	RTG transportation

The Federal Environmental, Industrial and Nuclear Supervision Service (Rostechnadzor) is responsible for regulatory control of safe RTG management.

Safety regulation in RTG decommissioning covers the following areas:

- development of radiation safety requirements for RTG decommissioning and disposal;
- development of requirements to the package and contents of documents related to RTG operation and decommissioning, and licensing of the mentioned activity (decommissioning of nuclear facilities, radioactive waste management during transportation)
- supervision of safety in RTG decommissioning and disposal.

So, bodies for control (including those in the field of use of atomic energy), operating organisations and organisations rendering services to the operating organisation are involved in RTG operation (decommissioning).

The Rostechnadzor Headquarters and its Interregional Territorial Offices for Nuclear and Radiation Safety Supervision are responsible for state safety regulation of RTG handling activities.

Provisions on licensing of activities in the field of the use of atomic energy (Decree of the Russian Federation Government of 14.07.1997 N 865) establish a List of activities in the field of use of atomic energy which are subjected to licensing by Rostechnadzor. In particular, works on RTG operation, decommissioning, management of radioactive substances during transportation, reprocessing and disposal (storage) require to obtain license(s) from Rostechnadzor for each activity.

In accordance with the Federal Law "On the Use of Atomic Energy" (Article 26) licenses can be issued not only to operating organisations but also to organisations carrying out works and rendering services to the operating organisations in the field of use of atomic energy.

That is why, arrangements for RTG decommissioning works require to develop a list of organisations involved in these works and assess them in terms of their competence to implement specific works taking into account the right given by Rostechnadzor licenses.

According to the procedure established within Rostechnadzor, issuing of licenses for activities involving RTGs, is assigned to the Interregional Territorial Offices of Rostechnadzor.

That is why, all organisations (operating organisations, support organisations) involved in RTG-related activities are obliged to have a Rostechnadzor license.

To obtain a license for RTG decommissioning an organisation shall submit to Rostechnadzor documents justifying safety of the decommissioning activities. The list of these justifying documents is determined by a regulatory document "Requirements to the Package and Contents of Documents Justifying Radiation Safety of the Licensed Activity in the Field of Use of Atomic Energy in the National Economy" (RD-07-08-99).

The package of the justifying documents for obtaining a RTG decommissioning license shall include:

1. RTG Safety Analysis Report which contains:

a) information on structures (premises) of a nuclear facility including the following information about each such structure (premise):

- description of radiation hazardous works (productions, technologies) carried out inside the structure (premise) during decommissioning of the nuclear facility with indication of the class of works;
- actual data on types and number of radiation sources (including sealed radionuclide sources) available inside the structure (premise) at the time when operation of the nuclear facility has been terminated;
- actual data on activity, radioisotope composition, state of aggregation of radioactive substances (including radioactive substance contained in radionuclide sources) and (or) radioactive waste available inside the structure (premise) at the time when operation of the nuclear facility has been terminated;

- description of technical solutions and means used to ensure radiation safety of the nuclear facility and declared activity;

b) information about the organisation of radiation monitoring, structure and staff of the radiation safety service unit for decommissioning of the nuclear facility;

c) description of technical solutions and means used to ensure radiation safety in decommissioning of the nuclear facility;

d) description of the system for collection, reprocessing and disposal of radioactive waste generated during decommissioning of the nuclear facility;

e) information about physical protection of the nuclear facility, radioactive substances and (or) radioactive waste during decommissioning of the nuclear facility;

f) information about availability of material and technical means intended to be used in case of a radiation accident and justification whether they are adequate and sufficient;

g) information about the procedure of training, knowledge examination in radiation safety standards and rules, qualification, briefing and granting of permits to employees for carrying out radiation hazardous works;

h) list of regulatory documents establishing radiation safety and physical protection requirements for the nuclear facility of an appropriate category, and information about availability of the mentioned documents in the organisation-applicant;

i) radiation safety analysis of the nuclear facility (at the decommissioning stage).

2. Decommissioning program for the nuclear facility.

3. List of design, engineering, operating and process documentation developed for the decommissioning of the nuclear facility.

4. Design, engineering, operating and process documentation in accordance with the list specified in para 3 of these requirements (to be submitted under Rostechnadzor request).

5. The copy(ies) of the radiation safety guide(s) for the decommissioning of the nuclear facility.

6. The copy of manuals for prevention of accidents and fires and elimination of their consequences during the decommissioning of the nuclear facility.

7. Decision-making criteria in case of initiation of radiation accidents.

8. The copy of the action plan to protect employees (personnel) and population against radiation accident and its consequences during the decommissioning of the nuclear facility.

9. Quality assurance program for the decommissioning of the nuclear facility.

10. List of organisations rendering engineering and technical support of the declared activity, as well as carrying out works and rendering services in the field of use of atomic energy during implementation of this activity indicating the scope of works (services).

To make a long story short, it should be mentioned that RTG decommissioning works require a Rostechnadzor license. The package of the documents submitted by an organisation to obtain a license shall include the Decommissioning Program for the nuclear facility.

The Federal standards and rules “General Safety Provisions for Radiation Sources” (NP-038-02) contain requirements to this Program which shall include a list and sequence of organisational measures and works on RTG dismantling and transportation of the dismantled RTG.

The Program shall be developed on the basis of the engineering and radiation survey to be conducted by the operating organisation.

As examples, the following documents developed by FSUE “VNIITFA” for RTG decommissioning works can be mentioned:

- Decommissioning program for RTGs available at the facilities of the Hydrographic Service of the North Fleet to be implemented in 2005;
- Radiation Protection Program for RTG transportation from the facilities of the Hydrographic Service of the North Fleet to FSUE “VNIITFA”;
- Justification of the environmental and radiation safety for RTG disposal works.

The mentioned documents are available for familiarisation within the frames of the industrial Russian-Norwegian Project for RTG Decommissioning.

A-2. Assessment of the current state of the Russian regulatory basis, which provides for the radiation safety requirements for the management of radiation sources, and the possibility of its use to carry out RTG decommissioning and disposal operations taking into account IAEA recommendations and the European experience (Deliverable D2)

1. Code of Conduct on the Safety and Security of Radioactive Sources

(approved by IAEA on 08.09.2003)

The Code of Conduct applies to all radiation sources that may pose a significant risk to individuals, society and the environment.

Article 18. Every State should have in place legislation and regulations that:

(a) prescribe and assign governmental responsibilities to assure the safety and security of radioactive sources;

(b) provide for the effective control of radioactive sources;

(c) specify the requirements for protection against exposure to ionising radiation; and

(d) specify the requirements for the safety and security of radioactive sources and of the devices in which sources are incorporated.

Article 20. Every State should ensure that the regulatory body established by its legislation has the authority to:

(a) establish regulations and issue guidance relating to the safety and security of radioactive sources;

(b) require those who intend to manage radioactive sources to seek an authorisation, and to submit:

- a safety assessment; and
- a security plan or assessment as appropriate for the source and/or the facility in which the source is to be managed, if deemed necessary in the light of the risks posed and, in the case of security, the current national threat assessment.

2. IAEA - TECDOC – 1344: Categorization of Radioactive Sources[2]

Radioactive sources are used in many types of the activities in the industry, medicine, agriculture, scientific studies and education, and also in military and defence applications. Within these types the categorisation system includes a range of radionuclides, forms and amount of radioactive material which shall be ranked. High-level sources, if not used and stored in a safe way, may cause severe deterministic effects to people during the short time period. At the same time, low-level sources unlikely may lead to such effects. Consequently, the categorisation system is a relative ranging and grouping of the sources and types of the activity on which (practical) decision may be based.

IAEA developed concrete radionuclide activity levels for the purposes of the emergency planning and response. These levels, hereinafter referred to as “D-values”, are given in terms of the activity. Should this activity be exceeded, a radioactive source is considered as a ‘hazardous source”, since it has a

[2] It should be noted that this TECDOC has been superseded by an IAEA Safety Guide (“Categorization of Radioactive Sources”. IAEA Safety Standards Series No. RS-G-1.9, International Atomic Energy Agency, Vienna 2005). However, the essential features of the categorisation system relevant to this discussion are unchanged in the later publication.

considerable potential possibility to cause severe deterministic effects if it is not used and stored in a safe way.

For each type of the activity and radionuclide used in practices, the activity in TBq is divided by an appropriate specific “D-value” to have a dimensionless normalised ratio - A/D.

For example, some low-level RTGs might be attributed to Category 2, should only activity be taken into account. However, since, probably, RTGs should be placed in remote locations, not under control and might have big amounts of plutonium or strontium, all RTGs were attributed to Category 1.

Category	Categorisation of common practices	Actrivity ratio A/D
1	Radioisotope thermoelectric generators (RTGs) Irradiators Teletherapy Fixed, multi-beam teletherapy (gamma knife)	A/D ≥ 1000
2	Industrial gamma radiography High/medium dose rate brachytherapy.	1000 > A/D ≥ 10
3	Fixed industrial gauges -level gauges -dredger gauges -conveyor gauges containing high activity sources -spinning pipe gauges Well logging gauges	10 > A/D ≥ 1
4	Low dose rate brachytherapy (except eye plaques and permanent implant sources) Thickness/fill-level gauges Portable gauges (e.g. moisture/density gauges) Bone densitometers Static eliminators	1 > A/D ≥ 0,01
5	Low dose rate brachytherapy eye plaques and permanent implant sources X ray fluorescence devices Electron capture devices Mossbauer spectrometry Positron Emission Tomography (PET) checking .	1 > A/D ≥ Exempt / D

Category 1

Personally extremely dangerous: This amount of radioactive material, if not safely managed or securely protected would be likely to cause permanent injury to a person who handled it, or were otherwise in contact with it, for more than a few minutes. It would probably be fatal to be close to this amount of unshielded material for a period of a few minutes to an hour.

Category 2

Personally very dangerous: This amount of radioactive material, if not safely managed or securely protected, could cause permanent injury to a person who handled it, or were otherwise in contact with it, for a short time (minutes to hours). It could possibly be fatal to be close to this amount of unshielded radioactive material for a period of hours to days.

Category 3

Personally dangerous: This amount of radioactive material, if not safely managed or securely protected, could cause permanent injury to a person who handled it, or were otherwise in contact with it, for some hours. It could possibly — although it is unlikely — be fatal to be close to this amount of unshielded radioactive material for a period of days to weeks.

Category 4

Unlikely to be dangerous: It is very unlikely that anyone would be permanently injured by this amount of radioactive material. However, this amount of unshielded radioactive material, if not safely managed or securely protected, could possibly — although it is unlikely —temporarily injure someone who handled it or were otherwise in contact with it, or who were close to it for a period of many weeks.

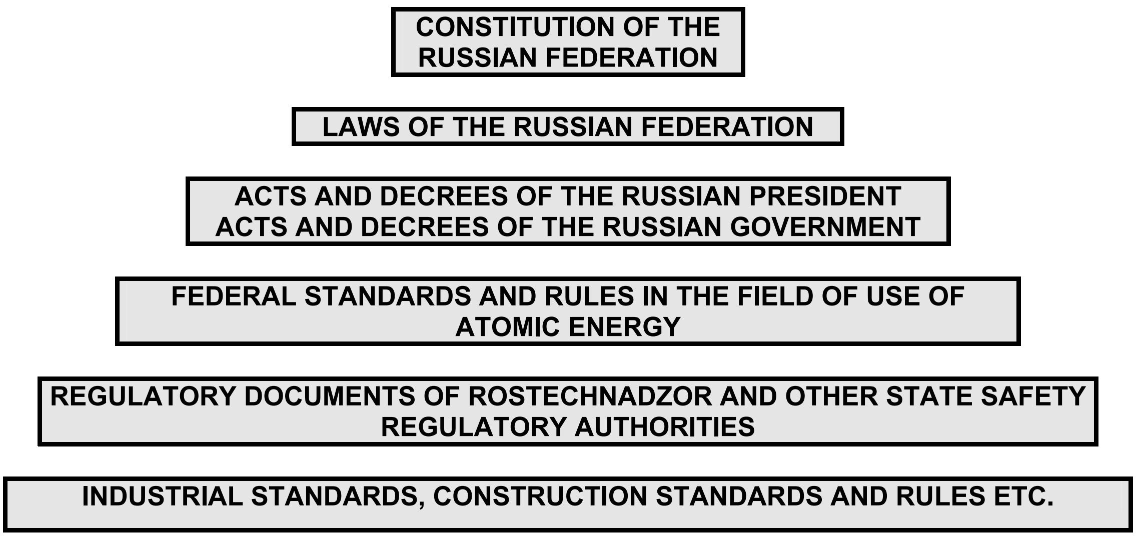
Category 5

Not dangerous: No one could be permanently injured by this amount of radioactive material.

3. Structure of the legal and regulatory documents of the Russian Federation for the activity in the field of use of atomic energy

The Russian Federation legislation is a part of the system for ensurance and regulation of the nuclear and radiation safety in Russia.

In whole, the hierarchy of the documents in Russia is similar to structures accepted in the developed countries. Figure 1.1 presents a hierarchical structure of legal and regulatory documents for relations in the field of use of atomic energy.



Contents of documents are determined by their place within the hierarchical structure: the upper level documents include more general legal provisions and provide for validity of the low level documents; the low level documents should be consistent with the upper-level documents and address specific issues in greater detail.

Issues related to safety in the use of atomic energy are regulated by the Constitution of the Russian Federation, international treaties and conventions, federal laws and other legal acts and regulatory documents.

In total, radiation safety of a facility is ensured on the basis of an integrated and systematic approach and maintained by the following measures:

- design solutions accepted in the process of development of radiation sources, RTG fabrication, operation and decommissioning;
- regulatory documents, provisions, procedures;
- monitoring of RTG and safety parameters;

- safety control and management during normal operation and accidents;
- safety culture;
- system for state and departmental safety control and supervision, investigation of events and accidents;
- measures to prevent emergency situations and preparedness of emergency-rescue teams.

The system of safety safeguards in the use of atomic energy is provided by three components:

- availability of the legal and regulatory framework within which practical activity related to safety in the use of atomic energy is implemented;
- availability of the state safety system including well established structure of state radiation protection authorities;
- use of such methods of state management as licensing, certification and mandatory insurance of nuclear activities.

Note: The Federal Law “On the Use of Atomic Energy” is, in whole, a legal act on control of activities implemented by enterprises and institutions in the field of use of atomic energy. It also includes provisions on safety regulation while implementing the activity in the field of the use of atomic energy.

Such issues related to control of activities implemented by enterprises and institutions in the field of use of atomic energy include requirements to obtain a license for the specified activity, to undergo mandatory certification of equipment, products and technologies for radiation sources and storage facilities, to provide for financial coverage of the civil liability for damage and injury caused by the radiation impact.

The legal and regulatory framework in the field of use of atomic energy is comprised of the federal laws, Presidential Acts and Governmental Decrees of the Russian Federation, federal standards and rules, guiding documents of Rostechnadzor.

In particular, the federal laws existing in the field of use of atomic energy include:

- the Federal Law “On the Use of Atomic Energy”;
- the Federal Law “On Radiation Safety of Population";
- the Federal Law “On Environmental Protection”;
- the Federal Law “On Protection of Population and Territories against Natural and Man-induced Emergency Situations";
- the Federal Law “On Funding of Particularly Radiation- and Nuclear-Hazardous Productions and Facilities’.

The Federal Law “On the Use of Atomic Energy” establishes that the operating organisations bear the full responsibility for safety of radiation source and appropriate handling of radioactive substances. The Law determines that the operating organisation shall obtain a permit (license) to carry out nuclear activity to be issued by an appropriate state safety regulatory authority.

The Federal Law “On Environmental Protection” establishes that legal entities and physical persons shall meet rules for fabrication, storage, transportation, use, disposal of radioactive substances (ionising irradiation sources), prevent exceedance of established maximum permissible standards for ionising radiation and, should these standards be exceeded, inform immediately executive authorities in the field of radiation safety about the increased radiation levels hazardous for the environment and human health, take measures to eliminate the source of radiation contamination.

The Federal Law establishes that legal entities and physical persons, who do not provide for compliance with the rules for radioactive substances and radioactive waste management, shall bear the responsibility in accordance with the Russian Federation legislation.

By-law decrees in the field of handling of radiation sources adopted by the Russian Federation Government are:

- "On Approval of Rules for Organisation of the State Radioactive Substances and Radioactive Waste Accounting System" (1997);
- "On Procedure for Establishment of the Uniformed State System for Monitoring and Recording of Individual Exposure Doses of Citizens" (1997);
- "On Approval of Provisions for Licensing of Activity in the Field of Use of Atomic Energy" (1997).

Rules for Organisation of the State Radioactive Substances and Radioactive Waste Accounting System define a procedure for organisation of the system for state accounting and control of radioactive substances including their use in the radiation sources. These Rules are mandatory for all legal entities independently from the form of property and organisational and legal structure which carry out activity related to fabrication, use, utilisation, storage and disposal of radioactive substances and radioactive waste, including federal executive authorities implementing state control of the use of atomic energy and state regulation of safety within their competence, respectively.

Provisions for Licensing of Activity in the Field of Use of Atomic Energy establish that licensing of activity in the field of use of atomic energy is carried out by Rostechnadzor which issues licenses for such types of the activity as siting, construction, operation, decommissioning of radiation sources including RTGs.

The next set of requirements for handling, operation and decommissioning of radionuclide sources is presented in the **Federal Standards and Rules:**

- General Safety Provisions for Radiation Sources (NP-038-02);
- Requirements to the Contents of Safety Analysis Report for Radiation Sources (NP-039-02);
- Physical Protection Rules for Radiation Sources, Storage Facilities, Radioactive Substances (NP-034-01);
- Radiation Safety Standards (NRB-99) – regulate basic dose limits for radioactive material handling;
- Basic Sanitary Rules for Radiation Safety (OSPORB-99) – set up requirements related to people protection against hazardous radiation impact under all exposure conditions caused by the ionising radiation sources;
- Sanitary Rules for Radioactive Waste Management (SPORO-2002) – establish requirements for radiation safety of personnel and population for all types of radioactive waste management;
- Sanitary Rules for Radiation Safety of Personnel and Population during Transportation of Radioactive Materials (Substances) (SanPin 2.6.1.1281-03) – establish hygienic requirements for radiation safety of population for all types of radioactive material handling during transportation starting from shipment by a consignor up to receipt by a consignee;
- Safety Rules for Transportation of Radioactive Materials (NP-53-04) – establish safety requirements for transportation of radioactive materials.

The following documents should be addressed in more detail:

General Safety Provisions for Radiation Sources (NP-038-02)

Standards and Rules were developed taking into account provisions of the Federal Laws "On the Use of Atomic Energy" and "On Radiation Safety of Population", and recommendations contained in the documents of the IAEA and other organisations as regards safety of radiation sources (RS).

The federal standards and rules establish objectives, principles, criteria and general requirements, engineering and organisational measures targeted to ensure safety and taken into account in RS design, siting, construction, commissioning, operation and decommissioning, as well as requirements for action plans to protect RS personnel and population but do not describe methods which shall (or may) be used to achieve them.

The federal standards and rules include a List and categorisation of the main RS types which represent by themselves complexes, facilities, apparatus, products and equipment.

The document sets up five defence-in-depth levels which are the part of the system of engineering and organisational measures:

- *Level 1* – RS siting conditions and prevention of violations of normal operation;
- *Level 2* – prevention of design basis accidents by normal operation systems;
- *Level 3* – prevention and mitigation (keeping under control) of beyond design basis accidents by safety systems;
- *Level 4* – management of beyond design basis accidents;
- *Level 5* – emergency planning.

RS safety criteria, adequacy of organisational and engineering measures to ensure safety shall be justified in the RS design and presented in the safety analysis report for RS (SAR RS).

The federal standards and rules establish RS categorisation in terms of the following features:

- RS purpose;
- Potential radiation hazard of RS;
- RS transportability;
- Type of radionuclide comprising the RS.

In terms of the purpose RSs are subdivided into complexes, facilities, apparatus, equipment and products.

In accordance with the categorisation RTGs are attributed to products containing radioactive substances.

Potential radiation hazardous of RS is defined by its possible radiation impact on the population in case of radiation accidents.

RSs are subdivided in four categories in terms of the potential radiation hazard:

- *Category 1* – such RS where an accident may cause the radiation impact on the population and measures to protect it may be required;
- *Category 2* – such RS where an accident causes the radiation impact limited to the territory of the controlled area;
- *Category 3* – such RS where an accident causes the radiation impact limited to the territory of the site or building where it is located;

- *Category 4* – such RS where an accident causes the radiation impact limited to the building or room where it is located.

The category in terms of the potential radiation hazard for RSs under design is set up in the RS design, and for RS in operation – by the operating organisation.

In terms of the potential radiation hazard RTGs are attributed to Category 4 (in separate cases – to Category 3).

In terms of transportability RSs are subdivided by:

- *stationary* – RSs which purpose and design provide for their operation within the whole design service life at the permanent location; their siting and operation require specially equipped structures (or premises) and additional engineering systems and means (for example, ventilation system, filters etc.);
- *mobile* – RSs assembled and used (operated) for their purpose in transport (self-propelled or specially designed for transportation) means;
- *portable* – RSs which have constituents with a design and mass allowing to carry RSs (or, if necessary, to transport them in the assembled form) and use (operate) them for their purpose inside the premises (without their re-equipment and improvement of their protection) directly at the places where operations are carried out or in the field conditions.

According to this categorisation RTGs are attributed to the stationary sources.

In terms of the type of radionuclide sources being a part of complexes, facilities, apparatus, equipment and products RSs are subdivided by:

- RSs which use only SRnS (sealed radionuclide source) as a constituent;
- RSs which use only ORnS (open {unsealed} radionuclide source) as a constituent.

The federal standards and rules provide that the operating organisation shall develop Action Plans to protect personnel and population in case of accidents and eliminate their consequences taking into account RS category in terms of the potential radiation hazard, decision-making criteria as regards measures to protect personnel and population in case of the accident.

As regards Category 1 and 2 RSs in terms of the potential radiation hazard, action plans to protect both the personnel and population in case of the accident shall be developed, concurred, approved and ready for implementation, taking into account its radiation consequences.

As regards Category 3 and 4 RSs in terms of the potential radiation hazard, action plans to protect the personnel in case of the accident shall be developed, concurred, approved and ready for implementation taking into account its radiation consequences.

The federal standards and rules provide for that the operating organisation shall develop a RS **decommissioning program** for all RS types and categories in terms of the potential radiation hazard taking into account results of engineering examination and radiation survey.

As regards Category 1 and 2 RSs in terms of the potential radiation hazard the operating organisation shall provide for the development of the RS decommissioning program not later than **one year** before the RS design service lifetime expires.

As regards Category 3 and 4 RSs in terms of the potential radiation hazard RS the decommissioning program shall be developed not later than **six months** before the **RS design service lifetime** is expired.

The federal standards and rules include a separate section addressing the RS decommissioning:

RTGs with the expired design or extended operating period and faulty RTGs shall be decommissioned and transferred either to the enterprise-fabricator or specialised organisation for temporary storage and disposal.

In case of RTG decommissioning, the engineering examination is carried out to determine whether dismantling and transportation are feasible within the regulatory requirements and licence conditions. The radiation and contamination survey includes monitoring of gamma- (bremsstrahlung) radiation dose rate on the product's surface and at a given distance from the product's surface, monitoring of the product surface contamination level and monitoring of the surface contamination level of the RTG and immediate environment.

Note: The requirement of this paragraph corresponds exactly to para 5.4 of General Safety Provisions for Radiation Sources (NP-038-02).

On the basis of the engineering examination and radiation and contamination survey the operating organisation shall develop the RTG decommissioning program which shall include a list and sequence of organisational measures and operations related to RTG dismantling and transportation of dismantled RTG.

Operations related to the RTG engineering examination and radiation and contamination survey, dismantling and transportation may be combined in one stage by a decision made by the operating organisation.

The RTG dismantling and transportation from the place of its location shall be carried out by the trained personnel according to a developed procedure and requirements of the engineering documentation for the specific product.

Dismantling of each RTG is documented in a report to be signed by persons who carried out the dismantling and to be approved by a Head of an operating organisation.

The report shall include the following information: type of the product, year of fabrication, serial number of the product, number of a specification for a radionuclide source, date of commissioning, place of operation, results of engineering examination of the product conditions prior to the dismantling, date of the start and end of the dismantling.

Requirements for the Contents of the Safety Analysis Report for Radiation Sources (NP-039-02)

These federal standards and rules establish:

- Purpose and scope of the safety analysis report for RS (SAR RS);
- SAR RS development procedure;
- Requirements to the SAR RS contents, structure, format and updating procedure.

In total, the SAR RS shall include the following sections:

1. Introduction
2. Description of the location region of the radiation source
3. Basic information about the radiation source
4. Safety concept for the radiation source
5. Organisation of the radiation safety service unit
6. Safety justification for commissioning and operation of the radiation source
7. Physical protetection of the radiation source

8. Analysis of possible radiation accidents and emergency planning
9. Radiation source decommissioning
10. Quality assurance

As it can be seen from this list, one of the Sections is "RS Decommissioning" which presents:

- results of the performed engineering examination and radiation and contamination survey in the scope sufficient to select and justify the RS ultimate state after all relevant decommissioning operations have been completed;
- description of the selected ultimate RS state after decommissioning has been completed;
- sequence of RS decommissioning activities and list of organisational and engineering measures to ensure radiation safety during these activities;
- list of the main RS decommissioning stages indicating their estimated duration and concrete executors (organisations) involved in these stages;
- list of special equipment required for the activities indicating the extent of their readiness (availability) by the time when SAR RS for RS decommissioning is completed;
- scope of radiation monitoring (with justification of its sufficiency) and a procedure to reduce it at different RS decommissioning stages;
- RS decommissioning project - based sequence of loss of integrity of physical barriers in RS decommissioning including justification of safety measures at each of the RS decommissioning stages;
- information whether the organisation possesses sufficient funds and technical resources to ensure implementation of all activities provided for in the RS decommissioning project in the full scope.

It shall be demonstrated how the following is provided for all RS decommissioning stages:

- removal of radionuclide sources related to the given RS and their transfer for storage (disposal of) or reuse in the specialised organisations;
- RS physical protection during its decommissioning (including ensurance of security of radioactive waste, contaminated equipment, instrumentations, fragments of biological shield etc. generated during the decommissioning);
- generation of minimum amount (volume) of radioactive waste during the RS decommissioning, RW temporary storage and timely transfer for storage or disposal of to the specialised organisations;
- reduction in radiation burdens on the personnel and population and radionuclide release into the environment up to the minimum possible level.

Note: The Federal Law "On Radiation Protection of Population" (Article 3) includes basic safety principles. One of them is a principle of optimisation. It means that during the use of any ionising radiation source an individual exposure doses and number of exposed persons shall be maintained at as low as possible and adequate level taking into account economic and social factors.

As regards those RSs for which the decommissioning procedure determined by the NP-038-02 requirements does not provide for the development of a special SAR RS for decommissioning, this section includes brief information about:

- brief results of the RS radiation survey (and, if necessary, engineering examination);
- brief description of the RS decommissioning program including RS ultimate state after all operations have been completed;

- list and sequence of routine (provided for by the RS decommissioning schedule) activities to remove the radionuclide sources, decontamination of equipment and premises specifying concrete executors and justification of safety measures to be taken during these activities;
- procedure to write-off and transfer of the radionuclide sources to the specialised organisations for the subsequent storage or reuse;
- radiation monitoring procedure for RS decommissioning activities (in such case when its contents and scope differ from that defined in the RS operating regulations).

Safety Rules for Transportation of Radioactive Materials (NP-53-04)

The rules establish safety requirements for transportation of radioactive materials including requirements for operations and conditions related to the movement of the radioactive material which are a part of this process (design, fabrication, maintenance and repair of the package; preparation, loading, shipment, transportation including temporary (transit) storage, unloading and receipt at final destination of radioactive materials and packages).

For radioactive material shipments, including RTG shipments, the following certificates (certificates-permits) shall be issued in the Russian Federation:

- certificate (certificate-permit) for a special form radioactive material;
- certificate (certificate-permit) for a low dispersible radioactive material;
- certificate (certificate-permit) for type A package design;
- certificate (certificate-permit)) for type B(U) and B(M) package design;
- certificate (certificate-permit) for type C package design;
- certificate (certificate-permit) for transportation of type C, B(U), B(M), A package;
- certificate (certificate-permit) for transportation under special arrangements.

These rules include a Section “Measures to be taken in case of accidents during transportation of radioactive materials” and Section “Physical protection requirements for radioactive materials”.

Other documents that contain RTG-related requirements are **state** standards:

- **GOST 20250-83** “Radioisotope Thermoelectric Generators. Acceptance Rules and Test Methods” – establishes acceptance rules and test methods for different RTG types;
- **GOST 18696-90** “Radioisotope Thermoelectric Generators. Types and General Technical Requirements” – establishes RTG types and general technical requirements for RTG fabrication at enterprises.
- Interdepartmental and departmental regulatory documents addressing separate issues related to RTG handling and operation are also available.

4. Conclusion

This section addresses safety requirements for operations involving radiation sources at all stages of their life cycle. Task 1 demonstrated that a legal and regulatory framework applicable to the decommissioning of RTGs exists in the Russian Federation. There are nevertheless measures that might be taken to strengthen the framework, particularly in terms of further clarifying the responsibilities of the different organisations involved in the process, and developing regulatory guidance specific to RTG decommissioning at the more practical level. Such measures could contribute to the important goal of ensuring that operational procedures by all of the organisations are fully consistent with the framework at all times.

Appendix B
Review of applications for licensing and authorisations (Task 2)

B-1. Initial risk assessments performed for all stages of RTG decommissioning (Deliverable D3)

1. Crucial factors of danger in management of RTGs

Radionuclide thermoelectric generators (RTGs) are independent electric power sources with long life service (usually up to 25 years).

In these devices the heat power released in the radionuclide heat source (RIT-90) due to beta-decay of strontium-90, which is in moving equilibrium with yttrium-90, with the use of a semiconductor thermoelectric transducer is transformed in direct-current electric energy with the power from several units to dozens of Watt in one RTG.

The unique source of potential radiation danger in using RTGs in national economy for personnel, population and environment are radionuclide heat sources of RIT-90 type, which contain up to 4.35×10^{15} Bq (~ 118 000 Ci) by parent strontium-90 in one instrument. A single RTG depending on specific type can comprise between 1 and 6 heat sources of different power (as, for instance, in RTG of IEU-1 type).

The main radiological danger is represented by:

- Intensive gamma bremsstrahlung of beta-particles (basically, from beta-particles of yttrium-90 with boundary energy of 2274 keV, since the contribution of "soft" beta-particles from decay of strontium-90 with boundary energy of 546 keV is low). Equivalent dose rate (EDR) of bremsstrahlung from one RIT-90 with allowance for its absorption in the source casing made from refractory steel more than 5 mm thick may amount to ~ 5.4 Sv/hr at a distance of 1 m, so their use in RTGs requires a significant biological (radiation) shielding, for this reason the weight of radiation shielding is between 60 % and 80 % of total generator weight.
- Possible arrival of radionuclides strontium-90 + yttrium-90 to the environment (and human organism) in case of integrity loss of RIT-90.

In accordance with radiation safety requirements and GOST 18696-90 "Thermoelectric radionuclide generators: types and general technical requirements", biological shielding of a RTG should be designed in such a manner that EDR on its surface would not exceed 0.56 μSv/s (or 200 mrem/hr), 0.028 μSv/s (10 mrem/hr) at a distance of 1 m from the surface and no more than 2.8×10^{-4} μSv/hr (0,1 mrem/s) at a distance of 0.2 m. These values should be adopted as minimum values of EDR received near the RTG in good condition.

At present, the elements of RTG radiation shielding are made from lead, tungsten-nickel alloy, depleted uranium and alloys based on it.

The design features of RTGs ensure radiation and environmental safety both in normal operation and in potential accident situations including all stages of RTG decommissioning.

Radiation and environmental safety are provided by the following factors:

- multi-barrier protection of personnel and environment against intensive bremsstrahlung of radionuclides strontium-90 + yttrium-90 – constituents of RIT-90;

- as radionuclide sources, there are used compositions based on strontium titanate that is an exclusively solid substance, practically insoluble in water;
- this composition is placed in a sealed capsule from heat- and corrosion-resistant alloy EP-437, which is tolerant to any impacts (thermal, mechanical, corrosion, climatic and the like);
- a radionuclide heat source (RIT-90) is located in the center of the RTG providing an additional protection against emission of RIT and difficulties in extracting it in case of unauthorised dismantling.

All these factors ensure high reliability of RTG units and their radiation safety. A probability of trouble-free operation of a RTG during the life service with confidence probability 0.8 should be no less than 0.95 for RTG of NSNU, NSVU, A and T types and no less than 0.99 for RTG of M type.

At the same time, taking into account a possible combination of all factors affecting the capsule RIT-90 in the event of accidental scenario consisting in penetration and long residence of RTGs in sea water, one has to foresee the potentiality of partial or full loss of integrity of the radioactive core of RIT-90 leading to contact with the environment. Therefore, for a radioactive material strontium titanate has been selected, which has a minimum solubility in water.

In the assessment of the potential danger of a radiological accident with RTGs on land, it is essential to bear in mind that the partial or full destruction of RIT capsule by external impacts is extremely unlikely, and is practically feasible only on purpose. However, even in case of opening of the capsule there practically will not be any release of strontium-90 and yttrium-90 from the monolith fuel composition RIT-90 (strontium titanate) because strontium titanate has a high melting temperature, a low rate of evaporation at a temperature ~ 1200^0C and a very low leachability (see above).

In the event of a radiological accident with a drop from RTG or seal failure of RIT-90 on land, the only way of radiation impact on biological objects is external irradiation by beta-particles bremsstrahlung (primarily of radionuclide yttrium-90) in close contact with RTG, RIT-90 in emergency condition or in case of staying in zone of this emission.

An approximating calculation of EDR of bremsstrahlung from RIT-90 free from biological shielding, performed with the use of experimental and calculated data from [1,4,5], as well as Viard formula [2,3] and consideration of the factor that the fuel composition of radioactive core from strontium titanate is placed in a sealed metal capsule with walls that have thickness for different types of RIT-90 from 5 to 12 mm through which the low-energy part of bremsstrahlung spectrum is “cut off”, results in the value of kerma constant of $\Gamma_\delta \approx 0.35$ Gy×m^2/s×Bq. So for RIT-90-650 with activity ~ 4.14×10^{15} Bq equivalent dose rate (EDR) at a distance of 1 m will be ~ 1.5×10^{-3} Sv/s, or ~ 5.4 Sv/hr. Thus in 1-hour residence near RIT-90 without biological shielding at a distance of ~1 m a person can receive a lethal dose of external irradiation.

This value of EDR presents a maximum value for single RIT-90-650 without biological shielding, which may be adopted for subsequent calculations of EDR received by personnel and population in various accidental situations, which might take place in management of RTGs, including cases if radiation accidents with loss of biological shielding (drop of one or few RIT-90 from RTGs, for example in unauthorised dismantling).

In accidents with damaged RTGs, EDR is significantly less than the received maximum calculated value of EDR for these cases can be assessed on a basis of experience in elimination of accident situations associated with drop of RTGs during transportation by helicopter from the height ~ 100 m on rocky ground. In this case, RTG experiences stress close to the level of mechanical impact designed in RTG specifications as a special type of radioactive material (STRM) [6,8].

In [7] with reference to research performed by the US specialists, it is demonstrated that damage in packages is equivalent to a drop from 9 m (speed of fall ~ 13.3 m/s) on rigid base, which will take place with an impact at a speed of 29.4 m/s from a height of 43 m on solid rock, 33.5 m/s from 57 m on soft rock and 40 m/s from 81 m on solid ground, 93.8 m/s from 447 m on soft ground and 60 m/s from 183 m on water. Therefore, it may be thought that in case of a drop from a height of 40-80 m on rocky ground an impact upon the package with the RTG will be equivalent to that of testing on STRM, which it should withhold without loss of radioactive content [8].

As indicated an actual accident with the drop of RTG of EFIR-MA type of the Tiksi Hydrographic base after throwing from the external carrier arm of the helicopter on rocky surface from a height of 100 m (Act No.16-T-2004 of 21.09.2004), the level of gamma radiation due to the damaged shielding amounted to at a distance of 2 m from the damaged RTGs ~ 0.8 mSv/hr, and at a distance of 5 m – (52-55) μSv/hr. No release of radioactive strontium-90 from RTGs was registered.

As an approximation of point source a maximum calculated EDR from damaged RTGs at a distance of 1 m would be ~ 3.2 mSv/hr. This value was taken for calculation of population dose (PD) of accidental irradiation of personnel in work from a damaged RTGs.

Hypothetically, a loss of RTG integrity can occur as a result of mechanical and thermal impact. Taking into account physical, chemical and design features of RIT-90 and fuel composition, in case of violation of integrity of RIT casing, we take for atmospheric release of radionuclide in aerosol form based on [12] a conservative approximation enclosure value of 6×10^{-9} hr^{-1}.

As an example of the assessment of consequences of a loss of RTG integrity in open air we can consider an accident related to fire in transportation of RTG by truck which would result in superimposition of thermal and mechanical impacts upon RIT of Beta-M type contained in RTG with activity ~ 40 kCi.

A conservative approximation is applied, where a produced aerosol comprises only fine particles of respiratory fraction, which in case of intake do not retain in the windpipe and are practically fully delivered to lungs. Duration of radioactive release in this case is 1 hour. It is thought that such lapse of time is sufficient to take urgent measures to assess radiation situation, enclose the place of accident, evacuate population from the radiation dangerous zone and localise the basic source of radiation danger using protection means and so on.

In the event of a radiation accident related to fire on the vehicle, a part of radioactive substances coming from the damaged source is deposited in the immediate vicinity of the truck in the area of aerodynamic shadow. Another part is taken off beyond the limits of aerodynamic shadow and distributed over a big territory. A calculation of radioactive contamination of the surrounding space is made using the Methodology [13].

In calculating the radioactive contamination of the area of aerodynamic shadow, the following conservative model of distribution of activity is used, in case of inflammation of the transportation facility:

- - all activity from the damaged source comes to the area of aerodynamic shadow,
- - level of activity in air is regulated only by the process of radionuclide arrival to the area of aerodynamic shadow with no consideration for reduction of activity due to deposition by gravity.

Calculated dose loads for personnel who are near the vehicle at the moment of the accident are presented in Table 1.

Table 1. *Values of equivalent doses and density of contamination of underlying surface by strontium-90 along the axis of the area of aerodynamic shadow*

Distance to the truck, m	Equivalent dose, mSv	Density of contamination, Bq/m^2
0	0.4	1.28×10^5
2	0.3	7.7×10^4

Distance to the truck, m	Equivalent dose, mSv	Density of contamination, Bq/m^2
4	0.23	5.5×10^4
6	0.19	4.4×10^4
8	0.16	3.6×10^4
10	0.15	3.1×10^4
12	0.13	2.8×10^4
14	0.12	2.5×10^4
16	0.11	2.3×10^4

Table 1 also gives the results of calculation of deposition of activity from air volume within the area of aerodynamic shadow. In calculation of density of soil contamination by strontium-90 it is suggested that the deposition velocity is 0.01 m/s (standard value of dry deposition velocity [14]) and the duration of activity precipitation is 1 hour.

Calculation shows that in this accident dose loads do not exceed the maximum irradiation levels prescribed by NRB-99 for personnel and population (respectively 20 mSv and 1 mSv per year).

According to [3], a level of contamination by strontium-90 creating a dose load of 1 mSv/year is 1000 Bq/m^2. Thus, according to NRB-99, one can specify the following segments of contaminated territory:

- Radiation monitoring area (> 1000 Bq/m^2)
- Area of restricted residence of population (> 5000 Bq/m^2)
- Area from which population has to be evacuated (> 2×10^4 Bq/m^2).

Therefore, contamination of territory to dangerous values in this accident is restricted by the distance up to 16 – 20 m from the vehicle.

These calculations were based on conservative assumptions, however, the actual values of radioactive contaminated areas can be lower than the calculated ones. Bearing this in mind it is necessary to consider that at a small height of radioactive release the real picture of radioactive contamination has significant heterogeneity. Spots with a higher density of contamination are possible. So a decision on decontamination and removal of soil layer should be taken on the basis of outcomes of survey of the territory shortly after the accident.

To assess collective dose it may be assumed that in occurrence of fire of the transportation facility it is extinguished by two members of staff of Group A and a fire brigade consisting of 6 people. It is deemed that people in liquidation of the accident do not approach to the vehicle closer than 2 m. Then a maximum value of collective dose in fire extinguishing would be 2.4×10^{-3} man Sv. The remaining components of collective associated with elimination of radioactive contamination of the territory are considerably smaller than this value.

As a whole, it may be concluded that in case of an accident with fire of the vehicle and loss of integrity of the source, doses of inner irradiation due to arrival to organism of radioactive aerosol containing strontium-90 do not pose a threat. Decontamination of the area within 100 m^2 may be required. In addition, with this accident one should take into account possible elevated external radiation which can occur in case of aforementioned damaged biological shielding if RTG.

A certain degree of danger could be presented by emergency situations with loss of seal by the active part of RIT-90 in sea water. In this case, considerable amounts of strontium-90 can come to the adjacent water area, as a consequence, radionuclides will be accumulated by sea organisms and ultimately it may lead to delivery of radionuclides in seafood to organisms or inhabitants of coastal regions.

From calculations reported in "Substantiation of environmental and radiation safety in works for RTG disposal" (EIA) approved by the RF Deputy Minister of Atomic Energy S.V. Antipov on 12.03.2004, it follows that a maximum value of radioactive contamination of sea water already at a distance of ~ 10 m from the source (RIT-90) is ~ 1 Bq/l by strontium-90, that is by a factor of 5 less than the level of intervention in case of delivery of strontium-90 by water for population, which according to NRB-99 amounts to 5 Bq/kg. An annual intake of strontium-90 within seafood by humans under the most unfavorable conditions is ~ 1.1×10^3 Bq/y. The obtained value is about 12 times lower than the maximum permissible annual intake of strontium-90 by human organism with food, which is according to NRB-99 is 1.3×10^4 Bq/y.

It should be pointed out that the values above were obtained for penetration into sea water of "naked" fuel pellets (that is without ampoules) with a reduced area of contact of the fuel pellet with water by 20-30 %, i.e. in the most conservative conditions.

Therefore, the data above show that the application as an active part of RIT-90 of fuel composition in form of strontium titanate with a significant safety margin provides environmental safety in the event of accidental release of RIT-90 to sea water under the most unfavorable circumstances, moreover the limits of annual intake of strontium-90 by human organism established in NRB-99 for population will not be exceeded.

For more than 25-year period of RTG operation, several units became trapped in extreme situations such as:

- forest fire;
- fire in a room lined with wood;
- they were dropped from the board of the ship in unloading;
- they were washed by waves into tide during storm;
- they were fired on by unidentified persons;
- there were registered attempts of unauthorised opening of RTG by unidentified persons.

In addition to these unintended situations listed above, a test of RTG resistance to explosion was conducted. An experimental explosion of a powerful anti-ship explosive device attached to a RTG destroyed a small RTG(57IK), but its RIT-90 was found out undamaged. This result serves as a justification of assumption that an attempt of premeditated destruction of RTG using the antitank grenade launcher will cause only violation of the radiation shielding of RTF, however, RIT-90 destruction is excluded.

Therefore, RIT-90 radiation shielding in form of RTG structure or a transport cask protects RITs against a sharp impact of external factors.

Taking into account insignificance of consequences of the loss of RIT integrity in conditions of fire or flooding, a unique possibility of spreading big amount of strontium-90 is by explosion of a separate RIT, free from radiation shielding, by a powerful explosive device. In so doing, RITs should be retained for several minutes at a temperature higher than 2000°C.

Occurrence of these conditions by chance is practically non-existing and can be created only deliberately. To carry out such an explosion the following needs to be performed:

- extract the RIT from radiation shielding;
- prepare a detonating device of special design;
- install into this device the RIT devoid of radiation shielding; and
- perform the required conditions of heating and demolition of the RIT.

At present no other actions can be thought of but the performing of an organised terrorist act. Taking into account the complicated number of steps to be performed to cause such an explosion, as well as the long time associated with its preparation, it is reasonably safe to suggest that such terrorist act is practically impossible in the normal process of transport and interim storage of RTGs dismantlement.

In RTG decommissioning the greatest risk for population and the environment is associated with accidents during transportation, as detailed below.

An assessment of probability of radiation accidents related to intensive damage of the transportation facility and/or the transported RTGs on the basis of different publications gives the following values:

- severe train accident with destruction of the special wagon (p_r) where packages with RTG are carried, $p_r \approx 1.8\times10^{-8}$ (year×km)$^{-1}$;
- severe road accident with the special truck '(p_t) where packages with RTG are carried, $p_t \approx 1\times10^{-5}$ (year×km)$^{-1}$;
- accident when the RTG is sunk in transportation on board of the special vessel, $p_v \approx 1\times10^{-6}$ (year×km)$^{-1}$;
- accident related to the drop of the helicopter (p_h)carrying the RTG, $p_h \approx 1.0\times10^{-4}$ (year×km)$^{-1}$;
- accident related to the collision of the special vessel ($p_{w)}$ carrying packages with RTGs from the White Sea to Atomflot against another ship $p_w \approx 1.5\times10^{-3}$ year^{-1}.

2. Description of the first (basic) options of transport arrangements and assessment of consequences of potential radiation accidents at each stage of RTG decommissioning

For collection of RTGs prior to transportation by rail the interim collection pad on the premises of FSUE Atomflot is used. A reserve pad is equipped at the coast of the Kola Bay opposite to FSUE Atomflot. List of RTGs to be dismantled and conveyed to the pad at Atomflot within the framework of this project is given in Table 2.

According to available data for 2005 – 2006 it has planned to dismantle and dispose 31 RTGs presented in the Kola Peninsula as well as on islands and on shore of the White Sea. Information on locations of these RTGs, types and technical state is given in Table 2. The last column of this table shows an approximate length of the route of delivery of each RTG to the collection pad at FSUE Atomflot, and the column – a probability of the accident in transportation of RTG thereto.

So, according to data in Table 2, it is intended to dismantle:

- Beta-M – 15 units;
- IEU-2 – 7 units;
- IEU-2M – 5 units;
- REU-3-2K – 2 units; and
- IEU-1 – 2 units.

Rated activity of RTG by strontium-90 is:

- Beta-M – 35.3 kCi;
- IEU-2 – 89.1 kCi;
- IEU-2M – 99.9 kCi;
- IEU-1 – 327.3 kCi; and
- REU-3-2K – 275.7 kCi.

Total activity of RTG by strontium-90 is – 2858.7 kCi.

A preliminary assessment of RTG state is two-fold:

- A – RTG is damaged, i.e. in 'accident state', not completed;
- U – RTG is in satisfactory state;
- TO – it is essential to perform a preliminary examination and a procedure of execution of the special permit for transportation.

Four RTGs of Beta-M type in accident condition are stored in the warehouse in the settlement Roslyakovo, so prior to dismantlement it is necessary to:

- carry out preliminary examination;
- on the basis of examination to develop and manufacture a necessary technological equipment and appliances;
- develop, and agree upon technological, regulation to eliminate these accident situations;
- test the regulation for activities for eliminating these accident situations using mock-ups at VNIITFA.

Afterwards it is essential to dismantle and transport the damaged RTGs.

Another damaged RTG of IEU-1 type is located on the island Golets in the estuary of the Severnaya Dvina. For this RTG the similar set of activities is needed as that for the damaged RTGs in the settlement. Roslyakovo needs to prepare a special permit for its transportation. A necessity of preliminary examination and execution of special permissions for transportation of other RTGs (items 4, 9 and 21 in Table 2) is caused by the fact that their 25-year service life has expired.

Table 2. *List of RTG planned for dismantlement and disposal in 2005 - 2006 under Russian-Norwegian Cooperation Program*

No	RTG location	RTG type	RTG number	Date of manufacture	RIT-90 power, W	RTG condition *	Distance to Atomflot, km	Probability of accident / year
1	Lighthouse Pechengsky	IEU-2M	8059	1989	650	U	100	1×10^{-2}
2	SNZ Eyna	Beta-M	422	1983	230	U	70	7×10^{-3}
3	SNZ Motka	Beta-M	234	1990	230	U	80	8×10^{-3}
4	PZS mark Motovsky leading	IEU-2	01	1978	550	TO	70	7×10^{-3}
5	ZSZ mark Motovsky leading	IEU-2	66	1981	580	U	70	7×10^{-3}
6	PZS mark Aragubsky input	Beta-M	398	1983	230	U	60	6×10^{-3}
7	ZSZ mark Aragubsky input	Beta-M	393	1983	230	U	60	6×10^{-3}
8	Lighthouse Vyevnavolok	IEU-2	65	1981	580	U	55	5.5×10^{-3}
9	PZS mark Bay Nasha	IEU-2	03	1978	550	TO	40	4.0×10^{-3}
10	SNZ Shurinovsky	Beta-M	142	1986	230	U	40	4.0×10^{-3}

No	RTG location	RTG type	RTG number	Date of manufacture	RIT-90 power, W	RTG condition *	Distance to Atomflot, km	Probability of accident / year
11	SNZ Lodeiny - Zapadny	Beta-M	319	1981	230	U	35	3.5×10^{-3}
12	PZS mark Topoc	IEU-2M	8039	1989	650	U	30	3.0×10^{-3}
13	PZS mark Medvezhy - input	Beta-M	190	1986	230	U	30	3.0×10^{-3}
14	PZS mark Medvezhy	Beta-M	194	1986	230	U	30	3.0×10^{-3}
15	CH3 Zeleny - Kolsky	Beta-M	257	1991	230	U	32	3.2×10^{-3}
16	PZS mark, basic, warehouse Roslyakovo	Beta-M	255	1992	230	A	20	-
17	PZS mark Palagubsky, warehouse Roslyakovo	Beta-M	259	1992	230	A	20	-
18	SNZ Yuzhny Goryachinsky, warehouse п. Roslyakovo	Beta-M	256	1991	230	A	20	-
19	SNZ Shurinov	IEU-2M	001	1984	650	U	20	2.0×10^{-3}
20	No.460, SNZ Volokovsky warehouse Roslyakovo	Бета-М	227	1990	230	A		
21	No. 795 Lighthouse Kildinsky Severny	IEU-1	042	1979	530 530 530 180 180 180	TO	50	5.0×10^{-3}
22	Lighthouse Russky	REU-3-2К	003	1989	513 513 513 85 85 85	U, TO	40	4.0×10^{-3}
23	Lighthouse Russky	REU-3-2К	004	1989	513 513 513 85 85 85	U, TO	40	4.0×10^{-3}
24	SNZ Bolshoy Oleniy	IEU-2	35	1980	550	U	30	3.0×10^{-3}
25	Sec No.3 mark Kol. Ml.	Beta-M	195	1986	230	U	30	3.0×10^{-3}
26	ASMk Abramovsky	IEU-2M	8099	1989	650	U	780	1×10^{-3}
27	Lighthouse Nikodimsky	IEU-2M	9031	1991	650	U	800	1×10^{-3}

No	RTG location	RTG type	RTG number	Date of manufacture	RIT-90 power, W	RTG condition *	Distance to Atomflot, km	Probability of accident / year
28	Lighthouse Nikodimsky	Beta-M	224	1990	230	U	800	1×10^{-3}
29	ASMk Golets	IEU-1	13	1982	530 530 530 180 180 180	A	820	1×10^{-3}
30	SNZ Tolstik	IEU-2	55	1981	580	U	850	1×10^{-3}
31	ASMk Unsky	IEU-2	71	1982	580	U	850	1×10^{-3}
				Total	18518			

* Notes:
A – RTG is in 'accident state', not completed; it is essential to perform a preliminary examination and works according to a separate regulation to install a radiator and a protective package or to reload RIT-90 from RTG to the transport container as well to execute the special permit for transportation;
U – RTG is in satisfactory state;
TO – it is essential to perform a preliminary examination and a procedure of execution of the special permit for transportation.

RTGs of REU-3-2K type are planned to be dismantled and delivered to VNIITFA without the further transportation to PO Mayak. It is conditioned by the fact that the design of this type of RTG does not allow for final disposal of radionuclide sources installed in it according to the technological procedure in force at PO Mayak. To do this, the development and approval of a special regulation will be needed.

2.1. Transport schemes of RTG delivery to the point of loading in a special wagon

2.1.1. Delivery of RTG, items 1-15, 19, 21-25 (Table 2)

The main requirements for the areas of interim storage of RTG: they must provide the safe hop of a helicopter and RTG loading by a ship crane.

The dismantled RTGs from the areas of interim collection along the coast of the Kola Peninsula should be transported by helicopters as it is very difficult to use for this purpose other transportation modes. Once the examination shows that a certain RTG is defined as a radiation B(U) package, it is subject to the following procedure. First, the flight line is approved. Then the RTG is equipped with the buoy, which would allow for locating it in case of the accidental drop above the water surface, and attached to the external carrier arm of the helicopter. The distances of transportation of RTGs by helicopter from locations to the areas of temporary collection should not exceed 150 km.

In case RTGs are carried by helicopter to the reserve pad, afterwards they are transported to the pad at FSUE Atomflot by batches of 10-12 units by a special vessel of the Hydrographic department of Northern fleet. To carry out transfer of RTGs to the pad at FSUE Atomflot a special wagon is used into which RTGs are loaded by 10-12 units.

2.1.2. Delivery of RT, items 16-18, item 20 (Table 2)

RTGs (items 16-18 and 20) from the warehouse of the department of radiation, chemical and biological protection of Northern fleet in the settlement Roslyakovo are planned to be transported using the following arrangements:

- a special wagon with a transport container of UKT1V-(IEU-1) type and required equipment supplied by VNIITFA arrives to the area of the warehouse;
- the container and the equipment is unloaded from the wagon to the truck and delivered to the working pad where RIT-90 from two damaged (in bad condition) RTGs is reloaded to the transport container (cask);
- the container and the equipment is taken by the truck-mounted crane are taken from the truck and made serviceable;
- according to previously developed and approved regulation, reloading of RIT-90 from two damaged RTGs, Beta-M 255 and 256, stored at the warehouse of Northern fleet is carried out to the delivered from VNIITFA certified transport container UKT1V -(IEU-1) by VNIITFA staff with participation of personnel of the department of radiation, chemical and biological protection of Northern fleet;
- the transport container UKT1V -(IEU-1) is changed over to transport position and after determination of transport category (it should be no higher than III) and surface contamination by radioactive substances, it is loaded to the special vehicle and delivered to the special wagon to install thereto.

Two remaining damaged RTGs, Beta-M 259 and 227, are completed with equipment delivered from VNIITFA *in situ* by VNIITFA staff to make them serviceable in conformity with requirements to radiation packages B(U) of III transport category according to the certificate/permit for the packed RTG Beta-M (No.RU/09N/T with effective date 18.07.2006). Completed RTGs are loaded to the special vehicle, delivered to the special wagon and reloaded in it.

The special wagon is transferred to FSUE Atomflot for loading other RTGs sent for decommissioning.

2.1.3. Delivery of RTG, items 26-31 (Table 2)

RTGs from operational locations along the coast of the White Sea (items. 26 -31 in Table 2) will be delivered according to the following arrangements.

- A special vessel will be used for collection and transportation of RTGs from their locations. Each RTG is delivered to the ship using a scow. A vessel should be anchored at a close and safe distance from the point of RTG loading on the scow.
- The RTG is delivered to the scow from coastline by helicopter or technological equipment and devices (rolls, decks, pinch bars, ropes, jacks and the like). Once the RTG is loaded on the scow, it is planned to equip the RTG with a buoy to locate it in the event of the ship sinking. The RTG from the scow is reloaded on the vessel by the ship crane. RTGs are placed and attached in the bilge or on the deck, in the most remote place from the areas of continuous or temporal residence of the crew. It is feasible to install 10-12 RTGs on board of one vessel. One by one all RTGs are loaded on the vessel.

Further two options are possible. First option consists in transfer of the vessel from the area of the White Sea to the Kola Bay to the pier of FSUE Atomflot, where RTGs are loaded to the temporary storing pad or directly to the special wagon.

According to the second option, the vessel goes to the pier of FSUE Zvezdochka (Severodvinsk, Archangelsk region), where RTGs are reloaded (probably, with storage on the special pad) from the vessel to the special wagon.

Particular emphasis should be placed on the damaged RTG located on Golets Island. To deliver it to the collection pad a special transport package intended for localisation of the damaged RTG IEU-1 ASMk Golets, with the required equipment supplied by VNIITFA, will arrive to Archangelsk region in the special wagon (or special truck). Further, the special transport package (with equipment and fittings) is reloaded from the wagon to the truck, delivered to the location of a helicopter, and using the latter is delivered to ASMk Golets.

In compliance with the developed and approved regulation, at ASMk Golets RTG IEU-1 is installed in the transport package by VNIITFA staff with participation of personnel of the operator. After placing RTG in the special transport package, determination of transport category (it should be no higher than III) and surface contamination by radioactive substances is carried out, then the package is brought to the transport position. The special transport package with RTG IEU-1 is carried by helicopter to the coastline for loading on the scow.

2.2. Transport scheme of delivery of RTG to FSUE PO Mayak

1. After loading to the special wagon on the interim storing pad at FSUE Atomflot (or FSUE Zvezdochka) RTGs are transported to the depot of FSUE V/O Isotope (settlement Staraya Kupavna, Moscow region). Special wagon for RTG transportation are delivered by FSUE Special switching service depot of Minatom of Russia. Transportation is performed by the RF Ministry of Transport Routes. RTG for transportation is accepted by the representative of VNIITFA who will escort the cargo. At the depot FSUE V/O Isotope the special wagon is unloaded; RTGs are loaded to the special vehicles and delivered to VNIITFA. Work is performed by FSUE V/O Isotope.
2. Unloading of RTGs from vehicles, interim storage of RTGs, RTG dismantlement with separation of radionuclide heat sources (RIT), placing RIT in technological containers to temporary store or in transport containers for transportation by railway to PO Mayak, loading of transport containers on special vehicles to deliver to the depot of FSUE V/O Isotope. All this work is performed by FSUE VNIITFA.
3. Transportation of containers with RIT-90 by special vehicles from FSUE VNIITFA to the depot of V/O Isotope, unloading from vehicles, loading of containers to the special wagon for transportation to PO Mayak. This is all performed by FSUE V/O Isotope.
4. Transportation of containers with RIT-90 in the special wagon to the PO Mayak. Transportation is carried out by the RF Ministry of Transport Routes. Special wagons are supplied by PO Mayak. RTGs intended for transportation at the depot FSUE V/O Isotope are accepted by the representative of PO Mayak who will escort the cargo.
5. Unloading of containers with RIT at PO Mayak, interim storage of containers, unloading RIT from containers, placement of RIT for long-term storage (first stage of RIT final disposal) under conditions totally identical to those of long-term storage of nuclear industry high-level vitrified waste. This work is performed by FSUE PO Mayak.

3. Characterisation of stages of work and radiological consequences in RTG decommissioning

3.1. Delivery of RTG by helicopter to the temporary collection pad

Delivery to the RTGs to temporary collection pad in the area of the Kola Bay will be carried out by helicopter of MI-8 type due to the difficulties in using any alternative transportation facilities and relatively long distances. It concerns RTG items 1-15, 19, 21-25 (see Table 2). Transportation of RTGs will be performed individually on the external carrier arm as B(U) packages according to III Transport category along the approved flight lines. The relevant permission (decision 04-05 dated 29.07.2005) was approved by Deputy Head of the Federal Agency of Atomic Energy S.V. Antipov and Acting Director of the Federal Agency of environmental, technological and nuclear supervision A.B. Malyshev.

Preparatory activities for transportation of the indicated RTGs are performed by a 6-men crew delivered by helicopter to the location of RTG. Members of the crew on land in the location dismantle the RTG with special tools, attach it to the external carrier arm of the helicopter. Labor input is estimated by experts as ~ 20 man-hr. As these RTGs are in satisfactory (not damaged) condition, so in accordance with GOST 18696-90 "Radionuclide thermoelectric generators: types and general technical requirements", EDR at a distance of 1 from the RTG surface should not exceed 0.1 mSv/hr (10 mrem/hr). Since all relatively long assembling work will be performed approximately at this distance from RTG, the calculated population dose (PD) received by workers in preparation of RTGs for transportation will be:

$d_{pop} = 6 \times 3 \times 0.1 \times 10^{-3} = 1.8 \times 10^{-3}$ man Sv (per RTG).

In this case population dose received by workers in preparation of RTG for transportation of 21 RTGs is:

$D_{pop} = 21 \times d_{pop} = 21 \times 1.8 \times 10^{-3} \approx 0.038$ man Sv.

In case of emergency in transporting RTGs associated with its drop on solid or soft rock we assume that the damage will be similar to that in accidental drop of RTGs of Efir-MA type with RIT-90 having activity ~ 4.3×10^{15} Bq by parent strontium-90 from the height ~ 100 m, described in the act 16-T-2004 of 21/09/2004. A level of gamma radiation as a consequence of damaged shielding at a distance of 2 m from the damaged RTG is ~ 0.8 mSv/hr. In approximation of point source, a maximum EDR at a distance of 1 m would be ~ 3.2 mSv/hr, i.e. EDR from a damaged RTG at a distance of 1 m is approximately 30 times higher as compared to that stated by GOST and NRB-99.

In this case detection, repair, packaging and preparation for transportation by helicopter will take ~ 36 man-hr, and if work is performed at a distance of ~ 1 m from the damaged RTG, the population dose for the crew will amount to:

D_{pop} (accident) = $6 \times 6 \times 3.2 \times 10^{-3} \approx 0.12$ man Sv (per damaged RTG).

In case of RTG dropping in the sea, as it is readily apparent from EIA, personnel will not receive any dose.

In calculation of consequences of potential radiation accidents in transportation of RTGs for decommissioning, it is advisable to take as a main index of risk a population dose received by personnel (and population).

A probability of helicopter accident in transportation of RTGs to the pad of interim storage at Atomflot is calculated for each RTG in conformity with the route of its delivery as well as with the value $P_{hel} \approx 1.0 \times 10^{-4}$ (year×km)$^{-1}$ and the length of the route. The relevant data are presented in Table 2.

3.2. Delivery of damaged RTG from the warehouse with radiation, chemical and biological protection of Northern Fleet in the settlement Roslyakovo

Delivery of damaged RTG items 16-18, 20 (see Table 2) from Roslyakovo is planned to be carried out in the special wagon with the transport container type UKT1V-(IEU-1). The special wagon with necessary equipment and fittings arrives at the territory of the warehouse. Further, container, equipment and fittings by the special truck are delivered to the working area where RIT-90 is reloaded from two damaged RTGs to the transport container. In compliance with the developed and approved regulation, reloading of two RIT-90-230 from two damaged RTGs of Beta-M type, items 16 and 18 (factory numbers 255 and 256) stored at the depot of Northern fleet, is carried out in the delivered VNIITFA certified transport container (see above), which after determination of transport category (not higher than III) and surface contamination by radionuclides, is loaded into the special truck, delivered to the special wagon and loaded in it.

Two other damaged RTGs, Beta-M items 17 and 20 (factory numbers 259 and 227), are completed with equipment delivered from VNIITFA *in situ* by VNIITFA staff to make them serviceable in conformity with requirements to radiation packages B(U) of III transport category (according to the decision 04-05 of 29.07.2005, see above). Completed RTGs are loaded to the special vehicle, delivered to the special wagon and reloaded in it.

The special wagon is moved to FSUE Atomflot for loading other RTGs sent for decommissioning.

The assessed value of risk in management of damaged RTGs (items 16-18,20), in this case the population equivalent dose received by personnel in repair, packaging and preparation for transportation of all damaged RTGs is calculated using the same scheme as above, but with correction for activity of RIT-90 located in these RTGs. It concerns RTGs items 17 and 20.

For RTGs, from which RIT-90-230 (items 16 and 18) are retrieved resulting with no biological shielding in EDR at a distance of 1 m equal to ~ 1.8 mSv/s, the operation of reloading RIT-90 in the container should be performed fast and accurately, so that population dose received by personnel in this accident situation would not exceed an annual limit of 100 mSv stated in NRB-99. To do this, two men are enough (one for each RIT-90-230), while the time of each operation should be limited to 50 s, or much less, if they use a remote tool ~ 500 mm long.

A total value of population dose in management of damaged RTGs (items 16-18 and 20) in this case will amount to:

D_{pop} (accident) = 4×0.12 + 2×0.10 ≈ 0.48 + 0.20 ≈ 0,68 man Sv.

A probability of radiation accident in transportation to the accumulation pad of 4 damaged RTGs by the special wagon has been calculated in accordance with the route of transportation to FSUE Atomflot, using the value $P_r \approx 1.8\times10^{-8}$ $(year\times km)^{-1}$ and the length of the route. Considering that the distance from Roslyakovo to the pad at Atomflot is ~ 20 km, it is $(p_i) \approx 3.6\times10^{-7}$ per trip of the special wagon.

3.3. Delivery of RTGs, items 26-31, from the White Sea to the pier of FSUE Atomflot

A special vessel will be used for collection and transportation of RTGs from their locations on the coastline of the White Sea (items 26-31, Table 2). Each RTG is delivered to the ship using a scow. A vessel should be anchored at a close and safe distance from the point of RTG loading on the scow.

Each RTG is delivered to the scow from coastline by the 6-men repair crew using either the helicopter or technological equipment and devices (rolls, decks, pinch bars, ropes, jacks and the like).

Once the RTG is loaded on the scow, it is equiped with a buoy to locate it in the event that the ship sinks. The RTG from the scow is reloaded on the vessel by the ship crane. RTGs are placed and attached in the bilge or on the deck, in the most remote place from the areas of continuous or temporal residence of the crew. It is feasible to install 10-12 RTGs on board of one vessel.

According to the basic option, the vessel with RTGs goes from the White Sea to the Kola Bay to the pier of FSUE Atomflot where RTGs are loaded to the temporary storing pad or directly to the special wagon. This option is discussed in the report. Other options are also possible (for example, the vessel goes to the pier of FSUE Zvezdochka (Severodvinsk, Archangelsk region), where RTGs are reloaded to the special wagon which later is either delivered directly to the station Staraya Kupavna (Moscow region) or is joined to the train which carries in special wagons RTGs from FSUE Atomflot to a junction. Other options are also possible.

From the above mentioned RTGs, only one is in an ‘accident state’ (IEU-1 13, item 29 in Table 2). It is RTG of IEU-1 type located on Golets Island. It is equipped with six RIT-90, three of them have heat capacity 530 W, other three – 180 W. To repair it and deliver it to the collection pad, a special transport package is needed with the required equipment, fitting and repair team to be delivered to Archangelsk region in the special wagon (or special truck), unloaded from the wagon to the truck, delivered to the location by helicopter and using the latter delivered to Golets Island.

In compliance with the developed and approved regulation, at ASMk the Golets RTG IEU-1 is installed in the transport package by VNIITFA staff with participation of personnel of the operator. After placing the RTG in the special transport package determination of transport category and surface contamination by radioactive substances is carried out and then the package is brought to the transport position. The special transport package with RTG IEU-1 is carried by helicopter to the coastline for loading on the scow and subsequently to the special ship.

A total activity of RIT-90 in the accident IEU-1 is ~ 13.5×10^{15} Bq by parent strontium-90. With consideration for total activity of radionuclides strontium-90 + yttrium-90 and a level of its damage (see above), EDR at a distance of 1 m from the damaged RTG will run as high as ~ 10 mSv/hr.

In this case the population dose received by the members of team in repair, packaging and preparation of the RTG for transportation by helicopter is:

D_{pop1} (accident) = $6\times6\times10\times10^{-3} \approx 0.36$ man Sv (per one accident IEU-1).

Population dose received by personnel in preparation for transportation by helicopter or in delivery of the remaining (not-damaged) 4 RTGs to the scow is (see above):

$D_{pop2} = 4\times d_{pop} = 4\times1.8\times10^{-3} \approx 0.0072$ man Sv.

A total value of population dose received by personnel in preparation for transportation of this group of RTGs case will amount to:

$D_{pop} = D_{pop1} + D_{pop2} \approx 0.37$ man Sv.

A probability of accident of the special vessel during transportation by sea to the pier to the interim storing pad for RTGs at FSUE Atomflot, for this route, is taken as ~ $P_w \approx 1.5\times10^{-3}$ (see [8]). Note that the length of this route (~ 850 km) is approximately equal to the length of the route between Stockholm and Cape de La Hague (France) along which SNF is delivered by sea from Sweden for reprocessing. The relevant data are given in Table 2.

3.4. Delivery of RTG to VNIITFA for dismantlement and RIT-90 to PO Mayak for subsequent storage and disposal

After loading 10-12 RTGs to the special wagon on the pad of the interim storage at FSUE Atomflot, the units are transported to the depot of FSUE V/O Isotope in the settlement Staraya Kupavna, Moscow region. The special wagons for transportation of RTG are delivered by FSUE special switching service depot of the Federal Agency of Atomic Energy.

For transportation of 31 RTGs, three trips of the special wagons will be needed for the route: the pad of interim storage at FSUE Atomflot – Staraya Kupavna. The length is ~ 2012 km.

A probability of a severe radiation accident connected with the total destruction of the special wagon has been calculated in accordance with the route of delivery to FSUE Atomflot, using the value $P_r \approx 1.8\times10^{-8}$ $(\text{year}\times\text{km})^{-1}$ and the length of the route. With the length of the route Atomflot – Staraya Kupavna, ~ 2012 km, a probability of a severe accident (p_r) will be $\approx 3.6\times10^{-5}$ for one trip of the special wagon.

At the depot of V/O Isotope, RTGs are reloaded to the special trucks, delivered to FSUE VNIITFA for dismantlement and extraction of RIT-90 from them. Three trips by truck will be needed for unloading each single special wagon. The length of the route from the depot of V/O Isotope to VNIITFA is ~ 80 km (with allowance for movement along the road).

Once RIT-90 are retrieved from RTGs in the special chamber of VNIITFA, they are loaded to the special containers UKT1V, on which basis the packages B(U) are completed. Depending on capacity, it is possible to load 1-3 RIT-90. Containers with RIT-90 are again transported by the special trucks to the depot V/O Isotope and loaded to the special wagon to be delivered to PO Mayak. One special wagon accommodates 10 containers with RIT-90 of different radioactivity levels. To load one special wagon, three trips by truck are needed. Therefore, to transfer all RTGs from one special wagon to VNIITFA and deliver back RIT-90 in transport packages to the amount to fill one special wagon 6 trips will be needed. The length of each trip is ~ 80 km.

A probability of a severe road accident in these trips s calculated with the value of $P_a \approx 1.0\times10^{-5}$ $(\text{year}\times\text{km})^{-1}$ and the length of the route of transportation is $\approx 8.0\times10^{-4}$ (for one trip).

All RIT-90, retrieved from 31 RTGs, can be transported by special wagon in three trips. The subsequent work on unloading the containers with RIT-90, their long-term storage and disposal is performed by PO Mayak.

A minimum length of transportation by rail from the depot of V/O Isotope to PO Mayak is ~ 1830 km. In this case a probability of a severe radiation accident connected with the full destruction of the special wagon, can be obtained with the value $P_r \approx 1.8\times10^{-8}$ $(\text{year}\times\text{km})^{-1}$ and the length of the route is $\sim 3.3\times10^{-5}$ (for one trip of the special wagon).

The obtained data on probabilities of accidents in transportation of RTGs are used in the calculation of risk at separate stages of the RTG transportation. As an example, the route of transportation of RTGs is by road from the base “V/O Isotope” located at the railway station Staraya Kupavna to FSUE VNIITFA (for disassembling and extraction of RIT-90) and back. To unload one railcar three trips by truck are required. The distance from the base “V/O Isotope” to VNIITFA is ~ 80 km (considering movement along detour roads).

After extracting RIT-90s from RTGs in a special cell of VNIITFA, they are loaded into special containers UKT1V. Depending on activity, one to three RIT-90s.can be loaded into each type B(U) package. The containers with RIT-90s are again transported by special vehicles to the base “V/O Isotope” and loaded in a railway special wagon to be then delivered to PO Mayak. One special wagon takes 10 containers with RIT-90s of different activity levels. To load one special wagon three trips by truck will also be required. Thus, to transfer all RTGs to VNIITFA and transfer RIT-90s back, a total of ~ 18 trips by truck will be required over a total distance of ~ 1 400 km.

With allowance for the given above probability of heavy car accident in one trip, a probability of heavy car accident in transporting all RTGs will amount to $P_a \approx 8.0\times10^{-4} \times 18 \approx 1.4 \times10^{-2}$ year^{-1}.

Calculation of consequences of heavy car accident with inflammation of the transportation facility and damage of RTG, presented in Section 1, demonstrated that collective dose received by personnel and firemen (D_{coll}) would be $\approx 2.4\times10^{-3}$ man Sv.

Assuming that radiation effect on personnel in the accident is one-time, and all members of the team and firemen (8 men) received similar doses, the calculation of life-long risk using the value (r_E) provided in NRB-99, equals 5.6×10^{-2} $(\text{man Sv})^{-1}$. Then a value of additional collective life-long risk (i.e. probability of reduction of duration of life) (R) for personnel in case of the accident will be:

$$R = P_a\times r_E\times D_{coll} = 1.4 \times10^{-2}\times5.6\times10^{-2}\times2.4\times10^{-3} \approx 1.9\times10^{-6}\ \text{year}^{-1}.$$

It is possible also to consider other options of the transport arrangements for RTG delivery. For instance, one of the options consists in dismantling the not-damaged RTGs located on the coast of the Barents Sea (items 1-15, 19 and 21-25), loading using the scow to the special ship and finally deliver them to the pier of the collection pad at FSUE Atomflot. To do this two trips of the special vessel will be needed, however, in that option the number of flights by helicopter from RTG locations to Atomflot will be significantly reduced.

A complete picture of formation of collective doses and risks with due allowance for all steps of RTG dismantlement is created with the help of a software. Results of calculation performed using the software complex ASM SZMA are presented in Section 4.

4. Development of functional integrity arrangement (FIA) of RTG transportation to decommissioning and calculation of risks

In calculation of reliability and risks of the arrangement of transportation of RTGs to disposal, software complexes (SC) SZMA and ASM 2001 [10,11] have been used and developed by the organisation Sevzapmontazhavtomatika and currently at the stage of certification in COEP at RNC Kurchatovsky institute.

Development of the scheme of functional integrity assessment (FIA) was based on the first option of transportation scheme (TS) to deliver RTGs to dismantlement at FSUE VNIITFA and later to disposal at PO Mayak illustrated in Figure1.

FIA shown in Figure 1 is based on intensity of trouble-free operation of elements at all stages of RTG transportation. It is compiled in conformity with the general logical-probabilistic method [9] on the basis of initial events presented in Table 2. As initial events (IE) FIA use potential accidents in transportation of RTGs, including in preparation for transportation (particularly, in dismantling, repair, placing in the transport packaging set for damaged RTG), loading on the transportation facility and during proper transportation to the collection pad at FSUE Atomflot and further along the transport scheme. Henceforth FIA with the data from Table 2 has been used for calculation of indexes of reliability and risk analysis for the whole scheme of RTG transportation and its individual steps.

The numbers of initial events in form of large-sized numbered circles in the FIA diagram correspond to those in Table 2 and are defined as functional peaks. Logical (fictitious) peaks (small-sized numbered circles) are results of logical interaction between elements. Arrows entering in the fictitious peak denote a logical action "OR" (disjunction), and points – logical action "AND" (conjunction). An inverse output from peaks ("NOT" or negation) corresponds to the change of the result of logical interaction to the opposite one (in more detail in [9]).

The logical criterion of operation (LCO) in [9-11] is taken to mean an index of reliability, which characterises the result of logical interaction between elements of FIA (for example, peak 47 in Figure1 corresponds to trouble-free operation of FIA of the whole transport arrangement of delivery of all RTGs to PO Mayak, while peak 34 – trouble-free delivery of all RTGs to the collection pad at FSUE Atomflot and so on). As LCO, we can use a probability of trouble-free operation of the transport system or an intensity of system failure (if FIA is based on failures and as initial events were chosen failures of elements). The choice of LCO is conditioned by the type of specific FIA, convenience of calculations and presentation of their results and a number of other factors.

Figures 2-6 show a diagram of positive contribution of elements in the probability of trouble-free operation at different stages of RTG transportation. It is worthwhile to explain that in the general logical-probabilistic method a positive contribution of the element presents a contribution of *i*-th element to the probability of trouble-free operation of the real system in case of its assured failure:

$$\beta_i^+ = \left(P_F(t)\Big|_{p_i(t)=1} \right) - P_F(t) \, .$$

SC SZMA and ASM 2001 allow for calculating also the significance of individual elements of the RTG transportation system, the negative contributions of the elements as well as risk indexes (depending on the extent of consequences of accidents for each element of arrangement of RTG transportation to decommissioning). Significance of i element means a difference between significance of probabilistic characteristic of the system with absolute reliability of element i and that with its assured failure, i.e.:

$$\xi_i = \left(P_F(t)\big|_{p_i(t)=1}\right) - \left(P_F(t)\big|_{p_i(t)=0}\right), \quad i = 1,2,...,H$$

Here $P_F(t)\big|_{p_i(t)=1}$ is the value of probabilistic characteristic of system with absolute reliability of element i, and $P_F(t)\big|_{p_i(t)=0}$ is the assured failure of element i within the considered interval t of time of operation.

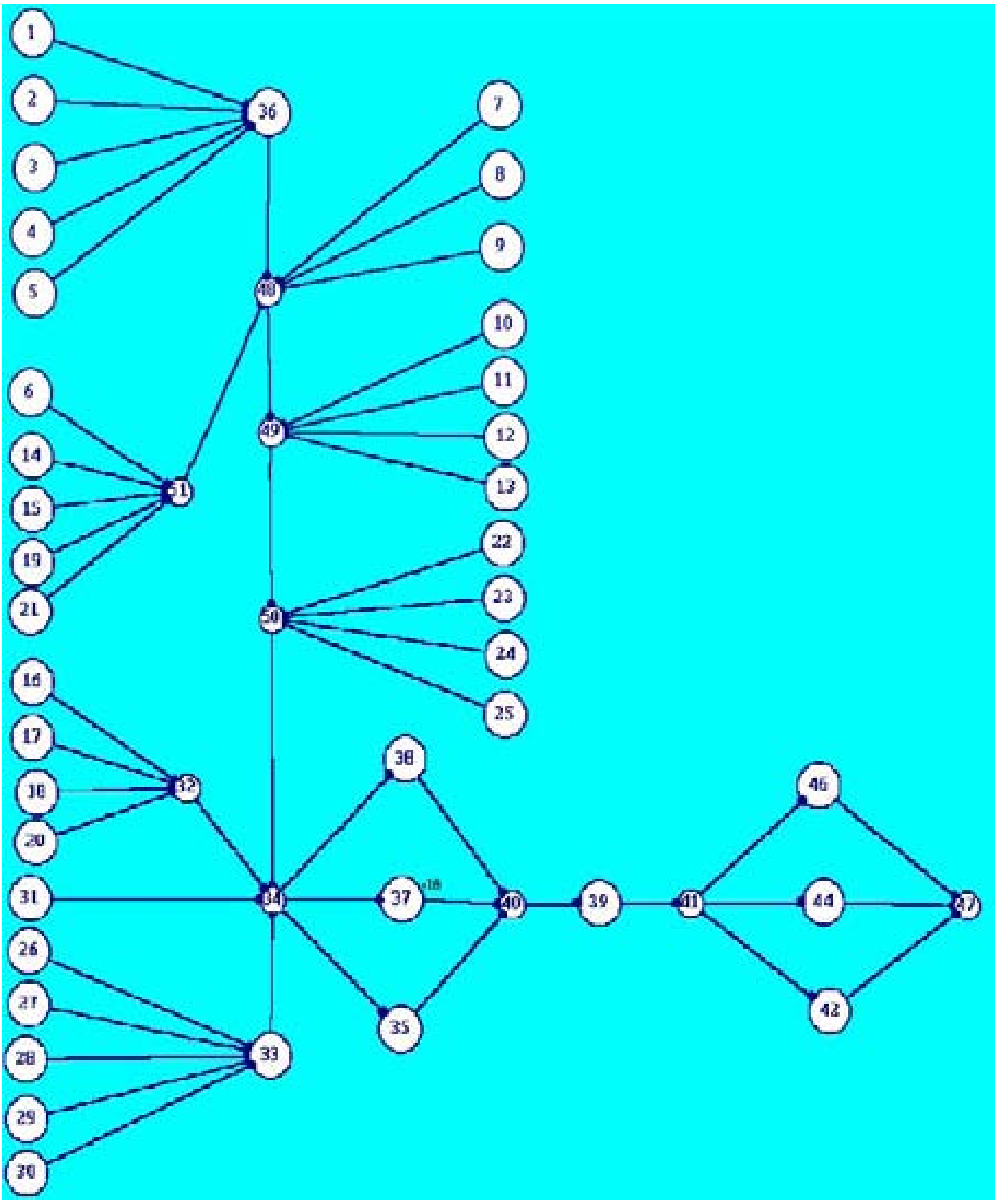
A negative contribution of the element presents a contribution of *i*-th element to the probability of failure of the real system in case of its assured failure (if element failures are taken as IE in construction of FIA):

$$\beta_i^- = -\left(P_F(t) - \left(P_F(t)\big|_{p_i(t)=0}\right)\right)$$

In SC SZMA and ASM (2001) using the operation of inversion, it is easy to move from one FIA based on trouble-free work of elements to another FIA, which is based on failures, and vice versa.

The results of calculation in form of a report, which includes the automatically derived logical function (LF), probabilistic function (PF), static probability of annual trouble-free operation as well as full operating time, characteristics of elements of system as a whole (significances, positive and negative contributions of elements and systems to indexes of system reliability and others) in form of a table, may be displayed on screen and printed out. The calculated results are partially illustrated in Figures 2-6.

Figure 1. *FIA for transport scheme of RTG delivery for decommissioning. Numbers of initial events (IE-1-IE-31) correspond to RTG numbers in Table 2.*



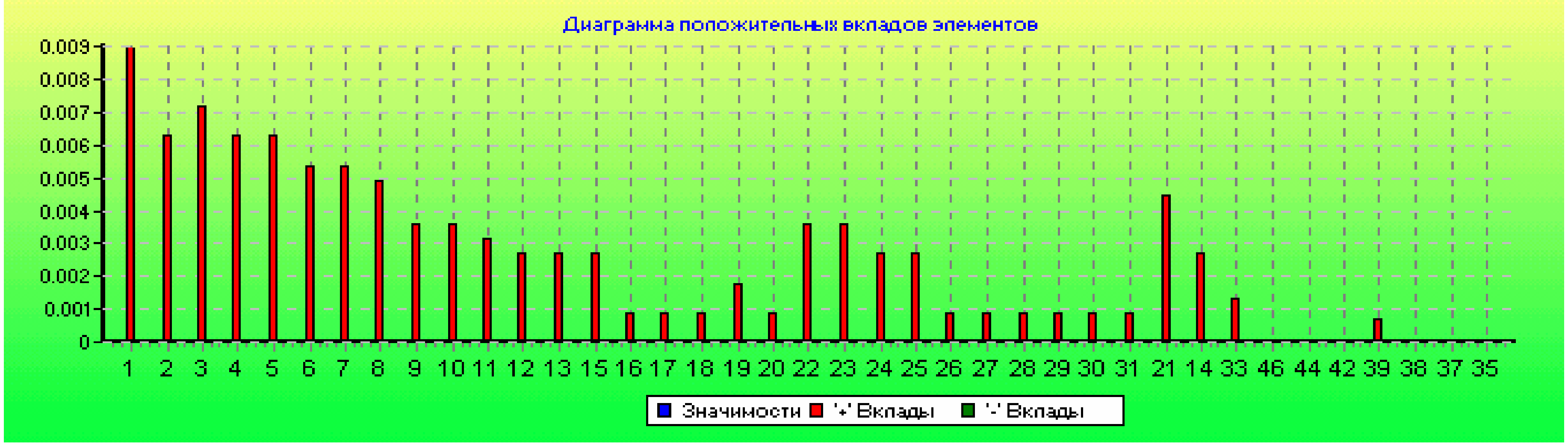


Figure 2. *Positive contribution of transport scheme (TS) elements to probability of its trouble-free operation (P_c). For peak 47 $P_c \approx 0.8924$ /year.*

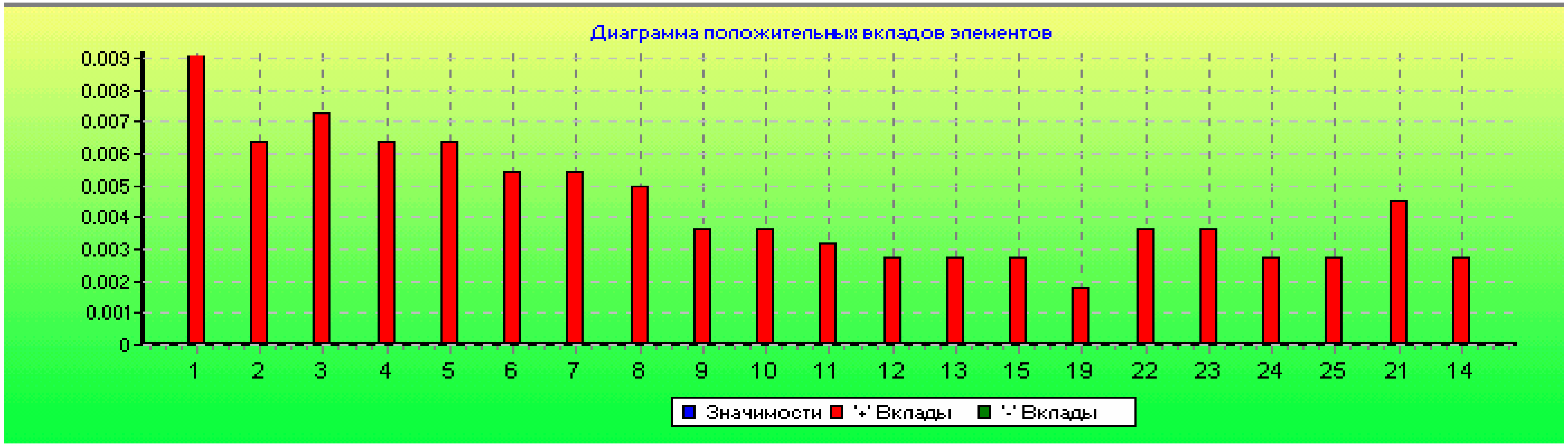


Figure 3. *Positive contribution of TS elements for peak 50, probability of trouble-free operation Pc≈ 0.9037 / year.*

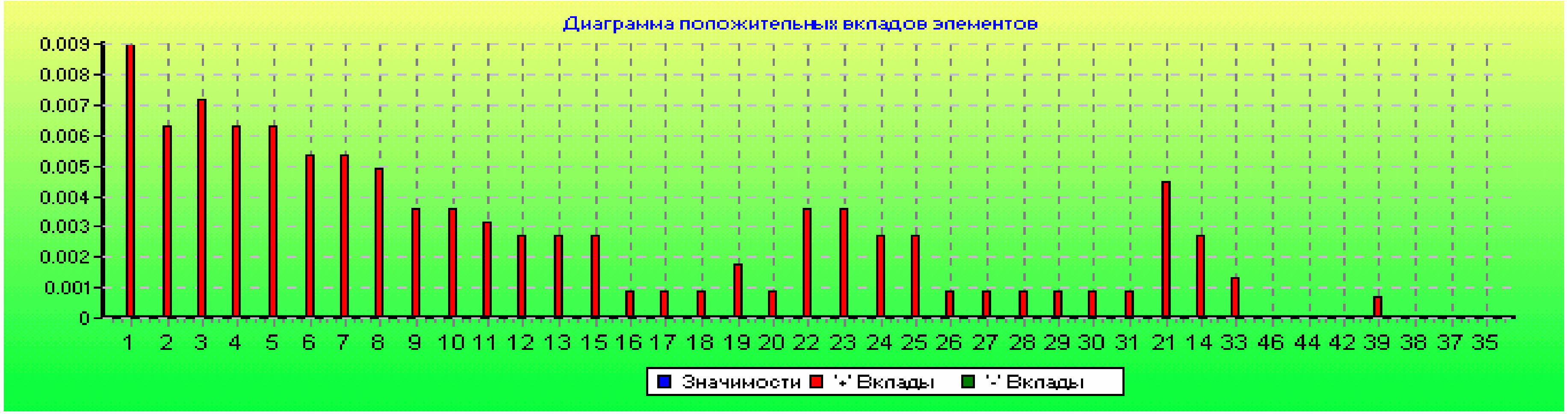


Figure 4. *Positive contribution of TS elements for peak 34, probability of its trouble-free operation* $P_c \approx 0.8934$ */ year.*

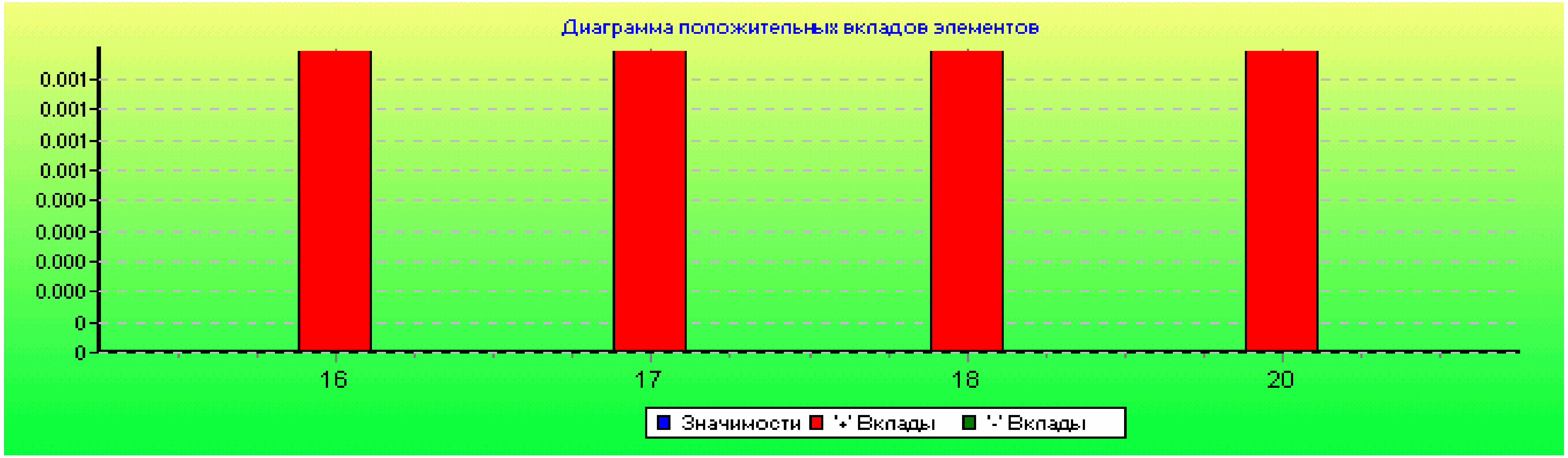


Figure 5. *Positive contribution of TS elements for peak 32, probability of its trouble-free operation* $P_c \approx 0.9960$ */ year.*

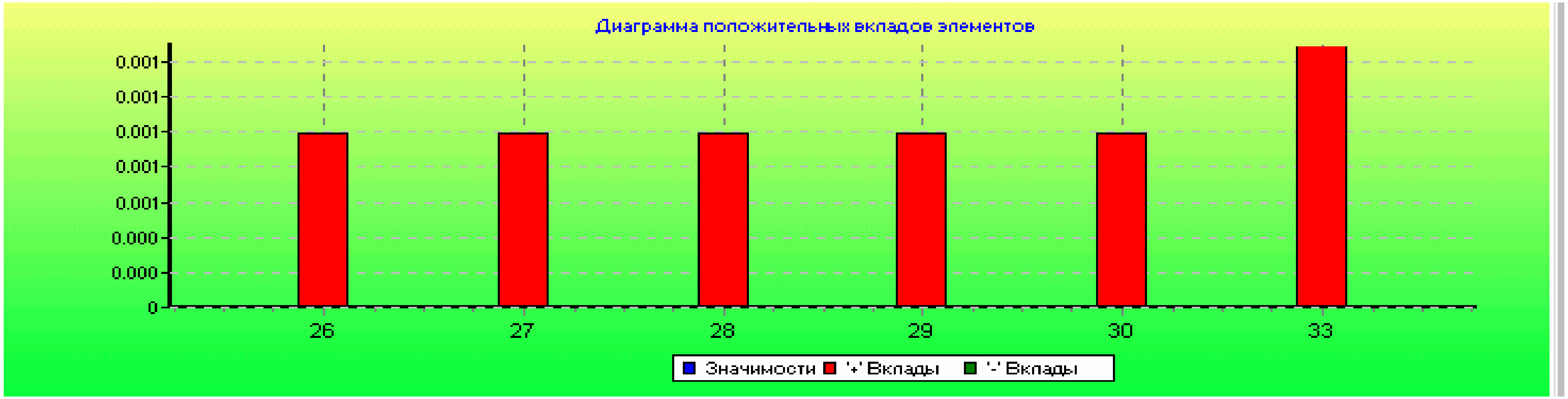


Figure 6. *Positive contribution of TS elements for peak 33, probability of its trouble-free operation* $P_c \approx 0.9935$ */ year.*

Table 3. *Events connected with direct participation of people. Coefficient of life-long risk (r_E) is taken in accordance with NRB-99 for personnel $r_E = 5.6\times10^{-2}$ (man Sv)$^{-1}$.*

No.	Operations of RTG management	Probability of accident, hr^{-1}	PD, man Sv		Collective risk	
			in normal conditions	in emergency	in normal conditions	in emergency
O1	Preliminary examination of RTG with life service exceeding 25 years	1×10^{-4}	1.8×10^{-3}	0.06	1.0×10^{-4}	3.4×10^{-3}
O2	Completion of accident containers and placement to transport container	6×10^{-4}				
O3	Attachment of container on carrier arm of helicopter	1×10^{-4}				
O4	Unloading from carrier arm of helicopter	1×10^{-4}				
O5	Loading on scow	3×10^{-4}	2×10^{-3}	0.12	1.1×10^{-4}	6.7×10^{-3}
O6	Loading on vessel and unfastening	3×10^{-4}				
O7	Unloading from vessel	3×10^{-4}	2×10^{-4}	0.06	1.1×10^{-5}	3.4×10^{-3}
O8	Loading to special wagon	3×10^{-4}	4×10^{-3}	0.12	2.2×10^{-4}	6.7×10^{-3}
O9	Unloading from special wagon	3×10^{-4}	4×10^{-3}	0.12	2.2×10^{-4}	6.7×10^{-3}
O10	Loading to special truck	5×10^{-4}	1×10^{-3}	0.032	5.6×10^{-5}	1.8×10^{-3}
O11	Unloading from special truck	5×10^{-4}	1×10^{-3}	0.032	5.6×10^{-5}	1.8×10^{-3}

Table 4. *Events connected with RTG transportation*

No. FIA peak	Arrangement of transportation to collection pad	Probability of accident / year	PD, man Sv		Risk	Additional Risk
			in normal conditions	in emergency	in normal conditions	in emergency
50	Transportation by helicopter	0.0964	0.06	0,18	$3,4\times10^{-3}$	$9,7\times10^{-4}$
32	Transportation by rail from Roslyakovo	0.0040	0.70	0,82	$3,9\times10^{-2}$	$1,8\times10^{-4}$
33	Transportation by special vessel from the White Sea	0.0065	0.37	0,49	$2,1\times10^{-2}$	$1,8\times10^{-4}$
34	Delivery to RTG collection pad at Atomflot	0.1067	1.13	1,49	$6,3\times10^{-2}$	$8,9\times10^{-3}$

From FIA presented in Figure1, it may be thought that in the first option of transport arrangements the majority of RTGs is delivered by helicopters to the collection pad at Atomflot. This method of transportation is the most dangerous in terms of accident and contributes most significantly in failure-proof character of the entire transport arrangements (it is shown by the value of contribution of peak 50 to peak 34, which corresponds to delivery of all RTGs to the collection pad). In so doing, contributions in trouble-free delivery of each RTG by helicopter primarily depend on the distance of transportation (it is illustrated in Figure3).

As all RTGs transported by helicopter are not in 'accident state', i.e. damaged, so population dose received by personnel in dismantlement and loading is the smallest among all remaining methods of delivery, and adds up to ~ 0.038 man×Sv (see above), but at the same time it provides a maximum risk due to a high probability of accident (see Table 4). Contributions of other methods of delivery of RTGs (by rail from Roslyakovo – peak 32, by sea from the White Sea – peak 33) are considerably smaller even with consideration for a possible sinking of the ship in transition from the White Sea to Murmansk (peak 33).

The consequences in form of population dose received by personnel in dismantling, repair and loading of damaged RTGs on the collection pad from Roslyakovo are more serious than in other cases and amount to ~ 0.70 man×Sv and in case of delivery of RTG from the White Sea (including the accident unit from island Golets) – 0.37 man×Sv.

From diagrams of positive contributions of elements of RTG transportation arrangements to the static probability of trouble-free operation shown in Figures 2-7, it may be deduced that this index of reliability and trouble-free operation mostly depends on the following elements of transport arrangements:

- delivery of RTG by helicopters from the coast of the Kola Bay to the collection pad at Atomflot (peak 50);
- delivery of RTGs (including the accident unit from island Golets) from the coast of the White Sea by scow to the special vessel and subsequent transportation to the collection pad at Atomflot (peak 33).

Risk assessment of the discussed methods of delivery of RTGs to the collection pad at Atomflot demonstrates (see Table 4) that the greatest risk is related to delivery of RTGs by helicopters, because in this case we deal with the greatest probability of accidental damage to the RTGs, in spite of the fact that PD received by personnel and population in potential emergency at this stage of transportation is the smallest one. The next risk is the delivery of damaged RTGs from Roslyakovo to the collection pad by rail. It is related to a low probability of railway accident and short length of the route, though PD in repair and preparation of damaged RTGs for transportation is the biggest. The smallest risk is associated with the delivery of RTGs (including the accident unit from island Golets) by the special ship from the White Sea.

Taking into account the absence of other methods of delivery but by rail and by truck to VNIITFA for RTG dismantlement and PO Mayak for disposal of RIT, no detailed calculations of population doses and risk were performed at this stage of work. However, preliminary assessment shows that the risk of accident in these cases will not exceed the relevant values obtained for the stage of RTG transportation to the pad at FSUE Atomflot. Preliminary assessments also demonstrate that replacement of helicopter delivery of not-damaged RTGs from the coast of the Kola Peninsula by two trips using the special vessel is able to reduce significantly the probability and the risk of potential radiation accident.

4. Conclusion

Evaluation of the transport and technological scheme and the relevant preliminary assessments of the level of risk for all stages of RTG decommissioning allows for concluding that:

- maximum population doses received by personnel in dismantling, repair, loading and delivery of RTG may take place in management of damaged RTGs from Roslyakovo and from Golets Island;
- highest additional risk corresponds to delivery of RTGs by helicopters;
- lowest additional risk corresponds to delivery of RTGs from the White Sea by special vessel; and
- replacement of helicopter delivery of not-damaged RTGs from the coast of the Kola Peninsula by two trips using the special vessel is able to reduce the level of additional risk.

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B-2. Analysis of Russian methodologies and software (Deliverable D4)

Introduction

A lot of systems being integral parts of nuclear power sites (NS) such as RTG with their infrastructure are characterised by large scale (a big number of elements) and high structural complexity. It considerably complicates, and often renders impossible an application of conventional manual (not automatic) technologies for probabilistic assessment of such important properties as reliability, safety and NS operational risk. Thus in recent years in a number of developed countries software means are actively developed to provide a possibility of using new information technologies of automatic simulation and calculation of probabilistic indexes of reliability, safety and operational risk of various structurally complicated and large-scale systems, among them sites where nuclear power is in use.

This work presents a brief comparative analysis of theoretical foundations of construction and potential application in assessment of safety and risks for human beings and the environment of there software complexes (SC). These listed below SCs have been certified (acknowledged) by the state regulatory body and are intended for automatic structural simulation and calculation of probabilistic indexes of reliability, safety and operational risk of various structurally complicated and large-scale systems:

1. "Risk Spectrum" developed by the company Relcon AB (Sweden) and widely used in nuclear industry for probabilistic NPP safety evaluation [1 – 4, 10];
2. "Relex" developed by the company "Relex Software" (USA) and widely used in different countries in evaluation of reliability of complicated technical systems [5-7, 10];
3. "SC ASM SZMA" developed by the company OAO SPEC SZMA (Russia) for automatic structural and logic simulation and calculation of reliability and safety of structurally complicated systems of different types, classes and purposes [8 - 10].

Applicability indicated the PC to such complicated objects of use of an atomic energy, as NPP, proves, that they are applicable practically to anyone NS, including to RTG. All three PCs are intended for account of parameters of non-failure operation and nonaccidental at all stages of the circulation with NS. The knowledge of these parameters is completely necessary for account of emergency risk for health of staff and population at all stages of salvaging RTG, including for want of transportation RTG by any methods, as just the origin of radiation failure has a probability character. There, where for the analysis of risk there is enough of deterministic parameters (for example, of individual or collective dozes) as principle it is possible to manage and without knowledge of probability of failures, but from our point of view of such approach is not complex.

This work has been performed by specialists of OOO RECcentre with participation of experts from FSUE SPbAEP (St. Petersburg), V.A. Trapeznikov IPU RAN (Moscow) and OAO SPEC SZMA (St. Petersburg).

1. Brief characterisation of SC Risk Spectrum

Methodology of simulation and calculation of indexes of reliability and safety with SC Risk Spectrum is based on the apparatus of logical and probabilistic methods which use as means of construction of graphical models of safety (reliability) the event trees (ET) and the fault trees (FT)

An event tree implies a graphical model describing the logics of different options of an emergency process caused by an initial (initiating) event of the accident (IE).

In SC Risk Spectrum of ET is presented in form of a table containing a heading line, a field with an open binary graph (event tree itself), several columns with characteristics of end (top) states of an object under simulation which are accomplished in the process of the realisation of accidental sequences. The heading of the 1st column of the table indicates the designation of initial events (IE) (IE groups). Next headings of columns from left to right give names and conditional designations of intermediate events corresponding to successful or unsuccessful performance of safety functions, efficient or failed states of systems of safety or individual components (equipment and technical means), correct or erroneous actions of operators. In columns which define end states (ES) there are given numbers of ES, their conditional designations, probabilities of implementation, probably, logical formulae corresponding to specific accidental sequences (AS).

With accidental sequences ET shows the options of development of an accidental process (AP). Here AP implies a sequence of events leading to a certain end state of the object including initial state of the accident, successful or unsuccessful responses of safety systems and actions of operators (personnel) in the course of accident development.

Fault tree implies a graphical model representing the logics of events leading to non-realisation of a set function (fault) of the system through the advent of different combinations of equipment faults and operator's errors.

In construction of fault trees in the editor of FT SC Risk Spectrum seven types of logical operators are used:

Table 1

Logical operator type	**Meaning**: logical element is TRUE if
OR	At least one input event is TRUE
AND	All input events are TRUE
K-from-N (K/N)	At least K from N input events is TRUE
NOR (OR-NOT)	None of input events is TRUE (all input events are FALSE)
AND-NOT	Not all input events are TRUE (At least one input event is FALSE)
Nonequivalence (excluding OR)	One input event is exactly TRUE

A maximum number of inputs and restrictions of K meaning depend on a possible memory volume and a full size of the fault tree. K/N-logical elements are extended to an equivalent number of OR - / AND - logical elements.

Apart from above logical elements, there is another, additional logical operator, which may be used in fault trees: NOT - operator. It can be thought as a logical "inventor". NOT - operator may be used in every nod in the fault tree which contains the primary event or external condition. A symbol of NOT – operator in Risk Spectrum is a little circle, but above the nod. NOT – operator influences logics in the following manner:

In the current version of Risk Spectrum negative logics is processed as "pseudonegative logics". It means that the added (refused) events are processed in the following manner in MCO – studies.

Table 2

Event in nod	**Nod (input of logical element)**
TRUE	FALSE
FALSE	TRUE

- Any set of cross-sections containing mutually exclusive events is eliminated. Such set of cross-sections cannot take place because mutually exclusive events cannot occur simultaneously.
- Added (completed) events are not included in sets of minimum cross-sections made in MCO-analysis, i.e. MCO contain only fault events and not any successful events.

SC Risk Spectrum allows for calculating the following values: unavailability, average unavailability, probability of fault, frequency of faults of system under investigation.

If a value of unavailability is constant with time, its value is equal to a value of average unavailability.

If a component or a system are non-recoverable, unavailability is equal to probability of fault.

The developers of Risk Spectrum employ terms “unavailability” and “unreliability” both for recoverable and non-recoverable components. In scientific and technical literature the term “unavailability” is usually employed just for recoverable components while “unreliability” is used for non-recoverable components.

The same holds for the term “frequency” for recoverable and non-recoverable components. In literature, the term “frequency of faults” is used only for non-recoverable components while “unconditional intensity of faults” is used for recoverable components.

The term “frequency” is used in Risk Spectrum by two slightly different methods:

1. As a type of parameter which may be used in one of the models of primary event. This model is named from the parameter, as this is a unique parameter in this model, i.e. we have a “model of primary event of frequency type”. In this case, “frequency” refers to the value which is constant in time. Actually, this is a parameter of Poisson fault flow.
2. Initial event in ET quite often is represented by Poisson process. Conventionally, in description of probabilistic parameters of initial events the term “frequency” is used. The most common unit of time used for this type of frequency is “number of events per year”.

Parameters of “frequency” and a type of “frequency” of primary events (type 5) are intended to use only for this type of event.

An expected number of occurrences of faults per time unit is calculated for upper event in time dependence analysis. It is also called “unconditional intensity of fault”.

2. Brief characterisation of SC Relex

Software complex Relex comprises 8 modules:

- Reliability Prediction;
- Maintainability Prediction;
- FMEA/FMECA;
- Reliability Block Diagram;
- Fault Tree/Event Tree;
- Markov Analysis;
- Weibull Analysis;
- Life Cycle Cost.

SC Relex may form from an arbitrary number of interacting and sharing the common base modules:

- Reliability prediction module comprises models for calculation of indexes of reliability elements. It contains an extensive database (~300,000 names) with classification features of elements and characteristics of reliability. Calculations are performed according to standards: MIL-HDBK-217, Telcordia (Bellcore) TR-332, Prism, NSWC-98/LE1, CNET93, HRD5, 299B.

- Maintainability prediction module meets the requirements of the standard on investigation of system maintainability - MIL-HDBK-472. It is aimed at solution of problems of prediction of preventive maintenance.
- FMEA/FMECA module. Analysis is carried out in conformity with standards MIL-STD-1629, SAE ARP 5580 and others. Dangerous faults are ranked and assessed on a basis of risk priorities.
- Reliability block diagram module is used for analysis of complicated reserved systems. It comprises both analytical and Monte Carlo methods.
- Fault Tree/Event Tree module. It employs procedures of deductive and conductive analysis of progression of faults and events progression within the system. It is used for evaluation of reliability and safety. The module contains an extensive set of logical and functional peaks.
- Markov analysis module. Markov simulation of reliability, efficiency, safety, risks. Starting from version 7.7, Markov processes with profits are added. It allows for taking into account complicated operating modes, different types of faults, specificities of maintenance.
- Weibull module. It is intended for processing statistics of tests and operation. A large spectrum of distributions is supported.
- Economic calculation (LCC) module. Life cycle cost is assessed at all stages of system construction, operation and decommissioning. Economic indexes of resource prolongation are assessed. It has a built-in formula editor which allows for implementing specific economic standpoints.

Modules have a visual editor to specify the model of the system under evaluation directly on screen. Customised reports, plotting and macros languages are possible**.** The system is fully documented, it has a well-developed Help. SC has a built-in master of exporting/importing initial data to/from text files, spreadsheets, databases, BOM files.

We dwell on two software modules of Relex complex which directly solve the problems of analysis of reliability and safety of structurally complicated systems.

2.1. Module of reliability block diagrams

Module of reliability block diagrams (RBD) is intended for investigation in reliability and working capacity of reserves, recoverable systems with arbitrarily laws of distribution of random error-free running times and element recovery. Computing unit of the module performs calculation of reliability, availability and efficiency values by analytical methods and statistical Monte Carlo simulation with acceleration.

In calculation of reliability and working capacity in RBD it is possible to consider for the following factors:

- type of reservation (constant, by replacement, varying);
- probability and time of successful introduction of reserve;
- state of reserve (connected or disconnected);
- mechanism of fault occurrence;
- different recovery strategies;
- availability of spare parts and equipment, routine maintenance and check-ups.

RBD work results in calculation of the following values:;

- probability of trouble-free work;

- mean time between failures;
- intensity of system faults;
- availability (fixed, non-fixed);
- parameter of fault flow;
- mean number of faults;
- mean time between failures;
- efficiency etc.

To calculate complicated, yet decomposable systems, in RBD the units can be inserted one into another in the event tree, in other words, every unit can be represented by other RBD, a number of inserted units is limited only by volume of working memory. Interaction of RBD with other Relex modules is carried out by linking units with relevant items (element or assembly from Reliability Prediction module, item of ABOSC module, fault tree item).

Starting from version 7.6, Relex RBD has a possibility to solve the optimal problems of reliability: determination of a number of reserve elements maximising the values of reliability/efficiency or minimising the cost of system; definition of optimal periods of routine maintenance and check-ups.

Version 7.7 is added by a new type of block diagrams – phase diagrams used for simulation of system reliability which operating time may be split into stages (phases), each of them is characterised by its duration, values of intensity of failed elements, reliable structure.

2.2. Fault tree module

Fault tree module (FT) is intended for investigation of system reliability and safety. Module Relex FT is free from shortcomings and limitations of classical fault trees owing to introduction of new logical-dynamical operators (peaks) considering for dependence of events, temporal relationships, priorities. The table below gives a list of peaks and events implemented in Relex.

Table 3

Name of peak	Description of peak
AND	logical AND
OR	logical OR
NAND	logical AND-NOT
NOR	logical OR-NOT
NOT	logical NOT
VOTING (k/n)	⇒ m/n voting (majority selection)
INHIBIT	logical AND with inhibiting entry (inhibiting AND)
XOR	excluding OR
PRIORITY AND	priority AND (dynamic operator)
FDEP	considers dependencies between events and temporal order
SPARE	considers state of reserve, particularly, connection
SEQ	considers sequence of event occurrence

Module of fault tree of Relex provides also simulation with common elements in different tree branches and with common reasons of faults. To account faults by common reason several models are employed (in literature they are called: β-factor model, MGL-model, α-model, BFR model).

Newly introduced operators, common elements and common reasons allow for considering in the model many peculiarities inherent to occurrence of dangerous consequences, and also technical, algorithmic, organisational measures to ensure safety.

Module calculates the following indexes:

- probability of fault;
- unavailability;
- parameter of fault flow;
- mean number of faults.

Values of indexes are calculated both for top event and for each intermediate event.

Moreover, for each highlighted event (both top and intermediate) sets of relevant minimum cross-sections can be looked through and evaluated.

If the fault tree is too big, in order to accelerate calculations one can make an approximate assessment without significant reduction of precision. It is achieved by restriction of the number of cross-sections under consideration, ignoring cross-sections with low probability, using methods of cross-sections summation, restricting a number of intersections, Ezary-Prosshan.

It is also possible to compare a relative significance of different events by methods of Birnbaum, criticality, Fussel-Wesely.

Fault trees are integrated with the remaining modules of Relex. Any event of tree can be related with

- elements and assemblies of reliability prediction module;
- types of faults from FMEA/FMECA;
- graph of transitions from Markov Relex;

The tree itself may be related to units of the module Relex RBD.

3. Characterisation of SC ASM SZMA

A theoretical basis of technology of automatic structural-logical simulation is a **general logical-probabilistic method** (GLPM) of simulation and computation of reliability, survivability and safety of structurally and qualitatively complicated system objects and processes [3-5]. In GLPM of calculation of reliability the apparatus of mathematical logics is used for primary graphical and analytical description of conditions for implementation of functions by individual elements and group of elements in the system under design, while the methods of probability theory and combinatorial analysis are applied for a quantitative estimate of reliability and/or danger of operation of the designed system as a whole. For GLPM to be applied there should be specified special structural schemes of functional integrity of investigated systems, logical criteria of their operation, probabilistic and other parameters of elements.

The basis of the definition and solution of all problems of simulation and computation of reliability of systems using GLPM is a so called event/logical approach. It provides a consecutive fulfillment of the four following stages of GLPM:

3.1. Stage of structural-logical definition of the problem

The basic content of the stage of definition of problems for application of SC ASM SZMA is characterised by the following diagram.

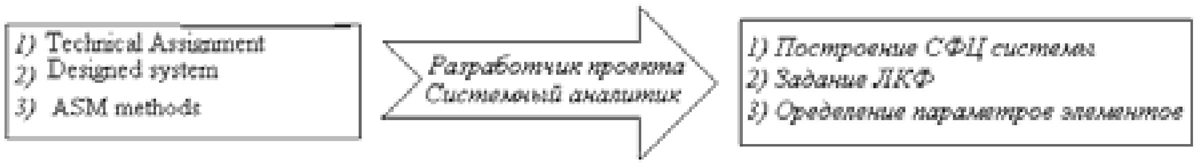

Fig.1. *Contents of the stage of definition of problems within ASM technology*

At this first stage of ASM technology the following basic actions are performed:

- the entire system under consideration is divided into a finite number of H elements, $i = 1, 2, \ldots H$, each of them is presented in the reliability model by a prime (binary) event x_i with two possible states $\tilde{x}_i = \{x_i, \bar{x}_i\}$, for instance, working capacity/failure, availability/unavailability, destruction/non-destruction, etc. and the given probabilistic parameters $p_i(t)$ or $q_i(t) = 1 - p_i(t)$;
- determination of content and logical conditions of realisation y_i and/or non-realisation $\bar{y}_i$ of output functions for each element in the system;
- logically strict verbal and graphical (analytical) description of a set of X individual elements of the system and a set of conditions Y of their realisation of system functions which in population $G(X,Y)$ form a special *functional integrity scheme* (FIS) of the system under consideration;
- logically strict description and specification with individual or group output functions *logical criteria of operation* (LCO) of the system $Y_F = Y_F(\{\tilde{y}_i\}, i = 1,2,\ldots,N)$ of implementation of basic functions and/or occurrence of dangerous states of the system.

A main part in the definition of the problems of automatic structural-logical simulation of reliability is played by construction of schemes of functional integrity for each given output function of the system under design. Graphic means and typical fragments of FIS are shown in the figure below.

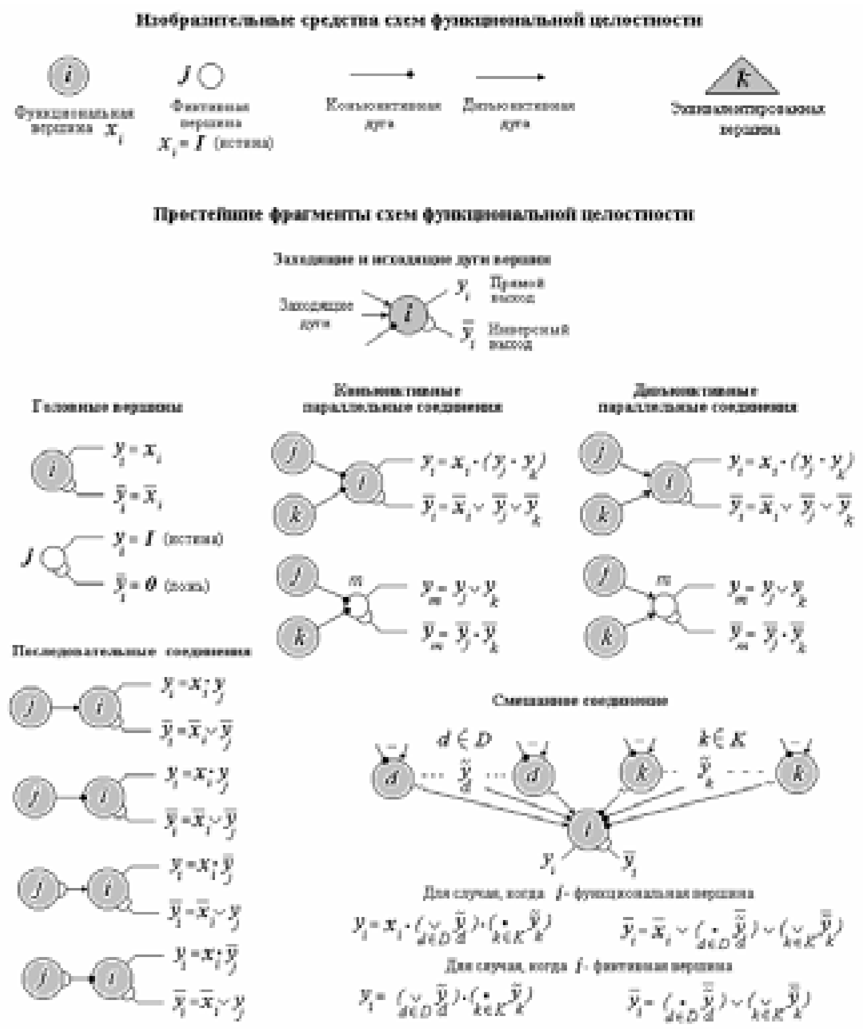

Fig.2. *Apparatus of schemes of functional integrity of GLPM*

The main creative work in the definition of the problem and analysis of results of design calculation of reliability is carried out by a designer and a system analyst. They describe logically the system under design, construct FIS for each of its main subsystems and functions, define parameters of element reliability, set logical criteria of realisation of functions, analyse results of computations, elaborate and implement design solutions and prepare the report.

Initial data for definition of the problem is prepared by the designer in a free, however, logically strict form of description of organisational and technical methods and means for provision of reliability of he system under design. It includes a description of functional structure of the system, its basic functions and accidental situations, composition and parameters of element reliability. There should be formulated (in text and/or in graphic form) conditions in fulfillment of which every element realises its functional purpose in the system.

A final formalised definition of the problem is performed by the system analyst. Based on the description of the system received from the designer, he constructs schemes of functional integrity for each of its functions, sets logical criteria of operation, fixes parameters of reliability for elements and makes more precise a list of calculated indexes of reliability of the system.

In the technology of automatic structural-logical simulation only the first stage of structural-logical definition of the problems of assessment of reliability, safety and risk of complicated systems is performed manually. The stages of construction of logical functions of system working capacity FSWC, polynomials of probabilistic function (PF) and performance of calculations of indexes in ASM technology are implemented automatically using SC ASM SZMA.

3.2. Stage of logical simulation

This figure illustrates a general scheme of solution of the problem of definition of logical FSWC in SC ASM SZMA.

Fig.3. *Diagram of stage of definition of logical FSWC*

At this stage using special methods of transformation of FIS and LCO, a logical function of system working capacity (FSWC) $Y_F = Y_F(\{\tilde{x}_i\}, i = 1,2,...,H)$ is built. Logical FSWC permits to define in a compact form and an analytically strict manner all combinations of states of elements $\tilde{x}_i, i = 1,2,...,H$, in which (and only in them) it realises its output function F (reliability, availability, failure-proofing or fault, unavailability, occurrence of emergency, etc.).

In SC ASM SZMA the problem of logical simulation is solved by software modules of the library LOG@PF [12]. Here initial data is FIS of the system under consideration and what is termed logical criterion of operation

$$Y_F^* = Y_F(\{y_i, \bar{y}_i), i = 1,2,...,N)$$

Hereinafter a letter *F* denotes the operating mode of the system, a system property of reliability or safety under investigation, or one of a host of input functions with which this property is related.

LCO is defined as a Boolean function without brackets which arguments are designations of output integrative functions of those peaks of FIS, which in this totality represent the property of reliability or safety of the system at hand. LCO is set by the user after FIS has been built, just before start of solution of the problem SC ASM SZMA.

In the "fault tree" technology, a prototype of LCO is a notion of "upper event" [1-4]. LCO gives to the user more wide possibilities for specifying different problems, as using it one can define a great variety of system events (working capacity, fault, safety, occurrence of emergency situation, level of efficiency, risk, availability, unavailability, etc.) both of the system being studied and different structural fragments and subsystems thereof.

A procedure of definition of logical FSWC is based on special methods and software for solution of a system of logical equations presented by FIS for any given LCO [11]

$$\left.\begin{array}{ll} СФЦ: & G(X,Y) \\ ЛКФ: & Y_F^* \end{array}\right\} \Rightarrow ФРС: \quad Y_F = Y_F(\{x_i, \bar{x}_i\}, i = 1,2,...,H).$$

A logical FSWC automatically formed in SC ASM SZMA may represent a full plurality of the shortest ways of successful operation (minimum cutting-off combinations [13]), minimum cross-sections of faults (minimum transmitting combinations [13]), as well as their different non-monotonic combinations. Every FSWC also exactly and unambiguously matches up a set of states of the system at hand, in which (and only in them) it represents the given logical criterion of operation. In an event sense FSWC is an accurate and unambiguous mathematical description of that complicated random event which probabilistic features are the desired quantitative estimate of properties of reliability or safety of the system under study and/or its various fragments and subsystems.

Contrary to classical LPM, in GLPM it is a common practice to interpret a notion of logical FSWC in a wide sense. That is FSWC, depending on the type of FIS and LCO, may represent not only working capacity or safety, but also failures or accidents of the system at hand, as well as its different non-monotonic combinations.

3.3. Stage of probabilistic simulation

This figure shows a general scheme of definition of polynomial of computed probabilistic function in SC ASM SZMA.

Fi

g.4. *Diagram of stage of definition of polynomial PF*

At this stage using special methods of transformation of FSWC [14], the polynomial of computational probabilistic function (PF) $P_F(\{p_i(t),q_i(t)\},\ i=1,2,...H;t)$ is constructed. Polynomial PF allows for defining in an analytically strict fashion a law of distribution of time of trouble-free operation of the system on a basis of realisation of output function F set by logical criterion of operation.

Construction of a rated polynomial of probabilistic function is performed in SC ASM SZMA by a special routine of the library LOG@PF [12]. With it, the logical FSWC of the system being studied< which was achieved at the previous stage, is directly transformed to the computing polynomial of probabilistic function

$$Y_F(\{x_i,\bar{x}_i\}, i=1,2,...,H) \Rightarrow P_F(t) = P_F(\{p_i,q_i\}, i=1,2,...,H;t)$$

In the library LOG@PF of SC ASM SZMA a program of construction of polynomial of probabilistic function is based on what is termed a combined method of transformation of logical FSWC to polynomials PF [14].

3.4. Stage of performance of computed indexes

A generalised diagram of the closing stage of calculation of probabilistic indexes in SC ASM SZMA is given in the figure below.

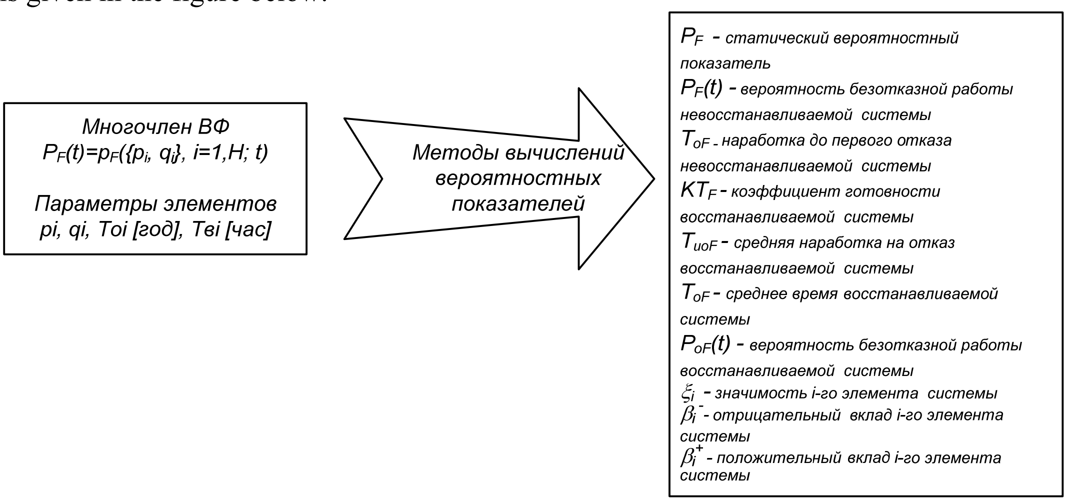

Fig.5. *Diagram of the stage of calculation of probabilistic indexes in SC ASM SZMA*

On the right of this figure are given the typical probabilistic values calculated in SC ASM SZMA for assessment of reliability and safety of the system. Let us consider them separately.

3.4.1. Calculation of statistical probabilistic indexes of the system

In order to perform statistical calculations in SC ASM SZMA at the stage of definition of the problem there should be specified in an explicit form the probabilities of outcomes p_i, $i=1,2,...H$ of all elementary events represented in FIS system by functional peaks. A significance of these probabilities is defined by the index of SC ASM SZMA in the course of development of FIS system. These could be probabilities of trouble-free operation or failure of elements, their availability or unavailability, probabilities of response or non-operation to request and the like. After downloading these parameters and initiation of solution of the problem SC ASM SZMA (on a basis of polynomial PF and given static parameters of elements) performs calculation of the relevant static probability P_F of the system at hand as a whole. The significance of this characteristic corresponds to a type of FIS prepared by the user, and always determines the probability of realisation of the set logical criterion of operation of the system.

3.4.2. Calculation of probability of trouble-free operation of unrecoverable system

Non-recoverable are thought to be system objects in which in the time interval of operation under study t all elements $i=1,2,...H$ are able to fail independently with an intensity $\lambda_i = 1/T_{oi}$ [1/year], but none of them recovers after fault.

Initial data for calculating this value in SC ASM SZMA are as follows:

- polynomial $P_F(t)$ of function of probability of trouble-free operation of the investigated mode F of operation of the system under study;
- numerical values of mean time before failure T_{oi} of all elements $i=1,2,...H$ of the system in years;
- time t of system operation (full operating time) in hours.

First SC ASM SZMA carries out calculations of probabilities of trouble-free operation and failure of all elements of the system for exponential law of time distribution of their trouble-free operation

$$p_i(t) = e^{-\frac{1}{T_i}t};$$
$$q_i(t) = 1 - p_i(t).$$

Substituting analytical expressions (15) in polynomial PF, we obtain the law of distribution of time of trouble-free operation of the system by realisation of the function F. On the basis of this polynomial SC ASM SZMA performs calculations of probability $P_F(t)$of trouble-free operation of the system for the given full time t.

3.4.3. Calculation of mean time between failures of unrecoverable system

Analytical solution of this problem is associated with pin-pointing the integral of polynomial $P_F(t)$ of probabilistic function of reliability of the system:

$$T_{oF} = \int_0^\infty P_F(t)\,dt;$$

If polynomial $P_F(t)$ is presented in an explicit form (without using parameter $q_i(t)$), then this integral for exponential law of time distribution of trouble-free operation of elements is taken directly in a general form, and the appropriate computing formula of mean time before first failure of the system is

$$T_{oF} = \sum_{j=1}^{M} (çí_j) \frac{1}{\sum_{i \in K_j} \frac{1}{T_{oi}}}$$

Here M — number of monomials in a direct form of polynomial PF, $(çi_j)$ - sign before j-th monomial and K_j - set of numbers of elements i, which parameters $p_i(t)$ enter in the j-th monomial.

3.4.4. Calculation of availabilities of elements of recoverable system

There are also considered such recoverable systems where all elements, $i=1,2,...H$, can independently fail with a given intensity $\lambda_i(t) = \lambda_i = const$ and indefinitely recover (i.e. change-over to state of efficiency) with a given intensity of recovery $\mu_i(t) = \mu_i = const$.

In SC ASM SZMA reliability of elements in the recoverable system is characterised by two parameters

$$T_{oi} = \frac{1}{\lambda_i}; \quad T_{âi} = \frac{1}{\mu_i}.$$

Here T_{oi} - is called a full time of recoverable element. It is equal to a mean time of element' operation between adjacent failures. For the exponential law it is equal to a mean time of operation before the first failure of an unrecoverable element. Parameter $T_{âi}$ defines a mean time of recovery of the failed element.

As a generalised initial parameter of reliability of the recoverable element we can use its availability which is equal to

$$\hat{E}\tilde{A}_i = \frac{T_{oi}}{T_{oi} + T_{âi}} = \frac{\mu_i}{\lambda_i + \mu_i}$$

We can speak about the following significances of availability. First, its value determines that mean proportion of time ($\hat{E}\tilde{A}_i \cdot t$) from the full time t, within which the element is efficient, i.e. fulfils its functions in the system. Within the remaining time $(1 - \hat{E}\tilde{A}_i) \cdot t$ the element is in failure, i.e. being recovered. On the other hand, availability is equal to probability of event – to find the recoverable element i in any moment t of its efficient operation. Similarly, unavailability $1 - \hat{E}\tilde{A}_i$ is equal to probability of finding the element at any moment in its inoperative state (fault, recovery). For the admitted assumptions this probability is independent of time and is constant within the entire period of operation of the object (except a short initial transitional period).

3.4.5. Calculation of availability of recoverable system

In SC ASM SZMA system availability is calculated on a basis of polynomial of probabilistic function P_F and two types of reliability parameters of all elements:

- mean operation before failure T_{Oi} [year];
- mean recovery time T_{Bi} [hour].

Thereafter SC ASM SZMA automatically calculates values of availability of elements $p_i = \hat{E}\tilde{A}_i$, and based on polynomial PF computes a value of availability $\hat{E}\tilde{A}_{\mathrm{F}}$ of the system. This value is calculated both for monotonic and non-monotonic models of system objects under study.

Constraints: This procedure of calculation of $\hat{E}\tilde{A}_{\mathrm{F}}$ is rightful under assumption of independency of faults and unlimited recoveries of all elements of the system under study.

3.4.6. Calculation of mean full time and mean recovery time of the system

Availability is the most popular, unfortunately, far from complete characteristic of reliability of the recoverable system. Thus, in particular, knowing only $\hat{E}\tilde{A}_{\mathrm{F}}$ does not allow for defining such important characteristics as mean time between failures $T_{\hat{i}\hat{i}F}$, mean recovery time $T_{\hat{a}F}$ and probability of trouble-free operation $P_{\hat{a}F}$ of the recoverable system.

In SC ASM SZMA for calculation of the above values the well-known and new approximated analytical methods [28, 29] are applied:

$$\grave{O}_{\hat{i}\hat{i}F} = \hat{E}\tilde{A}_F * \left(\frac{1}{\sum_{i=1}^{H} \frac{\partial \hat{E}\tilde{A}_F}{\partial \hat{E}\tilde{A}_i} * \lambda_i * \hat{E}\tilde{A}_i} \right)$$

$$\grave{O}_{\hat{a}F} = (1 - \hat{E}\tilde{A}_F) * \left(\frac{1}{\sum_{i=1}^{H} \frac{\partial \hat{E}\tilde{A}_F}{\partial \hat{E}\tilde{A}_i} * \lambda_i * \hat{E}\tilde{A}_i} \right)$$

3.4.7. Calculation of probability of trouble-free operation of recoverable system

Calculation of this characteristic is based on the following assumptions:

Probability of trouble-free operation of recoverable system is a characteristic of event of occurrence of the first, even very short failure of the system as a whole;

Random time prior to advent of the first failure of the recoverable system is distributed according to the exponential law with the parameter

$$\lambda_{\acute{Y}} = \frac{1}{T_{\hat{i}\hat{i}F} + T_{\hat{a}F}}$$

In this case the appraised calculation of probability of the first failure of the recoverable system is performed to the well-know formula for exponential law

$$P_{\hat{a}F}(t) = e^{-\lambda_{\acute{Y}} t} = e^{-\frac{1}{T_{\hat{i}\hat{i}F} + T_{\hat{a}F}} t}$$

Constraints: Indexes $T_{\hat{i}\hat{i}F}$, $T_{\hat{a}F}$ and $P_{\hat{a}F}$ are calculated in SC ASM SZMA only for straightforward monotonic models of efficiency of recoverable systems. Availability (or unavailability) is calculated for all kinds of monotonic and non-monotonic models.

3.4.8. Calculation of probabilistic characteristics if mixed systems

Mixed systems are those where a part of elements is recoverable and another part of elements – unrecoverable. In SC ASM SZMA as an index of reliability of such system probability of availability of the mixed system $P\hat{E}\tilde{A}_{\text{F}}(t)$ [15] is calculated.

This index is calculated according to the following rules:

- for elements of the unrecoverable part of the system as probabilistic parameters, probabilities of their trouble-free operation $p_i = p_i(t) = e^{-\lambda_i t}$ or fault $q_i = q_i(t) = 1\text{-}p_i(t)$ are calculated;
- for elements of the recoverable part of the system as parameters their values of availability $p_i=K\Gamma_i$ and unavailability $q_i=1\text{-}K\Gamma_i$ are used.

Substituting these parameters in polynomial PF, SC ASM SZMA calculates probability of availability of the mixed system as a whole.

$$P\hat{E}\tilde{A}_{\text{F}}(t) = p(\{p_i(t), q_i(t), \hat{E}\tilde{A}_j, 1-\hat{E}\tilde{A}_j\}, i \in \text{N}, j \in W)$$

Here N is a set of numbers of unrecoverable elements, and W — a set of numbers of recoverable elements of the mixed system.

In physical terms, $P\hat{E}\tilde{A}_{\text{F}}(t)$ is a probability that by the end of the time t of operation of the system there exists at least one combination of states of efficiency of recoverable elements and trouble-free operation of unrecoverable elements, which ensures efficiency of this system as a whole. Therefore, by its definition, the characteristic $P\hat{E}\tilde{A}_{\text{F}}(t)$ steers a middle course between indexes of its availability $\hat{E}\tilde{A}_F$, if all elements are recovered, and a probability of trouble-free operation $P_F(t)$, if all elements are unrecoverable. At the same time, SC ASM SZMA calculates significances and inputs of all elements into the index of probability of availability of the mixed system.

3.4.9. Calculation of significances and inputs of elements

The basic version of SC ASM SZMA calculates three indexes of a role of elements in provision of reliability and safety of systems under study – significance, positive and negative contribution [15].

3.4.10. Calculation of significance of elements of the system

Calculation of the index of significance ξ_i of an individual element i of the system at hand is carried out in SC ASM SZMA on a basis of the following relationship:

$$\xi_i = P_F / p_i = 1 \; - \; P_F / p_i = 0 \quad , i = 1,2,...H$$

Where $P_F / p_i = 1$ - significance of probabilistic characteristic of the system with absolute reliability of element i, a $P_F / p_i = 0$ - with a plausible failure of element i within the interval under consideration t of time of operation. It means that:

- A value of significance ξ_i is exactly equal to the change in significance of the system characteristic P_F due to a change of proper parameter p_i from 0 to 1, and with fixed values of parameters of all other elements of the system;
- A range of values of probabilistic index of significance ξ_i is [−1, 0, + 1] inclusive;

- A negative value $\xi_i < 0$ characterises a harmful (decreasing), as it is called, influence of element *i* on probability of realisation of the given operating mode of the system. In this case, for example, an increase of reliability of the proper element *i*, evidently leads to decrease in reliability P_C of the system as a whole, and more precisely – of the mode of its operation being studied. Negative significances of elements innate to non-monotonic logical-probabilistic models of the systems;
- A zero value of characteristic of significance $\xi_i = 0$ indicates that this element *i* is insignificant for realisation of the considered operating mode of the system as a whole (element *i* is redundant, unneeded);
- A positive value $\xi_i > 0$ determines that maximum possible increase in reliability P_F of the system, which it can achieve with change of reliability of just one element *i* from zero to one inclusive;
- All elements of monotonic systems may have only positive or zero values of the characteristics of their significance;
- In case when processes of failures (or failures and recoveries) of all elements of the system are independent in the aggregate, significances (23) of elements of the system are equal to the relevant partial derivatives

$$\xi_i = {\partial P_F}/{\partial p_i}, \; i = 1,2,...H$$

3.4.11. Positive and negative contributions of elements of system

Along with characteristics of significance in SC ASM SZMA are calculated the indexes of positive β_i^+ and negative β_i^- contribution of all elements.

A positive contribution β_i^+ demonstrates how a system index P_F changes with modification of just one parameter p_i of element *i* of studied system from its current value p_i to 1.0

$$\beta_i^+ = P_F/_{p_i = 1} - P_F$$

A negative contribution β_i^- demonstrates how a system index P_F changes with modification of just one parameter p_i of element *i* from its current value (p_i) to 0.0, taken with the opposite sign.

$$\beta_i^- = -(\mathrm{P}_C - \mathrm{P}_C/_{p_i = 0})$$

Contrary to the index of positive contribution, in calculation of the index of negative contribution a compulsory change of sign is made in an effect that in all indexes of the role of elements the positive values of characteristics always mean an increase in P_F with appropriate changes of p_i from 0 to 1, for ξ_i, from p_i to 1, for β_i^+ and from p_i to 0 for β_i^-, and vice versa.

3.4.12. Account for stochastically dependent events

In SC ASM SZMA is possible to account for some types of stochastic dependencies between events of trouble-free operation and/or failures of groups of elements that may be correctly represented with the developed in GLPM apparatus of groups of inconsistent events (GIE). In so doing, certain laws of algebra of logic and rules of construction of polynomials of probabilistic functions. Thus if, for instance, direct outcomes of the group from two elemental events $x_l \cdot x_k = \mathrm{O}$ are inconsistent, new laws of algebra of logic and the relevant rules of calculation of probabilities are as follows:

$$\bar{x}_l \vee \bar{x}_k = I; \quad \bar{x}_l \cdot x_k = x_k; \quad x_l \vee \bar{x}_k = \bar{x}_k.$$

$$p\{\bar{x}_l \vee \bar{x}_k) = 1; \quad p\{\bar{x}_l \cdot x_k) = p_k; \quad p\{x_l \vee \bar{x}_k) = q_k;$$

$$p\{x_j \vee x_k) = p_l + p_k; \quad p\{\bar{x}_l \cdot \bar{x}_k) = 1 - (p_l + p_k).$$

Basic initial data for account for GIE in SC ASM SZMA are:

- attributes of combination of sets of elements in groups of inconsistent events;
- attributes of outcomes (direct and invert) of elemental events which are inconsistent in GIE;
- static probabilistic parameters of events as parts of GIE which are set with consideration for normalising condition

$$\sum_{l \in \tilde{A}\hat{I}\tilde{N}} \tilde{p}_l \leq 1.0$$

where $\tilde{p}_l$ — probabilities of summed inconsistent outcomes of all elements being part of GIE.

A number of groups of inconsistent events, used by SC ASM SZMA in one project is indefinite.

3.4.13. Account for proper operational time of elements

In SC ASM SZMA to each element of the system under study can be given a proper time $t_{\gamma i}$ of its operation (proper full time) and assigned an attribute “Consideration for time of operation of elements” on the panel of simulation and calculation mode. In this case SC ASM SZMA in calculating probabilistic-temporal characteristics of the system automatically accounts for the given proper time $t_{\gamma i}$ of operation of elements if it is less than the set common full time t of the system under study as a whole ($t_{\gamma i} < t$).

3.4.14. Use of multiple peak

SC ASM SZMA is able with any functional peak i to represent two standard types of subsystems comprising several single-type elements. For this purpose is used a special parameter "Multiple" (multiplicity) of functional peak of FIS. In SC ASM SZMA by default a value of this parameter is set equal to "0" implying that this element of the system is an ordinary (single) with specified proper (own) probabilistic characteristics. If this parameter of functional peak i is assigned a positive integer value $+K_R$, it means that the corresponding functional peak FIS represents a subsystem made from K_R single-type elements (with similar specified probabilistic parameters) functioning according to conjunctive logic (all elements are combined by logical operator "AND"). If a parameter of multiplicity of functional peak i is assigned a negative integer value $-K_R$, it means that a subsystem consists of K_R single-type elements (with similar specified probabilistic parameters) functioning according to disjunctive logic (all elements are combined by logical operator "OR").

The given multiplicity of elements in SC ASM SZMA is accounted for automatically by preliminary calculation of probabilistic characteristics of the relevant multiple subsystem application of these results in subsequent calculations of indexes of reliability or safety of the system under study as a whole.

3.4.15. Use of attributes of laws of element distribution

An attribute of the law of element distribution is set in the column "Law" of the table of element parameters. In the basic version of SC ASM SZMA it is designed to use only two values of this parameter:

- "**0**" – implies application of a static value of probabilistic parameter of the element (shown in column Pi of the table of parameters) in the mode of performance of probabilistic-temporal calculations;
- "**1**" – is set by default and implies application of exponential laws of distribution of time of trouble-free operation and time of element recovery in the mode of probabilistic-temporal calculations. Parameters of exponential laws of elements are set in columns ***Toi*** and ***Tвi*** of the table of element parameters.

4. Basic findings of comparative analysis of existing technologies and software for automatic simulation

Study in references [1-10] has shown that the most important, for all practical purposes, are the following lines of comparative analysis of technologies and software of automatic simulation and calculation of values of reliability and safety of structurally complicated systems:

- classes of problems to be solved;
- precision of simulation and calculations of system characteristics of reliability, safety and operational risk of systems under consideration;
- capabilities of graphical apparatus of representation of structural properties of reliability, safety and risk of systems;
- dimensionality of problems to be solved;
- selection of a basic technology of subsequent development of methods and tools of automatic simulation.

In our opinion, the most deep and justified are conclusions made by experts from SPbAEP, IPU RAN and OAO SPEC SZMA on the basis of their findings in comparative analysis of three software complexes used at present: Risk Spectrum (Sweden), Relex (USA) and SC ASM SZMA (RF). Therefore we present here an opinion of specialists from the above mentioned organisations given in [10].

4.1. Opinion of SPbAEP experts

1. All three compared software products conceptually used the same methodology of simulation implying a stage-by-stage construction of different kind models of reliability and safety:

- model formalisation by graphs of one or another kind;
- automatic transformation of graphical model in function of algebra of logic;
- automatic transformation of logical function in computing probabilistic polynomial (probabilistic function);
- performance of calculations of the required indexes of reliability and safety.

At the same time, this technology is differently implemented in practice that significantly affects the adequacy of obtained results.

2. The code Risk Spectrum represents a practically classical technology of formalised statement of simulation task using event tress and fault trees. There is no escape from sharing the opinion of SPK

SZMA experts that this technology has a number of shortcomings. The results of solution of above mentioned examples show that the graphical models of the same systems presented in form of fault trees are much more cumbersome than block diagrams and FIS. It also results in their relatively greater time consuming construction. It is conceivable that this circumstance has led to the situation where in the Relex code for graphical simulation both fault trees and block diagrams are used. In this context, the application of FIS apparatus which allows for simulating both straight and reverse logic of reasoning is more preferential.

3. Unfortunately, the code Risk Spectrum does not realise a possibility of using one of the basic logical operation – that of negation which reduces in the quality of obtained models. In other codes this possibility is realised, in Relex, among other things, in application of fault trees.

4. All three codes allows for obtaining automatically with the original graph a logical function of system efficiency. At the same time, ACM and Relex codes allow for obtaining automatically as well logical functions of efficiency that in some cases may be an important advantage.

5. ACM code provides transformation of logical function into probabilistic function, which is represented in an orthogonal disjunctive normal form excluding a loss of precision in probabilistic calculations. In Risk Spectrum for these purposes are used approximations providing only approximate estimates of indexes of reliability and safety. In analysis of reliability and safety of systems comprising highly reliable elements (probability of fault is $q_i \leq 0.001$), the use of this approach is permissible in concept, however, in case when systems include some pieces of low reliable equipment, calculations with Risk Spectrum give overestimated (sometimes too overestimated) assessments of fault probability that may result in wrong design and other solutions.

This drawback of Risk Spectrum manifests itself, particularly, in analysis of personnel reliability, because probabilities of operators' errors, as a rule, are high. At the same time, as is often the case, contribution of errors of personnel, especially in standby mode is quite high (96% - for Tianvan NPP, about 100% - for Unit 3 of Kalinin NPP). Influence of errors of personnel is also decisive in management of RTG.

Judging from results of solution of examples, the code Relex provides precise calculated results, however, from the materials presented by IPU experts is not clear how it is accomplished.

6. Specialists from SPEC SZMA and SPbAEP have solved all examples with the same (in each organisation their own) technology. Experts of IPU RAN have used a number of technologies. On one hand, it emphasises the Relex merits, however, on the other side, it does not make possible to compare, for instance, pros and cons of DS/DO technology implemented in codes Relex and Risk Spectrum. Taking into account that in performing probabilistic analysis of safety for nuclear facilities, the technology ET/FT is a standard de facto (particularly in Western countries), this is a definite drawback.

7. The code Risk Spectrum ensures a possibility of using more complicated models, than conventional ones, of reliability of elemental events, for example, models accounting for adopted at NPP strategy of periodical checks and recoveries of elements being parts of different channels of safety systems. Our understanding is that it is better than using the law of Weibull-Gnedenko and the like, in particular, if we are aware of the well-known problem of collecting statistics on reliability of equipment. In nuclear power generation where highly reliable equipment is in use, which is produced in small batches, it is hardly ever possible to define correctly the parameters of scale and form of 2-parameter laws of distribution. It casts some suspicion on the importance of their using in solution of practical problems of analysis of reliability and safety of NPP.

8. An important merit of Risk Spectrum code is in our opinion its orientation towards solution of large-scale problems. It is common knowledge that the models of safety of such complicated facilities as NPP include a huge amount of elements. (For example, the model of safety of Busher NPP incorporates 84 event trees, 984 fault trees, 2678 operators, 3399 basic events, 73 functional events, 205 groups of common cause failure). Solution of problems of such degree of complexity, as is well

known, is related to a big number of problems. Unfortunately, no problems have been posed to compare codes in analysing reliability and safety of large-scale systems. For problems of calculation of safety of RTG the code Risk Spectrum is in many respects tedious and excessive.

9. The circumstantial evidence is that the core of Risk Spectrum code works (actually) in environment of operational system MS DOC that imposes severe restrictions on the scale of safety models and leads to rough errors in calculation associated with cutting-off of so called “cross-sections of minor importance”. The code ASM SZMA is free from this shortcoming and solves this problem through correct solution of the problem of semiautomatic decomposition. We cannot guess how this problem is solved in the Relex code.

4.2. Opinion of specialists of IPU RAN

We shall now highlight the main features of three software complexes for analysis of system reliability and safety.

1. Software complexes of the company SPEC SZMA and ″RISK SPECTRUM″ of the company ″RELKON″ realise one class of “reliability” models for assessment of indexes of systems – a class of logical-probabilistic simulation (“reliability” models imply both models of classical reliability and models of safety and technical efficiency, particularly, throughput, risk). This class of models can be called a class of static models as they allow for calculating indexes of reliability, safety and efficiency of systems at the point in time t, depending on potential sets of efficient and inefficient states of elements of the system at this instant. With it, the processes of operation, failures, recoveries of any element of the system are unaffected by other elements, so analysis of events in the interval of operation is not required. These indexes are as follows:

- availability (standby, steady, unsteady) or generally a probability of finding the system at the point of time **t** in the specified class of states of the system;
- parameter of fault flow (steady, unsteady);
- mean efficiency at the point in time **t**.

2. In systems, where recovery of elements is not designed, unsteady (non-stationary availability) coincides with the probability of trouble-free operation (TFO) within the interval (0, t), so in this case logical-probabilistic models allows for calculating TFO. In systems with recoverable elements it is possible to assess TFO approximately using, for example, asymptotic results of regenerating process theory. But it is feasible only in the event of all recoverable elements and exponential distributions of random values, in this case $\mu i \gg \lambda i$ (where μi , λi – intensities of recovery of a failed element i). So, in some examples the calculated estimates of TFO have coincided. In case of mixed systems (with recoverable and unrecoverable elements) or systems with non-exponential distributions of initial data (times prior to fault and recovery) for elements, when mean recovery time is not far less than mean time of operation before failure, it is hardly possible to obtain an estimate of TFO by logical-probabilistic methods. Solution of differential or integral equations may be needed, or if only integration of functions of fault flow parameter. So, in some examples the estimates of TFO for this class of systems were obtained only by SC “RELEX”. The situation is similar with mean full times. Only for cases of all recoverable elements exponential distributions of times prior to fault and recovery times of each element and for systems with unrecoverable elements and exponential distribution of time prior to failure of elements there could be obtained the estimates of mean times using logical-probabilistic methods without integration of different expressions. In a general case there will be needed realisation of more complicated procedures of calculation and assessment which at present are represented only in SC “RELEX”.

3. In SC “RELEX” are represented both static models of “reliability” analysis of systems (logical-probabilistic simulation with logical functions AND, OR, NOT, K/N both in RELEX RBD and in

RELEX Fault Tree) and dynamic models in all analytical modules (RELEX RBD, RELEX PBD, RELEX Fault Tree, RELEX MARKOV).

4. Software complexes produced by the company SPEC SZMA are characterised by an exceptionally convenient and vivid apparatus of definition of models (FIS) integrating the best features of technologies of block diagrams of reliability, link graphs fault trees, event trees. The classical logical-probabilistic simulation is completed by account for groups of inconsistent events and procedures of PAS (probabilistic analysis of safety) assessment (for above mentioned cases). These factors (account for groups of inconsistent events and possibilities for assessment of TFO) significantly enhance the field of application of the complex (compared to the classical logical-probabilistic simulation), especially from the viewpoint of analysis of dangers (safety). Currently software complexes of the company SPEC SZMA are being elaborated specifically for account of a number of dynamic factors (for instance, sequence of faults occurrence). Therefore a sufficiently “powerful” and high-quality logical-probabilistic simulation is added with methods of Markov simulation, other methods of assessment of values of reliability, safety. It may turn to be decisive for problems of calculation of safety and risk in management of RTG.

5. Dynamic models make possible to consider principally any factors, dependencies and calculate any values. Another matter, what exactly factors are considered for in development of software and what methods of assessment of indexes are implemented (in particular, in SC “RELEX”). Let us enumerate these possibilities of SC " RELEX " both demonstrated in examples and beyond the chosen examples:

- consideration of arbitrarily distributions of full times and recovery times for elements;
- simplified, moving reservation;
- operation phases (stages) of elements, units and system as a whole;
- consideration of fault inconsistency and sequence of their occurrence;
- consideration of time delays in response of logical peak (for example, certain types of temporal redundancy);
- consideration of common causes of faults not only in proposed models (α, β factor models and the like), but also development of own models based on Markov processes with their insertion both in trees and block diagrams;
- consideration of constraints on number of crews for performing recoveries and spare parts and equipment;
- consideration of possible recovery of the system after its failure and/or shutdown (when in the process of operation no recovery is admissible);
- realisation of certain models of efficiency monitoring (and not only a model with instant occurrence and detection of failure);
- consideration of maintenance with possible recovery of not only efficiency bur resource as well (for elements with “ageing” distributions).

6. In opinion of representatives of IPU RAN, in analysis and assessment of indexes of safety (danger) it is intolerable to use models which do not consider inconsistent types of failures of elements and system as a whole, a consequence of occurrence of failures, and methods, which referring accidental states with various consequences, do not allow for obtaining interval values such as probability of occurrence of an accident of i type within the interval of operation for the systems with recoverable elements. Just these features set off the class of probabilistic models of safety from all models of “reliability” analysis.

7. SC ″RISK SPECTRUM″ employs a classical logical-probabilistic simulation (moreover, approximate one, based on representation of models just in form of trees). Using it for solution of serious problems of analysis of reliability of complicated systems with specific features is not possible (bearing in mind the adequacy of simulation). The biggest blunder of the designers of RISK

SPECTRUM is that software does not calculate two-side assessments for any single structure (minimum cross-sections or minimum paths) and for any one tree both of faults and events minimum cross-sections and minimum paths are not defined (although it is not difficult to accomplish). Even if this complex can be used than only for a sufficiently simple analysis and at the earliest stages of design work.

8. Without Markov simulation, which is used, particularly, in SC SPEC SZMA, without statistic simulation none of problems in the field of dynamic models cannot be solved at all. For example, unconnected reserve, sequence of failures and even inconsistency (just ask what is origin of these probabilities of inconsistent faults, if laws of distribution are set, moreover, non-exponential, and what is more, with recovery). These dynamic problems are infinite contrary to static definitions and factors considered in them. Nevertheless, we shall say a couple of words about Markov simulation. The growing power of computers and automation of construction for some cases of Markov models gradually solve the problem of scale. Not only in RELEX these methods are implemented (otherwise they could not have solved a number of dynamic problems, for which we have not built a Markov model). There is already developed the domestic SC UNIVERSAL based on Markov simulation making possible to construct models with a dozen thousand states (naturally, not manually). Furthermore, Markov models may be "enlarged", both precisely (when it is feasible) and approximately (otherwise). These algorithms have been developed, particularly, by ourselves. This simulation should be used not to whole system, but to individual parts, i.e. to decompose, then comes simulation, then aggregation of assessments of indexes.

4.3. Opinion of specialists of SPEC SZMA

1. The development of summary tables of comparative results for every SC allows for making the following general conclusion:

- all in all summary tables give **179** simulated and calculated indexes of reliability, safety and risk for systems, out of which **161** indexes (models of computation) are determined with technological means realised in different modules of SC Relex Software;
- **112** indexes were obtained by program modules and utilities of ASM technology;
- out of **112** indexes obtained by ACM technology, **111** values practically coincide with results obtained by different modules of SC Relex;

The result of comparative analysis, in our opinion, is an objective confirmation of scientific correctness of scientific grounds and program realisations of technology and SC ASM developed by specialists of OAO SPEC SZMA.

2. Methods and means of ASM technology currently do not allow for constructing automatically a number of mathematical models and calculating certain indexes which are already implemented in technologies Relex and Risk Spectrum for complicated NS. For majority of these problems in SC ASM there have been made more precise the approaches, methods and ways of their realisation in technology.

3. The obtained results have demonstrated once again that logical completeness of graphical and analytical (method, algorithm and program "LOG") means of FIS ensure implementation in technology and SC ASM of all possibilities of the basic apparatus of simulation – algebra of logic. Thus using FIS in this work there have been successfully presented practically all typical forms of structural description of systems – block diagrams, fault trees, safety trees, event trees and combinatory links, and also one Markov model.

4. Development of method, algorithm and software module "LOG", which is a basis (core) of all versions of SC ASM, has provided a possibility of successful solution (on the unified methodical base ASM) of all problems of logical simulation of systems and obtaining straightforward and inverse, monotonic and non-monotonic logical FSWC. Precisely a logically universal (on a basis of operations

"AND", "OR", "NOT") graphical apparatus FIS and the relevant method, algorithm and software module “LOG” are the main positive basis and the distinctive property of technology and SC ASM developed in OAO SPEC SZMA

5. It is practically confirmed a possibility of means FIS of ASM technology to implement both the straightforward (block diagrams, coherence graphs, etc.) and the inverse (fault trees, event trees) structural definition of different problems. Selection of straightforward or inverse approach for solution of practical problems is offered to the user of technology and SC ASM. This selection is convenient in cases when the systems under consideration have significantly different in terms of scale and complicity straightforward or inverse structural models. At the same time, ASM technology make possible with FIS means to carry out all kinds of inverse definition of problems, i.e. represent fault trees, event trees and their joint combinations.

6. A separate example is dedicated to the problem of automatic construction with ASM technology means of a new class of non-monotonic logical and probabilistic models of the system. These models allow for defining and solving a lot of important special problems of system analysis of reliability, safety and risk. For example, only with non-monotonic models it is possible to analyse “second type” systems (qualitatively complicated), which in different inconsistent states are characterised by different indexes of efficiency and operational risk. At the moment, the technology of solution of this new and promising class of problems is implemented just in GLPM and SC ASM.

7. In ASM technology the priority analytical methods are those of precise automatic, logical, probabilistic simulation and calculation of reliability and safety indexes of systems. Thus all logical models of the system obtained in the above examples by software means of different technologies (Relex, ASM and Risk Spectrum) have totally coincided. The outcomes of analytical calculations of values of reliability and safety obtained by Relex and ASM have practically coincided in 111 cases out of 112 comparable computations.

8. The results of solution of examples showed that the differences between precise calculations of indexes of reliability and safety by Relex and ASM, and approximate calculations by SC Risk Spectrum, with probabilities of failed elements < 0.01 ($q_i <= 0.01$), as a rule, are insignificant. With $q_i > 0.01$ discrepancies between calculations of system indexes can be significant. In our view, approximate calculations should be only a supplementary means for analysis of reliability and safety of complicated systems in automatic simulation technologies.

9. Apart from indicated above, there exists a great amount of other special lines of development of the theory and the technology of automatic structural-logical simulation which should be worked out now. These lines are mostly determined by objective needs of practice aimed at adaptation of this technology and SC ASM to solution of problems of automatic simulation and calculation of indexes of reliability and safety of special system objects in various branches of industrial production. One such important direction, in our opinion, is development of special software systems of comprehensive (complex) automatic simulation and assessment of expected damage from potential accidents at dangerous sites. RTG also fall in this category. The main feature of this direction is an effective combination of methods and means of automatic simulation and calculation of probabilistic characteristics of scenarios of accident progression using methods and means of automatic simulation and calculation of potential consequences of accidents at dangerous sites. This approach has been implemented in SC ASM.

4.4. General conclusion of experts of SPbAEP, IPU RAN, SPEC SZMA

1. Analysis of the obtained results allows for stating that there have been achieved justified, qualitative and quantitative characteristics of three technologies of automatic simulation and calculation of indexes of reliability and safety of structurally complicated systems:

- technologies and software for automatic simulation and calculation of indexes of reliability and safety (software complex Relex of the company Relex Software, USA), applied by specialists of IPU RAN in calculation of NPP safety;
- technologies of fault trees and event trees (software complex Risk Spectrum of the firm Relkon AB, Sweden), applied by FSUE SPbAEP for probabilistic analysis of safety (PAS) and calculation of indexes of reliability of systems of nuclear power plants (NPP) under design.
- technologies of automatic structural-logical simulation (software complexes SC ASM, developed and applied by OAO SPEC SZMA, Russia) in assessment of reliability and safety of any industrial facilities.

All these technologies and software complexes are suitable for use to their proper purposes within assumptions and constraints indicated in technical documentation.

2. The development of domestic software complexes of industrial purpose is actual for automatic simulation and calculation of static and dynamic indexes of reliability and safety of complicated systems which is conditioned by:

- objective needs of the developing Russian industry to increase competitiveness of production (assurance of state-of-art level of quality, reliability and safety) in development of new high-class processes and equipment, specifically for dangerous industrial facilities of different purposes;
- objective difficulties with application for these purposes foreign software complexes connected to their high cost, technological dependence, staff training, upgrading and adaptation to new fields, application in defence industry;
- need to support a high level of domestic science and introduction to production of new information technologies for tackling the problems of provision of reliability and safety of designed systems of different types, classes and purposes.

5. Conclusion

1. The detailed comparison of three program complexes (Relex, ASM SZMA and Risk Spectrum) was conducted for fulfillment of work under the probability analysis of safety NS AES and ASMTP with the purpose of determination of their possibilities.

2. All three PCs above mentioned, are intended for account of parameters of non-failure operation and nonaccidental at all stages of the circulation with NS. The knowledge of these parameters is completely necessary for account of emergency risk for health of staff and population at all stages of salvaging RTG, including for want of transportation RTG by any methods, as just the origin of radiation failure has a probability character. There, where for the analysis of risk there is enough of deterministic parameters (for example, of individual or collective dozes) it is possible to manage and without knowledge of probability of failures, but from our point of view such approach is not complex. The methodology of account of parameters of risk (in particular of chronic risk) as for "normal" salvaging RTG, as in emergencies (Additional " risk) is indicated in final variant of our report [21].

3. Applicability indicated the PC to such complicated objects of use of an atomic energy, as АЭС, proves, that they are applicable practically to anyone NS, including to RTG. From the point of view of demonstrating possibilities of a common logic-probability method, obviousness and simplicity of the interpretation of received outcomes, on our sight most applied to a solution of a problem of salvaging RTG is the PC ASM SZMA. The use of all three PCs for the analysis of process of salvaging RTG in the present moment is inexpedient, as by virtue of huge expenditures of labour and high complexity of their application, and in absence of such necessity, as their applicability to anyone complicated NS is already proved.

4. The performed analysis of certified (acknowledged) by the Russian body of state safety regulation methodical and software for calculation of safety of RTG and assessment of risks for population and environment has allowed for declaring advisable to use the software complex ASM SZMA in this work for assessing risks at all stages of RTG decommissioning.

5. The evaluation and comparison on a parameter of radiation risk of the various scripts of failures represents a problem of the following works, when the list of the potential scripts of salvaging RTG will be composed, the beginning events causing to radiation failures are determined with their probabilities. Drawing up of the full scheme of a functional wholeness for the transport scheme with allowance for various it of variants and account of parameters of risk both for "normal" salvaging RTG, and for emergencies in this case is possible.

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Appendix C
Adaptation of procedures for monitoring of radiological safety (Task 3)

C-1. Methodology regarding the procedure for radiation safety supervision during decommissioning, transportation and long-term storage of radioisotope thermoelectric generators (Deliverable D5)

Introduction

The primary purpose of this task was to draft a Regulatory Guide setting out a methodology for inspections related to radiation safety during decommissioning, transportation and long-term storage of RTGs. The draft Guide was reviewed by regional agencies of Rostechnadzor, and the final approved version of the Guide is being promulgated. The text of the Guide is reproduced in this Appendix.

I. GENERAL

1. The Methodology regarding the procedure for radiation safety supervision during decommissioning, transportation and long-term storage of land-based radioisotope thermoelectric generators (RTG), which are equipped with sealed radionuclide heat sources (RHS) of «RIT-90», «RITu-90», «TRIB-90» type made of strontium-90 (hereinafter referred to as "Methodology"), has been developed on the basis of the requirements of the regulatory documents listed in Appendix № 1 and do not set forth any additional requirements on the issues of radiation safety or safe performance of the work mandatory for operating organisations or the organisations rendering services.

2. The Methodology is intended to assist the inspectors of the Federal Environmental, Industrial and Nuclear Supervision Service (hereinafter referred to as the "Service") in realisation of state supervision and control of safety assurance in conducting the work on RTG decommissioning by the enterprises, organisations and military units of the Russian Federation Ministry of Defence (hereinafter referred to as the Organisations).

3. The Methodology has specified the kinds and types of the inspections of RTG decommissioning activities, the dates of their performance, types of the documents substantiating safety of the given type of work, the order of preparation for conducting the inspections, and has identified the areas subject to verification during inspections of the given type of work.

4. The Methodology contains the generalised standard safety requirements established in the regulatory and departmental documents; it is recommended to control that the above documents are followed during RTG transportation (movement[3]) in the course of RTG decommissioning activities[4].

5. The Methodology contains the reference data on the algorithm and general plan of actions on the decommissioning related to RTG dismantling at the sites of operation in the Baltic, North-west, North and Far East regions (Appendix № 2, 3), on transportation to the sites of temporary storage and on temporary storage of the given products.

6. Information, which could help the inspectors of the Service to understand the activity essence (applied RTG evacuation transport schemes, possible emergencies at different work stages, model

[3] The term "movement" shall provide, within the frames of this document, for the process of operations in changing the RTG location at the site for a distance up to 50 m using muscular force and/or one type of transport facilities.
[4] Hereinafter in the text, the expression "RTG decommissioning" and "decommissioning" shall be used as synonyms.

certificate/permissions and emergency cards, RHS long-term storage arrangements) is listed in Appendixes № 4 – 8.

7. For the purpose of the Methodology, the RTG decommissioning activities has the following meaning (Appendix № 2):

a) decision-making on the RTG group decommissioning, defining funding sources for the given activity;

b) administrative and technical preparatory activities (obtaining permissions from competent authorities, development of the documents substantiating safety, concluding contracts, fitting out with necessary equipment and technical facilities);

c) radiometric and engineering examination of each RTG by commission at the site of operation (field stage) and making decision of possible (impossible) dismantling and transportation of each decommissioned product;

d) transportation of radiation packages with RTG (RHS) to the sites of temporary storage;

e) temporary (intermediate) storage of RTG in specialised organisations;

f) delivery of radiation packages to the specialised organisation authorised to accept the RTG (RHS) for long-term storage and disposal - the Federal State Unitary Enterprise "Production Association "Mayak" (hereinafter – FSUE "PA "Mayak").

8. The date of decision-making on decommissioning of one or several RTG shall be taken as the start of decommissioning process within the frames of this Methodology; the date of arrival of train or other transport vehicle with decommissioned RTG (RHD) to FSUE "PA "Mayak" – as completion of the above process.

9. For the purpose of the Methodology, examination of administrative and regulatory documents (programs and projects for RTG decommissioning, safety analysis report, orders, instructions, programs, etc.) has the following meaning – identify the availability thereof and determine the compliance of the requirements therein with the provisions of legislative deeds and regulatory documents, which are listed in Appendix № 1.

10. In formalising the section "Inspection of physical protection", the final inspection documents shall take into account that in accordance with the Decree of the President of the Russian Federation of 11.02.2006 № 90 the "List of the data referred to state secret", the data on the system of security of radiation hazardous facilities are referred to state secret (paragraph 25 in the List).

11. The Methodology is mandatory for the personnel of headquarters and territorial bodies of the Service making arrangements and conducting the inspections of the activity of organisations in the field of the use of atomic energy (hereinafter FUAE), related to RTG decommissioning process.

II. KINDS AND TYPES OF INSPECTIONS, CONDUCTING DATES

2.1. Types of inspections

12. The inspections conducted in the process of RTG decommissioning are the inspections of the activity fulfilled by operating and transport organisations in the FUAE, as well as by the organisations exercising temporary storage of RTG (RHS) before their shipment to FSUE "PA" Mayak" (Appendix № 3,4)

13. The inspections conducted in the process of RTG decommissioning are subdivided according to the types and kinds, specified in Table № 1

Table 1 Kinds and types of inspections[5] conducted in the process of RTG decommissioning

Types of conducted inspections	Inspected organisation /types of conducted inspections		
	Operating	Transport	Exercising temporary storage
Inspection of preparedness (type 1)	Complex, (target)	Target (complex)	Target
Inspection of safety (type 2)	Operative	Operative	Not conducted
Inspection of compliance (type 3)	Target	Not conducted	Not conducted
Inspection of storage conditions (type 4)	Not conducted	Not conducted	Target, Operative

14. The necessity to plan and conduct the inspections indicated in Table № 1 shall be defined by the decision of the territorial authorities of the Service.

15. The programs and schedules of the inspections, the final documents prepared by the results of above, shall be developed (drafted) in accordance with the requirements of the Service existing regulatory guides regulating the supervision (inspection) activity

16. Administrative sanctions and measures shall be applied according to the legislation of the Russian Federation, Provision on the Federal Environmental, Industrial and Nuclear Supervision Service and its territorial authorities.

2.2. Inspections of preparedness

17. The inspections of preparedness are targeted to verify that the administrative and technical (preliminary) stage of the work on RTG decommissioning activities (see sub-paragraph 7-b) is fulfilled.

18. The inspections of preparedness of operating organisations are the complex ones, as a rule. The inspections shall be conducted upon development, agreement and approval of the administrative and regulatory documents on safety analysis, complete training of the personnel involved in the work, manufacturing (selection) and certification (testing) of the technical facilities intended to be used in the course of decommissioning activities.

19. The inspections of transport organisations are the target ones, as a rule. They are conducted with the purpose to verify the design documentation, the administrative and regulatory documents regulating safety measures during transport operations, the level of personnel training and the procedure of admission of the personnel to handling the hazardous freight of class 7 (radioactive substances).

20. The inspections of preparedness of the organisations exercising temporary storage of RTG (Appendix № 3, 4) are the target ones. They are conducted with the purpose to verify that the radiation safety requirements are met prior to acceptance of a decommissioned RTG batch for temporary storage.

21. The inspections of readiness specified in paragraphs 18, 19 shall be arranged and conducted directly before the start of the field stage of decommissioning activities, while those specified in para. 20 – prior to placement of each RTG batch dismantled from their locations of operation, for temporary storage.

[5] Unless otherwise agreed, all kinds and types of the inspections specified in Table №1, are generalised under the term “inspections”.

2.3. Inspections of safety

22. Inspections of safety are conducted in the course of field stage operations on RTG decommissioning by the operating and/or transport organisation. The inspections of safety are targeted to verify, directly in the course of decommissioning activities, that the requirements of federal and departmental regulatory documents, programs, design documents are met, and that the restricting conditions of permission documents, quality assurance and radiation protection programs, as well as safety measures during RTG transportation, are observed.

23. Such inspections are the operative ones and are conducted directly in the course of decommissioning activities by an official (officials) of the Service included as members of the commission for RTG survey.

24. The findings of RTG engineering examination at the sites of operation shall be formalised in a report drafted by the commission that carried out the inspection. In the event of disagreement between the representatives of operating organisation and the RTG design organisation with regard to the decisions and actions taken in the course of engineering survey, it is recommended that the Service official formulates his particular opinion in writing as an attachment to the above report

2.4. Inspections of compliance

25. The inspections of compliance are conducted, as a rule, upon completion by the operating organisation of every next (annual) stage of operations on RTG (RHS) batch decommissioning. In the course of the above target inspections the following shall be investigated:

a) inspection and disassembly deeds for the RTG decommissioned in the course of inspected stage of the work

b) final documents drafted basing of the results of inspections of preparedness and safety;

c) deeds (reports) on investigation of the violations in the course of the work on decommissioning ;

d) other information about the achieved level of safety in the course of the completed stage of the work on decommissioning.

26. Orders to correct the work process for decommissioning or to introduce changes in the below indicated administrative and regulatory documents shall be given in the case if discrepancies in the documents, violations of radiation safety principles or any reasons for the above, weak points in quality assurance and radiation protection programs, in other documents for radiation safety assurance, are revealed.

27. It is recommended to conduct the inspections involving the Service official who took part in the field stage of the work on decommissioning (see para. 23).

2.5. Inspections of storage conditions

28. The inspections of storage conditions shall be planned, organised and conducted by the Service territorial authorities that have specialised centers for temporary storage of decommissioned RTG (RHS) in the territory subject to their supervision.

29. The inspection is concerned with the radiation hazardous facilities where the decommissioned RTG (RHS) are stored, as well as with the documents regulating temporary storage of the given products, the level of personnel training, preparedness for elimination of radiation accident consequences at the given facilities.

30. The inspections of storage conditions shall be planned, organised and conducted with the periodicity established by the Service regulatory guides after receipt of the first RTG batch for storage, throughout the entire period of temporary storage.

31. Unplanned inspections of storage conditions can also be conducted.

III. DOCUMENTS SUBSTANTIATING SAFETY

3.1. Types of documents substantiating work safety

32. Upon making a decision on decommissioning of the next RTG batch, and defining funding sources for the work on decommissioning, the operating organisation shall provide for the following (Appendix № 2):

a) define the list of the RTG intended for decommissioning and prepare a work schedule for their decommissioning;

b) draft the following permits-certificates, in the established routine, in the competent state body of the Russian Federation (see Appendix № 1, paragraphs 14,19):

1) for the radioactive material of special type;

2) for the design[6] of transport packages of B(U) type;

3) for transportation[6] of corresponding RTG types in transport packages;

c) draft the permits-certificates for transportation under special conditions if the total residual radioactivity of strontium-90 radionuclide in the RHS making up a set with the RTG, exceeds the limit established for packages of B(U) type[7];

d) develop the radiation protection and quality assurance programs in the course of conducting the design process activity on decommissioning;

e) conclude the contracts for:

1) RTG transportation, including, if necessary, transportation on helicopter external load;

2) manufacturing of reserve shielding containers[8] (transport packages) for the RTG.

33. The organisations performing the work (including the work on transportation) and rendering services to the operating organisation should have, in the course of the work on decommissioning, the Service licenses for corresponding type of activity in the FUAE.

34. It can happen that for transportation of the RTG at helicopter external load, the aviation companies that have no licenses from the Service for handling of radioactive substances during their transportation, are invited (see Appendix № 1, para. 27). Before starting the work such enterprises should develop the instructions on radiation safety, actions of personnel in emergency situations and other administrative and regulatory documents regulating safe performance of the above work and

[6] Permits-certificates for the design of transport packages and transportation can be covered by one permit-certificate by the decision of the competent state authority.

[7] Permits-certificates for transportation under special conditions shall be formalised if, in the course of RTG field inspection, the commission makes a decision that transportation under the terms of existing regulations is not possible.

[8] Here and hereinafter the shielding containers and RTG design is considered as the transport package of B(U) type for one or several RHS making up a set with the RTG. For the RTG of "Beta-M" and "Beta-C" type manufactured before 1986, transport package can be represented with the RTG structure (without shielding containers).

submit them for approval to the territorial authorities of the Service. The above enterprises should arrange training of the personnel that will take part in transportation operations in the course of decommissioning activities.

3.2. Quality assurance and radiation protection programs

35. The programs of quality assurance and radiation protection shall be developed and approved at the initial stage of decommissioning activities (Appendix № 2).

The quality assurance programs shall be developed by all the organisations listed in Table № 1.

The radiation protection program shall be developed by the operating organisations and the organisations that exercise the RTG (RHS) temporary storage.

36. The quality assurance program is aimed to assure the organisation administration that the system of safe operations in the FUAE (decommissioning activity) corresponds to the standard requirements.

37. The quality assurance program shall:

a) establish the goals and purpose of the program;

b) determine the policy of the organisation in the sphere of quality assurance;

c) mark the limits of responsibility for quality assurance between the organisations performing operations and those rendering services;

d) define the list of the documents containing standard requirements to quality assurance and determine their hierarchic structure;

e) mark the limits of responsibility for quality assurance between the officials and the services of the organisation;

f) analyse the management structure of the organisation as far as the effective quality assurance is concerned;

g) provide the list of principal undertakings for quality assurance and characterise their interrelation;

h) establish the internal system of control of non-compliances and define the control procedure.

38. The radiation protection program shall include:

a) goals and purpose of the program;

b) principles, documents and technical facilities ensuring radiation protection in the course of the work performance;

c) the measures ensuring radiation protection of personnel and population in the course of the work;

d) the list of regulatory documents on radiation protection assurance and its hierarchic structure;

e) principal undertakings on radiation protection and their interrelation;

f) organisation and procedure of implementation of the internal system of control of discrepancies in the course of radiation protection activity.

3.3. RTG decommissioning program

39. Before starting the work on decommissioning, the operating organisation shall undertake to collect and analyse the retrospective data on the history of operation of each RTG (group of RTG), included in the list. The above analysis and other materials shall be used as a basis for the development and approval of the decommissioning program which should contain the following information:

a) decommissioning activities schedule;

b) general information on the RTG dismantling process, transportation schemes of evacuation of the radiation packages with the RTG;

c) the branches or separate subdivisions of the operating organisation involved in the work and the types of the work they perform;

d) quantity and qualification level of the personnel involved in the work;

e) the prognosis of the collective effective radiation doze which the personnel will be exposed to in the course of the work performance;

f) organisation and methodology of inspection of the radiation packages with RTG (RHS) at the sites of their location;

g) the list of organisations conducting the work and rendering services during decommissioning activities;

h) tentative list of RTG field inspection commission members in the locations of operation, procedure for decision-making on possible (impossible) continuation of the work on decommissioning;

i) procedure of emergency response measures planning and realisation, communication scheme for transmission of the established form of messages concerning the violations occurring in the course of the work, the interaction of emergency response units;

j) composition, time period and procedure for RTG decommissioning deliverables.

40. The program should establish the following general requirements:

a) to the methodology of radiation and engineering inspection of RTG in the locations of operation, procedure of making and realisation of the decision on possible dismantling and transportation;

b) to the observance of justification and optimisation principles (ALARA) in selection of the methods of RTG dismantling, transportation, including the type of transport and the transportation route for each group of the RTG operated in similar conditions;

c) to the procedure for evaluation of the impact from hazardous natural and technogenic (man-induced) factors to safety during decommissioning work;

d) to the system of measures for prevention of accidents and elimination of the consequences thereof.

41. The program should define the requirements for physical protection system at all the stages of RTG decommissioning, temporal and spatial boundaries and limits of responsibility for safety assurance of the organisations involved in conducting particular stages of the work, on contractual basis.

3.4. RTG decommissioning project

42. The RTG decommissioning project is developed on the basis of decommissioning program. The Project shall be agreed on with RTG designer and approved by the federal executive body which the operating organisation is subordinated to.

43. The Project is required to have sanitary and epidemiological finding by federal executive body authorised to state sanitary and epidemiological supervision or by authorised territorial representation of the above body of the subject (subjects) of the Russian Federation, where the activities are planned.

44. The project, as a rule, consists of the main part justifying general requirements to the administrative, engineering and sanitary and epidemiological measures on RTG decommissioning and a special part defining safety requirements at separate stages of the work.

45. The projects shall not envisage RTG partial disassembly in the course of the work on dismantling and evacuation.

46. It is allowed to make separate projects for:

a) the work on RTG inspection and dismantling from locations of operation, as well as on delivery to the organisation exercising temporary storage;

b) The RTG delivery from the locations of temporary storage to FSUE "PA "Mayak" for long-term storage and disposal.

47. The list of initiating events, analysis of design basis accident consequences is made on the basis of the conservative approach.

48. It is appropriate that the project provides for a stock of reserve shielding containers and the method of their delivery to the RTG operation locations, as well as for the process of operations for replacement of shielding containers in field condition for each RTG type.

49. The project shall contain:

a) the data on geographical, climatic and geo-morphological peculiarities of the RTG location in the locations of operation;

b) the data on hazardous natural and technogenic (man-induced) factors which may have impact on the decommissioned products in the course of decommissioning activities;

c) general information on the RTG operation background, including the data on current radioactivity of strontium-90 radionuclide in the RHS making up a set with the RTG;

d) retrospective data of radiation monitoring;

e) justification of the necessity to formalise permit-certificates including the permit-certificates for transportation under special conditions;

f) justification of the efficiency and safety of process flow sheets used for RTG dismantling from operation sites, including replacement of inadequate shielding containers, selected types of transport an transportation routes;

g) radiation monitoring methodologies and technical facilities including those used in the design basis accident conditions;

h) justification of the measuring instruments planned to be used;

i) potential initiating events and analysis of the evolution of potential radiation accidents followed by assessment of the consequences thereof and prognosis of radiation situation;

j) material support of emergency response measures;

k) justification of the most safe transportation scheme for delivery of the RTH (RHS) radiation packages to specialised organisations exercising their temporary and long-term storage;

l) measures for organisation and upkeep of the RTG (RHS) physical protection system in the course of decommissioning activities;

m) safety measures during RTG transportation, including emergency response measures;

n) justification of the RTG radiation and engineering characteristics assessment methodologies.

3.5. Safety justification report

50. The decommissioning project serves as a basis for the operating organisation to develop a report of justification of safe RTG decommissioning. No later than one month before the start of the field stage of work the report shall be submitted for approbation to the Service territorial authority exercising state supervision over the activity in the FUAE in the corresponding subject of the Russian Federation.

51. If a large number of the RTGs operated in different environmental conditions is involved in the decommissioning process, safety justification reports shall be made for each area where operations are carried out .

52. The report shall contain:

a) general information about the operating organisation;

b) general information about the area where the work is planned;

c) RTG (RHS) technical characteristics;

d) summarised design safety requirements;

e) analysis of the retrospective data accumulated in the process of operation for each RTG planned to be decommissioned;

f) list of mandatory requirements to be met during the work, including those set forth in НП-053-04, section 1.2 «Basic provisions on safety assurance in transportation”.

53. The report shall justify the observance of radiation safety principles and regulatory requirements at all the stages of decommissioning activities, specified in para. 7 of the Methodology, except for sub-paragraph 7-e.

IV. PRE-INSPECTION PREPARATORY ACTIVITIES

4.1. Documents subject to be reviewed

54. Prior to the inspection, the Service official (officials) shall review the regulatory documents that establish safety requirements during such inspections:

a) federal and departmental regulatory documents that regulate the activity of organisations in the FUAE (Appendix № 1);

b) permission documents entitling the organisation to perform decommissioning activity and specifying the terms of its performance;

c) inspected organisation inspections background by the materials of previous inspections;

d) administrative and regulatory documentation regulating safety measures during the work;

e) technical documentation representing the RTG (RHS) radiation and engineering characteristics;

f) operating documents containing information about the peculiarities of the RTG location and operation;

g) deeds (reports) of investigation of the violations of the RTG proper operation;

h) The Service regulatory guide specifying the procedure of inspections of the activity in the FUAE, including the given Methodology.

55. The recommended list of basic regulatory documents subject to be reviewed, as the type of inspection requires, is provided in Table 2.

Table 2 *The documents used in the course of state supervision*

Documents to be reviewed	Types of inspections (Table № 1)			
	tType 1	tType 2	tType 3	tType 4
Legislative deeds and regulatory documents listed in Appendix № 1	+	+	+	+
Service regulatory guide specifying the procedure of inspections activity	+	–	+	+
Permission documents issued by authorised state bodies (Service license and permission conditions, sanitary and epidemiological findings on compliance of the work being performed with state sanitary and epidemiological rules and standards)	+	–	+	+
Available certificates (permit-certificates) for radioactive material of special type, the RTG design as packages of B(U) type, for shipment (transportation) including shipment under special conditions	+	–	+	–
Inspection background of the organisation (violations revealed in the course of inspections, timeliness and completeness of their elimination)	+	–	+	+
Materials of investigation of the violations in the course of RTG operation	+	–	+	+
Documents formalised by the results of the RTG inspection prior to dismantling	+	–	+	–
Quality assurance program	+	–	+	+
Radiation protection program	+	+	+	–
RTG decommissioning program	+	+	–	–
RTG decommissioning project	+	+	–	–
Safety justification report	+	+	–	–

4.2. Recommendations for regulatory documents review

56. In reviewing the regulatory documents the following aspects should be specifically noted:

a) conformance (difference) of planned operations process to the safety requirements established in the Legislative deeds and regulatory documents;

b) limitations set forth in the Service license and permit conditions, sanitary and epidemiological findings, permits-certificates;

c) availability and content of the insurance contract (insurance policy);

d) justification of the established categories of radiation facilities according to the potential radiation hazard;

e) timeliness and completeness of information on compliance, within prescribed time periods, with the requirements, contained in license terms and conditions;

f) current state of radiation safety in the organisation registered in radiation and sanitary passport (onward – RSP), findings of state sanitary and epidemiological supervision bodies on RSP content;

g) content of radiation and ecological passport of the hazardous radiation facility;

h) information on the radiation situation at the sites of RTG operation, disclosed facts of unauthorised actions with regard to the RTG;

i) information on the system of personnel training and test of knowledge at the organisation, including safety measures during RTG transportation by different kinds of transport;

j) nature and reasons of the violations registered in the course of previous inspections, orders issued for their elimination, and trustworthiness of the information on fulfillment of the orders;

k) information on the measures undertaken by the organisation to prevent radiation accidents and ensure preparedness to eliminate consequences thereof;

l) content of the deeds (reports) on violation investigation of RTG proper operation (if any);

m) information about the inspected radiation hazardous facility (facilities) contained in the operating organisation's radiation safety analysis reports;

n) materials of emergency response training.

57. It is necessary to become familiar with the general characteristic of the organisation's activity, as well as with:

a) the peculiarities of decommissioning processes applied, including the types of transport facilities and the peculiarities of their use;

b) operational documentation for main types of equipment, mechanisms and devices used for carrying out the processes (engineering specifications, operational, installation and dismantling instructions, logbooks and passports).

58. Using the data registered in each RTG card, familiarise with its operation background.

59. Review the general safety requirements in carrying out the entire complex of RTG-related works.

60. If the process of decommissioning activities provides for usage of hoisting devices during RTG dismantling and movement, it should be noted that the above operations are falling under the effect of the regulatory document НП-043-03 (see Appendix № 1, para. 6).

4.3. Order of RTG operation background review

61. In the course of preparation for inspection one should get familiar with the results of the analysis carried out by the operating organisation with regard to the information collected during the period of RTG operation. Special attention should be paid to the products located nearby populated sites, especially, if in the course of operation, any unauthorised actions were registered.

If the operating organisation does not have the documentation (complete package or partially) escorting the product to be decommissioned, it is allowed to use other copies of the documents for the given RTG type. In such case the operating organisation drafts and submits the Deed of RTG operational documentation loss.

The analysis of information shall address the following factors:

a) comparison of the values of dose rate generated by RTG, which are measured at the manufacturing plant and during the RTG operation. Special attention should be paid to the products where dose rate increase was noted even if the measured values were within the prescribed limits;

b) estimate of geographical, geo-morphological and climatic characteristics of RTG operation locations (climate, relief, accessibility for unauthorised persons, remoteness from water area, excess, soil etc.) when selecting the decommissioning technology;

c) correct analysis of the hazardous natural events, that may exert impact on the RTG, and the decommissioning process;

d) analysis of RTG technical condition, in particular, notes in logbooks, deeds of shielding container inspection, availability of official reports, notes and memorandums and other evidence of RTG proper operation violations;

e) documentation on the RTG movements from one operational station to another and the reasons for these movements.

62. Analyse the RTG decommissioning program approved by the operating organisation head, paying attention to:

a) administrative an engineering measures, envisaged to ensure the RTG safe decommissioning;

b) quantity and qualification level of the personnel of the operating organisation branches and separate subdivisions, which participate in the work on decommissioning;

c) approved RTG decommissioning action plan and information on the course of its completion.

63. To become familiar with the safety instructions for transportation of hazardous freight class 7 (radioactive substances), developed by the organisations rendering RTG (RHS) transportation services.

The given instructions shall be:

a) adopted to the method of transportation, to radiation and engineering characteristics of the transported freight;

b) agreed on by the territorial body (structural unit of the territorial authority) of the Service which implements state supervision and monitoring at the location of transport organisation.

64. Instructions should allow for the model safety requirements cited in chapter 6 of the present Methodology.

65. Make sure that the air crew and drivers of the transport vehicles used for transportation of radiation packages with RTG (RHS), have the certificates (permits) for hazardous freight class 7 (radioactive substances) transportation, as well as permits for surface transport facilities for transportation of the indicated hazardous freight, drawn up in accordance with the established routine.

V. LIST OF ISSUES SUBJECT TO VERIFICATION

5.1. General issues subject to verification

66. Prior to the inspection, the inspectors shall be briefed, as appropriate, on the occupational safety, and, if required, be equipped with radiation monitoring and personal protective equipment. During the safety inspections (type 2) the usage of radiation monitoring equipment is obligatory.

67. During inspections the inspectors shall focus primarily on verification of the following:

> 67.1. Conformity with the terms and conditions of licenses, permissions and implementation of the previous orders.
>
> 67.2. Conformity of existing procedure for personnel selection and training with the established requirements.
>
> 67.3. Organisation and technical support of RTG mandatory survey prior to dismantling and radiation monitoring.
>
> 67.4. Preparedness of the organisation to eliminate radiation accidents and incidents (radiation and non-radiation) during RTG decommissioning and preventive measures.
>
> 67.5. Arrangements for and RTG (RHS) transportation.
>
> 67.6. Compliance with radiation safety requirements during RTG decommissioning program and project implementation.
>
> 67.7. State of physical protection of the radiation hazardous facilities which exercise storage of decommissioned RTG (RHS).
>
> 67.8. State of RTG (RHS) accounting, control and storage.
>
> 67.9. Arrangements for investigation of radiation and non-radiation incidents during RTG handling (if any).

68. The list of issues subject to be verified depending on the type of inspection and the stage of RTG decommissioning activity, is given in Table 3.

69. In the course of inspections of preparedness and safety, it is necessary to make sure about the availability of reserve shielding containers, conforming to the types of RTG intended for decommissioning, as well as the means of their delivery to the site of operations.

Table 3 *Issues subject to verification during different types of inspections and work stages*

Types of inspections	Work stages	issues subject to verification - + (★ - priority issues)								
		Conformance with license and permit conditions, implementation of previous orders	Conformance of the existing procedure of personnel selection and training in the organisation with preset requirements	Organisation of mandatory RTGs survey prior to their dismantling and radiation monitoring	Preparedness of the organisation for liquidation of radiation accidents and incidents during RTG decommissioning	Organisation and realisation of RTG (RHS) transportation	Fulfillment of radiation safety requirements during execution of RTG decommissioning program and project	State of physical protection of RTG (RHS) storage sites	State of accounting, control and storage of RTG (RHS) состояние	Organisation of the work on investigation of incidents (if any) during handling of RTG (RHS) организация
Inspection of prepared-ness	Inspection of fulfilled preliminary stages of the work on RTG decommissioning by operating and/or transport organisation (Appendix № 2)	★	+	★	+		★		+	
Inspection of safety	Examination of RTGs in their operation locations (Appendix № 4)	+	+	★					+	+
	Dismantling of RTGs from their operation locations (Appendix № 4)	+	+	★	★	+		+		+
	Unloading of the carrier ship, loading of RTGs in special railcars or their temporary storage (Appendix № 4)	+	+			★		★	+	+
	Transportation of RTG packages in special railcars to FSUE V/O Izotop, FSUE DalRAO or FSUE PA Mayak (Appendix № 4)	+	+		+	★		+		+
	Unloading of special railcars, transportation of RTG packages by road to FSUE VNIITFA for RHS removal (Appendix № 4)	★	+		+	★		+		+
	Unloading of trucks with RTGs, RHS removal and loading of RHS packages to trucks (Appendix № 4)	+	★		★	★		+		+
	Delivery of RHS packages to FSUE V/O Izotop base, loading of special railcars to ship packages to FSUE PA Mayak (Appendix № 4)	+	+		+	★		+		+
	Transportation of RHS containers (RTG packages) in special railcars to FSUE PA Mayak (Appendix № 4)					★		+		+
	Processing of RHS (RTG) at FSUE PA Mayak (Appendix № 4). [This work stage shall be inspected within the frames of scheduled inspections of FSUE PA Mayak activity]	+	+				+	+	+	+
Inspection of comp-liance	Analysis of the summary documents based on examination findings, information about the level of safety in the course of the work fulfilled, summary documents based on the results of safety inspections	+	+	+	+	+	+	+	+	+
Inspection of storage conditions	Inspection of decommissioned RTG (RHS) storage conditions at the sites of temporary storage (safe storage conditions, briefed personnel, preparedness of facilities for emergency response)	+	★		★			★	+	

70. If the transportation scheme of RTG decommissioning operations suggests use of helicopter for RTG transportation (installation) to sea vessel on external load, it is necessary to make sure of availability of the lengthened cables and “spiders” with the total length exceeding the maximal height of the ship masts by no less than 10 m.

71. If in the course of decommissioning activities dismantling of the RTGs located at the distance less than 15 m from navigation aids (hereinafter NA) is anticipated, make sure of availability of a lengthened cable system with the total length exceeding the maximal height of NA by 10 m, at least.

5.2. Verification of conformity with permission documents conditions

72. As provided for in sub-paragraph 67.1, inspection efforts are focused on:

72.1. Conformity, in the course of RTG decommissioning, with the safety requirements preset in Service license conditions.

72.2. Availability of the Service permissions for the right to perform the work in the FUAE by corresponding personnel of the organisation.

72.3. Fulfillment of the Service permission conditions by the personnel of the organisation.

72.4. Conformity with the restricting conditions specified in:

a) the Service and Rosatom decision "On transportation of RTG packages (RHS-90, RHSu -90) by helicopter on external load" (see Appendix № 1, para. 18);

b) permit-certificates for transport packages design and transportation;

c) sanitary and epidemiological findings on compliance of the performed work with the state sanitary and epidemiological rules and standards.

72.5. Conformity with the limitations established to ensure safety during transportation of hazardous freight class 7 (radioactive substances).

73. Character of the detected violations of safety requirements, timeliness and completeness of implementation of the orders.

74. The level of radiation safety achieved and registered in RSP for the previous two years.

5.3. Verification of procedure of personnel selection and training

75. As provided for in sub-paragraph 67.2, inspection efforts are focused on:

75.1. Availability at the working stations of permission copies issued by the Service and certified by the organisation Head to carry out the activities in the FUAE. Organisation of control on compliance with the standards and rules in the FUAE and with permit conditions.

75.2. Inspection of administrative orders on:

a) the procedure for personnel training, work permission, testing of knowledge of radiation safety rules for radiation hazardous works and fulfillment of the established types of briefings;

b) assignment of radiation safety unit or the person responsible for radiation safety control (radiation safety duty);

c) establishing the commission to test the knowledge of safe operation with RTGs by personnel and legitimacy of the commission (its members) to arrange such tests of knowledge (as concerns necessary training for the members of the commission);

d) determining the list of individuals referred to personnel of Group A and B;

e) work permission for the personnel dealing with radiation sources (approved list of the individuals having permission to work with radiation source);

f) assignment of a responsible representative of the operating organisation authorised to escort the radiation packages with RTG (RHS), including their transportation on helicopter external load (assignment of such specialist and his due authorisation should be envisaged in the instructions of transport organisations and, correspondingly, in the agreement for rendering transportation services)

g) forming a commission for inspection of RTG radiation and engineering condition in the location of operation, and appointment of the commission chairman;

h) assignment of a person responsible for transfer of information about the violations taking place in the course of decommissioning work;

i) availability of the programs for personnel training and initial briefing or re-briefing on the occupational safety and health agreed by the relevant state supervision bodies.

75.3. Conformity with the preset periodicity of knowledge testing and availability of the relevant protocols.

75.4. Inspection of logbooks (cards) of briefings, conformity with the preset periodicity of briefings on radiation safety measures during the work.

75.5. Documents confirming special training of the person responsible for radiation safety.

75.6. Theoretical and practical training of specialists of the operating organisation, including branches and separate subdivisions, for the work on decommissioning. Awareness of the personnel of:

a) safe methods in conducting engineering process operations in the course of the work;

b) requirements to the use of individual protection and sanitation means in the course of process operations;

c) procedure of work with individual dosimeters;

d) engineering and radiation characteristics of the RTG, its systems;

e) requirements to the RTG as a radiation source;

f) peculiarities of the RTG location at the sites of operation, including the approaches to above;

g) procedure of operations on replacement of shielding containers for different RTG types;

h) safety requirements at planned stages of decommissioning activity.

76. The operating organisation personnel involved in the work on fastening (unfastening) the radiation packages on the external load of helicopter, should pass special program of theoretical and practical training and be provided with permits for operations with external load.

5.4. Organisation and technical support of RTG mandatory survey documents drafted by the results of above

77. As provided for in sub-paragraph 67.3, inspection efforts are focused on the organisation and technical support of RTG survey in the locations of operation:

77.1. Inspection commission for RTG survey in the locations of operation shall include the representatives of the operating organisation, executive authorities for the use of nuclear energy, RTG designer, state bodies for safety control during the use of nuclear energy, bodies of state authorities of the subject of the Russian Federation where the RTGs are located (upon agreement).

77.2. Availability of the reserve shielding containers for each type of RTG planned for decommissioning. If the commission makes a decision that the engineering (strength) characteristics of standard shielding containers do not comply with preset requirements, it is necessary to ensure installation of RTG in the reserve shielding containers before transportation is started.

77.3. Verification of the inspection program. Availability in the program of the procedure to verify correspondence of radiation parameters for the case when the surveyed facility incorporates an RTG group.

78. In case of sufficient retrospective information gathered in the course of RTG operation, the RTG inspection program in the location of operation can be shortened by the decision of the operating organisation. Such decision shall be agreed with the RTG designer experts.

79. It is recommended to make, in the process of survey, the photos of the RTG at NA site, of the detected RTG defects and shielding container structure. The photographs should illustrate the findings of the commission on possible or impossible dismantling and transportation of RTG. Photos shall be attached to the Inspection Deed, which contains reference to the photos.

80. Organisation and technical support of radiation monitoring in the course of the work on decommissioning:

80.1. List and technical characteristics of radiation monitoring facilities:

a) conformity of technical characteristics of the applied measuring instruments with the monitored parameters range;

b) type of devices or facilities, year of manufacture;

c) availability of sufficient amount of individual dosimeters for the personnel of group A;

d) technical condition of the measurement aids, availability of valid certificates on state metrological calibration test.

80.2. Organisation of radiation monitoring in the zones determined in accordance with the category of potential radiation hazard and class of operations.

80.3. Organisation of personal radiation monitoring.

80.4. Verification of the accounting of radiation monitoring results (logbooks and cards for individual exposure dose record keeping, logbook for radiation monitoring data keeping) and procedure for keeping the staff informed about the summarised radiation monitoring results.

81. The results of RTG radiation and engineering inspection for making a decision on its possible safe dismantling from the site of operation and further transportation.

82. In the course of inspections of safety (type 2) one should focus on:

82.1. Conformity of the measured exposure rate with the limits established for the radiation packages of transport category «III-YELLOW on the exclusive use terms».

82.2. Lack of mechanical damages of RTG load-bearing elements (cracks in welded joints, in load-bearing elements of the structure intended for transportation of RTG, etc). If the above defects are revealed in the RTG shielding containers (with the exception of RTG of "Beta-M" or "Beta-C" type manufactured before 1986) the product should be installed in a reserve shielding container.

82.3. Presence of hazardous natural factors which can have impact on safe RTG dismantling, installation in reserve shielding container, and also RTG loading on a transport facility or fixing on the external load of a helicopter.

82.4. Conformity of the radiation parameters and engineering condition of RTG load-bearing elements with the criteria for making a decision on its possible evacuation from the site of operation (requirements of the operating documents and engineering specifications for manufacturing of this type of RTG).

82.5. Radiation parameters are:

a) presence or lack of removable radioactive contamination on the RTG elements;

b) values of the equivalent dose rate at the RTG surface and at the distance of 1 m from the above. In the course of inspection, it is recommended to make at least 4 measurements at the frame surface and same - at the distance of 1 m;

82.6. Engineering parameters are:

a) availability, completeness and oxidation level of shielding containers;

b) technical condition of load-bearing elements, sling units and RTG shielding containers;

c) condition of RTG fixing elements and units of the transportation package (shielding containers);

d) technical condition of external elements of RTG structure;

e) presence of any defects in RTG frame and the level of their impact on safety during dismantling and transportation of the given products;

e) condition of the welded joints in the structure of the product and shielding containers;

f) condition of the mechanical and lock joints in RTG frame.

83. By the results of inspection of each RTG in the location of operation, the commission drafts a Deed which should contain unambiguous assessments –separately for the findings with regard to radiation inspection and with regard to engineering inspection of the RTG.

84. Basing on the inspection results, the commission makes a decision on RTG dismantling and transportation to sea vessel or other type of transport provided for in the project.

85. If RTG engineering and radiation characteristics conform with the requirements of engineering documents, the commission makes a decision on its possible dismantling and transportation (movement) from the site of operation. The operating organisation personnel dismantles the RTG, replaces the shielding containers (transportation package), if necessary, and fulfils the transportation (movement) of RTG, in accordance with the program of decommissioning.

86. If specified parameters do not comply with the preset criteria, the commission makes a decision on irrationality or impossibility of RTG dismantling and transportation. In such case, the inspection Deed provides recommendations on the dates and most safe method of evacuation of the given product. Decommissioning of the given product is carried our later, basing on permit-certificate for transportation under special conditions. Request for such permit-certificate shall be made by the operating organisation on the basis of the inspection Deed, recommendations of the commission and RTG designer.

87. If commission states, in the course of inspection, that the dismantling and evacuation process flow sheet does not account (insufficiently accounts) for the impact from hazardous natural and/or technogenic factors, the RTG dismantling and transportation should not be carried out. Considering the recommendations of the commission with regard to the above factors the operating organisation shall redraft RTG decommissioning project and agree upon supplements to the project with authorised bodies, in the established routine.

88. After dismantling, a record is made in the RTG card and a Deed of dismantling is formalised and signed by the individuals conducting dismantling. After that it is approved by the operating organisation leader. The Deeds of inspection and dismantling are sent to RTG designer, territorial authority of the Service, TU Rospotrebnadzor, Ministry of Interior, Rosatom and the departments operating with RTG (Ministry of Defence of Russia, Federal Agency of Sea and River Transport).

5.5. Verification of preparedness for radiation accidents consequences liquidation

89. As provided for in sub-paragraph 67.4, inspection efforts are focused on:

a) conformity of radiation facility location and zoning with the project (sanitary and epidemiological findings);

b) availability of the procedure of transfer of information on radiation accidents and incidents contained in the administrative and regulatory documents;

c) the order (resolution) of the organisation on the assignment of the individual responsible for real-rime information exchange on radiation accidents (incidents) during decommissioning activities ;

d) instruction on accident prevention and elimination during RTG handling in the course of decommissioning activities;

e) list of possible violations in the course of decommissioning activities;

f) prognosis of possible radiation accidents (depending on the distance between the facility and populated areas);

g) the action plan to protect personnel and population (for Category I and II facility depending on potential radiation hazard)) or action plan to protect personnel in case of radiation accident considering the radiation accident consequences;

h) instructions on personnel actions in case of emergencies;

i) the program for training and methodologies for emergency response training of personnel to perfect the action under radiation accident;

j) the emergency response training schedule for personnel in the current year;

k) the deeds and other documents on personnel emergency response training results in the current year;

l) the order (resolution) on establishing special emergency response unit (team) for ensuring the decommissioning activities;

m) the technical and engineered devices for radiation accident localisation and consequence elimination;

n) availability of the memos in the premises of personnel permanent attendance containing the list of urgent measures to be undertaken in case of emergency, job descriptions shall contain the provisions for employee (personnel) actions in case of alarm signal;

90. Verification of the efficient operation of personnel alert system in warning the personnel, population and state authorities in case of radiation accident.

91. Availability and completeness of:

a) emergency sets of personal protective equipment at the aircraft and special vehicle to carry out personnel and population protection measures;

b) emergency sets of engineered devices, first aid kits containing also spare sets for sanitary treatment of radioactive contamination zones;

c) Measuring instruments with expanded range of measurements allowing to measure the ionising radiation dose rate under conditions of design basis accidents;

d) communication means ensuring the required communication distance range.

92. Procedure for informing about radiation and non-radiation incidents and compliance with the established requirements.

93. Organisation of interactions between the operating organisation and the bodies of state authority of the subject of the Russian Federation (for Category I facility depending on potential radiation hazard) and units of the Ministry of the Russian Federation on Civil Defence, Emergencies and Natural Disaster Consequence Elimination.

94. Level of awareness of the organisation personnel (officials) of:

a) list of possible emergencies and related action plan for liquidation of design basis accidents consequences;

b) procedure for investigation and accounting of violations during operations in the FUAE.

95. Availability, staffing and preparedness of special unit (emergency team) to the actions during radiation accidents and consequence elimination.

96. Completeness and timely investigation of radiation accidents and incidents, implementation of measures to eliminate the causes.

97. Compliance of actual periodicity of emergency preparedness training (exercises) with the methodology of their organisation and performance.

5.6. Organisation and fulfillment of RTG (RHS) transportation

98. As provided for in sub-paragraph 67.5, the organisation and fulfillment of RTG (RHS) transportation will be discussed in detail in section 6 of the Methodology.

5.7. Conformance with safety requirements in fulfillment of decommissioning program and project

99. As provided for in sub-paragraph 67.6, inspection efforts are focused on the conformance of planned measures to the standard requirements and the available information on the RTG to be decommissioned.

100. Verification of conformance with the requirements of RTG decommissioning program, includes:

a) measures on fulfillment of justification and optimisation principles during realisation of the decommissioning process plan;

b) implementation of quality assurance and radiation protection programs;

c) measures to maintain the qualification skill of the personnel involved in the work;

d) measures to reduce the personnel dose burden in the course of decommissioning activities;

e) implementation of general organisational and technical measures to ensure RTG safe decommissioning and the schedule of the work of RTG decommissioning;

f) fulfillment of the work program on RTG decommissioning by the branches and/or separate subdivisions of the operating organisation;

g) realisation of the RTG decommissioning schedule planned for the current year.

101. Verification of implementation of the RTG decommissioning project includes:

a) project accounting for restrictions specified in the permission documents issued by authorised federal executive bodies, state competent authority (see sub-paragraph 72.4);

b) realisation of the conservative approach in producing a list of initiating events and analysis of design basis accident consequences;

c) complete account of possible hazardous natural factors;

d) efficiency of the administrative and engineering components of the physical protection system in the course of decommissioning activities;

e) conformance of the administrative and engineering measures taken in the course of RTG (RHS) radiation packages transportation with the standard safety requirements including those described in section 6 of the Methodology;

f) technical support in RTG survey at the site of operation;

g) conformance of the design data on geographical and geo-morphological conditions at the sites of RTG location with the data provided in operating documents.

102. When checking the conformity of the work being fulfilled with the project and program, it is recommended to use the data contained in the report of justification of RTG safe decommissioning.

5.8. Requirements to physical protection system

103. As provided for in sub-paragraph 67.7, inspection efforts are focused on fulfillment of the requirements to organisation and support of operation of physical protection system:

103.1. Conformity of the administrative measures of physical protection system with the requirements of the regulatory documents and availability of the necessary documents related to administrative arrangements and physical protection:

a) list of threats;

b) protection and defence plan;

c) orders on assignment of the official responsible for physical protection system;

d) provisions on security service of the organisation;

e) document establishing the category of the facility by potential radiation hazard (as applied to the physical protection system organisation);

f) provisions on the system of access for employees (personnel), seconded personnel, visitors and vehicles access to the secured premises, buildings and on the territory where RTG (RHS) management or storage is taking place;

g) plan for interaction with the administration, security service, guard units and employees (personnel) of the organisation under normal situation and emergencies;

h) provisions on self-protection;

i) maintenance and efficiency schedule for engineered devices of physical protection system;

j) document establishing the procedure for tempering detection device application;

k) job description of organisation physical protection official;

l) job descriptions of the employees managing security service;

m) documents on certification of physical protection system engineered devices.

103.2. Availability and condition of engineered devices of physical protection system:

a) alarm ensuring continuous detection of the intruder;

b) engineered device control console of physical protection system;

c) radioactive substance detection devices at personnel control post;

d) radioactive substance detection devices at vehicle control post;

e) communication means, securing the required range of transmission reception;

f) building and room tempering detection devices;

g) supply system (electric power supply, electric lighting etc.);

h) backup power supply source ensuring performance of engineered devices of RTG (RHS) storage facility physical protection by automatic switch of main supply to standby system in case of electricity loss.

103.3. Availability and condition of engineered devices of physical protection system:

a) construction structures (walls, bars, gates, doors);

b) specially developed structures (barriers, grate, reinforced doors, containers);

c) personnel control post and vehicle control post;

d) counter-ram devices at vehicle control;

e) conformity of guard unit actions at violator (unauthorised actions) detection with the requirements of the regulatory documents.

104. The cited list of requirements to physical protection system organisation covers all inspection types defined in section II, including the inspections on storage conditions. During inspection types 1-3 the list can be shortened depending on the specifics of the inspected organisation activity.

105. The documents regulating RTG decommissioning (program, project, safety justification report, decommissioning schedule etc.) should envisage effective measures for restriction of disclosure of information about the schedule of planned works, implemented process diagrams.

5.9. Requirements to organisation of RTG account, control and storage

106. As provided for in sub-paragraph 67.8, inspection efforts are focused on fulfillment of the requirements for RTG account, control and storage:

106.1. Availability and conformity with established requirements of:

a) record-keeping logbook for RTG (RHS), including those delivered for temporary storage;

b) passports for RTG (RHS) sent for long-term storage;

c) RTG (RHS) acceptance deed.

106.2. Compliance with the procedure to provide for the information on RTG (RHS) availability and movements to the information and analytical organisations and centers for state accounting and control system (at industrial and regional levels) data collection, processing and transfer.

106.3. Inspection of:

a) certified methodologies for safety analysis of RTG storage conditions in temporary storage specialised stations;

b) certified methodologies for safety analysis of engineered devices used for RTG storage safety analysis;

c) certified methodologies for taking measurements of radiation characteristics of the RTG kept in temporary storage;

d) measurement of radiation package radiation characteristics at temporary storage sites;

e) quality assurance (program) programs;

f) procedure instructions on safe handling of radioactive wastes;

g) the document setting up the order and periodicity of radiation characteristics and technical condition control of the RTG on storage.

107. Responsibility for ensuring safety at RTG temporary storage is held by the organisation exercising the storage. The operating organisation is authorised to fulfill the internal control of quality assurance program during RTG temporary storage.

5.10. Organisation of investigation of radiation and non-radiation incidents during RTG handling

108. As provided for in sub-paragraph 67.9 the inspection efforts are focused on the preparedness of the organisation for investigation of radiation and non-radiation events which may occur at any stage of RTG decommissioning:

108.1. Availability of the orders:

a) on assignment of a responsible person entitled to transfer the information messages, in established form, about violations of the proper work procedure (storage conditions);

b) on establishing the Violation Investigation Commission.

109. In case of radiation (non-radiation) incident, the following is to be inspected: availability, timeliness, trustworthiness and completeness of the information contained in:

a) the operational, tentative information on the violations;

b) deeds and reports issued by commissions on investigation of violations at the facility and their conformance with the established requirements.

110. The inspections of compliance are to verify the organisation and registration of all the violations occurring during RTG handling in the course of decommissioning, in accordance with the classes established by НП-014-2000 (see Appendix № 1, para. 5).

5.11. Additional issues subject to verification

111. Selection of additional issues is conducted in accordance with the inspection goals and considering the facility specifics. The list of additional issues is determined in the inspection working program. These issues could be, e.g., as follows:

a) receipt of detailed information on engineered devices of physical protection system (considering the requirements of para.9);

b) on supplementary safety measures during evacuation of the RTG which were damaged during operation;

c) on characteristics and certification of transportation packages intended for evacuation of the RTG (RHS) damaged during operation;

d) on availability of certificates/permissions for transportation under special conditions in case of RTG being damaged;

e) detailed information about the organisations rendering engineering support to the work on RTG (RHS) decommissioning,

and other issues directly or indirectly affecting radiation safety during execution of RTG decommissioning activities.

VI. STANDARD SAFETY REQUIREMENTS DURING RTG TRANSPORTATION (SHIPMENT)

6.1. General

112. The below safety requirements are the generalised requirements established in the effective certificates/permissions (see Appendix № 6) and inter-agency regulatory documents (see Appendix № 1, paragraphs 2, 18, 20, 26-27).

113. It is recommended that the Service officials would control, at the stage of agreement of transportation safety instructions, that the required safety requirements, indicated in the given section, are introduced in the administrative and regulatory orders (instructions) of transport organisations.

6.2. Safety measures during RTG transportation on helicopter external load

114. The use of helicopters external load for transportation of the dismantled RTG (RHS) radiation packages to sea vessel shipment area is the principal technological method applied in the course of RTG decommissioning process.

115. Consignor should the report to FSUE "Department for nuclear and radiation safety of Rosatom" and FSUE "Emergency Technical Centre of St. Petersburg" on the starting time of transportation well in advance.

116. Before helicopter take-off to NA for participation in the field stage of the work on RTG decommissioning it is necessary to provide:

a) briefing of helicopter team and technical personnel on hazardous freight character, specifics and handling procedure;

b) briefing of trained (see para.76) employees of the operating organisation participating in preparation of RTG radiation packages for transportation, as well as fixing (unfixing) for helicopter external load.

117. During implementation of engineering and radiation inspection of the transported package, directly before fixing the package for helicopter external load, special attention should be paid to the condition of all slings fixing the freight, lack of transportation package visible defects and damages.

118. Each sling used for RTG radiation package transportation should be furnished with a metal tag fixed at the place of rope ends fixing by "braiding". The tag shall indicate:

a) the name and trade mark of the manufacturer;

b) the sling hoisting capacity;

c) the date of next testing (month, year).

119. Transportation route should be agreed on with the operating organisation. It should not pass over residential area and industrial works, and the flight time over the water surface should be minimal.

120. The members of land team executing radiation package fixing (unfixing) on external load should be provided with overalls, chin-strapped helmets, closed-type protective goggles, gloves, respirators for protection of respiration organs against dust. The clothes should be tight-fitting, bright and contrast in color against the local background.

121. Visual (photo-) control of the package fixed at load carrier prior to transportation, state of package fixing during and after transportation should be provided.

122. Additional requirements during transportation route over the water area:

122.1. The aircraft should have onboard an emergency buoy which cable length exceeds the maximum sea depth along the flight route, by 5-10 m. The buoy is designated for registration of the point of radiation package fall in the water. Method of application of the emergency buoy is determined by the transport organisation. The buoy fixing on radiation package (if such method is chosen as the principal one) is conducted by the RTG designer expert (FSUE VNIITFA) upon agreement with the aircraft team.

122.2. The aircraft should be equipped with operating GPS (Global Position System) receiver, ensuring the coordinates error of no less than ± 20 m.

123. Additional safety measures during transportation:

123.1. Transportation of no more than one RTG radiation package on external load is permitted.

123.2. Just before start of transportation operations a confirmation of favorable weather conditions on the entire route, with favorable stable weather forecast up to the end of transportation, should be received.

123.3. The radiation package should be accompanied by the consigner (consignee) representative responsible for radiation safety of work execution and providing for operational radiation monitoring during transportation, from the moment the RTG radiation package is fixed on external load and up to the moment of the package is unfixed at the destination point.

124. Availability of radiation equipment on board and the preparedness of the escorting person to conduct operational radioactive control on board during transportation.

6.3. Actions in emergency during transportation by external load

125. In case of emergency threatening the crew and aircraft safety the RTG radiation package is subject to external load emergency release.

126. In case of RTG emergency release the helicopter captain shall urgently report to the flight administrator when the situation is stabilised.

127. In case of emergency during transportation over the land:

127.1. The freight should be released from minimum height on to sand soil or any other soft soil. The team shall visually identify the release area, provide the photographing of released freight from 10-20 m height and ensure helicopter landing nearby.

127.2. The escorting person and crew shall immediately undertake measures to ensure safety according to emergency card requirements (Appendix № 7).

127.3. If RTG structure is not visibly damaged, the escorting person shall conduct initial examination of the radiation situation by measuring the equivalent radiation dose rate (onward-ERDR) at approaching the RTG to a distance up to 1 m from the side where the visible damage to external elements of the structure is the least:

a) if, when approaching the RTG, the ERDR exceeds the maximum value obtained in the course of RTG radiation inspection in the location of operation before commencement of transportation ($ERDR_{max}$), further measurements shall not be conducted;

b) if, when approaching the RTG, the measured ERDR does not exceed the $ERDR_{max}$, the escorting person shall take several measurements along the line at a distance of approximately 1 m from RTG radiation package. It is recommended to take measurements on the side where RTG structure has visible damages;

c) the maximum dose rate value obtained at a distance of 1 m is compared with $ERDR_{max}$:

- The excess values mean that the RTG physical barrier is damaged;
- In case of no excess, the physical barrier is supposed to have no damages.

It is **PROHIBITED** to repeat external load for released RTG to continue transportation if no specialised studies are held at the released RTG area for "removable" radioactive contamination of RTG surface and radioactive contamination of the environment.

127.4. If landing nearby the released RTG is impossible the team ensures helicopter hovering at a minimum but safe height above released RTG. The escorting person and team staff shall fix the coordinates using the helicopter GPS, and visually assess the engineering condition of released RTG, make photographing, and, if necessary, hold radiation monitoring measurements at hovering height.

127.5. If upon reaching the ground, the radiation package falls on one side or is overturned, all possible measures should be taken to put the package back into vertical position as soon as possible.

128. In case of transportation over the water area:

128.1. After radiation package release to water area the following measures are to be provided:

a) maximal fast (following flying safety requirements) helicopter lowering and hovering over released RTG location (during 1-2 minutes there is a spot generated by the bubbles released by the product structure cavities);

b) the emergency buoy release (if transported onboard the aircraft);

c) determination by GPS and fixation of the coordinates of helicopter hovering over the release location;

d) photographing of the buoy on the water surface;

e) the helicopter heaving 30-50 m to the initial route of RTG transportation and hovering to make repeated (check) coordinates' measurement by GPS.

129. After return to the base after RTG radiation package emergency release all the persons participating in the transportation shall be questioned by commission, and, if necessary, shall state in writing the emergency release circumstances they know of.

130. In case of crash of helicopter with external load, the reserve helicopter shall ensure urgent delivery of emergency response unit of consignor or consignee, equipped with radiation measurement instruments and necessary technical facilities.

131. RTG radiation package emergency release should be classified as radiation accident class A. The released product is to be inspected by commission in accordance with the program developed for RTG inspection in locations of operation. Further transportation of the package is possible only by certificate/permission for the transportation under special conditions.

6.4. RTG transportation to fixing site by towing on external load fixing of RTG located near navigation aids

132. The RTG radiation package transportation to the site of fixing on helicopter external load by towing is carried out in the cases when the product is located either in the immediate closeness (up to 15 m) to the NA from which the RTG is evacuated, or within its land surface projection area.

133. It is prohibited to use helicopter for RTG transportation by towing to a free place if the RTG is installed closer than 5 m from NA, and if the hovering height exceeds NA height by less than 10 m.

134. For the purpose of movement, it is allowed to use wooden or metal levers with length of 2.5 m, at least. It is recommended to perform RTG movement in such a way that the workers would not approach RTG closer than 1 m.

135. During RTG transportation by towing for fixing to external load, measures to exclude the possibility of RTG overturning, should be envisaged.

136. RTG transportation from NA to a free place is allowed with use of helicopter equipped with lengthened cables and a "spider" for external load, subject to their total length exceeding the NA height by no less than 10 m. Helicopter shall hover over RTG radiation package at a height exceeding the NA height, the radiation package shall be fixed and the package transported on external load to a convenient place.

137. If RTG transport package is to be loaded on ship for sea transportation, the load shall be transported to the ship on extended external load and installed on deck subject to compliance with the condition indicated in para.70.

138. If further RTG transportation on helicopter external load to a significant distance is supposed:

a) the aircraft shall land after RTG is moved and installed at the distance of 30-40 m from NA;

b) the cable system shall be replaced for a shorter one to be applied for further transportation of RTG radiation package by air.

6.5. RTG package loading to vessel and transportation by sea

139. During RTG radiation package loading to vessel for subsequent transportation by sea with the use of helicopter external load it is necessary to make sure that the cable sling length, including "spider" cables, exceeds the maximal height of the vessel's highest mast by no less than 10 m.

140. The vessel crew members involved in RTG radiation package stowage should be trained according to para.76.

141. The sea vessel crew members directly involved in RTG radiation package unfixing and on-deck positioning operations, should:

a) be specially briefed;

b) be equipped with personal protective equipment in compliance with p.91.

142. In RTG loading to sea vessel it is recommended to unfix RTG at the open deck sector, only. Radiation package stowage in holds for further sea transportation is carried out by vessel crew using the vessel hoisting facilities.

143. Each RTG after loading should be reliably secured inside the hold. It is not recommended to transport other freight in the compartment (-s) of the hold intended for RTG transportation. It is recommended to place massive items along the wall of the hold's adjacent compartments on the side

of crew cabins to create additional shielding against ionising radiation (creation of additional physical barrier).

144. Make sure that upon termination of the vessel loading with planned quantity of RTG radiation packages the following is done:

a) radiation monitoring is carried out on the vessel deck and in the rooms adjacent to the hold, where RTG radiation packages are stowed;

b) the vessel deck zone where ERDR exceeds 3 μSv/h, is fenced with radiation hazard signs;

c) measures are taken to limit the time of presence of crew members and escorting persons in the zone specified in sub-paragraph 144-b;

d) total radiation package transport index shall not exceed 200;

e) measures are taken to prevent RTG radiation package overheat during transportation:

1) RTGs are not covered with any materials impairing the conditions of heat exchange to ambient air;

2) no other RTGs or freight is placed on the RTG upper surface;

3) a gap of not less than 200 mm is left between the RTG and the hold walls.

6.6. RTG transportation to vessel freight area by towing

145. RTG radiation package transportation to sea vessel freight area by towing or with the help of a winch and cable equipment is allowed in exceptional cases, when neither helicopter nor hoisting facilities can be used.

146. The application of the given method of transportation in the course of RTG decommissioning is accepted if the following conditions are fulfilled:

a) availability of the commission conclusion stating the impossibility to apply other transportation methods;

b) lack of relief differential over 0.5 m range between the site of RTG installation and the water cut-off line. (Before starting the transportation it is allowed to level artificially the relief surface on the way of RTG movement);

c) measures taken to prevent the RTG from overturning.

147. The route of supposed RTG transportation by towing shall be photographed, the photo is to be attached to the inspection deed.

148. RTG package transportation by towing is allowed only using a ready-made metal sheet: one edge of the sheet should be curved and have fittings (rings) for fixing a hook.

149. After pulling the metal sheet with radiation package to water cut-off line, the package shall be unfastened off the sheet and lifted onto the pontoon by the vessel rigging team using the vessel hoisting facilities.

6.7. RTG (RHS) package transportation by motor cars

During RTG (RHS) transportation by motor cars the following is to be inspected:

150. Availability of:

a) sanitary and epidemiological findings on the compliance with sanitary rules for carriers and transportation packages used for RTG (RHS) transportation;

b) the certificates for transportation packages and equipment subject to certification in accordance with the legislation of Russian Federation;

c) the program for radiation protection of the personnel and population;

d) the instructions for RTG (RHS) transportation and accident consequence elimination during transportation thereof;

e) the action plan for the driver (escorting persons) in case of emergency;

f) the transportation routes agreed on with the Road Police of the Ministry of Interior of Russia, permission for personnel and transportation means to transport hazardous freights, emergency cards and information boards;

g) radiation protection shielding device on a special motor car, locking device, emergency kit, preventive signs placed at two external side walls and external back wall of the vehicle, radiation monitoring instrumentation, communication means to inform the administration and services ensuring elimination of accident and incident consequences during RTG (RHS) transportation.

151. Condition of the transportation means and equipment used to transport RTG (RHS) and radiation packages.

152. Preparedness of the escorting person (-s) responsible for radioactive freight convoy and the driver to transport RTG (RHS).

153. Procedure for interaction with consignor (consignee), regional emergency units, other organisations involved in handling of RTG (RHS) radiation packages, in the course of possible accident consequence elimination.

154. RTG (RHS) radiation package transportation by the roads of general use is recommended to be convoyed by an escort car with trained personnel, instrumentation and personal protection emergency kits.

155. By resolution of state authority bodies of the subject of the Russian Federation where the transportation is conducted, the RTG (RHS) radiation packages may be escorted by motor cars of the Road Police of the Ministry of Interior of Russia.

6.8. RTG transportation by trailer for loading onboard vessel

156. The RTG radiation package delivery for loading to vessel should be scheduled so that pre-loading holding time would not exceed 3 hours. The parking site for RTG radiation package trailer should be remote from populated sites and from other transport facilities.

157. During RTG package loading from trailer to vessel, safety measures stipulated in paragraphs 140-144, should be implemented.

158. Upon arrival of trailer with radiation package (-s) to sea port area, freight operations are to be handled by port personnel according to safety regulations for hazardous freight treatment in the given commercial sea port.

159. Before starting decommissioning activities, the administration of the sea port where the decommissioned RTGs are to be delivered, shall provide the operating organisation with the instructions on handling of hazardous freight class 7 (radioactive substances).

6.9. RTG package loading (unloading) to special railway cars and transportation by railway

160. RTG (RHS) package loading/unloading to special railway cars is to be carried out according to the process scheme adopted for loading special railway cars at the station of loading.

161. If selected decommissioning plan suggests that RTG radiation package is delivered on helicopter external load, the RTG package shall be unfastened off the external load at the nearest temporary platform outside the populated settlement and loaded to the motor car (trailer). Loading can be carried out either directly from external load or using hoisting machinery of appropriate power-rating.

162. The delivery of RTG radiation packages to railway station or railway station area should be carried out observing the requirements specified in para.156.

163. Transportation of RTG radiation packages in freight cars is allowed under conditions of exceptional use, subject to compliance with the following terms:

a) the issue is agreed on with the federal executive body operating with RTG, the state sanitary and epidemiological supervision bodies and the Ministry of the Russian Federation on Civil Defence, Emergencies and Natural Disaster Consequence;

b) the summary transport index of transported packages does not exceed 50.

164. During radiation package transportation, the safety rules established for railway transportation shall be followed.

165. Special railway cars with loaded RTG (RHS) radiation packages shall be transported by direct trains.

Conclusions

The Regulatory Guide has been completed and is being promulgated: the next challenge will be to ensure its effective application. The following particular recommendations for future work have been identified:

- Experimental implementation of the guidance by Rostechnadzor inspectors has indicated a clear need for training of inspectors in implementing the guidance, and information sessions for RTG operators and organizations rendering services on the purpose and application of the guidance.
- Western experts recommend that a fifth type of inspections should be considered, namely 'reactive' inspections to be performed following a possible incident or accident. Although these would in some respects be similar to compliance inspections, some other specific guidance could be added.
- In cases where RTGs are to be kept in operation beyond their design lifetimes rather than decommissioned, specific regulatory inspections should be made before authorisation is granted for their continued operation.

APPENDIX 1

LIST OF REGULATORY DOCUMENTS APPLIED TO RTG DECOMMISSIONING

1. General safety provisions for radiation sources, NP -038-02.

2. Rules of safety for transportation of radioactive materials, NP -053-04.

3. Regulations on physical protection of radiation sources, storage facilities and radioactive substances НП-034-01.

4. Requirements for planning and preparedness to mitigation of consequences of radiation accidents at transportation of nuclear materials and radiation substances, NP-XXX-06 (draft).

5. Rules for investigation and accounting of violations at handling radiation sources and radioactive substances used in the national economy, NP -014-2000.

6. Requirements for design and safe operation of hoisting cranes for the facilities of use of nuclear energy, НП-043-03.

7. Requirements for justification of extension of the assigned service life of nuclear facilities, NP -024-2000

8. Radiation safety standards, NRB-99

9. Basic sanitary rules of radiation safety, OSPORB-99.

10. Composition and content of report of radiation safety at radiation hazardous facilities RB—12-04.

11. Sanitary rules of design and operation of radioisotope power sources for independent coast and water area monitoring facilities, # 1901-78.

12. Sanitary rules of radiation safety of the personnel and population during transportation of radioactive materials (substances), SanPiN 2.6.1.1281-03.

13. Rules of establishing, functioning and funding of regional emergency response units of the operating organisations used for liquidation of accident consequences during transportation of nuclear materials and radioactive substances. Approved by resolution of the Government of the Russian Federation as of 20.06.1997 №761.

14. Provision of state competent authority of nuclear and radiation safety during transportation of nuclear materials, radioactive substances and products thereof. Approved by resolution of the Government of the Russian Federation as of 19.03.2001 № 204.

15. Radioisotope thermoelectric generators. Types, main parameters and general specifications, GOST 18696-90.

16. Planning of measures and preparedness for the case of transport accidents related to radioactive substances. Series of IAEA issues on safety № 87, 1989.

17. Safety manual in design, manufacturing and use of RTG for some applications at land and sea. Series of IAEA issues on safety № 33, 1970 г.

18. Decision # 04-05 "Regarding transportation of packages with RTG (RIT-90, RITu-90) by helicopter external load. Approved by the Deputy Director of the Federal Atomic Energy Agency and Acting Chairman of the Federal Environmental, Industrial and Nuclear Supervision Service, 2005.

19. Temporary provision on the procedure of issue of permit-certificates for special type radioactive substance, design and transportation of packages with radioactive substances (PBSR-92) (ПБСР-92). Approved by Gosatomnadzor of Russia and by Minatom of Russia in 1992 considering subsequent approved addendums № 1, 2, 3.

20. Rules of operation and decommissioning of radionuclide power generators based on strontium-90 radionuclide heat sources, as approved by the First Deputy Minister of Atomic Energy, 1999.

21. Quality assurance program during operation and decommissioning (dismantling and transportation to FSUE Atomflot, Murmansk) of RTGs with Sr-90 RHS, as approved by the Director General of FSD “Hydrographic Enterprise” of the Ministry of Transport of the Russian Federation, 2004.

22. Decommissioning program (dismantling and transportation to FSUE Atomflot, Murmansk) of RTGs with Sr-90 RHS, as approved by the Director General of FSD “Hydrographic Enterprise” of the Ministry of Transport of the Russian Federation, 2004.

23. The program and methodology of examination of RTG with Sr-90 RHS at their operation locations, as approved by the Director of FSUE VNIITFA of the Federal Atomic Energy Agency, 2001.

24. Rules of Hydrographic service № 23. Radioisotope power equipment. (PGS № 23), 1990.

25. Rules of navigation aids maintenance (PTO-88), 1987.

26. On measures to prevent accidents and incidents with radioisotope power equipment in the Navy Hydrographic service, instructions of Head of Chief Administration for Navigation and Oceanography №708/21/1185 of 03.09.1999.

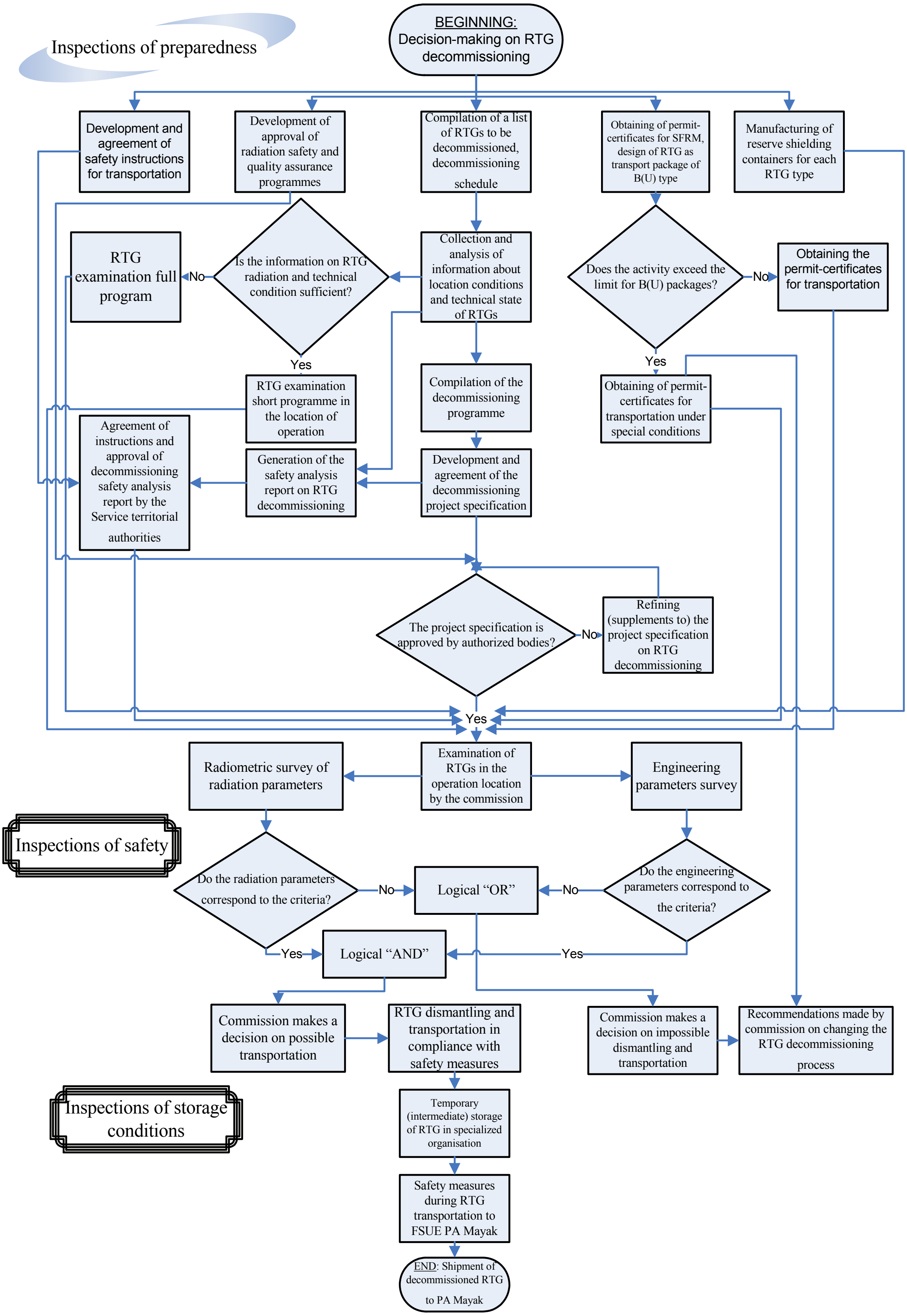
27. Instruction on transportation of cargo by helicopter external load. Approved by resolution of the Ministry of Transport of the Russian Federation of 08.01.2004 № Кр-2-р.

28. Organisation and realisation of state supervision of radiation safety of radiation hazardous facilities. Guide for inspectors training. Federal Environmental, Industrial and Nuclear Supervision Service, 2004.

29. Principles of supervision over activities with radioactive substances in military detachments and organisations of the armed forces of the Russian Federation Army. Guide for inspectors training. Federal Environmental, Industrial and Nuclear Supervision Service, 2005.

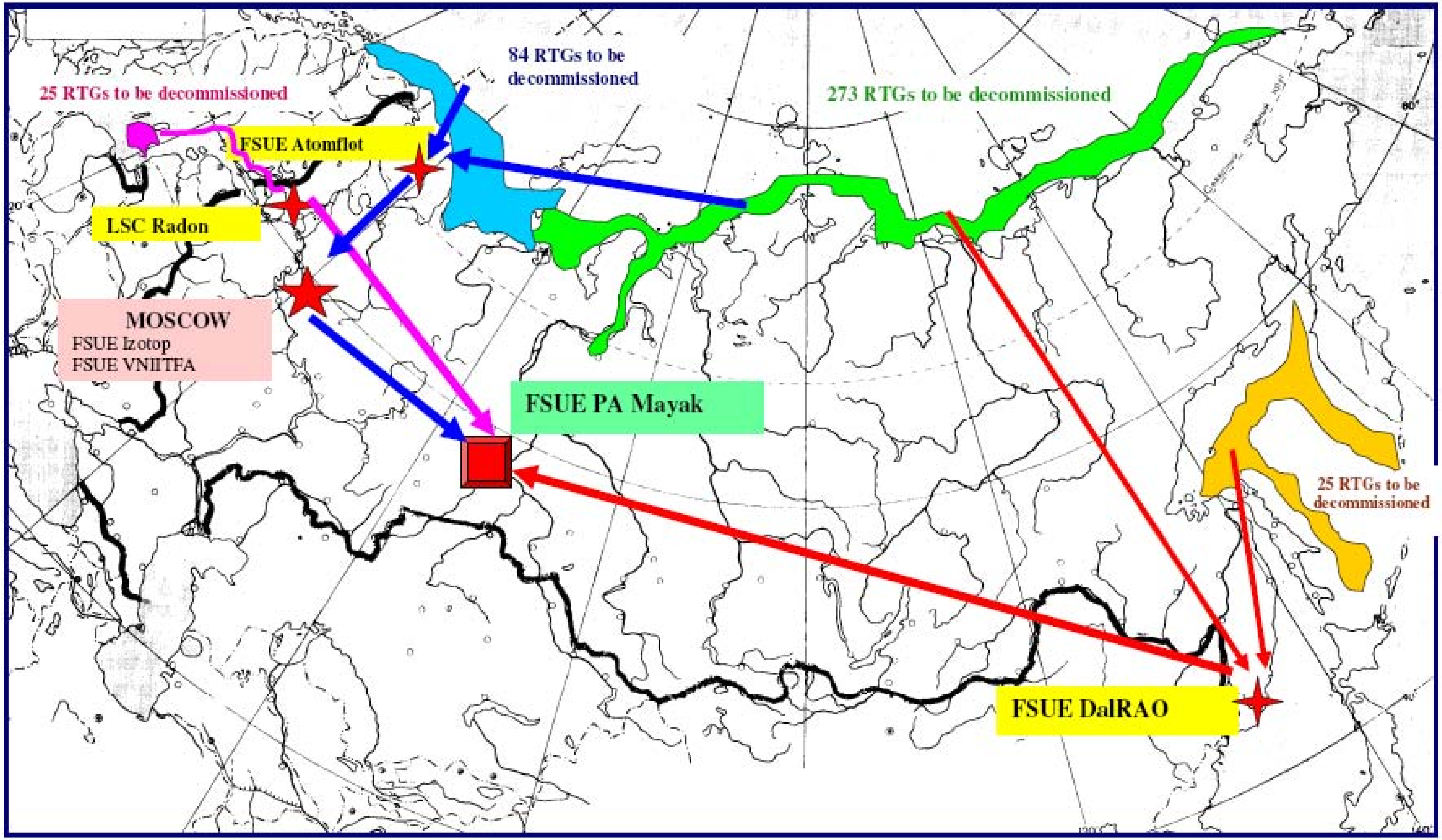
APPENDIX 2

RTG DECOMMISSIONING ALGORITHM



APPENDIX № 3

GENERAL SCHEMATIC OF RTG DECOMMISSIONING



The scheduled RTG decommissioning and disposal operations started in 2001. By the end of 2005 **243 items** had been delivered to FSUE VNIITFA; all funding sources involved. **210 items** were sent to FSUE Mayak for a long-term storage.

No deviations from routine process were recorded during the RTG shipments.

Planned dates of RTG decommissioning

Decomm. year	Number of RTGs owned by the Ministry of Defence of Russia (Hydrographic Service of the Northern Fleet). The decommissioning is to be carried out in frames of the Russian-Norwegian cooperation	Number of RTGs owned by the Federal Agency for Sea and River Transport and located along the Northern Marine Route. Decommissioning is planned, including the international assistance	Number of RTGs owned by the Ministry of Defence of Russia (Hydrographic Service of the Pacific Fleet). The decommissioning is to be carried out in frames of the Russian-American cooperation	Number of RTGs owned by the Ministry of Defence of Russia (Hydrographic Service of the Baltic Fleet). The decommissioning is to be carried out in frames of the Russian-German cooperation
2006	**30**	**28**	**25**	**95**
2007	**27**	**40**		
2008	**27**	**34**		
2009		**45**		
2010		**39**		
2011		**19**		
2012		**20**		
2013		**31**		
2014		**17**		
Итого	**84**	**273**	**25**	**95**

The transportation of RTGs at all shipment stages from their operation locations to FSUE VNIITFA was carried out on the basis permits-certificates issued by the Competent Authority of the Russian Federation for nuclear and radiation safety during shipment of nuclear materials, radioactive substances and products thereof – The Federal Atomic Energy Agency, as agreed upon with the Federal Environmental, Industrial and nuclear Supervision Service.

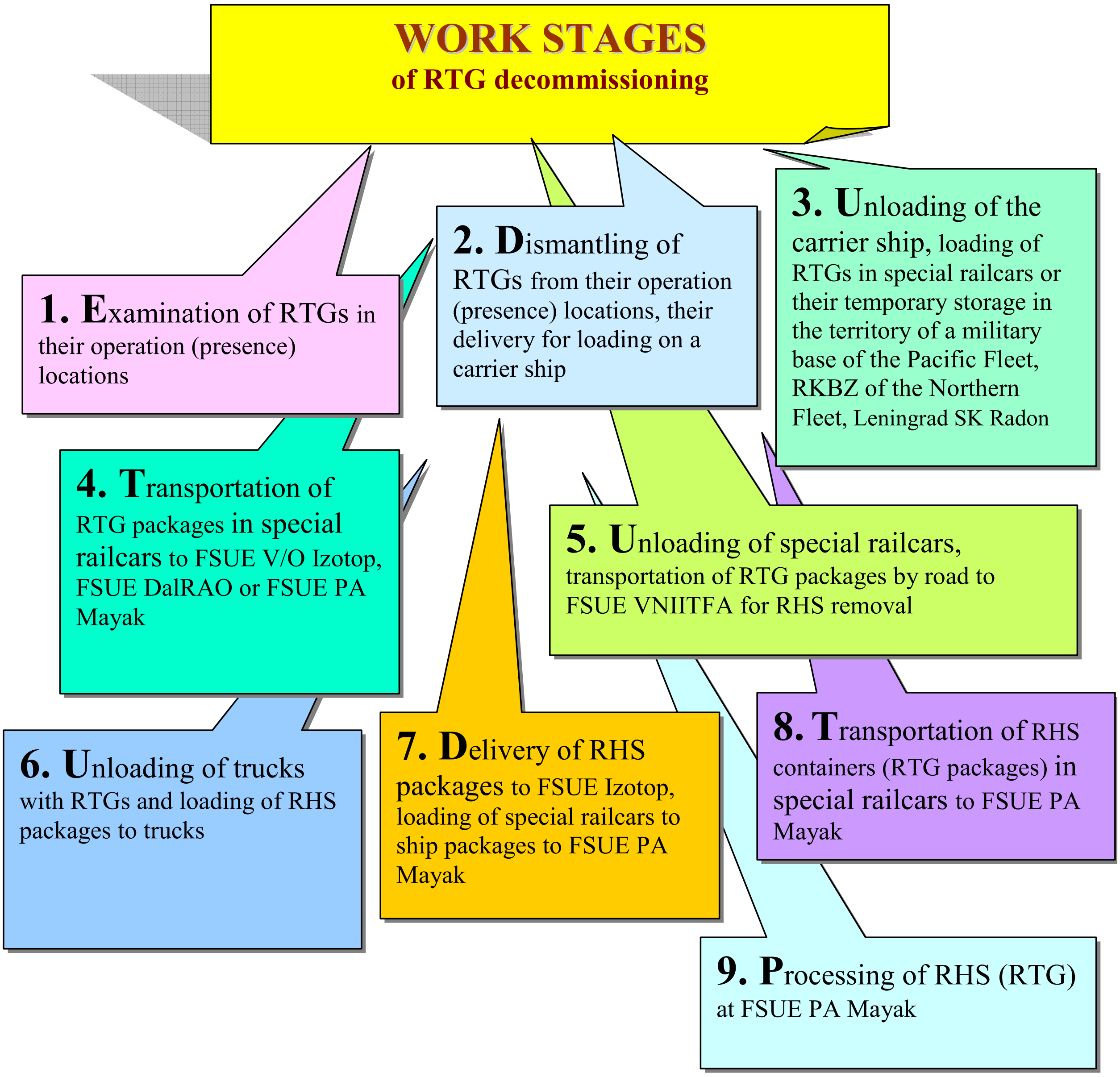
TASK OF REGIONAL OFFICES: Exercise control over annual activities of the operating organisations as regards decommissioning of RTGs and carry out inspections as tied up to specific dates of the operations!

APPENDIX 4

RTG DECOMMISSIONING STAGES

The content, sequence of operations, as well as roles and functions of the participants of the RTG decommissioning are established at large in the inter-industry regulatory document “Rules of operation and decommissioning of radionuclide power generators based on strontium-90 radionuclide heat sources, as approved by the First Deputy Minister of Atomic Energy 22.12.1999”.

Standard operation scheme includes **9 stages**.



Scheme 1. *RTG decommissioning stages*

Detailed description of stages

1. Examination of RTG in the place of its operation (presence) to identify whether it is possible to transport it in accordance with the existing regulatory and technical documents and RM transportation rules.

This work is carried out by a Working Group of the Rosatom's Central Commission (Minatom of Russia's directive # 255-r of 14.05.2003). A record produced by the Working Group Акт is reviewed by the Central Commission and approved by the Head of the Department for Safety and Emergencies of Rosatom who also is the Chairman of the Central Commission.

2. Dismantling of RTG and its placing on a vehicle to ship to a temporary storage, possibly, with a trans-shipment to the RTG assembling site.

The **temporary storage facilities** for RTGs to support decommissioning projects are (see Appendix № 3):

In the Baltics – **Leningrad SC Radon**;

In the North-West and Northern (up to 105^0 long.E.) regions – **FSUE Atomflot** or a base of the Navy's Northern Fleet's RKBZ (settlement Rosliakovo, Murmansk region);

In the Northern (from105^0 long.E.) and the Far East regions – **FSUE DalRAO**.

In the Baltics the delivery of decommissioned RTG to a temporary storage is planned to be fulfilled, primarily, by motor transport.

Two activity options are considered for the two last projects.

<u>Option 1.</u> A part of RTG packages is planned to load on the ship directly at their location and transport to the temporary storage facility by the same ship.

This work is carried out by the operating organisations – the Hydrographic Service of the Northern and Pacific Fleets and FSD Gidrographicheskoye Predpriyatie.

The process tooling and tools (rolls, flooring, crow-bars, ropes, jacks etc.) can be used to move RTG packages from the installation location to the coastline.

After having been placed on the pontoon the package is attached with a buoy that helps to identify the RTG location in case emergency sinking.

The RTG package is delivered to the ship on the pontoon. The pontoon personnel should be minimal. The ship should be anchored at a possibly close and safe distance from the RTG loading on the pontoon.

About 10-12 RTGs can be placed on one vessel. The ship goes to berths of FSUE Atomflot or FSUE DalRAO.

<u>Option 2.</u> Another part of the decommissioned RTG packages, which are impossible, in practical terms, to be directly put on the ship are planned to be preliminarily delivered to the RTG assembling site by a helicopter external load and then to put on the ship from this assembling site and transport to the temporary storage facility.

RTG packages are transported to the site by a helicopter with them being fixed on the helicopter external load.

Before fixing a RTG package on the helicopter load, a buoy should be attached to it that would help to identify the RTG location in case of its emergency drop into water.

3. The unloading of the ship with delivered RTG packages into the temporary storage facility, temporary storage of packages, loading of RTG packages into special railcars.

Special railcars for transportation of RTG packages are supplied by FSUE "Special Shipments" of Rosatom. At the temporary storage facility the acceptance of RTGs for shipment is carried out by a representative of FSUE VNIITFA who escorts the shipment.

The shipment is carried out by the Ministry of Communications of Russia.

4. Transportation of RTG packages in special railcars to FSUE V/O Izotop (the settlement of Staraya Kupavna, Moscow Region) or FSUE DalRAO (cape Sysoeva, Primorskyi region) or FSUE PA Mayak (Ozersk, Chelyabinsk Region).

5. Unloading of the special railcar, placing of RTG packages on special trucks, delivery of RTG to FSUE VNIITFA for dismantling.

The work is carried out by FSUE V/O Izotop.

6. Unloading of RTG packages from the special trucks, temporary storage of RTG and removal of RHS, placing of RHT to handling containers for temporary storage or trans-portation containers for shipment to FSUE PA Mayak, loading of transportation containers on special trucks for shipment to FSUE V/O Izotop.

The work on this project is carried out by FSUE VNIITFA.

7. Transportation of RHS containers by special trucks from FSUE VNIITFA to FSUE V/O Izotop base, unloading of special trucks, loading of containers to a special railcar for RHS to FSUE PA Mayak ".

The work is carried out by FSUE V/O Izotop.

8. Transportation of RHS containers (or RTG containers from Leningrad SC Radon and FSUE DalRAO) in a special railcar to FSUE PA Mayak.

Special railcars for the shipments are supplied by FSUE PA Mayak. RHS (RTG) acceptance inspection for shipment is carried out by a FSUE PA Mayak's representative who is escorted the cargo.

The shipment is carried out by the Ministry of Communications of Russia.

9. Unloading of RHS containers at FSUE PA Mayak, RTG dismantling operations, temporary storage of containers, unloading RHS containers, placing of RHS for a long-term storage (the first stage of RHS disposal) in conditions that identical to those of a long-term storage of vitrified high-level waste produced by nuclear power facilities.

The work is carried out by FSUE PA Mayak.

APPENDIX 5

POSSIBLE ACCIDENTS AND SAFETY ANALYSIS FOR RTG DECOMMISSIONING WORK STAGES

Possible impacts of a RTG (RHS-90) to the population and ecological characteristics of the environment are determined by its design and nature of impacts it can be affected by in the course of routine and anticipated accident conditions at their decommissioning work stages

From the date of manufacturing, storage, transportation, loading of RHS-90 in RTG, testing, operation, return transportation until the source disposal RHS-90, RTG and their components can be affected by impacts of different factors, separately or in combination and taking into account possible accidents at each of these stages, which can be of thermomechanical, physico-chemical and radiation nature depending of their origin.

With that, in terms of environmental safety the highest hazard is posed by accidents where RTGs (RHS-90) can be affected by a combined adverse effect of a number of factors, including those that can last for indefinitely long periods of time. For these conditions the ecological safety basis of RTGs (RHS-90) is the principle that the selected initial technical and process solutions are to reduce effects of total influence of possible impact factors down to the levels that ensure that the radioactive substance in the RHS-90 is securely confined under all circumstances

Let us consider the assessment of possible emergency impacts to RTGs (RHS-90) and some safety analysis findings prepared by the materials of FSUE VNIITFA and RESCenter, carried out within the frames of RTG decommissioning activities.

1. Impacts to RTG and RHS-90 under possible accidents

It is necessary to anticipate the following emergency impacts to RTG and RHS-90 components, which would be certainly more rigid than impacts of standard operation conditions:

- heat impacts of **fire** at all RTG and RHS-90 life stages;
- **heat shock** when RHS-90 possibly gets into snow, ice, water as a result of accidental distraction of the RTG;
- **overheating** due to possible RTG (RHS-90) getting into a low heat conductance environs (sand, clay) due to a vehicle accident;
- shock impacts during **accidents with vehicles** (collision, explosion, drop from the helicopter load etc.) where destruction or damage to the RTG casing or integrity of its radiation shielding is possible;
- external **hydrostatic pressure** at planned or emergency sinking of an RTG.

Possible natural cataclysms in the RTG locations (landslides, earthfalls, floods, earthquakes, tsunami etc.) as extreme impacts to the item and its components, at least, do not exceed the above impacts of the man-made accidents in terms of their parameters.

Therefore, **extreme and highest potential hazards** for ecological RTG and RHS-90 are **fires, drop from a height and getting into the sea water**, including great depths.

In assessment of the potential hazard to RTG from radiation accidents at land it should be noted that complete or partial RHS capsule damage under the effect of external conditions is hardly probable; in practice it is possible only subject to premeditated action. However, even in case of capsule opening no strontium-90 or yttrium-90 will be released from the monolithic fuel composition (strontium titanate) due to the fact that strontium titanate is characterised with high melting point, low evaporation rate at t -1200 C and very low leachability Under radiation emergency conditions, with RHS falling out of RTG or RHS-90 seal failure at land the radiation impact on biological objects is possible exclusively by way of external irradiation with braking gamma-radiation of beta-particles (first of all, by yttrium-90 radionuclide) in case of close contact with the emergency RTG, RHS-90 or in case of staying in the zone of exposure to above irradiation. The approximate calculation shows that braking irradiation from the RHS lacking biological shielding with intensity of radioactivity ~ $4,14\times10^{15}$ Bq at the distance 1 m shall be equal to ~ $1,5\times10^{-3}$ Sv/c, or ~ 5,4 Sv/час. So, the lethal radiation doze from external irradiation can be received after one hour nearby the RHS lacking biological shielding at the distance of approx. 1 m. The given $ERDR_{max}$ value is the maximal value for single RHS lacking the biological shielding, which can be accepted for subsequent assessment of the $ERDR_{max}$ received by personnel and population during various emergency situations possible in the course of RTG handling including the emergencies with loss of biological shielding (one or several RHS falling out of RTG, e.g. during its unauthorised dismantling).

At the same time, considering the possibility of all factors' combined effect on RHS-90 capsule in case of getting into the sea water and staying there for indefinite time, such RTG accident scenario should envisage the possibility of partial or full loss of sealing of the RHS-90 radioactive core leading to its contact with the environment. That is why strontium titanate was selected as the radioactive material, taking into account its lowest solubility in water. In such case a significant amount of strontium-90 may be released into the adjacent water basin resulting in radionuclide accumulation by marine organisms and finally in radionuclide consumption with sea food by people living in coastal areas. The analysis provided in the "Justification of ecological and radiation safety of RTG disposal activities", approved by Deputy Minister of the Russian Federation for atomic energy of 12.03.2004 shows that the maximal value of water radioactive contamination at the distance of about 10 m from the source (RHS-90) will be equal to ~ 1 Bq/l for strontium-90, which is 5 times less than the impact from strontium-90 contained in water supplied to population, equal to 5 Bq/kg according to NRB-99. The total annual amount of strontium-90 consumed with sea food will make, in the most unfavorable conditions, the value ~ $1,1\times10^{3}$ Bq/year. The obtained figure is 12 times lower than intake of strontium-90 ПГП by a human organism with food, which is equal to $1,3\times10^{4}$ Bq/per year, according to NRB-99. It should be noted that the above assessments were obtained for the case of "plain" fuel tablets (i.e. without ampoule) getting into the sea water, in reduced contact area of the fuel tablet with water by (20-30)%, i.e. in the most conservative conditions.

2. Safety analysis during RTG handling.

In the analysis of possible radiation emergency consequences during RTG delivery for disposal it is reasonable to take the collective doze received by personnel (and population), as the main risk index.

Preparation for transportation of dismantled RTGs (according to 2004-2005 work practice) is carried out, as a rule, by expert team of 6 persons delivered to the site of RTG location. The team members arrive to the place of destination and dismantle the RTG using special tooling; after which they fulfill the work on preparation for transportation (fix the product on helicopter external load, deliver it to the coast by towing, load on pontoon, etc.) The estimated labor time is 20 man/hours.

For the RTG in satisfactory (not emergency) condition the value $ERDR_{max}$ at the distance of 1 m form RTG surface does not exceed 0,1 mSv/hour (10 mrem/hour). Considering that all installation operations of relatively long duration will be carried out at the above indicated distance from RTG the estimated collective dose received by personnel (CD) during RTG preparation for transportation will be equal to:

$D_{coll} = 6\times3\times0,1\times10^{-3} = 1,8\times10^{-3}$ pers.- Sv (for one RTG).

The collective dose received by the personnel during preparation of the entire RTG batch for transportation by helicopter (e.g., 21 units like in 2005), will equal to:

$D_{coll} = 21\times d_{coll} = 21\times 1{,}8\times 10^{-3} \approx 0{,}038$ pers.- Sv

$ERDR_{max}$ assessment for the case of emergences with RTG damage.

The above analysis can be made basing on the available experience of liquidation the emergences consequences associated with RTG falling, when transported by helicopter, from the height ~ 100 on rocks. With this, the RTG shall experience stresses close to the mechanical action stated in specifications for RTG as a special type of radioactive material.

It is stated that if dropped from the altitude 40÷80 m on rocks the RTG package will experience a force equal to its being tested for radioactive material of special type which the RTG package should endure without losing its radioactive contents.

The actual accident that occurred in September 2004 as a result of dropping two RTGs with RHS-90 (radioactivity ~ $4{,}3\times 10^{15}$ Bq) on rocks from the altitude 100 m after emergency release from helicopter external load (see Fig. 13), the level of gamma radiation from damaged shielding was equal, at the distance of 2 m from the emergency RTG, to ~ 0,8 mSv/hour, and at the distance of 5 m – to (52-55) μSv/hour. No radioactive strontium-90 release from the RTG was registered.

Reference note: In 2006 the operations on emergency liquidation were completed in full, the RTGs were evacuated and handed over for burial.

In point source approximation the maximal $ERDR_{max}$ **at the distance** of 1m will be **~ 3,2 mSv/hour**, i.e. the $ERDR_{max}$ at the distance of 1m from the emergency RTG is approximately 30 times higher that the value established by GOST 18696-90 and NRB-99. This value is taken for calculation of the emergency collective dose (CD) to which the personnel is exposed during operations with emergency RTGs. In such case, the repair team labor time for detection, repair, packing and preparations for transportation by helicopter will require about ~ 36 man/hours, and during operations at the distance of ~ 1 m from the emergency RTG the collective dose received by personnel will be equal to:

D_{coll} (emergency) = $6\times 6\times 3{,}2\times 10^{-3} \approx 0{,}12$ pers.- Sv (for one emergency RTG).

Handling of the **RTG accepted as emergency ones**

Let us consider, for example, the option where operations are fulfilled through storage facility of the RHBZ of the Northern Fleet.

The emergency RTGs are supposed to be delivered from settlement Rosliakovo in special railcar. The special railcar containing transportation container and required special and engineering equipment arrives in advance to the storage area. After that the container and equipment is delivered to the work platform where RTG undergoes preparation for transportation (RHS-90 reloading from emergency products into transportation container, according to the developed and approved procedure, final preparation of RTG for transportation according to III transportation category established for packages of B(U) type).

Upon determination of the transportation category (not higher than III) and assessing the surface contamination with radionuclides, the packages will be loaded in special motor car and delivered to special railcar for reloading.

The risk index in handling of the emergency RTG taken as the equivalent collective dose received by personnel in the course of repair, packing and preparation of all emergency RTGs for transportation, **is calculated by formula as above, with a correction for radioactivity of the RHS-90**, which is inside particular RTG.

So, for the RTGs with RHS -90-230, generating without biological shielding, the $ERDR_{max}$ is equal to ~ 1,8 mSv/s at the distance of 1m. RHS-90 installation in container should be fulfilled quickly and accurately, so that the personnel individual doze in such emergency situation would not exceed the established by NRB-99 annual limit of 100 mSv. The operation can be fulfilled by two members of personnel (one for each RHS-90-230), and the time of each operation should be limited with 50 seconds or less, subject to the use of a remotely operating instrument ~ 500 mm long.

On possible emergency situations during the work at FSUE Atomflot, FSUE DalRAO, Leningrad SK Radon.

Initiating events:

- gantry cranes de-energisation during RTG hanging on a hook.
- failures in the work of gantry cranes.
- mistakes of servicing personnel.

Emergency situations:

- RTG hanging on gantry hook.
- RTG package dropped on ship structures, wharf area or car.

Personnel actions in case of emergency situations:

- evacuate the personnel beyond the radioactive freight irradiation zone;
- cover the floor surface under the hanging freight with polyethylene film;
- lower the freight manually to a prepared place, cover, if necessary, with removable shielding and polyethylene film to protect against precipitation;
- restore gantry crane serviceability;
- move freight to the site of destination;
- carry out radiation survey and decontamination, if necessary.

3. To the issue of accident probability assessment during transportation and risk assessment

At RTG decommissioning the main risk for people and environment will be from accidents during transportations.

The probability assessment of radiation accidents associated with severe damage of transport facility and transported RTGs gives, according to various reference materials, the following values:

- severe **railway accident** associated with damage of the special railcar carrying the RTG packages, $\mathbf{p_{rail} \approx 1{,}8\times10^{-8}\ (year\times km)^{-1}}$;
- severe **car accident** associated with damage of the special motor car carrying the RTG packages, $\mathbf{p_{car} \approx 1\times10^{-5}\ (year\times km)^{-1}}$;
- accident associated with RTG **sinking** during transportation by special ship, $\mathbf{p_{ship} \approx 1\times10^{-6}\ (year\times km)^{-1}}$;
- accident associated with **fall** of helicopter carrying the RTG, $\mathbf{p_{heli} \approx 1{,}0\times10^{-4}\ (year\times km)^{-1}}$;
- accident associated with **collision of the special ship** carrying RTG packages to a temporary storage, with another ship, $\mathbf{p_{wat} \approx 1{,}5\times10^{-3}\ year^{-1}}$.

As concerns the decommissioning transportation schemes the calculations are as follows:

The probability of helicopter accident during RTG transportation to Atomflot temporary storage platform calculated for each RTG planned to be decommissioned in 2005-2006 in accordance with the route and the way length, and using the value $P_{heli} \approx 1{,}0\times10^{-4}$ (year×km)$^{-1}$ is **from 1x10^{-2} to 1 - 6x10^{-3}**

The probability of radiation accident during emergency RTG transportation by **special railcar** to a temporary storage platform is calculated taking account of the route of delivery to FSUE Atomflot and using the value $P_{rail} \approx 1{,}8\times10^{-8}$ (year×km)$^{-1}$ and the route length. With the route length between s.Rosliakova – Atomflot collecting platform equal to ~ 20 km it is equal to (p_i) ≈ **$3{,}6\times10^{-7}$** per one transport by special railcar.

The probability of severe radiation accident associated with **complete breakdown of special railcar**, using the value $P_{rail} \approx 1{,}8\times10^{-8}$ (year×km)$^{-1}$ and the route length between «Atomflot platform – Staraya Kupavna" ~ 2012 km, will be equal to ≈ **$3{,}6\times10^{-5}$** per one transport by special railcar.

At FSUE V/O Izotop, RTG are installed in special motor cars which deliver the RTGs to FSUE VNIIRFA for dismantling and withdrawal of RHS-90. Three car runs will be required to complete unloading of one railcar. The route length is ~ 80 km (taking into account moving by circular road).

Upon withdrawal of RHS -90 in "hot" cell they are loaded in special containers UKT1B, which are used to form the packages of B(U) type, and can take, depending on the power, from one to three RHS-90. The containers with RHS-90 are transported back to FSUE V/O Izotop by special motor cars and loaded in a special railcar which delivers them to PA Mayak. One special railcar can take up to 10 containers with the RHS-90 of different power. Three car runs will be required to fulfill loading of one railcar. So, for transportation of all RTGs from one special railcar to FSUE VNIITFA and return transportation of RHS-90 in the transportation packages fitting into one special railcar, about 6 car runs of ~ 80 km each, will be required.

The probability of severe **car accident in the course of such transportations**, calculated using the value $P_{car} \approx 1{,}0\times10^{-5}$ (year×km)$^{-1}$ and the route length will be ≈ **$8{,}0\times10^{-4}$** (for one transportation).

Three special railcar runs can fulfill the conveyance of all the RHS-90 withdrawn from 30 RTGs (this number is taken from plan for 2006). Further operations on unloading the containers with RHS-90, their long-term storage and disposal shall be fulfilled by PA Mayak.

The minimal length of the railway route from FSUE V/O Izotop to PA Mayak is ~ 1830 km. Then, the **probability** of severe radiation accident associated with **complete breakdown** of special railcar obtained using the value $P_{rail} \approx 1{,}8\times10^{-8}$ (year×km)$^{-1}$ and the route length will be ~ **$3{,}3\times10^{-5}$** (per one transport by special railcar).

The obtained data on emergency probability during RTG transportation were used in risk assessment. The results obtained by RESCenter (St.Petersburg) with regard to particular operations on RTG handling during transportation, collective doses and risk assessment (considering the probability of radiation accidents calculated using the program sets C3MA and ACM 2001), are given in Table 4, 5.

One of the possible transportation options envisages the RTG delivery by helicopters to Atomflot collecting platform. The risk of emergency during above method of delivery is the highest, as can be seen from the data of Table 5.

The risk of consequent collective dose received by personnel during dismantling, repair and loading of emergency RTGs from s. Rosliakovo is significantly higher than in other situations and is equal to ~ 0,70 pers.- Sv., while with RTG delivery from the White Sea it is– 0,37 pers.- Sv.

The next, by accident risk probability, is the delivery of emergency RTGs from s. Rosliakovo to the platform, by railway transport which results from lower probability of railway accident and short route length. Nevertheless, the collective dose received during repair and preparation of emergency RTGs for transportation is the highest.

The lowest accident risk probability is noted for RTG delivery by special ship from the White Sea.

For lack of any alternative (to railway and car transport) ways of RTG delivery for dismantling to FSUE VNIITFA, and RHS for disposal to PA Mayak, no detailed calculations of collective doses and risk for other transportation methods were made; however, tentative assessments show that the risk of emergency in such cases will not exceed the relevant values obtained for the stage of RTG transportation to the collecting platform of FSUE Atomflot.

Table 4

Events associated with direct involvement of personnel

(Life risk index adopted for personnel in accordance with NRB-99 as value $r_E = 5{,}6\times10^{-2}$ pers.- Sv^{-1})

№	Operations on RTG handling	Accident probability, $hour^{-1}$	CD, pers.- Sv		Collective risk	
			In standard conditions	In emergency	In standard conditions	In emergency
1	Preliminary inspection of the RTG after over 25 years' service life	1×10^{-4}	$1{,}8\times10^{-3}$	0,06	$1{,}0\times10^{-4}$	$3{,}4\times10^{-3}$
2	Re-equipment of emergency containers and installation in transportation container	6×10^{-4}				
3	Container fixing on helicopter load	1×10^{-4}				
4	Unloading from helicopter load	1×10^{-4}				
5	Loading on pontoon	3×10^{-4}	2×10^{-3}	0,12	$1{,}1\times10^{-4}$	$6{,}7\times10^{-3}$
6	Loading on ship and fastening onboard the ship	3×10^{-4}				
7	Unloading from ship	3×10^{-4}	2×10^{-4}	0,06	$1{,}1\times10^{-5}$	$3{,}4\times10^{-3}$
8	Loading in special railcar	3×10^{-4}	4×10^{-3}	0,12	$2{,}2\times10^{-4}$	$6{,}7\times10^{-3}$
9	Unloading from special railcar	3×10^{-4}	4×10^{-3}	0,12	$2{,}2\times10^{-4}$	$6{,}7\times10^{-3}$
10	Loading in special motor car	5×10^{-4}	1×10^{-3}	0,032	$5{,}6\times10^{-5}$	$1{,}8\times10^{-3}$
11	Unloading from special motor car	5×10^{-4}	1×10^{-3}	0,032	$5{,}6\times10^{-5}$	$1{,}8\times10^{-3}$

Table 5

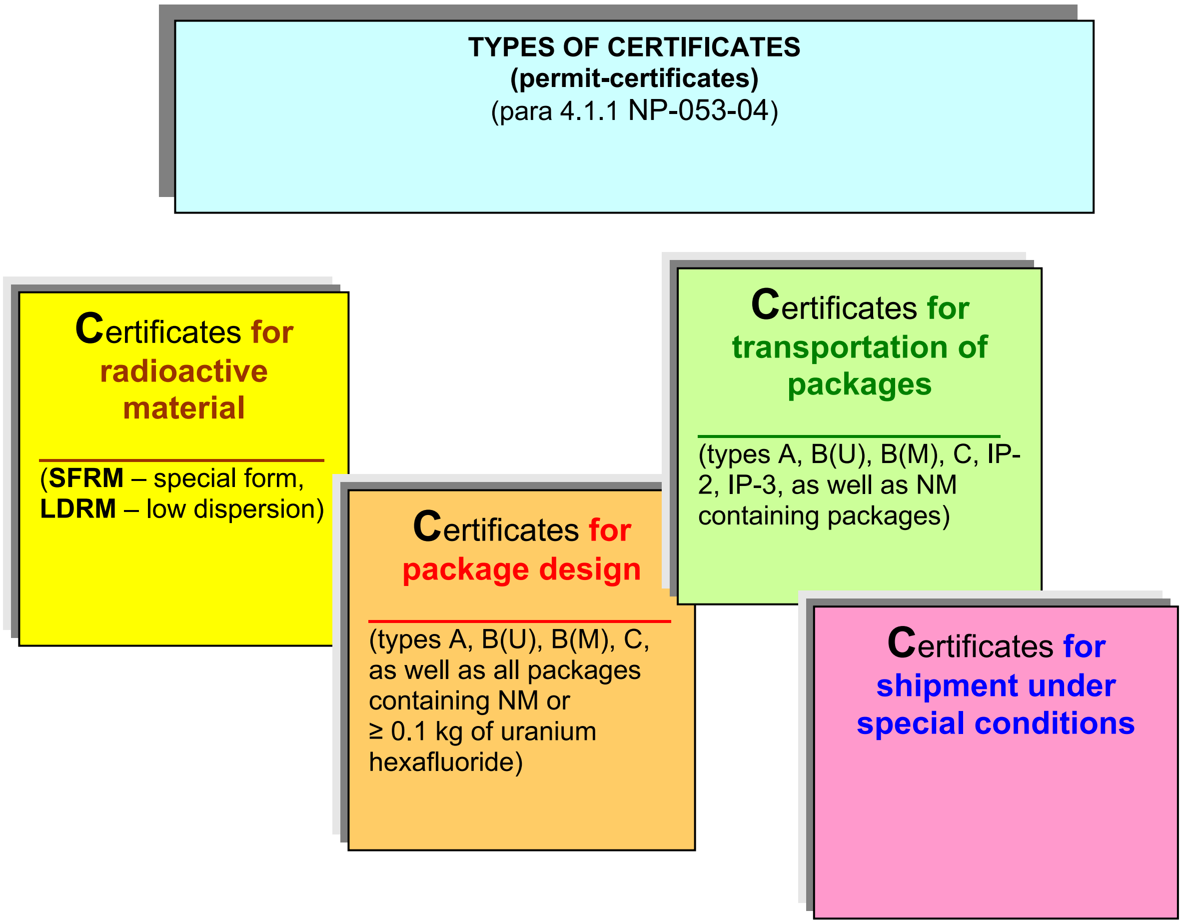
Events associated with RTG transportation

№№ верш. СФЦ	Scheme of transportation to assembly platform	Accident probability, $year^{-1}$	CD, pers.- Sv		Risk	
			In standard conditions	In emergency	In standard conditions	In emergency
1	Transportation by helicopter	0,0964	0,06	0,18	$5,8\times10^{-3}$	$1,74\times10^{-2}$
2	Transportation by railway from s.Rosliakovo	0,0040	0,70	0,82	$2,8\times10^{-3}$	$3,3\times10^{-3}$
3	Transportation by special ship from the White Sea	0,0065	0,37	0,49	$2,4\times10^{-3}$	$3,2\times10^{-3}$
4	Delivery by helicopter to RTG collecting platform of «Atomflot»	0,1067	1,13	1,49	0,011	0,024

APPENDIX 6

STANDARD CONTENT OF PERMIT-CERTIFICATE FOR SHIPMENTS, RMO AND DESIGN OF PACKAGES

According to the Rules of Safety of Radioactive Materials (NP-053-04), the following certificates (permit certificates) should be get to effect shipment of a radioactive material cargo in the Russian Federation.



Only two types are permitted to be covered by one certificate, namely: the certificate for package design and certificate for shipment (para. 4.2.1 NP-053-04); it is a common practice.

The development, agreement and issue of certificates is carried out in accordance with established procedure by the **S**tate **C**ompetent **A**uthority appointed by the Government of the Russian Federation (para 4.1.2 NP-053-04).

The Directive of the Government of RF # 204 of 19.03.2001 defines Rosatom as the SCA.

The procedure for the development, agreement and issue of certificates is established in the Temporary Provisions for the Procedure for Issue of Permit-Certificates for a Special Form Radioactive Substance, Design and Shipment of Packages with Radioactive Substances (**IPPC-92**), considering supplements #1, 2, 3.

Generally, the identification signs of certificates look as below:

RUS/100/B(U)-96,

RUS/6062/X,

RUS/150/B(U)-96T,

RUS/245/B(U)-96(Rev.1),

where **RUS** – the Russian Federation,

number – assigned by SCA,

code of the certificate type – can be **I** (IP industrial packages), **A**, **B(U)**, **B(M)**, **C**, **S** (it is for SFRM), **T** (it is for shipment), **X** (it is for special conditions of shipment), **LD** (it is for LDRM).

Besides code of the certificate type the SFRM and LDRM certificates contain "**-96**"; it means that the package design meets the IAEA requirements and "**(Rev.1)**" mean the first review of this certificate.

Certificate should be issued for not more than 5 years.

One of the permit-certificates is given below and gives a general impression of their standard structure and content.

FEDERAL ATOMIC ENERGY AGENCY

PERMIT-CERTIFICATE

for transportation under special conditions of the radioisotopic thermoelectric generators RTG-90-80/28-NSNU-S (RTG “Senostav”) serial number No 007 and serial number No 008 in transportation packages eI4.059.083

RUS/6062/X

The Federal Atomic Energy Agency, being the state competent authority of the Russian Federation for shipments of nuclear materials, radioactive substances and products thereof, certifies that the shipment under special conditions of the radioisotopic thermoelectric generators RTG-90-80/28-NSNU-S (RTG “Senostav”) serial number No 007 and serial number No 008 in transportation packages eI4.059.083 meets the Rules of Safety for Transportation of Radioactive Materials (NP-053-04), the Sanitary Rules of Radiation Safety for the Personnel and Population during Transportation of Radioactive Materials (Substances) (SanPiN 2.6.1.1281-03), GOST 16327-88, Transportation Packages for Radioactive Substances. General Technical Conditions, the Rules of Safe Transportation of Radioactive Materials (Vienna, IAEA, Safety Series No ST-1, 1996).

The Permit-Certificate has been issued by the FSUE All-Russia Research Institute of Technical Physics and Automation.

The Permit-Certificate is valid from 03.11.2005 until 03.11.2006.

Identification sign,	**Deputy Director of**
assigned by the competent	Federal Atomic Energy
authority	Agency
RUS/6062/X	_______________
	«___»__________200x

1. Main purpose

Transportation packages eI4.059.083 are designed for shipments of radioisotopic thermoelectric generators RTG-90-80/28-NSNU-S (RTG “Senostav”) manufactured to the technical conditions eI3.410.344 TU and being decommissioned.

2. Permissible radioactive content

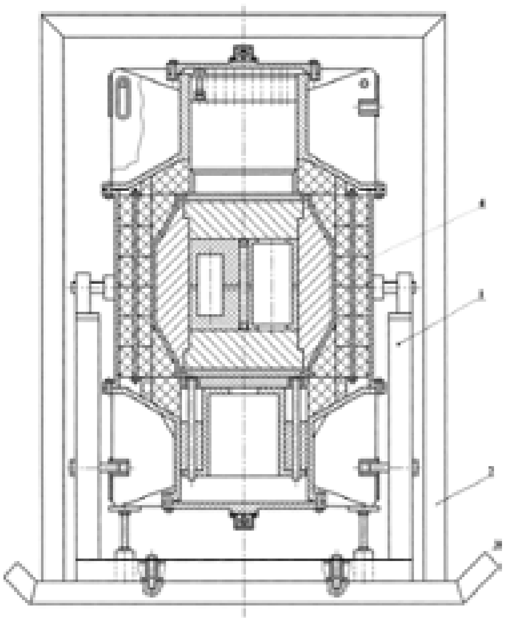
The transportation packages eI4.059.083 are permitted to ship RTG “Senostav” serial number No 007 and serial number No 008, of which each is fitted with six radionuclide heat sources RITu-90 based on radionuclide strontium-90 with a total activity at the moment of shipment of 7.52 PBq (203.2 kCi) and meets the requirements set forth for a special form radioactive material (SFRM).

3. Description of transportation package eI4.059.083

The transportation package eI4.059.083 (see Fig. 1) meets requirements set forth for B(U) type packages; it has the permit-certificate RUS/6062/B(U)-96T and consists of their shielding containers and RTG “Senostav”.

The shielding container is made as a steel welded frame (2) with hinged mesh panels fixed on four sides by bolts. The upper side of the shielding container is closed with a steel cap fixed by bolts.

The bottom of the shielding container is made as a welded frame in the shape of “sleigh” (3) of steel channels; the RTG “Senostav” (4) on a support (1) is placed on it during shipment.



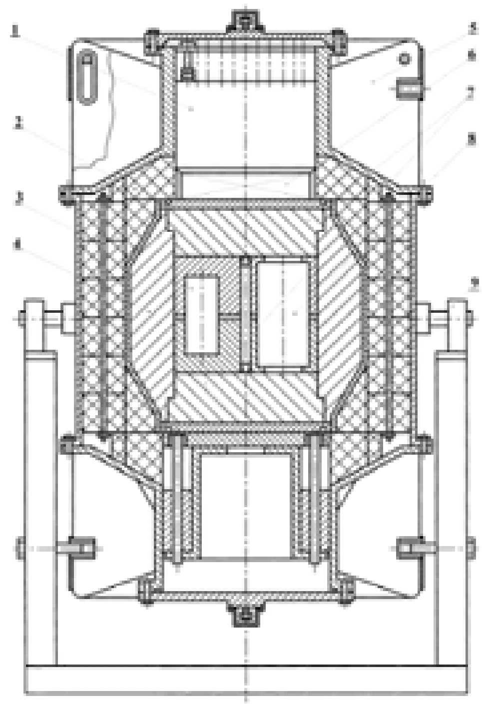
1 – support; 3 – sleigh;
2 – frame; 4 – RTG.

Fig. 1 *Transportation package eI4.059.083*

The RTG “Senostav” (see Fig. 2) is a leak tight structure which consists of:

- heat transfer unit (1);
- heat insulation (2);
- three radionuclide heat sources RITu-90-64 (3);
- radiation shielding made of depleted uranium (4);
- aluminum heat radiator (5);

- unit of thermoelectric batteries (6);
- tungsten radiation shielding (7);
- three radionuclide heat sources RITu-90-513 (8);
- supports (9).



- 1 – heat transfer unit; 5 – heat radiator;
- 2 – heat insulation; 6 – unit of thermoelectric batteries;
- 3 – RITu-90-64; 7 – radiation shielding;
- 4 – radiation shielding; 8 – RITu-90-513;
- 9 – support.

Fig. 2. *RTG "Senostav"*

The transportation package and RTG "Senostav" includes fixtures for lifting machinery and sealing.

Sizes of the transportation package eI4.059.083 with RTG "Senostav", not more, mm:

length - 1470;

width - 1100;

height - 1450.

Mass transportation package eI4.059.083 with RTG "Senostav", not more, kg – 1600.

3. Conveyances, shipment conditions and route

The shipment of transportation packages eI4.059.083 with RTG "Senostav" serial number No 007 and serial number No 008 can be carried out by a helicopter if requirement are met as stipulated in the "Requirements for Transportation of Radiation Packages with RTG (RHS) on the Helicopter Load to Ensure Radiation Safety and Prevention of Possible Accidents" given in the appendix to the "Decision No 04-05 Regarding Transportation of RTG (RIT-90, RITu-90) Packages by Helicopter Load" as approved by the Rosatom and Rostechnadzor's management under the transportation category "III-YELLOW" under the exclusive use conditions, with the equivalent radiation dose rate from the transportation package eI4.059.083 with RTG "Senostav" being not more than, mSv/h (mrem/h):

in any point on the package outer surface – 2.0 (200) and at a distance of 1 m from the outer surface of the package – 0.1 (10).

The following compensatory measures should be effected during the shipment:

- the shipment should be escorted by the personnel trained in assessing conditions of the transportation packages eI4.059.083 with RTG "Senostav" and radiation situation in the event of an accident; the personnel should have the corresponding equipment;
- in case of the emergency drop of the transportation packages eI4.059.083 with RTG "Senostav" the drop should be carried out at a minimum height on a sandy or other soft soil, as possible;
- after the drop the helicopter should land in the drop region and the crew should immediately take initial safety measures as per the emergency card;
- in case of an accident with the helicopter carrying the transportation package eI4.059.083 with RTG "Senostav" as a helicopter load an expedite delivery of the emergency personnel (consignor, consignee or carrier) equipped with the dosimetry instrumentation should be arranged for by another helicopter;
- during the helicopter shipment the radio communication should be continuously maintained along with transmission of the helicopter location coordinates each 5 minutes;
- the consignor should inform about the shipment commencement in advance the Department of Nuclear and Radiation Safety of Rosatom and FSUE ETC of St. Petersburg.

The shipment route of the transportation packages eI4.059.083 with RTG "Senostav" serial number No 007 and serial number No 008 as a helicopter load under the special conditions is:

- Lighthouse Letinsky – pad of Mishukovo settlement in Murmansk Region;
- Route length – 40 km.

The consignor and consignee of the transportation packages eI4.059.083 with RTG "Senostav" serial number No 007 and serial number No 008 is the military base 90719.

5. Safety precautions

Operations with the transportation package eI4.059.083 during loading and unloading of RTG "Senostav" at shipment and storage should be carried out with respect to the applicable Radiation Safety Standards (NRB-99), the Basic Sanitary Rules of Radiation Safety (OSPORB-99), the Safety Rules of Transportation of Radioactive Materials (NP-053-04), the Sanitary Rules of Radiation Safety of the Personnel and Population during Transportation of Radioactive Materials (Substances) (SanPiN 2.6.1.1281-03), as well as in accordance with the technical description and operator's manual.

In the event of an accident during shipment of the transportation package eI4.059.083 with RTG "Senostav" the situation should be promptly reported on to:

the dispatcher of the Industry Dispatcher Office of the FSUE Atomspetstrans (round-the-clock) by telephone No (495) 239-44-81;

the FSUE SCC of Minatom of Russia by telephone No (495) 933-60-44, fax No (495) 933-60-45, 239-24-35;

the dispatcher of the FSUE ETC St. Petersburg (round-the-clock) by telephone No (812) 247-56-53; and be guided by the Emergency Card No 923, requirements of Section 7 of NP-053-04 and requirements of Section 3 of the Rules of Investigation and Accounting of Violations during Handling of Radiation Sources and Radioactive Substances Used in the National Economy (NP-014-2000).

All issues related to the permit-certificate should be addressed to the Department of Nuclear and Radiation Safety (DNRS) of the Federal Atomic Energy Agency (24/26 B. Ordynka St., Moscow

119017; tel.: 239-48-28, 239-29-27) or to FSUE ETC St. Petersburg (28 2nd Michurinsky Proezd, St. Petersburg 194021; tel.: (812) 247-73-10, fax (812) 247-57-98).

The valid copies are only the registered copies of the permit-certificate with the original seal of FSUE ETC St. Petersburg or DNRS of the Federal Atomic Energy Agency.

Acting Chairman of Federal Environmental, Industrial and Nuclear Supervision Service

________________A.B. Malyshev

«___»___________2005

Head of Department for Nuclear and Radiation Safety of the Federal Atomic Energy Agency

_______________A.M. Agapov

«___»__________2005

Head of Division for Special Shipments of the Department for Decommissioning of Nuclear and Radiation Facilities

_________________V.V. Ananiev

«___»____________2005

Director of FSUE ETC St. Petersburg

_______________V.I. Stovbur

«___»___________2005

APPENDIX 7

(Reference)

MINISTRY OF ATOMIC ENERGY OF RUSSIAN FEDERATION

AGREED ON BY		APPROVED BY
First Deputy Minister of Interior of Russia *Ref. letter #* 20/5/1061 V.I. Fedorov "07" December, 2000	First Deputy Minister of Public Health of Russia –the State Head Sanitary Inspector of Russia *Ref. letter #* 2510/248-02-23 ____G.G. Onischenko "11" January, 2002	First Deputy Minister of Atomic Energy of Russia ___ L.D. Ryabov 25.01.2002
Deputy Minister of Emergency of Russia *Ref. letter #* 38-1212-9M.I.Faleev "28" April, 2000		

Emergency card #923

for transportation of radionuclide strontium-90 + yttrium-90

(Effective by Minister Order as of 17.01.2002 #24)

Head of 8 Chief Department of Ministry of Interior of Russia *Ref. letter #* 15/10-176 A.A. Terehov "23" May, 2000	Head of Department of fertile cycle of Ministry of Atomic Energy of Russia ________ V.V. Shidlovsky 07.03.2000
Head of the First Department of Chief Division of State Fire-prevention Service of Ministry of Interior of Russia *Ref. letter #* 20/5/779 V.T. Kishkurno "12" September, 2000	Head of the Department for Safety and Emergencies of Ministry of Atomic Energy of Russia __________ A.M. Agapov 07.03.2000
Deputy State Head Sanitary Inspector of Russia on objects and territories serviced by MEDBIOEXTREM Federal Department _______ O.I. Shamov 04.01.2002	Head of Department for protection of information, nuclear materials and objects of Ministry of Atomic Energy of Russia ________ V.I. Limonaev 28.03.2000
Head of State Sanitary and Epidemiological Supervision Department of Ministry of Public Health of Russia *Ref. letter #* 1100/84-2-112 _________S.I.Ivanov "11" January, 2002	Head of Transport Department of Ministry of Atomic Energy of Russia _________ S.I. Kaptelov 03.04.2000

Emergency card # 923

For transportation of radionuclide strontium-90 + yttrium-90

1. Freight Information

Emergency card is the mandatory initial executive document for radionuclide product transportation.

Information on freight hazard class

Class of hazard	Hazard sign	Urgent measures code
7	"radioactive"	45 КЕ

Physical and chemical properties of the substance

Chemical composition	State of aggregation	Melting point, C°	Boiling point, C°	Volatility	Solubility in water	Fire and explosion risk
Strontium carbonate	Powder	925	1340	None	low	None
Strontium glass	Granules	-	-	None	None	None
Strontium chloride	Liquid	-	100	None	None	None

Radionuclide characteristics and types of risk according to NRB-99

Type of emission	Half-life period	Radiation hazard group	Annual limit on intake with air MPI_{pub} (maximum annual intake) Bq/year	Admissible volume activity in air, MPA_{pub}. Bq/m^3	Annual limit on intake with food, MPI_{pub} Bq/year	Intervention level, water, UV, Bq/kg
β, γ, X, e	29.1 year	B	2.0×10^{4}	2.7	1.3×10^{4}	5.0

Ecological hazard: radioactive contamination of the territory is possible when strontium-containing compound is spread or spilled.

The interaction of radioactive substances with the environment leads to its ionisation, destruction of organic matter molecules and change of compounds' chemical structure.

Long-time exposure to irradiation from a non-shielded radioactive material (strontium-90) may cause serious radiation injury.

Direct contact with radioactive material may lead to contamination of skin and cloths.

Breathing in the airborne particles may cause internal irradiation.

1.1. The characteristics of transport package sets is given in the freight waybill.

The level of radiation hazard is different depending on the type, quantity and form of the radioactive material.

Biological hazard for man:

With single intake of the dose above 50 ПГПнас the following symptoms are registered: hypoplasy of spinal cord, changes in the organs through which the isotopes are taken in and brought out: mucous membrane of mouth, respiratory tract, mucous of the lower part of large intestine, bowels, pneumonia (if lungs are affected)

2. Precautionary measures, fire-fighting measures

2.1. Following the requirements of the “Basic sanitary rules of radiation safety”, OSPORB-99, all the works in the emergency zone are to be carried out subject to:

- availability of personal radiation monitoring of external and internal exposure of the person;

- radiation monitoring using the instruments type DRGZ-04, RUP-1, DP-58, RKSB-104 or similar;

- availability of special cloths and use of personal protective means (PPM) (protective goggles, aprons, oversleeves, respirators type “Lepestok”, ShB-1, ShB-200b, “Astra-2”, gas-masks GF, GP-5, GP-7);

2.2. In case of package seal failure and contained substance release, the work should be carried out in plastic protective suit type LG-1, rubber or plastic footwear, rubber gloves.

2.3. In fighting the fire use standard isolating PPM and all fire-extinguishing means: asbestos cloth, sand, special non-organic powders, water, foam and carbon-dioxide fire extinguishers of all types.

Sewage during fire fighting activities or decontamination may lead to soil contamination.

If radioactive substance gets on skin, it is necessary to wash it off with water or take a shower and change cloths.

2.4. The number of people should be limited in the direct vicinity to the damaged package, it is necessary to stay on windward side, avoid touching the radioactive materials that fell out of transport, without using protective means and instruments.

2.5. Follow the personal hygiene rules. Do not smoke, eat or drink in the emergency area.

2.6. After leaving the emergency zone it is necessary to wash the skin thoroughly with warm water and soap, and, depending on radiation monitoring results, change cloths and place the one that was taken off at a special site.

3. General requirements of emergency categories, initial actions and procedure of providing information

3.1. Using Table 1 and the emergency liquidation plan as guides, the emergency category shall be defined urgently, urgent measures taken to inform about the category of emergency and initial actions for its liquidation - taken.

Table 1

Emergency category		Initial actions	Order of providing information
1	The emergency situation when radiation packages do not have visible damages as a result of mechanical action, have insignificant damages, loosening or breakage of separate elements of fastening to carrier, or if the packages were exposed to slight heating effect as a result of a fire that occurred outside the freight location or the carrier.	1. Put on gas-mask and protection means. 2. Exclude admittance of unauthorised persons into the 10 m zone of the transport facility (carrier). 3. Conduct radiation monitoring. 4. Conduct external survey of packages and arrange and fasten the packages on the carrier again. 5. Check fitness of the carrier to continue transportation or organise reloading to a serviceable carrier. 6. Continue transportation by the route.	Take appropriate measures for immediate notification about the emergency by radio link, telephone, telegraph indicating: - The emergency category; - The emergency location, date and time; - surname of the person passing the information. Information shall be communicated to the consigner (consignee), carrier, Ministries and Departments by 24-hour telephones: Ministry of Atomic Energy of Russia (095) 239-24-28 (095) 953-23-05 (095) 239-44-81 Ministry of Railways of Russia (095) 262-61-65 (095) 262-31-08 Ministry of Transport of Russia (095) 200-25-45 Sea Fleet Department (095) 926-10-05
2	The emergency when radiation packages were subjected to significant mechanical damages or the paint coating was burnt. Release of radioactive substances from package is possible, however radiation and radioactive contamination levels will not lead to exposure of people above the basic dose limits indicated in Table 5.1 of NRB-99. The package can be thrown out of the carrier or be inside the overturned difficult to access.	1. Put on gas-mask and protection means. 2. Exclude admittance of unauthorised persons into the 50 m zone of the carrier. 3. Conduct radiation monitoring of the emergency site and determine its square area. 4. Evacuate unauthorised persons to a separate zone on the windward side. 5. Install danger signs of the emergency area. 6. Collect radioactive substances in a hermetically sealed metal container, plastic bags or cover them with earth. 7. Take the packages out of the damaged carrier, move them to a dry site, and set guard. 8. Further actions are determined by special Emergency Special Units and Special Emergency Teams, the order	Take appropriate measures for immediate notification about the emergency by radio link, telephone, telegraph indicating: - The emergency category; - The emergency location, date and time; - surname of the person passing the information. Information shall be communicated to the consigner (consignee), carrier, Ministries and Departments by 24-hour telephones: Ministry of Atomic Energy of Russia (095) 239-24-28 (095) 953-23-05 (095) 239-44-81 (812) 247-56-53

		of their work is specified in the "Emergency liquidation regulations" (ELR).	Ministry of Railways of Russia (095) 262-61-65 (095) 262-31-08 Ministry of Transport of Russia (095) 200-25-45 Marine Department (095) 926-10-05 Ministry of Emergency Situations of Russia (095) 926-37-38 Ministry of Public Health (095) 927-25-72 (095) 923-84-06 Federal Directorate for Problems of Ministry of Public Health of Russia (095) 190-33-25 Territorial bodies of Ministry of Internal, of Federal Security Service, Civil Defence Headquarters
3	The emergency situation when the radiation packages are partially or completely broken, and the contents is released. The packages or the carrier are buried in collapsed material, submerged in water or happen to be in durable fire zone.	1. Put on gas-mask and protection means. 2. Exclude admittance of unauthorised persons into the 100 m zone of the carrier. 3. Conduct radiation monitoring of the emergency site and determine its square area. 4. Evacuate unauthorised persons. 5. Install danger signs of the emergency area. 6. Collect radioactive substances in a hermetically sealed metal container, plastic bags or cover them with earth. 7. Take the packages out of the damaged carrier, move them to a dry site, and set guard. 8. Further actions are determined by special Emergency Special Units and Special Emergency Teams, which working order is specified by "Emergency liquidation regulations" (ELR). 9. If radioactive substances get into the water basins, warn the local authorities of Sanitary / Epidemiological Station (SES) and of Ministry of Internal.	Take necessary measures for immediate notification by the order indicated for emergency category 2.

3.2. All emergency-related reconstruction works, carried out after the emergency of 2 and 3 category, as well as decontamination activities connected with elimination of radiation after-effects as such, are conducted by Special Emergency Teams (SET) of organisations-consignors (consignees) and Emergency Special Units (ESU). The chief of SET, ESU shall be the person in charge (the manager) of elimination of emergency 2 and 3 category after-effects, while prior to his arrival to the emergency site the above shall be the responsibility of the person in charge of freight escort or the responsible person of the carrier.

3.3. The actions of freight carrying technical staff by railway, motor transport, aircraft or sea (river) vessel shall be fulfilled in accordance with the departmental instructions and requirements of the present emergency card.

3.4. In all the cases of emergencies of 2 and 3 category, all train and transport traffic is to be stopped. Regular traffic shall be recommenced after required restoration works and radiation monitoring is fulfilled.

3.5. If the people involved in freight escort and transportation are injured – call the local first aid ambulance for the injured.

3.6. In case of fire:

- call the local fire service;
- immediately start the liquidation of fire by all available fire-extinguishing facilities, indicated in section 2, prevent fire expansion and impact on packages, evacuate, where possible, transports with packages out of the fire zone;
- if evacuation is not possible cool the packages with water.

3.7. In case of emergencies of 2 and 3 categories the freight escorting person or SES radiologist (of carrier or of local region) shall:

- monitor contamination of the emergency site and determine its square area using standard DPGZ-04, RKSB-104, RUP-1, DRL-5B or similar;
- set danger signs of the emergency site;
- arrange the freight watch.

4. Actions of fire guard subdivisions during liquidation of fires on transport during freight transportation.

4.1. Upon receiving the information about fire (emergency) on transport facility, the fire guard shall act according to the departmental documents.

4.2. Upon arrival to fire (emergency) site, fire guard subdivisions shall establish communication with the manager of emergency liquidation and act by his instructions.

4.3. The Head of fire guard subdivision shall receive the following information from emergency liquidation manager: information on the current situation, characteristics of the transported freight, accident prevention measures during liquidation of emergency and the given emergency card.

4.4. The required quantity of staff for fire extinguishing shall be defined. The fire guard personnel, which does not participate in fire extinguishing work, shall be immediately evacuated to a safe place.

4.5. If the emergency liquidation manager is not at the site of emergency, fire guard subdivisions shall act in accordance with the instructions on fire extinguishing during transportation of radioactive substances and in accordance with the given emergency card.

4.6. The work on fire extinguishing is to be carried out under constant radiation monitoring by freight escorting personnel or SES radiologist, using personal protection means (gas-masks, protective clothes and footwear).

4.7. In fire extinguishing operations, the distance to transport and packages..., using water is not limited.

4.8. After liquidation of fire the personnel shall undergo radiation monitoring, and, if necessary, sanitary treatment, while fire-fighting instruments and technical equipment shall be exposed to decontamination.

5. First medical aid

5.1 Urgent evacuation of the staff and other involved persons from the emergency zone shall be fulfilled IMMEDIATELY after occurrence of personal hazards conditions. If the clothes are burning, fire shall be suppressed by all possible means.

5.2. Urgent first medical aid is to be provided within the first 30 minutes (prior to arrival of the medical team).

5.2.1. If injured persons are within the emergency zone, it is necessary to evacuate them outside the limits of the zone of possible environmental contamination.

5.2.2. It is necessary to take out, dig out and free the injured persons from under the debris, collapsed materials. Apply a tourniquet, take measures for anaesthetisation, cooling of the injured zone. In case of penetrating chest wounds apply occlusive bandage (in order to eliminate air infiltration into thorax).

5.2.3. Render medical aid as required to save life (elimination of all kinds of asphyxia, temporary stoppage of arterial bleeding, indirect heart massage and artificial respiration).

Note: It is inadmissible to perform artificial breathing by "mouth-to-mouth", "mouth-to-nose" method – there is a real danger for the person providing aid. It is necessary to use the Ambou bag or other appropriate medical equipment.

5.2.4. Arrange the following special treatment to prevent radionuclide penetration into the organism:

- Apply abundant and durable washing (up to 30 minutes) with water of wounded and burned areas;
- Irrigate of the burned area with lioxazol, cover the burn or wound (if any) area by sterile bandages;
- Rinse the mouth, throat and nose cavities with 2% soda solution;
- Wash eye conjunctivas with cool (33-35^{o}C) water during 5-10 minutes;
- Take algisorber 0.5 g.

The injured persons, who happened to be in the emergency zone at the time of container seal failure, are subject to skin decontamination with running water and soap. Apply decontamination means ("Protection") and wash abundantly with water in shower after that.

5.2.5. If possible, dress the injured persons in clean clothes, warm them up, cover with cloaks, additional overalls.

Note: In case of severe, possibly life-threatening injuries, the risk of potential radionuclide penetration is considerably lower than the risk from delay in specialised medical aid. Decontamination measures may be postponed to give priority to the urgent medical aid measures, especially those connected with vital requirements.

5.3. The arrived ambulance team is not allowed to work in the emergency zone. The assistance to the ambulance team consists in providing all available and necessary information about the emergency and the injured. The first aid shall be rendered to the injured persons by the ambulance team according to the general rules and criteria stated in para. 5.2.

5.4. In case of emergencies with radionuclide sources the following is to be done, in addition to the above:

- To prevent radionuclide absorption by organism it is necessary to take perorally algisorber 0.5 g or barium (absorber) 30.0 g with 2 glasses of water and irrigate the stomach after that. Give high purifying enemas;
- Inject intravenously 5% pentacyne in the quantity of 10.0 ml;

- dilute isotope concentration by strontium lactate (perorally 500-1500 mg) or slow intravenous injection of strontium gluconate (600 mg in 500.0 ml of 5% glucose solution);
- Calcium gluconate perorally (6-10 g by 3 doses a day) or slow intravenous injection of 10% calcium gluconate (1-520 g in 500.0 ml of 5% glucose solution). Give Polysurmine 4.0-200.0 ml perorally, oxidate organism by taking peroral ammonium chloride ;

5.5. To reduce the consequences of radiation contamination by external irradiation inject the desoxynate preparation 0.5% - 5.0 ml intramuscularly.

If mucous membranes are injured, wash them and pour drops of cod-liver oil or peach oil, or 30% natrium sulfacille solution.

If eyes are burning, pour 1-2 drops of 0.5% dicaine solution into the conjunctiva bag.

If skin is injured (burn of 2 grade and higher), the burn areas are irrigated with lioxazol, the burn and wound (if any) areas are covered with sterile bandages (if not already done) and anaesthetic injections are made. The injured persons pertaining to this group need to be subject to immediate measures against emphysema and shock according to accepted programs of intensive therapy.

5.6. The victims are to be evacuated to the nearest specialised medical institution, and be provided, if necessary, with the consultations of appropriate specialists.

5.7. A medical registration card shall be started for each injured person, and biological analysis will be taken.

6. Principal requirements for preparation of transport, special motor car drivers and escort staff

6.1. The escort staff must be aware of the requirements of the regulatory documents regulating the transportation, have the knowledge of safe handling of transported freight, use radiometric devices, fire-extinguishing and communication facilities, be able to render first medical aid.

6.2. Prior to freight shipment the transportation and storage service administration shall conduct:

- Acceptance of carriers and transportation packages by commission;
- Briefing of the escort staff according to the items of the emergency card.
- Check that escort staff is supplied with overalls, personal protection means, personal dosimeters, verified radiometric devices, equipment (spade, claw tongs, rope, flashlight, decontaminators, signal flags or radiation hazard warning signs).

Chief engineer of PA Mayak

24.12.99 A.P.Suslov

APPENDIX 8

HANDLING OF RHS (RTG) AT FSUE PA MAYAK

A construction of the “hot cell” for dismantling of RTG is planned at FSUE PA Mayak; the RTG are to come from the Leningrad SC Radon and FSUE DalRAO (see work stages 3, 4, 8 of Appendix 4).

At present, FSUE PA Mayak executes a long-term storage of RTGs that come from FSUE VNIITFA.

The RIT-90 containers having arrived to FSUE PA Mayak are unloaded. The RIT-90 are removed from the containers, examined and their compliance with the accompanying documentation (the disposal certificate of a batch of radioactive waste issued by FSUE VNIITFA that accompanies the container) is established. After the compliance is established the received RIT-90 are categorised as high-level radioactive waste (HRW). It is disposed of similarly to the disposal of other high-level waste generated at the FSUE PA Mayak. It is necessary to note that RIT-90 converted into waste now is an essentially perfect way of disposal of high-level radioactive waste.

Heat removal issues that influence selection of such parameters like heat load, specific energy release in waste, mechanical strength have a special place in the HLW disposal. Considering the hazard posed by radioactive waste and its quantities, the FSUE PA Mayak has adopted the technology of vitrification of highly radioactive solutions.

Then the vitrified HLW is sent for a long-term storage in the especially equipped storage facility. The facility is on the ground surface above ground water. It is adjacent to the vitrification building (furnace) and is connected with it by a transportation corridor. Cans with vitrified waste are delivered to the storage facility by the remotely controlled crane. The storage facility consists of concrete bays with stands for vitrified waste vessels that arranged at a certain distance from each other. Each bay is designed to be filled with glass blocks during several years. Vessels (tubes with cans) are loaded into the stands through hatches which are closed with concrete plugs. Cans are placed in tubes in three pieces one on another and two filled tubes, in turn, are placed one on another into the storage stand.

To maintain the temperature regime for cooling of vessels the cooling air is blown through the annulus between the tube and internal surface of the stand. Having passed through the stands the hot air (up to $t \leq 90$ °C) is collected in the upper channels running above the stands and, after clean-up on filters is released into the atmosphere.

During the first year of operation of the storage facility the air circulation is arranged for by fans. Then, after the waste heat release is decreased it is possible to use natural convection (the use of the exhaust pipe). The natural circulation of air takes place within the existing gap between the walls of the tube and can.

According to the present concept, after the 50-year holdup in the aboveground storage facility the vitrified waste is planned to send to an underground disposal. If necessary, the storage period of high-level waste in the storage facility can be extended up to 100 years.

The standard equipment used for storage of the vitrified HLW is also used for storage of RHS with ended service life and being returned to FSUE PA Mayak. According to the transportation and handling scheme, the spent RHS are transported to the vitrified waste storage facility for storage where they are placed in cans with glass. When the return items of different types are placed into cans with glass various criteria are taken into account; those are the permissible temperature of the storage facility concrete structures, heat release from glass and sources, duration of the sources’ holdup in the storage facility until the ultimate disposal along with glass in deep geological formations.

According to conditions of disposal of the vitrified waste in deep geological formations, one can should contain such activity that before the can is put into a well or trench its energy release should not be greater than 0.9 kW. The limitation of energy release from the can and tube is conditioned by limitations imposed by temperature conditions of the dry well or trench (the well wall temperature should not be more than 100°C). Considering these limitations, the time is calculated after which the cans with items can be put into deep geological formations.

The same temperature limitations are adopted also for loading of cans with items into the storage facility (temperature of concrete walls of the storage cells should not exceed 90°C).

The vitrified waste and returned items have a rather high energy release therefore, it was necessary to solve the problem of heat removal that is released due to radionuclides' radioactive decay.

The self-heating temperature of the vitrified waste of return items occurring during their storage is determined by their specific heat release and heat release conditions into the environment. One of a few ways of prevention of an increase of the composite material temperature above the level that determines their heat resistance under the existing heat removal conditions is the limitation of heat release of the vitrified waste and return RHS.

The calculation of thermo-physical parameters of the storage facility is done proceeding from the condition that in any point of the working cell the temperature of concrete does not exceed the limiting value of 100°C and the temperature of air going out of the channel does not exceed 90°C. Temperature parameters of the cell have been obtained from the calculation of the load of the return sources in the last can of the upper channel of the cell against the glass mass of different volume activity.

Considering the above circumstances, the calculations are done to determine limiting loads of the different types of return items in to one tube depending on the glass volume activity.

Therefore, according to the concept of handling of high-level waste at FSUE PA Mayak, the cans with return items are stored jointly with glass in the vitrified waste storage facility with a prospect of their disposal in deep geological formations in 50 or 100 years.

Appendix D
Improvement of regulatory activities in the area of emergency preparedness (Task 4)

D-1. Safety assurance in RTG decommissioning and prevention of emergency situations involving RTGs during transportation by different modes of transportation (Deliverable D6)

1. Introduction

The problem of assuring safety of works in decommissioning of radionuclide thermoelectric generators (hereinafter referred to as "RTG") is among the priorities of cooperation between Norway and Russia, and governmental and public organisations of both countries keep an eye on it.

The justification of ecological and radiological safety of works is contained in the "Ecological assessment of the impact on the environment and human being" which is submitted for the justification of ecological and radiological safety of the works in decommissioning of RTGs in March 2004 by the following organisations which participate in performing the works:

Federal State Unitary Enterprise "All-Russia Scientific and Research Institute of Technical Physics and Automation" of the Ministry of the Russian Federation for atomic energy (hereinafter referred to as FSUE VNIITFA);

Federal State Unitary Enterprise "Production Association "Mayak" of the Ministry of the Russian Federation for atomic energy (hereinafter referred to as FSUE PO "Mayak")

Federal State Unitary Enterprise of nuclear icebreakers of the Ministry of transportation of Russia (hereinafter referred to as FSUE "Atomflot");

The Department of natural resources and environment protection of the Ministry of natural resources for Murmansk region (hereinafter – MPR Department for Murmansk region).

The report presents the analysis of the measures to assure safety in decommissioning of RTG and RHS-90 and to prevent emergencies in handling of the items including transportation emergencies by different modes of transport.

The assessment criteria are the requirements of normative documents presented in section 6, subsection 6.1.

The documents subjected to analysis are named in section 6, subsection 6.2.

The report uses acronyms, terms and definitions used in legislative and normative documents.

2. RTG decommissioning stages – radiological hazard assessment

The mechanism of RTG and RHS-90 radiological impact is described in sufficient detail in the Assessment of the impact on the environment and human being. It gives the idea of Sr-90 impact on human organism through the food chain and through inhalation. Minimum absorbed dose which affects human organism is within the range of 42 – 50 Gray ($5x10^3$ rad).

2.1. RTG decommissioning – main stages of works

The main stages of the works for decommissioning of RTGs, composition of the works and their production technology sequence, the performers of the works are determined by inter-industrial normative document "The Rules for operation and decommissioning of radionuclide power installations on the basis of Sr-90 radionuclide thermal sources" and are presented in the Justification of ecological and radiation safety of works for RTG disposal". The operating organisation is the Hydrographic Service of the Northern Fleet which has the permission of the Ministry of Defence to perform such works.

Table 1 shows the generalised technological sequence of stages of RTG decommissioning basing upon the results of the analysis performed in 2004-2005.

Table 1

Stage #	Work content	Work performer	Work results
1.	Examination of RTG in the place of its operation to assess the condition and the possibilities for dismantling and transporting	The working group of the Central Commission of Rosatom	Report of the WG to the Cenral Commission
2.	RTG dismantling, its transporting to the place of loading to the transport vehicle, loading and delivering to the point of provisional storage (interim collection site)	Personnel of Chemical and Radiation protection service of Northern Fleet and Murmansk Aircompany Ltd.	RTG delivery to the collection site
3.	RTG loading to the sea vessel	VNIITFA and the personnel of Chemical and Radiation protection service of Northern Fleet	Documents on RTG transfer
4.	Vessel unloading in the provisional storage point – FSUE "Atomflot" , loading to specialised railcars	FSUE "Atomflot"	Documents on RTG transfer
5.	Transporting by specialised railcars (special transportation base of Rosatom) to FSUE "Isotope"	Transportation – by Ministry of Transportation, acceptance and convoy by VNIITFA	Documents on RTG transfer
6.	Specialised railcar unloading, RTG loading to specialised road vehicle, delivery to VNIITFA	V/O "Isotope"	Documents on RTG transfer
7.	Unloading of specialised road vehicles, interim storage, RTG disassembly and RHS-90 removal, placing RHS into transport containers, loading of transport containers to special road vehicles for the delivery to V/O "Isotope" base	VNIITFA	Documents as per production technology stages
8.	Transportation of containers with RHS by special road vehicles from VNIITFA to V/O "Isotope" base, unloading road vehicles, loading containers to specialised railcars for the delivery to PO "Mayak"	V/O "Isotope"	Documents on RHS transfer
9.	Transportation of RHSs to PO "Mayak by "Mayak" specialised railcars	Acceptance – PO "Mayak", transportation - Mintrans	Documents on RHS transfer
10.	Unloading containers with RHS at "Mayak", interim storage, unloading RHSs from transportation containers, placing RHSs for long-term storage	PO "Mayak"	Documents as per production technology stages

With the consideration for the specifics of RTG disposal during the last two years the works may be subdivided into four groups:

1. Works with RTGs in the locations of operation.
2. Works with RTGs in satisfactory condition.
3. Works with RTGs **in emergency condition**, which require for preliminary examination as well as performing preparatory works prior to transportation (installation of a radiator, replacement of components, protective package, issuing special permission for transportation (transportation certificate).
4. Works with RTGs and RHS-90s sent for disposal by specialised railcars from the interim storage facility of FSUE “Atomflot”.

The information on the works which are performed during the disposal of RTGs contains the list and the sequence of implementing organisational measures and works for dismantlement and transportation of the items which are determined by the normative document NP-038-02, p. 5.4.3.

2.2. Analysis of accidents (emergency situations) during RTG decommissioning in 2001 – 2005

Annex 1 gives the scenarios of accidents in performing technological operations for RHS-90B - based RTGs decommissioning. The Table evaluates 32 technological operations which may be accompanied by 35 possible violations. The document made the assessment of possible condition of an RTG after an accident, of the consequences of accidents; the measures to mitigate the consequences are determined.

Among all assessed accident the most severe consequences are caused by dropping RTG to the mainland when transported by a helicopter as the external load.

In such kind of an accident the integrity and leak tightness of RHS-90 is retained and Sr-90 release into the environment is prevented. Radiation shielding disintegration is possible, as well as radiation “shooting” from RHS-90, growth of exposure dose on RTG surface up to the level of tens of rem/hr, oxidation of uranium, local contamination of RTG body and surrounding soil by powdered uranium oxides in the location of the drop.

In all other technological operations and accident scenarios the integrity of RTG radiation shielding may be damaged, but the integrity and leak tightness of RHS is maintained and Sr-90 release into the environment is prevented.

Practical work for the disposal of RTGs during 2004 – 2005 which was performed within the frames of cooperation between Norway and Russia, gave the opportunity to dismantle and to evacuate from the north-west region 58 RTGs for further disposal in VNIITFA and burial in PO “Mayak” (see Annex 1).

Totally, 39 RTGs in Murmansk region were dismantled and transported by helicopters as external load and 19 RTGs in Arkhangelsk region were dismantled and transported by ships.

During the period of works performed in 2001 – 2005 there were three incidents associated with unauthorised access of outsiders to RTGs.

- In **May 2001** the authorities of the Ministry of Internal Affairs (MVD) have detained 5 civil persons who have confessed **to destroy three RTGs** of “Beta-M” type which are a part of navigational equipment of Kandalaksha sea port.

  RHSs from the destroyed RTGs were thrown away by the thieves at the water edge due to the high temperature of the items and obvious impossibility to sell them to the nonferrous scrap metal collector.

Further examination of the emergency site has revealed that the surface exposure dose of the orphaned RHSs was up to 1000 R/hr.

In this case the work for mitigation of the consequences of the accident required for radiological survey of the accident sites, for searching for the radiation sources which were the part of the destroyed RTGs, manufacturing of non-standard special remotely operated tools and provisional transportation vehicles, as well as a number of other relevant operations up to loading of radiation sources into transport containers and sending them to the producer.

Special difficulty in this particular case was caused by the necessity to carry out the whole set of works in the conditions of extremely high surface exposure doses.

On June 9, 2001 all the above mentioned accidents were eliminated by the emergency response groups, which included the specialists from the chemical and radiation protection units of the Northern Fleet (the majority), as well as the specialists of Emercom (Emergency and Civil Defence Ministry) Murmansk regional unit and Kola NPP.

- We'll mention two incidents just from the statistical view point:
  - In **September 2003**, Arkhangelsk region, island Golets, RTG of "IEU-1" type is cannibalised;
  - In **November 2003**, Kola Bay, **three** RTGs of "Beta-M" type are cannibalised.

In the process of decommissioning several more cannibalised RTGs were found with no damage to the radiation shielding. Dismantlement and transportation of the cannibalised units was performed without overdose to the personnel with no radioactive contamination of the environment.

The development of **EIA** (the environmental impact assessment) **in 2004** gave the opportunity :

- To review and to assess alternative approaches to the objective and to chose optimal variant in each particular case;
- To determine and to analyse possible emergencies and consequences thereof;
- To perform coordination of works among the performers and to demarcate their responsibilities;
- To determine the requirements to organising and performing safe transportation of RTGs by helicopters as external load.

The analysis of the dismantling works in the sites of operation during 2001 – 2005 and transportation of RTGs and RHS-90 to the producer shows that no emergencies are recorded. The analysis of the information on the emergencies with RTGs during handling of the items in the Eastern regions of Russia which will be useful for further work on Task 4, may be performed during further work with the report.

2.3. Emergencies in RTG transportation by different modes of transport

The following transportation schemes (combinations) were used for transportation and disposal of RTGs and RHS-90:

First scheme:

- relocation of an RTG from the site of operation to the shore line by improvised means;
- loading to pontoon and fixing buoy to the RTG for the case of emergency pontoon sinking;
- RTG transportation by pontoon to the vessel;
- Reloading RTG from the pontoon to the vessel by the ship crane;
- Locating and fixing RTG in the vessel hold or on the deck;

- Loading all RTGs to the vessel;
- Transfer of the vessel to FSUE “Atomflot” berth.

Second scheme:

- organising an RTG interim storage pad on the shore of Kola Bay;
- transportation of the dismantled RTGs with fixed buoys by helicopters as an external load to the interim storage pad;
- after 10 RTGs are accumulated on the pad – loading to the vessel;
- transportation of RTGs by the vessel to FSUE “Atomflot”.

Third scheme:

- Use of a specialised railcar with a certified transport container of UTK-1V(IEU-1) type with technological rigging by VNIITFA, supplied to the territory of the storage facility of radiological and chemical protection service of the Northern Fleet;
- Reloading of the container with the rigging from the railcar to the specialised road vehicle and the delivery to the working area for reloading RHS-90 from damaged RTGs to the transport container;
- Removing the container with the rigging from the road vehicle by a truck crane and putting it into operational position;
- Reloading of RHS-90s from the damaged RTGs to the certified container UTK-1V(IEU-1) by VNIITFA personnel;
- Putting the container into transportation position, determining surface contamination and turning the container into III category condition, loading it to the special road vehicle and delivering it to the special railcar, loading it to the railcar;
- Fixing of the damaged RTG by VNIITFA personnel by means of VNIITFA tooling, putting it into the condition which satisfies the requirements for radiation packages of B(U) type of transportation category in compliance with the certificate-permission. Loading of the fixed RTG to the specialised road vehicle, transportation to the specialised railcar and reloading the RTG to it;
- Transportation of the specialised railcar to FSUE “Atomflot” for loading of other RTG for the delivery to the railcar.

The reviewed transportation schemes to the RTGs which require for special handling due to their condition, allow to plan for and to implement the measures of safe performing of the above measures. However these schemes are characterised by the highest probability of emergencies as they differ from usual ones by greater number of operations associated with the works of increased radiation impact.

Annex 2 presents the information on the quantity of RTGs, both decommissioned and planned for decommissioning within the frames of cooperation with Norway, as well as on the issued certificates-permissions.

Finally it should be noted that the absence of emergencies with RTGs and RHS-90s in transportation in the course of decommissioning is the evidence of high professionalism and responsibility of the involved personnel, satisfactory material supply and high level of management of the works.

3. Analysis of scenarios of possible radiological emergencies during RTG decommissioning

The "Justification of ecological and radiation safety of RTG decommissioning", Annex 1, gives the list of possible emergencies during the works for decommissioning of RTGs based on RHS-90s. The development of such document is determined by the requirements of Federal Norms and Rules [6.1.1] and [6.1.3].

The above list generally complies to the requirements determined by [6.1.3].

The list comprises the initiating events op possible radiological emergencies, including:

- Due to external impacts of man-caused nature;
- Due to external impacts of natural origin;
- Due to failures of the systems and components of radiation sources.

The list of possible radiological emergencies envisages:

- RTG dropping to the land;
- RTG dropping to the sea;
- RTG and helicopter falling to the land ,
- RTG and helicopter falling with consequent fire on the place of the catastrophe,
- RTG dropping from the loading crane to the berth or the structures of the vessel;
- Fire on board the vessel in the location of the RTG;
- Sinking of the vessel;
- RTG dropping to the berth or the structures of the vessel or the railcar;
- RTG dropping from the pellet of the forklift truck from the height of 1…2 metres;
- Fire, turnover of the pontoon and RTG falling into sea water.

The presented list comprises the analysis of possible radiological accidents as per the above initiating events with the description of radiological consequences as it is applied to the stages of work in the following sequence:

- kind of works for RTG decommissioning;
- initial RTG condition as shown by the results of inspection;
- initiating event and the scenarios of accident development;
- possible condition of the item after the accident;
- emergency consequences assessment, including radiological consequences, the borders of radiological contamination zones of the objects of the environment showing the levels of possible radioactive contamination;
- measures to mitigate the consequences of an accident.

However the requirements p. 7.3 NP-039-02 for the assessment of the collective and maximum individual dose of the personnel as well as the effective public collective dose are not taken into consideration.

The Justification of ecological and radiation safety of works for RTG decommissioning does not give the analysis of the failures of RTG systems and components as well as the failures of the equipment for RTG handling. The analysis of the impact of such failures on the safety of the works is presented in Annex 1.

The following failures of the systems for packages handling are analysed:

- Active components failures,
- Passive components failures ,
- Common cause failures resulting in RTG dropping.

The following initiating events are analysed:

- Package sticking;
- Package dropping;
- Fire starting in the zone of works;
- Loss of power of the crane during the works;
- Failure of the fastening of the package;
- Equipment failures;
- Personnel mistakes;
- Earthquakes and hurricanes.

The scenarios of emergencies development are given.

The concrete digital values of calculation parameters are given which are verified experimentally and confirm that the package maintains the integrity of RTGs and RHS-90s and eliminate radioactive substances release beyond the designed barriers.

It is important that the safety data are supported by the results of actual tests of the package mock-up dropping from the external suspension of the helicopter, of submersion of the package into water, of enveloping the package in fire, of loss of power of the crane, of failures of fastening of the package, of equipment failures, personnel mistakes, earthquakes and hurricanes.

However:

- In the presented materials mitigation of the consequences of radiological accidents is not reviewed to the full extent as it is prescribed by p. 7.5 NP-039-02, the means are not named:
  - for the decontamination of the equipment and production areas on the site of radiological accident;
  - for rendering help to the irradiated personnel and public;
  - for the decontamination of the environment.
- In the “Justification of ecological and radiation safety of performing works on RTG disposal” the terms “minor” and “serious” radiation accidents are used, which are not defined and are not used in normative and project and design documents.

4. The assessment of current notification schemes and systems in case of RTG emergency with radiological consequences

The requirements to the personnel activities in case of radiation accidents and incidents are given by the “Program of RTG decommissioning from the facilities of hydrographic service of the Northern Fleet” issued in 2005 (see p.12.5[6.2.13]).

Categorisation of the accidents is given, the levels of intervention for different categories of accidents are determined, the activities of the personnel in different categories of radiation emergencies are determined.

In accidents of the 1-st category the mitigation of the consequences is performed by the personnel which accompanies the cargo; it is also responsible for fixing the packages. The emergency report is compiled and the decision on further transportation is made by the person who accompanies the cargo in association with the officers of the transport organisation.

P. 12.10 determines the actions in accidents of the 2-d and 3-d categories.

The person who accompanies the cargo is responsible for the notification about the location and time of an accident and the degree of its hazard in the following succession: consignor (consignee), carrier organisation, police authorities, civil defence and emergency response authorities, nuclear safety regulating authority in the uses of atomic energy, nuclear energy authorities.

P. 12.11 determines the routine for notification and the list of organisations to be notified.

Annex №1 [6.2.6] presents the routine of emergency works in mitigation of a radiation incident in the region of the city of Kandalaksha and in Kola Bay; it names the organisations which participated in mitigation of the radiological consequences, namely:

- Three services (units) of the Northern Fleet;
- FSUE VNIITFA;
- Kola NPP;
- Civil defence and emergency response Department, Murmansk region;
- Civil defence and emergency response Department of the city of Kandalaksha;
- State Sanitary and Epidemiological Service;
- Administration of the city of Kandalaksha;
- Administration of Murmansk region.

The Program for RTG decommissioning from the facilities of hydrographic service of the Northern Fleet in 2005 [6.2.8], p..8 gives just a reference to the document NP-014-2000 and the telephones of the inspectorate and of the district (command), the types of notifications are listed.

FSUE VNIITFA Program [6.2.12] does not determine activities in an emergency. There are no references to other documents where these activities are described.

Section 3 of "the Rules for Investigation and Accounting for violations in handling of radiation sources and radioactive substances used in the national economy" (NP-014-2000) determines the requirements to:

- the information and determines the presentation of a prompt report on the violation, preliminary report on the violation, report on the investigation of the violation (p. 3.1.1).
- the prompt report has to be transmitted within 1 hour after the violation was revealed (p.3.1.2.);
- the content of the prompt report (p.3.1.3.);
- who is the addressee of the prompt report in accordance with class A (p.3.1.4.);
- the preliminary report is transmitted within 24 hrs. After the violation is revealed (p.3.1.5.);
- the contents of the information and the addressee are determined in p.3.1.6, p.3.1.7;
- the requirements to the content of the report and the report on investigation of a violation are given in p. 3.1.8 and p. 3.1.9.

The generalised scheme of actions is given below (translator's note – the scheme is presented in a separate file).

Conclusions and recommendations

1. The operating organisation and the organisations which perform the works in RTG dismantlement, transportation, disposal and burial of disposed RHS-90 have developed and are implementing in practice a highly efficient system of measures to assure ecological and radiation safety. This system of organisational and technical measures during the period of 2001 – 2005 has ensured no overdose to the personnel who performs radiation hazardous works and eliminated radioactivity release to the environment.

2. However the necessity to improve the system should be pointed out as well as the need to assure its strict compliance to the requirements of the developing normative basis of assuring safety, including the General Regulations to assure radiation sources safety, Requirements to the contents of the report for the justification of the safety of a radiation source, Rules of investigation and accounting for violations in management of radioactive sources and materials used in national economy, Statute of Integrated State system of notification and mitigation of emergencies, which makes it necessary:

- For the radioactive sources of the 1-st and 2-d categories of potential radiation hazard – for the operating organisation to develop radioactive source (RS) decommissioning program *not later than one year before the end of the designed life of the source* (*p*.5.1.5. NP-038-02) including the Programs for 2006 and 2007);
- On the basis of RS decommissioning project – for the operating organisation to develop *safety justification report for RS decommissioning* and to submit it in accordance with established routine to the authority for state regulation of safety in the area of uses of atomic energy (p.5.1.9. NP-038-02) including the report for 2004-2006 and 2007;
- On the basis of RTG engineering and radiation examination - for the operating organisation to develop RTG decommissioning program which should include the list and the sequence of organisational measures and works for the dismantlement and transportation of RTGs (p. 5.4.3. NP-038-02), including the Programs for 2006 and 2007);
- Dismantlement and transportation of RTGs from their locations should be performed by the trained personnel in compliance *with the developed manual* and in compliance with the requirements of technical documentation for the specific items (p.5.4.5. NP-038-02), the manuals should be submitted within the package of documents justifying the safety of the works.

3. In the programs of organisations which participate in the works on RTG disposal, there should be given the information on emergency response in accordance with the requirements of NP-014-2000, reviewed with the consideration for the Statute of Integrated State system of notification and mitigation of emergencies approved by the Decrees of the Government of the Russian Federation on December 30, 2003 # 794 and of May 27, 2005 # 335. It is expedient to envisage "Emergency response" section in the programs in accordance with the established requirements or to make a reference to a specific document (if available) which provide this information.

6. References for D-1

6.1. List of normative documents

6.1.1. General provisions to ensure radiation sources' safety (NP-038-02).

6.1.2. Rules of investigation of and accounting for the violations in management of radiation sources and radioactive substances used in the national economy (NP-014-2000).

6.1.3. Requirements to the content of radiation sources safety justification report (NP-039-02).

6.1.4. Safety rules in transportation of radioactive substances (NP-053-04).

6.1.5. Sanitary rules of radiation safety of the personnel And public in transportation of radioactive materials (substances) SanPiN 2.6.1. 1281-03.

6.1.6. Radiation safety standards (NRB-99).

6.1.7. The Statute of Integrated State system of notification and mitigation of emergencies (approved by the Decrees of the Government of the Russian Federation on December 30, 2003 # 794).

6.2. List of departmental documents

6.2.1. Rules of operation and decommissioning of radionuclide power installations on the basis of radionuclide thermal sources using Sr-90, 1999, Minatom.

6.2.2. Program and methodology to examine RTGs on the basis of RHS-90 in the locations of operation.

6.2.3. Technological scheme for evacuation of RTGs to disposal along the technological chain from the operation site in the Arctic to the berth of FSUE “Atomflot”

6.2.4. Quality assurance program in operation and decommissioning (dismantlement and transportation to the territory of FSUE “Atomflot”, Murmansk) of RTGs based on RHS-90. 2004, Sankt-Peterburg.

6.2.5. Justification of ecological and radiation safety of performing the works for RTG disposal.

Ecological assessment - assessment of the impact on the environment and human being (ROSATOM) 2004.

6.2.6. Justification of ecological and radiation safety of performing the works for RTG disposal. Ecological assessment - assessment of the impact on the environment and human being. Annex 1. RTG disposal in 2005.

6.2.7. The list of RTGs planned for disposal in 2004 in the frames of Russia-Norway cooperation (Annex 1).

6.2.8. Program of decommissioning of radionuclide thermoelectric generators from the facilities of hydrographic service of the Northern Fleet in 2005. (Hydrographic service of the Northern Fleet of 11.04.2005).

6.2.9. List of possible emergencies during the works for the disposal of RTGs based on RHS-90 (Annex 7).

6.2.10. Transportation schemes of delivering RTGa to FSUE “Atomflot” (Annex 3).

6.2.11. Information on Murmansk region (Annex 4).

6.2.12. Program of radiation protection in transportation of RTGs from the facilities of hydrographic service of the Northern Fleet to FSUE “VNIITFA” in 2005. (FSUE “VNIITFA”)

6.2.13. Program of radiation protection in transportation of packages with RTGs from the facilities of hydrographic service of the Northern Fleet to the interim storage pads for loading to the specialised railcar (FSUE “VNIITFA” + hydrographic service of the Northern Fleet +Radiation and chemical protection service of the Northern Fleet)2005

6.2.14. Legal addresses of the performers of the works in implementation of Russia-Norway project (Annex 2).

6.2.15. Decision № 04-05 on transportation of a package with RTG (RHS-90, RHSu-90) as an external load (dated 29.07.2005 г.).

Annex 1

List of possible accidents during the decommissioning of RTGs, based on RHS-90

No.	Kind of decommissioning works	RTG condition by the results of the inspection	Possible accidents	Post-accident condition prognosis	Accident consequences assessment	Measures to mitigate accident consequences
1	RTG transportati-on by a helicopter as an external load to the interim collection pad	RTG – radiation package of B(U) type, RHS-90, special form radioactive material (SFRM) – IAEA regulations	a) RTG dropping on the land	RTG integrity and leak-tightness are maintained. Sr-90 release is ruled out. RTG radiation shielding is damaged (cracks, RHS-90 radiation "shooting"). RTG depleted uranium radiation shielding seal failure.	RTG surface exposure dose rate (EDR) increase up to tens of rem/hrs. Uranium oxidation, local contamination of RTG body and the soil in the location of RTG with uranium oxides powder.	Scanning of the area in the vicinity of RTG by radiometric instruments from distant approaches, clarification of the radiological situation, fencing of the dangerous area (organisation of guarding); measures mitigate the consequences of the accident, delivery of B (U) package and other protective equipment to evacuate RTG.
			b)RTG falling into the sea	Contact of RHS-90 capsule with sea water (for indefinitely long time). Sr release into the environment doesn't exceed the maximum permissible level.	No environmental hazard.	Organisation of works for the search and rescue of the damaged item to the surface, measures for further transportation.
			c)RTG and the helicop-ter falling on the ground	Similar to point a): mechanical impact of the helicopter fragments on the RTG	Similar to dropping tests of imitators on a steel ribbed plate. Local EDR increase at a distance of 1 m from the surface up to the level not higher than 1 rem/hr.	Same measures as in point a).
			d) RTG and the helicop-ter falling on the ground with fire in the location of the crash	Condition – as in case c), additional fire impact on RTG and RHS-90.	The results are checked during the tests of fuel and RHS-90 dummies for the resistance to thermal impact at 1100-1200 ^{o} C for 2 hrs.	Mitigation measures similar to p. a).
2	Reloading of an RTG from the interim collection pad, located on the shore of Kola Bay, to the vessel by means of a ship's crane.	RTG is a radiation package of B(U) type, RHS-90 is a special form radioactive material	Dropping RTG from the hoisting crane on the wharf or the structural compo-nent of the vessel	RTG integrity and radiation shielding are damaged, RHS-90 leak-tightness is maintained, no Sr-90 release into the environ-ment	Local EDR increase at a distance of 1 m from the surface up to the level not higher than 1 rem/hr.	Mitigation measures are similar to p. a).

No.	Kind of decommissioning works	RTG condition by the results of the inspection	Possible accidents	Post-accident condition prognosis	Accident consequences assessment	Measures to mitigate accident consequences
3	Transporta-tion of a batch of RTGs on shipboard to the wharf of FSUE "Atomflot"	As in p.2, column 3	Fire on board the vessel in the location of RTG Sinking of the vessel	RTG integrity and radiation shielding are damaged Contact of RHS-90 capsule with sea water. RHS-90 leak-tightness and integrity are maintained, no Sr-90 release into the environ-ment.	EDR increase at a distance of 1 m from the surface up to the level not higher than 1 rem/hr. No changes of EDR	Mitigation measures are similar to p.p. 1a), 1d). Mitigation measures are similar to p. 1b), RTG is equipped with an emergency signal buoy.
4	Unloading of an RTG from the vessel by the port crane to the wharf or to the retractable platform of the special railcar	As in p.2, column 3	Dropping RTG from the hoisting crane on the wharf or the structural compo-nents of the vessel or the railcar	Loss of integrity of RTG radiation shielding. RHS-90 leak-tightness and integrity are maintained, no Sr-90 release into the environ-ment.	EDR increase at a distance of 1 m from the surface up to the level not higher than 1 rem/hr.	Mitigation measures are similar to p. 1 a).
5	Relocation of an RTG from the wharf of FSUE "Atomflot" to the interim storage pad by means of an electric fork-lift truck.	As in p.2, column 3	Dropping of the RETG from the electric fork-lift truck from the height of 1-2 m.	Radiological accident is ruled out.	No consequences.	No measures are required.
6	Interim storage of a batch of RTGs from FSUE "Atomflot".	As in p.2, column 3	Fire	RHS-90 leak-tightness and integrity are maintained, no Sr-90 release into the environ-ment. The damage of RTG radiation shielding integrity is possible.	EDR increase at a distance of 1 m from the surface up to the level not higher than 1 rem/hr.	Mitigation measures are similar to p. 1 a).
7	Loading RTG by means of an electric fork-lift truck into special railcars for shipping to FSUE V/O "Isotope".	As in p.2, column 3	Dropping of the RETG from the electric fork-lift truck from the hight of 1-2 m.	Radiological accident is ruled out.	No consequences.	No measures are required.
8	Relocation of an RTG from the site to the shore-line and then to the barge by surface transport	As in p.2, column 3	Radiological accident is ruled out.	No consequences.	No consequences.	No measures are required.
9	Transportation of an RTG to the vessel by a barge	As in p.2, column 3	Turn-over of the barge, dropping the RTG into the sea	RHS-90 leak-tightness and integrity are maintained, no Sr-90 release into the environ-ment.	No environmental hazard (full-scale tests).	Equipping the RTGs with emergency buoys, organising salvage works to bring RTG back to the surface.
10	Loading RTG from the barge to the vessel	As in p.2, column 3	Dropping the RTG into the sea. Dropping the RTG on board the vessel	RHS-90 leak-tightness and integrity are maintained, no Sr-90 release into the environ-ment. ________ RTG radiation shielding integrity is damaged.	No environmental hazard (full-scale tests). ____________ EDR increase at a distance of 1 m from the surface up to the level not higher than 1 rem/hr.	Equipping the RTGs with emergency buoys, organising salvage works to bring RTG back to the surface. Mitigation measures are similar to p. 1 a).
11	Transportation of a batch of RTGs by the vessel to the interim storage facility of FSUE "Atomflot"	As in p.2, column 3	As in p.3.	As in p.3.	As in p.3.	As in p.3.

No.	Kind of decommissioning works	RTG condition by the results of the inspection	Possible accidents	Post-accident condition prognosis	Accident consequences assessment	Measures to mitigate accident consequences
12	Unloading of an RTG from the vessel by the gantry (or ship) crane to the wharf or the platform of the special railcar.	As in p.2, column 3	As in p. 4	As in p. 4	As in p. 4	As in p. 4
13	RTG interim storage on the territory of FSUE "Atomflot"	As in p.2, column 3	As in p.6	As in p.6	As in p.6	As in p.6
14	Loading RTG by means of an electric fork-lift truck into special railcars for shipping	As in p.2, column 3	As in p.5	As in p.5	As in p.5	As in p.5
Works with damaged RTGs						
15	Elimination of an emergency situation, resulting from vandalising of "Beta-M" ## 255, 256 on the operation site. Loading RHS-90 into transportation package of B(U) type to assure transportation category III.	RTGs are disassembled. RHS-90 are removed from the radiation shielding. RHS-90 retains the category of special form radioactive material. Increased radiation field around the RTGs in the storehouse of the radiation and chemical safety unit of the Northern Fleet.	RHS-90 was dropped to the floor during the loading to the protect-tive container.	RHS-90 leak-tightness and integrity are maintained, no Sr-90 release into the environ-ment, increased radiation background is detected around the RTGs.	Overexposure of the personnel, performing the works in accordance with the work-card, is possible.	Suspension of the works performed as per the basic regulations. Delivery of remotely controlled equipment and a certified packaging (IEU-1), removal of RHS-90 from RTG, loading it to the package (IEU-1). Further works are performed in compliance with the specifically developed regulations.
16	Kitting-up, assembling, bringing "Beta-M" #259 in compliance with the requireme-nts and to the condition of radiation package of B(U) type of the III transport category (as per NP-053-04)	The RTG is partially vandalised (stripped of some of the components), the security package and the radiator are absent. RTG is not a package of B(U) type, RHS-90 is special form radioactive material. RTG is in the storehouse of the radiation and chemical safety unit of the Northern Fleet.	Radiological accident is ruled out.	RHS-90 leak-tightness and integrity are maintained, no Sr-90 release into the environme-nt.	No radiological consequences.	Delivery of lacking components to the location of RTG #259, assembling RTG, bringing it in compliance with the requirements to a radiation package of B(U) type.
17	Loading of the assembled (kitted-up) "Beta-M" #259 and UTK1V (IEU-1) with two RHS-90 from RTGs ## 255 and 256 to the specialised road vehicle, transportation of the above named items to the specialised railcar, loading into the railcar, transportation of the railcar to "Atomflot" to load more RTGs to the railcar.	UTK1V (IEU-1) and RTG "Beta-M" #259 are radiation packages of B(U) type of the III transport category. RHS is special form radioactive material.	Similar to p.p.5,6 (dropping and fire)	Similar to p.p.5,6	Similar to p.p.5,6	Similar to p.p.5,6
Works with RTGs, RHS-90, shipped for disposal by specialised railcars from FSUE "Atomflot"						

No.	Kind of decommissioning works	RTG condition by the results of the inspection	Possible accidents	Post-accident condition prognosis	Accident consequences assessment	Measures to mitigate accident consequences
18	Transportation of UTK1V (IEU-1) with two RHS-90 and RTGs in specialised railcars accompanied by FSUE “VNIITFA” to the base of V/O “Isotope”	Returnable RTGs and UTK1V (IEU-1) are radiation packages of B(U) type of the III transport category. RHS-90 is special form radioactive material.	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
19	Specialised railcar with RTGs and UKT1 stays at the base of V/O “Isotope” (Interim storage)	Similar to p.18, column 3.	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
20	Unloading RTG and UKT1. Unloading V(IEU-1) from the specialised railcar to the specialised road vehicle	Similar to p.18, column 3.	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
21	Delivery of RTG and UKT1. Unloading V(IEU-1) by specialised road vehicle to FSUE “VNIITFA”	Similar to p.18, column 3.	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
22	Unloading RTG and UKT1. Unloading V(IEU-1) from the specialised road vehicle at FSUE “VNIITFA”	Similar to p.18, column 3.	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
23	RTG and UKT1(IEU-1) interim storage from 1 to 2 months in the storage facility of FSUE “VNIITFA”.	Similar to p.18, column 3.	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
24	Performing works in FSUE “VNIITFA” on RTGs disassembling, removal of RHS-90 from RTGs and UKT1V (IEU-1), inspection of the above named items, loading them to transport or technological protective containers.	Similar to p.18, column 3.	Radiological accidents are ruled out.	Damage is ruled out.	Safety is ensured by the equipment and organisation of works in a hot cell.	No measures are required.
25	Loading of certified UKT1V with RHS-90 to the specialised road vehicle at FSUE “VNIITFA” for shipping to V/O “Isotope”		Similar to p.5	Similar to p.5	Similar to p.5	Similar to p.5
26	Transportation of RHS-90 in UKT1V from FSUE “VNIITFA” to the base of V/O “Isotope”	Similar to p.25, column 3	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
27	Unloading of the specialised road vehicle with UKT1V, containing RHS-90, and loading the items to the specialised railcars for shipping to FSUE PA “Mayak”	Similar to p.25, column 3	Similar to p.5	Similar to p.5	Similar to p.5	Similar to p.5

No.	Kind of decommissioning works	RTG condition by the results of the inspection	Possible accidents	Post-accident condition prognosis	Accident consequences assessment	Measures to mitigate accident consequences
28	Interim storage of UKT1V with RHS-90, loaded to the specialised railcars at the base of V/O "Isotope" for the period of up to 3 days.	Similar to p.25, column 3	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
29	Transportation of UKT1V with RHS-90 by the specialised railcars with convoy to FSUE PA "Mayak"	Similar to p.25, column 3	Similar to p.6	Similar to p.6	Similar to p.6	Similar to p.6
30	Unloading of UKT1V with RHS-90 from the specialised railcars at the storage facility of FSUE PA "Mayak"	Similar to p.25, column 3	Similar to p.5	Similar to p.5	Similar to p.5	Similar to p.5
31	Reloading of RHS-90 from transport containers UKT1V to protective containers of FSUE PA "Mayak",	Similar to p.25, column 3	Similar to p.5	Similar to p.5	Similar to p.5	Similar to p.5
32	RHS-90 interim storage at FSUE PA "Mayak", relocation of them in protective containers to the long-term storage of vitrified radwaste and burial in this room.	Similar to p.25, column 3	Similar to p.5	Similar to p.5	Similar to p.5	Similar to p.5

Annex 2

Information on decommissioned RTGs and RTGs planned for decommission in cooperation with Norway and on the issued certificates-permissions

The works for decommissioning and disposal have started in the planned manner in 2001.

By the end of 2004 at the cost of all financing sources **204 items were dismantled and delivered to FSUE "VNIITFA"** (including 19 items in 2004).

210 items are disassembles and disposed at PO "Mayak", out of this number **54** items were stored in the institute before 2001 and 156 items were delivered in 2001 – 2004. .

2005 – 39 items.

RTGs decommissioning in 2005 was performed in compliance with the Contracts № 04-2668 dated 29.04.2005, and № 04-2706 dated 18.10.2005, signed between FSUE "VNNITFA" and the Department of Economic Development, Murmansk region.

RTGs shipping to FSUE "VNIITFA" was performed by four railcars (four batches).

The first batch was shipped on June 14, 2005 from the territory of the storehouse of Radiation and Chemical Protection Unit of the Northern Fleet (settlement Rosliakovo of Murmansk region), 10 RTGs totally: 1 RTG IEU-2; 2 RTG IEU-2M; 7 RTG "Beta-M".

Two RTGs "Beta-M" №№ 259 and 227 were partially disassembled; before shipping they were reassembled up to the designed condition.

The second batch was shipped was shipped on June 24, 2005 from the territory of the storehouse of Radiation and Chemical Protection Unit of the Northern Fleet (settlement Rosliakovo of Murmansk region),8 RTGs + 2 RHS: 3 RTG IEU-2; 1 RTG IEU-2M; 1 RTG IEU-1; 2 RTG REU-3-2K (Senostav) and one transport package UKT-1V; 1 RTG IEU-1 and two RHS-90 from completely disassembled RTGs "Beta-M" №№ 255 and 256.

The third batch was shipped on August 12, 2005 from the territory of Kandalaksha commercial sea port (city of Kandalaksha), 11 pcs. totally: 2 RTG IEU-2; 2 RTG IEU-2M; 6 RTG "Beta-M", 1 RTG IEU-1.

RTG IEU-1 No. 13, subjected to unauthorised disassembly, was brought back before transportation to the requirements of III transport category.

The fourth batch was shipped on November 9, 2005 from the territory of the storehouse of Radiation and Chemical Protection Unit of the Northern Fleet (settlement Rosliakovo of Murmansk region), 10 RTGs totally: 3 RTG IEU-2; 1 RTG IEU-2M; 3 RTG "Beta-M", 1 RTG IEU-1, 2 RTG REU-3-2K.

All stages of RTG transportation from the operation sites to FSUE "VNIITFA" is performed on the basis of permissions-certificates issued by the state competent authority of the Russian Federation for nuclear and radiation safety in transportation of nuclear material, radioactive substances and items based on the above – by the Federal Agency for atomic energy and approved by the Federal Service for ecological, technical and nuclear supervision. In the process of RTG transportation no deviations from normal transportation were observed.

2006 - 30 pcs.

It is planned to decommission and to ship for disposal to FSUE "VNIITFA" **30** RTGs:

- **17** RTGs from Kola peninsula - 13 RTGs "Beta-M", 1RTG – IEU-2, 1 RTG - IEU-2M, 2RTG – "Garant-2'.

- **13** RTGs from the White Sea: – 8 RTGs “Beta-M”, 3 RTGs – IEU-1; 1 RTG – IEU-2; 1 RTG – IEU-2M.

2007. - 27 pcs.

It is planned to decommission and to ship for disposal to FSUE “VNIITFA” **27** RTGs:

- from the White Sea – 2 RTGs “Beta-M”;
- from the South-East shore of the Barents Sea 21 RTGs: – 7 RTGs “Beta-M”; 6 RTGs IEU-2; 6 RTGs IEU-2M; 2 RTGs – IEU-1;
- from Novaya Zemlya – 4 RTGs “Beta-M”.

2008 - 27 pcs.

It is planned to decommission and to ship for disposal to FSUE “VNIITFA” **27** RTGs:from Nenetsk Autonomous County:

- **16** RTGs “Beta-M”,
- **5** RTGs - Gong,
- **4** RTGs –“Efir” –MA;
- **2** RTGs – “Gorn”.

In the process of transportation no deviations from normal process were observed.

CERTIFICATES-PERMISSIONS

For the design and transportation of different RTG under decommissioning
RUS/number/code of the type

RUS – international identification code of RF transportation vehicles
Number – number given when certificate is issued
Code type – designation of the type of the certificate (I, A, B(U), B(M), C, S, T, X, LD, H(U), H(M)
«**96**» - compliance of the design of the packaging for special form radioactive material to IAEA Regulations
«**Rev 1**» - information on the review of the certificate (first review)

№	Designation and period of validity	
1	RUS/6052/B(U)-96T from 03.08.2005 to 03.08.2006	Certificate-permission for the design of a transport package eИ4.175.058 and for the transportation of a radioisotope generator G-90-80/24 of an isotope power installation IEU-1 manufacturer No. 13 in it
2	RUS/6052/X from 03.08.2005 to 03.08.2006	Certificate-permission for the transportation as a special arrangement of a radioisotope generator G-90-80/24 of an isotope power installation IEU-1 manufacturer No. 13 in a transport package eИ4.175.058
3	RUS/6053/B(U)-96T from 03.08.2005 to 03.08.2006	Certificate-permission for the design of transport packages eИ4.175.059 and for the transportation of radioisotope thermoelectric generators «Efir-MA» manufacturer Nos. 04, 05 in them
4	RUS/6054/B(U)-96T from 26.08.2005 to 26.08.2006	Certificate-permission for the design of a transport package eИ4.059.037 and for the transportation of radioisotope thermoelectric generators «Beta-M» manufacturer No.341 in it
5	RUS/6055/B(U)-96T from 03.08.2005 to 03.08.2006	Certificate-permission for the design and transportation of radioisotope thermoelectric generators «Efir-MA»
6	RUS/6038/S-96(Rev.1) 03.08..2005- 03.08..2010	Certificate-permission for special form radioactive material. Sealed radionuclide thermal sources RHS-90
7	RUS/6056/B(U)-96T from 26.08.2005 to 26.08.2008	Certificate-permission for the design of transport packages 179.009-M and for the transportation of radioisotope thermoelectric generators RTG-90-NSNU-s (RTG “Horn”) in them
8	RUS/6057/B(U)-96T from 26.08.2005 по 26.08.2008	Certificate-permission for the design of transport packages eИ4.059.037 and for the transportation of radioisotope thermoelectric generators «Beta-M» («Beta-S») in them
9	RUS/6058/B(U)-96T from 26.08.2005 to 26.08.2008	Certificate-permission for the design and transportation of radioisotope thermoelectric generators «Beta-M» («Beta-S»)
10	RUS/6061/B(U)-96T from 26.08.2005 to 26.08.2008	Certificate-permission for the design of transport packages eИ4.059.056 and for the transportation of radioisotope thermoelectric generators RTG-90-18/14-NSNU-S (RTG «Gong») in them
11	RUS/6062/B(U)-96T from 26.08.2005 to 26.08.2008	Certificate-permission for the design of transport packages eИ4.059.083 and for the transportation of radioisotope thermoelectric generators RTG -90-80/28- NSNU-S (RTG«Senostav») in them

12	RUS/6063/B(U)-96T from 26.08.2005 to 26.08.2008	Certificate-permission for the design of transport packages еИ4.189.029 and transportation of radioisotope power sources IEU-2 in them
13	RUS/6064/B(U)-96T from 26.08.2005 to 26.08.2008	Certificate-permission for the design of transport packages еИ4.189.031 and transportation of radioisotope thermoelectric generators IEU-2M and transportation of radioisotope thermoelectric generators in them
14	RUS/6065/B(U)-96T from 26.08.2005 to 26.08.2008	Certificate-permission for the design of transport packages еИ4.189.010 and transportation of radioisotope thermoelectric generators G-90-80/24 (IEU-1) in them
15	RUS/6062/X from 28.10.2005 to 28.10.2006	Certificate-permission for transportation under special arrangement of radioisotope thermoelectric generators RTG-90-80-NSNU-S (RTG«Senostav») of radioisotope power sources IEU-2 007, 008 in a transport package еИ4.059.083
16	RUS/6063/X from 28.10.2005 to 28.10.2006	Certificate-permission for transportation under special arrangement of radioisotope power sources IEU-2 manufacturer №№ 27, 69, 70 in transport packages еИ4.189.029
17	RUS/6064/X from 28.10.2005 to 28.10.2006	Certificate-permission for transportation under special arrangement of a thermoelectric generator IEU-2M in a transport package И4.189.031
18	RUS/6065/X from 28.10.2005 to 28.10.2006	Certificate-permission for transportation under special arrangement of a transport package еИ4.189.010 with a radioisotope thermoelectric generator G-90-80/24 (IEUИЭУ-1) manuf. № 8227
19	RUS/6070/B(U)-96T from 08.12.2005 to 08.12.2010	Certificate-permission for the design of transport packaging UKTIV-(IEU-1) and for the transportation of radionuclide thermal sources of the types RHS-90, TRIB-90 and RHSu-90 in them
20	RUS/6071/B(U)-96T from 08.12.2005 to 08.12.2010	Certificate-permission for the design of a transport packaging UKTIV -90 and for the transportation of radionuclide thermal sources of the types IT-90, TRIB-90 and RHSu-90 in it
21	RUS/6003/B(U)-96T (Rev. 1) from 08.12.2005 to 08.12.2010	Certificate-permission for the design of a transport packagings UKTIV (IEU-2) and transportation of radionuclide thermal sources of the types RHS-90, TRIB-90 and RHSu-90 in them

D-2. Preparation of a draft of requirements for planning and ensuring of preparedness for elimination of consequences of radiation accidents during transportation of radioactive materials (Deliverable D7)

1. INTRODUCTION

Within the frameworks of D-7 report regarding Task 4 the purpose was:

- to draw up a review of basic requirements necessary for planning and ensuring of preparedness for elimination of consequences of radiation accidents during transportation of nuclear materials (hereinafter referred to as NM) and radioactive substances (hereinafter referred to as RS)[9];
- to prepare a draft of a regulation – normative document (hereinafter referred to as ND) realising the above requirements in the Russian Federation.

As the source data the legislative acts and regulatory documents of the Russian Federation and recommendations of international organisations regarding emergency response during transportation of radioactive materials (hereinafter referred to as RM) were defined, collected, reviewed and compiled.

Then, taking into account the existing practice of emergency response during transportation of RM in the Russian Federation, the basic requirements necessary for planning and ensuring of preparedness for elimination of consequences of accidents during transportation of RM and the draft of federal norms and rules "Requirements for Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" were developed.

2. REVIEW OF BASIC REQUIREMENTS FOR PLANNING AND ENSURING OF PREPAREDNESS FOR ELIMINATION OF CONSEQUENCES OF RADIATION ACCIDENTS DURING TRANSPORTATION OF RADIOACTIVE MATERIALS

2.1. Basic Requirements in the Russian Federation

At present in Russia there are no any concrete normative document of the federal level, which stipulates the requirements for planning and ensuring of preparedness for elimination of consequences of radiation accidents exactly during transportation of RM. However it does not mean that there is a lack of such requirements in general, since they are defined in a number of laws, rules and standards, as well as in the documents of the agencies dealing with transport of RM.

Below the most important Federal Laws and normative documents of the Russian Federation, which requirements must be taken into account at the planning of measures on and ensuring of preparedness for elimination of accidents with radiation consequences during transportation of RM, are given.

Name	General definition	Including details
Federal Laws		
"On the Use of Atomic Energy" dated from 21.11.1995, No. 170-FZ	Defines legal basis and principles of regulation of relations arising during the use of atomic energy in Russia, the aim is to protect the peoples' health and life, environment, property during the use of atomic energy, to promote development of atomic science and technique, to contribute to strengthening of international regime of the safe use of atomic energy. The present law does not apply to the nuclear-powered facilities for military	• Order of issuing permits (licenses) on the right to perform works in the field of atomic energy use; • Legal statute of the operating organisation carrying out its activity in the field of atomic energy use; • The operating organisation's responsibility for and duties on safety of nuclear facility, radiation source and storage point; • Duties of the operating organisation on protection of the staff of the objects of atomic energy use, population and the environment during an accident at the nuclear facility, in the radiation source and

[9] Later on in the text the general term "Radioactive materials" (hereinafter referred to as RM) is used.

Name	General definition	Including details
	purposes.	storage point; • Legal statute, responsibility and duties of the organisations fulfilling works and rendering services for the operating organisations; • Transport of NM and RS; • Prevention of transport incidents and accidents during transportation of NM and RS.
"On Radiation Safety of Population" dated from 9.01.1996, No. 3-FZ	Defines legal basis for ensuring radiation safety of population to protect their health.	• Ensuring of radiation safety during radiation accident; • Protection of population and staff (personnel) against radiation accident; • Duties of the organisations carrying out activity with the use of ionising radiation sources on the ensuring of radiation safety during radiation accident.
"On Environmental Protection" dated from 10.01.2002, No. 7-FZ	Defines principles of environmental protection, ecological requirements during the use of radioactive materials, standards for maximum accessible level of radiation impact, etc.	• Requirements in the field of environmental protection during the use of radioactive substances and nuclear materials.
"On Protection of Population and Territories against Natural and Man-Induced Emergency Situations" dated from 12.12.1994, No. 68-ФЗ (in the edition from 28.10.2002, No. 129-FZ)	Defines the organisational-legal norms, general for the Russian Federation, in the field of protection of population, the whole land, water, air space within the Russian Federation or its part, objects for production and social purpose, as well as the environment against natural and man-induced emergency situations. The present law applies to the relations arising in the process of activity of the authorities of state power of the Russian Federation, authorities of local government, as well as enterprises, institutions and organisations irrespective of their organisational-legal form, and population in the field of protection of population and territories against emergency situations.	• Duties of the federal authorities of executive power in the field of protection of population and territories from emergency situations; • Duties of the organisations in the field of protection of population and territories from emergency situations; • Supervision and control in the field of protection of population and territories from emergency situations.
"On Emergency-Rescue Services and Status of Rescuers " dated from 14.07.1995, No. 151-FZ	Defines general organisational-legal and economic basis for creation and activity of emergency-rescue services, emergency-rescue forces on the territory of the Russian Federation, regulates relations in the above field between the authorities of state power, authorities of local government, as well as the enterprises, institutions, other juridical persons irrespective of their organisational-legal forms and property forms, public associations, officials and citizens of the Russian Federation; establishes rights, duties and responsibilities of rescuers; defines fundamentals for the state policy in the field of legal and social protection of rescuers, other citizens of the Russian Federation, who are taking part in elimination of emergency situations of natural and man-induced character, and members of their families.	
"On Technical Regulation" dated from 27.12.2002, No. 184-FZ[10]	Regulates relations arising during: • development, acceptance, application and execution of mandatory requirements for products, production processes, operation, storage, conveyance, realisation and disposal; • development, acceptance, application and execution, on a voluntary basis, of requirements for products, production processes, operation, storage, conveyance, realisation and disposal,	Section "Atomic Energy" (18 in the Technical Regulations) includes: • Requirements for ensuring nuclear and radiation safety during transport of nuclear materials, radioactive substances and radioactive waste. Section "Medicine and Medicines" (2 in the Technical Regulations) includes: • On radiation protection. • On safety of radiation.

[10] It will be put into effect within seven years.

Name	General definition	Including details
	performance of works or rendering services; assessment of compliance. The present Federal Law defines also the rights and duties of the participants, whose interrelations are regulated by the present law.	Section "Ecology" (2 in the Technical Regulations) includes: • Monitoring of radioactive contamination.
Decrees of the Government of the Russian Federation		
"On Approval of the Rules of Forming, Functioning and Financing of the Regional Emergency Forces of the Operating Organisations Being Used for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" dated from 20.06.1997, No. 761.	The present Rules define the order of forming, functioning and financing of the regional emergency forces of the operating organisations being used for elimination of accident consequences during transportation of nuclear materials and radioactive substances.	1. Organisation of works on elimination of accident consequences during transport of NM and RS, which are owned by the federal authorities of executive power and organisations on the territory of the Russian Federation, shall be entrusted to the Ministry for Atomic Energy of the Russian Federation[11]. The present Rules do not apply to the activity dealt with nuclear weapon and nuclear-powered facilities for military purposes. 2. Professional emergency-rescue forces of Rosatom (hereinafter referred to as ERF), which are designated for elimination of emergency situations at the objects of nuclear industry of the Russian Federation, shall fulfill functions of the regional emergency forces of the operating organisations on protection of population and territories against emergency situations of a radiation character during transportation of NM and RS. 3. The emergency-technical centres of Rosatom serve as ERF being used for elimination of accident consequences during transportation of NM and RS. ERF serve the regions and territories as per the List according to the Annex. If necessary, Rosatom shall introduce changes in the above List. ERF are included into the forces of permanent readiness of the federal level of the unified state system for prevention and elimination of emergency situations. 4. Changes in ERF staff being used for elimination of accident consequences during transportation of NM and RS, as well as their location bases shall be defined by the Government of the Russian Federation upon Rosatom's submission. 5. The main ERF functions are as follows: • participation in performance of works on prevention of accidents during transportation of NM and RS; • organisation and ensuring of interaction with the transport organisations and enterprises of Rosatom for the purposes of safe transportation of NM and RS and elimination of accident consequences during transport; • providing for permanent readiness for performance of works on elimination of accident consequences during transportation of NM and RS; • co-ordination of the plans of elimination of accident consequences during transportation of NM and RS, being developed by the organisation–consignor or -consignee (if the latter transports the cargo); • participation in tracking of movement of NM and RS cargos; • creation and maintenance of reserves of material resources for elimination of accident consequences during transportation of NM and RS in the routine defined by the legislation of the Russian Federation; • participation in fulfillment of other measures on ensuring the safe transportation of NM and RS. 6. Works on prevention and elimination of accident consequences during transportation of NM and RS shall be carried out on the basis of contracts concluded between ERF and the organisation–consignor or -consignee (if the latter transports the cargo). 7. Rosatom jointly with the involved federal authorities

[11] It is indicated as stipulated in the Government's Decree, at present - Rosatom (hereinafter referred to as Rosatom).

Name	General definition	Including details
		of executive power shall approve statutes on the interaction with the organisations and enterprises participating in the works on elimination of accident consequences during transportation of NM and RS. 8. Rosatom implementing functions of a state competent authority on nuclear and radiation safety during conveyance of NM, RS and products made thereof, shall issue a certificate (permit) on conveyances of the above materials in the transport packing sets, if the following is available: • contract signed by ERF with the organisation–consignor or -consignee (if the latter transports the cargo); • plan of elimination of accident consequences during transportation of nuclear materials and radioactive substances, agreed with the relevant ERF. 9. Financing of ERF activity on prevention of emergency situations during transport of NM and RS shall be carried out at the expense of funds envisaged by the contracts between ERF and the organisations–consignors or -consignees (if the latter transports the cargo). Financing of ERF activity on elimination of emergency situations during transportation of NM and RS shall be carried out at the expense of funds allocated in the routine established by the legislation of the Russian Federation on elimination of emergency situations.
"Statute on the Unified State System of Prevention and Elimination of Emergency Situations" dated from 30.12.2003, No. 794	The present Statute defines the order of organisation and functioning of the unified state system of prevention and elimination of emergency situations (RSChS), hereinafter referred to as the unified system.	1. The unified system consolidates as follows: • Management authorities; • Manpower and means of the federal authorities of executive power, authorities of executive power of the subjects of Russian Federation, authorities of local government and organisations making decisions in the field of protection of population and territories against emergency situations. 2. The purpose is to accomplish the tasks envisaged by the Federal Law "On Protection of Population and Territories against Natural and Man-Induced Emergency Situations". 3. The unified system comprises: • Functional systems; • Territorial systems. 4. The levels of scope are as follows: • Federal; • Regional; • Territorial; • Local; • Object's. 5. Creation, by the federal authorities of executive power, of the functional subsystems for organisation of protection of population and territories against emergency situations in the zone of activity of the above authorities[12]. 6. In the subjects of the Russian Federation creation of the territorial subsystems for prevention and elimination of emergency situations within the above territories (they consist of the parts corresponding to the administrative-territorial division of the above territories)[13]. 7. At every level of the unified system creation of: • Co-ordination bodies;

[12] Organisation, forces and means of the functional subsystems, as well as the order of their activity shall be defined by the statutes thereon, approved by the heads of the federal authorities of executive power upon co-ordination with the Ministry of the Russian Federation on the Affairs of Civil Defence and Emergency Situations and Elimination of Consequences of Natural Disasters (hereinafter refereed to as MChS).

[13] Organisation, forces and means of the territorial subsystems, as well as the order of their activity shall be defined by the statutes thereon, approved by the authorities of executive power of the Russian Federation subjects in the established routine.

Name	General definition	Including details
		• Standing management authorities; • Day-to-day management authorities; • Manpower and means; • Reserve of financial and material resources; • Communication, notification and information provision.
"On Approval of the Statute on Licensing of Activity in the Field of Use of Atomic Energy" dated from 14.7.1997, No. 865	The present Statute has been developed for the purposes of realisation of the requirements of the Federal Law "On the Use of Atomic Energy", and it establishes the order and conditions for the licensing of activity in the field of use of atomic energy.	The Annex to the Statute on Licensing of Activity in the Field of Use of Atomic Energy defines the List of the Types of Activity in the Field of Use of Atomic Energy, which are licensed by Gosatomnadzor of Russia[14], including: • Management of NM and RS during transport; • Management of RW during transport.
Federal Norms and Rules		
Rules of Safety during Transportation of Radioactive Materials. (NP-053-04)	The present Rules set the requirements for safety during transportation of radioactive materials. The requirements of the Rules cover transportation of RM by all types of transport vehicles.	Section 7 "Measures during Accidents at Conveyance of RM" stipulates general provisions and requirements, classification of accidents and basic requirements for measures in case of an accident, as well as additional requirements for measures in case of an accident during conveyance by water transport.
Norms of Radiation Safety. (NRB-99)	NRB-99 shall be applied for the ensuring of man safety under all the conditions of impact thereon of ionising radiation of artificial or natural origin. Requirements and standards established by the Norms are mandatory for all the juridical persons, irrespective of their subordination and property form, which activity could lead to an exposure of people, as well as for the administrations of the Russian Federation subjects, local authorities, citizens of the Russian Federation, foreigners and stateless citizens residing on the territory of the Russian Federation.	The present Norms are the fundamental document regulating requirements of the Federal Law "On Radiation Safety of Population" in the form of basic limits of doses, permissible levels of ionising radiation impact and other requirements for limitation of man exposure.
Basic Sanitary Rules of Radiation Safety Ensuring. (OSPORB-99)	OSPORB-99 set the requirements for protection of people from harmful radiation impact under all the conditions of exposure from ionising radiation sources covered by NRB-99. The Rules are mandatory at designing, construction, operation, reconstruction, changing of types of activity and decommissioning of radiation facilities.	The Rules apply to all the organisations designing, extracting, producing, reprocessing disposing radioactive substances and other sources of radiation, the organisations carrying out mounting, repair and setup of instrumentation, equipment and installations, which operation is based on the use of ionising radiation, and equipment generating ionising radiation, as well as the organisations, which activity affects the level of man exposure from natural radiation sources, and the organisations performing works on the territory contaminated with radioactive substances.
Agency's Documents		
Statute on Organisation of Actions on Elimination of Accident Consequences during Conveyance of NM and RS by the Federal Railway Transport (PLA-2001)[15]	It defines: • Order of actions during the accident and elimination of its consequences; • Organisation of guidance and management of works on elimination of accidents of categories II and III and their consequences; • Order of performance of emergency-recovery works. It establishes: • Requirements for safety of personnel during actions on elimination of the accident and its consequences; • Requirements for forces and formations involved in elimination of the accident	1. Planning of elimination of accident consequences. 2. Phases of actions during elimination of accident consequences. 3. General and special measures in the zone of accident. 4. Notification of the accident. Schemes of notification. 5. Actions of escort-personnel during the accident. 6. Actions of escort-personnel during the accident of category I. 7. Actions of escort-personnel during the accidents of categories II and III. 8. Actions of sentry staff carrying out guard of the cargo, during the accident. 9. Actions of employees of the railway transport during the accident with NM and RS. 10. Involving of Rosatom ERF during the accidents.

[14] It is indicated as in the Government's Decree, at present – the Federal Environmental, Industrial and Nuclear Supervision Service.
[15] Developed jointly with the Ministry of the Russian Federation for Atomic Energy (at present - Rosatom) and the Ministry of Communications of the Russian Federation (at present – RAO "RZhD")

Name	General definition	Including details
	and its consequences.	11. Actions of Rosatom ERF on elimination of the accident and its consequences. 12. Urgent medical-preventive measures at the place of accident. 13. Order of actions during fires. 14. Implementation of radiation exploring at the place of accident. 15. Requirements for organisation and performance of decontamination works. Order of completion of works on elimination of accident consequences. 16. Ensuring of confidentiality and physical protection. 17. Requirements for norm-fixing of exposure, organisation and implementation of radiation monitoring. 18. Radiation protection measures. 19. Medical-sanitary support of works on elimination of the accident and its consequences. 20. Requirements for ERF staff. 21. Order of access to perform radiation-hazardous works at the place of accident. 22. Technical equipping of ERF.

2.2. Recommendations of the International Organisations

Below the documents of the international organisations are given, which recommendations have been taken into consideration (with due account of the Russian practice) at development of requirements for planning the measures on and ensuring the preparedness for elimination of accidents with radiation consequences during transportation of RM.

Name	General definition
IAEA	
TS-R-1: "Standards and Regulations for Safe Transport of Radioactive Material" (2003 version, with amendments), 2004.	The document sets safety standards providing for an acceptable level of radiation control, criticality and thermal hazard for the personnel, property environment. Standards and Regulations TS-R-1 provide for a regulatory basis for all the categories of radioactive material, including SNF.
TS-G-1.1: "Consultative Material for the Standards and Regulations for Safe Transport of Radioactive Material" (2002).	The document gives clarifications and consultations on the application of the Standards and Regulations TS-R-1.
TS-G-1.2 (ST-3) "Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material", 2002.	The given guidance defines the structure for planning and preparation of actions in case of an accident during transport of radioactive materials, distribution of responsibility, order of emergency planning and preparation.
EU	
European Agreement on International Motor Conveyance of Hazardous Cargos (ADR).	
International Standards and Regulations for Hazardous Cargo Transport by Railway (RID)	
92/3/Euratom's Directive from February 3, 1992, on Supervision and Control of Radioactive Waste Conveyance between the Member-States, inside and outside the Community.	
Standards and Regulations (Euratom) from June 8, 1993, on Conveyance of Radioactive Substances, between the Member-States.	
96/35/EK Directive on Appointment and Qualification of Consultants on Safe Conveyance of Hazardous Cargos by Motor and Railway Transport and by Water.	

The basic document defining recommendations on planning and preparing for actions in case of transport accident during radioactive material conveyance is the IAEA's safety guidance series -

"Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material" No. TS-G-1.2 (ST-3).

The above safety guidance has been taken as a basis for development of an ND draft "Requirements for Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances".

3. DRAFT OF REQUIREMENTS FOR PLANNING AND ENSURING OF PREPAREDNESS FOR ELIMINATION OF CONSEQUENCES OF RADIATION ACCIDENTS DURING TRANSPORTATION OF RADIOACTIVE MATERIALS

A draft of the federal norms and rules, namely, "Requirements for Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" has been prepared.

The draft was developed in accordance with the existing procedure for ND elaboration established by the Federal Environmental, Industrial and Nuclear Supervision Service.

The first edition of FNR was developed and sent for comments to the organisations and agencies dealing with transportation of RM and emergency response during RM transportation (15 organisations as per the Technical Assignment - TZ). Summary of comments was drawn up as per the remarks and suggestions submitted by the above organisations, and then the conciliatory meeting was held.

As per the outcomes of the conciliatory meeting the second draft of FNR edition was developed and again sent to the same organisations for comments. Summary of comments was drawn up as per the new (additional) remarks and suggestions submitted by the above organisations; and then the second conciliatory meeting was held.

As per the outcomes of the second conciliatory meeting the final draft of FNR edition was developed and submitted to the expert commission of NRS SEC.

As per the comments and suggestions made by the members of the NRS SEC expert commission the draft of the final FNR edition was completed and submitted to the working commission on normative documents of the Federal Environmental, Industrial and Nuclear Supervision Service.

As per the comments and suggestions made by the members of the NRS SEC working commission on normative documents of the Federal Environmental, Industrial and Nuclear Supervision Service the final edition of FNR draft was prepared and submitted to the Ministry of Transport /Mintrans/ and Rosatom to make a conclusion regarding its publication in the open press.

After receiving the conclusion on a possibility of FNR draft publication in the open press from the Ministry of Transport and Rosatom the document was submitted for its publication to the official printing body of NRS SEC. The FNR draft is planned to be published in 2006, III quarter.

In case of any well-grounded remarks and suggestions, which are accepted by the Developer, after publication of FNR draft in the open press, the document will be completed and submitted to the Head of the Federal Environmental, Industrial and Nuclear Supervision Service for approval.

Approval and putting of the given FNR into affect is planned in 2006, IV quarter.

Below the FNR draft submitted for its publication to the official printing body of NRS SEC is given.

4. DRAFT FEDERAL NORMS AND RULES

Federal Environmental, Industrial and Nuclear Supervision Service

FEDERAL NORMS AND RULES
IN THE FIELD OF USE OF ATOMIC ENERGY

Approved by
the Order of the
Federal Environmental,
Industrial and Nuclear Supervision Service
from "___"_______2006
No. ___

REQUIREMENTS
FOR THE PLANNING AND ENSURING OF PREPAREDNESS FOR ELIMINATION OF ACCIDENT CONSEQUENCES DURING TRANSPORTATION OF NUCLEAR MATERIALS AND RADIOACTIVE SUBSTANCES

NP-XX-06

Put into effect
Since "___" _________ 2006

Moscow
2006

UDK XXX.XX

REQUIREMENTS FOR THE PLANNING AND ENSURING OF PREPAREDNESS FOR ELIMINATION OF ACCIDENT CONSEQUENCES DURING TRANSPORTATION OF NUCLEAR MATERIALS AND RADIOACTIVE SUBSTANCES. NP-XX-06

Federal Environmental, Industrial and Nuclear Supervision Service
Moscow, 2006

The present normative document sets the requirements for the planning and ensuring of preparedness for elimination of accident consequences during transportation of nuclear materials and radioactive substances by all types of transport means, and defines the routine of elaboration and approval of a Plan of Organisation of Actions on Elimination of Accident Consequences during Conveyance of Radioactive Material Cargo in accordance with the requirements of the Rules of Safety during Transportation of Radioactive Materials.

Published for the first time*.

The document has been developed on the basis of the normative legal acts of the Russian Federation, federal norms and rules in the field of use of atomic energy, as well as the IAEA recommendations Safety Guide No. TS-G-1.2 (ST-3) Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material, 2002.

* The present normative document has been developed by the following team of authors: Bukrinskiy A.M., Kaliberda I.V., Kovalevich O.M., Slutsker V.P., Sharafutdinov R.B., Shempelev V.P., Shulgin A.Ya. (NTTs YaRB), Pluzhnikov I.M., Reka V.Ya., Ulanov S.A. (Federal Environmental, Industrial and Nuclear Supervision Service).

The proposals of the experts of the Federal Agency for Atomic Energy, Federal Department of Medicobiological and Extremal Problems of the Ministry of Health and Social Development of Russia, General Headquarters of Interior Troops of the Interior Ministry of Russia, Federal Agency for Sea and River Transport of the Ministry of Transport of Russia, Federal Agency for Air Transport of the Ministry of Transport of Russia, Department of the State Policy in the Field of Road Economy, Motor and Municipal Passenger Vehicles of the Ministry of Transport of Russia, Ministry of Emergency Situations of Russia, Department of Transportation Management JSC "Russian Railway Roads", FSUE "Kurchatovskiy Institute", JSC "Murmansk Shipping Company", SUE Moscow Scientific & Production Company"Radon", SC Scientific & Engineering Centre "Nuklon" have been taken into account during development of the document.

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TERMS AND DEFINITIONS

(used for the purposes of the present document)

Intervention – an action aimed at reducing of exposure probability or dose or unfavourable consequences of exposure.

Decontamination – removal or reduction of radioactive contamination from some surface or out of some media.

Radioactive contamination – presence of radioactive substances on the surface, inside the material, in the air, man body or in other place in the quantity exceeding the levels established by the radiation safety norms.

Removable (non-fixed) contamination of the surface – radioactive substances, which are transferred to other articles at contact or removed during decontamination.

Zone for surveillance of radiation accident place – the territory around the accident place, outside the boundaries of radiation accident zone, where radiation monitoring is implemented and on which the measures on population protection could be needed in case of an accident involving RM cargo.

Zone for surveillance of radiation accident place shall be established for the period till the completion of works on elimination of radiation consequences of the accident.

Radiation accident zone – the territory, where the fact of radiation accident is fixed, and the levels of exposure of population or employees (personnel), caused by the accident, can exceed the dose limits established by the radiation safety norms for normal operation of technogenic sources of ionising radiation[16].

Elimination of radiation accident consequences during transport of radioactive materials – a complex of measures (works) directed at rendering aid to victims of the radiation accident, recovery of control over the radiation source, elimination of roots and (or) consequences of the radiation accident and normalisation of radiation state in the radiation accident zone [17].

Emergency exposure – exposure as a result of the radiation accident.

Potential exposure – exposure, which can be resulted from the radiation accident.

Dangerous zone (area) – the territory (area) inside the radiation accident zone, where the levels of exposure caused by the accident for personnel of A group exceed the dose limits established by the radiation safety norms for the above category of exposed persons, and the emergency exposure is likely, and (or) the removable (non-fixed) radioactive contamination of the surface and (or) radioactive contamination of the locality[18] took place.

Radiation consequences of the accident during transport of radioactive materials – potential exposure of employees (personnel) and population over the established norms and (or) radioactive contamination of the surface and (or) the environment.

Radiation accident during transport of radioactive materials – damage of RM cargo, caused by failure of equipment, wrong actions of employees (personnel), natural disasters or because of other

[16] Presence of people not participating in the elimination of radiation consequences of the accident, in the radiation accident zone is forbidden.

[17] Actions (measures, works) on the elimination of radiation consequences of the accident shall be carried out according to the Plan of Organisation of Actions on Elimination of Accident Consequences during Conveyance of RM Cargo.

[18] Access to the dangerous zone (area) shall be carried out only according to the job-permit signed by the head of emergency works, through the temporary RMP located at the boundary of the dangerous zone (area).

reasons, which can or could lead to exposure of people over the established norms and (or) radioactive contamination of the environment.

Radioactive contamination of the surface – presence of RM on the surface of transport vehicles, cargo containers, packages and other articles in the quantities exceeding 0.4 Bq/cm^2 for the beta-, gamma- and alpha-radiators of low toxicity, and 0.04 Bq/cm^2 for all other alpha- radiators.

Radioactive material – a nuclear material and (or) a radioactive substance[19]. Hereinafter the RM is also referred to the products made on their basis.

Radioactive material contained in the products – the radioactive material placed in the technogenic radiation source specially created for its beneficial use (for instance, the radioisotope thermoelectric generator) or being the by-product of the above activity.

Urgent intervention – the necessary protection measures, if for the short period of time (2 days) the postulated exposure dose reaches the levels established by the radiation safety norms, for limitation of population exposure under the conditions of radiation accident.

[19] The term is used as a generalising one in the present normative document, when there are no differences in the requirements for conveyance of radioactive substances and nuclear materials.

1. Purpose and Scope

1.1. The present Rules "Requirements for the Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" (hereinafter referred to as the Rules) have been developed in accordance with the requirements of the Rules of Safety during Transportation of Radioactive Materials, and have set forth:

- requirements for the planning and ensuring of preparedness for elimination of accident consequences during transportation of nuclear materials and radioactive substances;
- routine of elaboration and approval of a Plan of Organisation of Actions on Elimination of Accident Consequences during Transportation of RM Cargo (hereinafter referred to as the Plan of Actions on Elimination of Accident Consequences).

1.2. The present Rules apply to the planning and ensuring of preparedness for elimination of accidents during transportation of RM, including those contained in the products, by all types of transport vehicles, by land, air and water ways, and are effective on the whole territory of the Russian Federation.

1.3. The present Rules do not apply to the planning and ensuring of preparedness for elimination of accident consequences during transportation of the following:

- RM in case of activity dealt with development, manufacturing, testing, operation and disposal of nuclear weapons and nuclear-powered facilities for military purposes;
- RM being an integral part of a transport vehicle;
- Natural materials and ore containing natural radionuclides either in their natural state or, which have been processed only for other purposes, except for radionuclide extraction, and which are not designated for reprocessing with the purpose to use the above radionuclides under the condition that the specific activity of these materials does not exceed the values specified in the Rules of Safety during Transportation of Radioactive Materials in 10 times more, or the effective specific activity thereof is not more than 10 Bq/g;
- RM, which specific activity or the total activity of the cargo does not exceed the values specified in the Rules of Safety during Transportation of Radioactive Materials.

1.4. The present Rules do not apply to the planning and ensuring of preparedness for elimination of accident consequences in case of inner movements (i.e. excluding the ways and roads for general use) of RM on the territory of the enterprises, where the above materials are produced, used and stored.

1.5. The present Rules are mandatory for all the juridical and physical persons carrying out activity in the field of transportation of RM, including transit storage of RM (packages with radioactive materials) in the course of their conveyance, and involved for elimination of accident consequences during transportation of RM cargo.

2. General Provisions

2.1. For the purposes of elimination of accident consequences, which are likely during transportation of RM cargo, the operating organisation (consignor or consignee in case of conveyance of RM cargo) prior to RM transportation must develop and approve a Plan of Actions on Elimination of Accident Consequences. The routine of development and approval of this Plan is set in the present Rules.

2.2. Plan of Actions on Elimination of Accident Consequences must be developed by the operating organisation (consignor or consignee in case of transport of RM cargo) taking into account the conditions of transportation and level of potential radiation hazard arising as a result of possible accident during transportation of RM cargo.

Except for the above, other hazardous properties of these materials or materials of the package must be taken into account, as well as a possibility of formation of products with hazardous properties, resulting from interaction of RM or package materials with atmospheric air, water, or impact of high temperatures or free flame because of the fire.

During development of the Plan of Actions on Elimination of Accident Consequences the following must be taken into due account:

- Rules of conveyance of hazardous cargos in the certain type of transport vehicle;
- Design characteristics of TPS, containers used for transportation of RM;
- Design characteristics of transport vehicles used for conveyance of RM cargo.

2.3. Plan of Actions on Elimination of Accident Consequences must be agreed with:

- Head of NRSD of the Federal Agency for Atomic Energy;
- Head of the Department on Decommissioning of Nuclear and Radiation Hazardous Facilities of the Federal Agency for Atomic Energy;
- Head of the organisation carrying out conveyance;
- Head of SPb EEC;
- Head of the territorial (regional) health authority;
- Manager of the territorial (regional) management authority on affairs dealt with civil defence and emergency situations;
- Manager of the territorial (regional) department of interior affairs;
- Commander-in-Chief of Interior Troops of the Interior Ministry of Russia, who provides the guard;
- Director of the territorial (regional) entity.

2.4. Plan of Actions on Elimination of Accident Consequences must be approved by the Head of operating organisation. It enters into force after approval thereof and order on its putting into affect, which must be issued by the Head of operating organisation no late than a month before RM transportation.

Prior to putting the Plan of Actions on Elimination of Accident Consequences into effect it must be logistically supported and ready for realisation.

2.5. Plan of Actions on Elimination of Accident Consequences must envisage co-ordination of actions of the operating organisation (consignor or consignee in case of RM cargo transport), carrier and outsider organisations, including authorities of local government, management authorities on affairs dealt with civil defence and emergency situations, authorities of interior affairs, medical institutions for the whole route of RM transportation taking due account of economic, natural and other characteristics, peculiarities of territories (water areas) and level of hazard for accident situation origin.

2.6. Development of a new Plan of Actions on Elimination of Accident Consequences, introduction of changes and supplements in the approved plan shall be made in case of changes in conditions of RM cargo transportation, as per prescriptions of the authorities of state safety regulation during the use of atomic energy, in case of introduction of new normative documentation and other necessity taking due account of the requirements stipulated in points 2.2 and 2.3 of the present Rules.

2.7. Requirements of the Plan of Actions on Elimination of Accident Consequences cover departments (employees) of the operating organisation participating in emergency response activity, during planning and taking measures (actions) aimed at ensuring the preparedness and elimination of accident consequences, which are likely during RM cargo transportation.

Plan of Actions on Elimination of Accident Consequences must envisage measures (actions) on emergency response in case of an accident during transportation of RM cargo on the whole route of its conveyance.

2.8. In case of potential and (or) emergency exposure of population, who is being and (or) can be within the zone of radiation accident, the protection thereof shall be carried out as per the Plan of Measures on Protection of Population, developed by the competent authorities of executive power in accordance with the legislation of the Russian Federation on protection of population and territories in case of ES of natural and man-induced character.

2.9. For timeliness of putting the Plan of Measures on Protection of Population into effect, as well as for co-ordination of actions and mutual assistance in realisation of envisaged actions (measures, works) on elimination of radiation consequences of an accident and protection of population, the Plan of Actions on Elimination of Accident Consequences must envisage as follows:

- Timely alert to a threat (case) of an accident with possible radiation consequences, informing the competent authorities of executive power, at which territory the accident took place;
- Transmission of current information (with indication of scope and periodicity) about accident evolution and radiation situation in the zone of radiation accident.

2.10. Plan of Actions on Elimination of Accident Consequences must envisage actions on elimination of failures and damages of transport vehicles, causing no impact on RM cargo, which must be eliminated in the established routine in every type of transport vehicle with the observance of requirements for radiation safety and under supervision of a person responsible for escorting the RM cargo, and (or) taking into account the data contained in the danger signs installed on the cargo and transport vehicles, as well as the requirements of sanitary rules during RM transportation, which must be reflected in the instructions for escort personnel.

3. Requirements for Planning the Measures on Elimination of Accident Consequences During Transportation of Radioactive Material Cargoes

3.1. In the course of planning of measures (actions, works) aimed at protection of people and elimination of accident consequences possible during transportation of RM cargo (elaboration of the Plan of Actions on Elimination of Accident Consequences and other documents defined by the above Plan), with the purpose of operative definition of a danger level, taking necessary primary measures by personnel escorting the RM cargo and adequate emergency response by the operating organisation (consignor or consignee, if they transport RM cargo) the Plan of Actions on Elimination of Accident Consequences must use the classification of accidents by categories according to the Rules of Safety during Transportation of Radioactive Materials.

3.2. At elaboration of the Plan of Actions on Elimination of Accident Consequences in order to distribute duties and responsibilities between consignor, consignee, carrier and other organisations and agencies participating in RM transportation, the measures (actions, works) during elimination of accident consequences must be divided into three phases:

- phase 1 – "Initial phase"; it lasts from the moment of accident origin till the moment of ERF (SET) arrival to the place of the accident;
- phase 2 – "Phase of combating with the accident"; it lasts from the moment of ERF (SET) arrival to the place of the accident till the moment of recovery of control over the radiation source (RM cargo) and elimination of accident consequences;
- phase 3 – "Post-accident phase"; it lasts from the moment of completion of works on phase 2 and decision-making on a possibility for further conveyance of RM cargo till the rehabilitation of the territory undergone to radioactive contamination.

3.3. Depending on a category of possible accident the Plan of Actions on Elimination of Accident Consequences must envisage:

3.3.1. In case of the accident of category I:

3.3.1.1. Elimination of accident consequences by personnel (in case of presence and capability of the personnel escorting RM cargo) jointly with employees of the transport organisation, officers of the authorities of interior affairs and (or) rescue units of the territorial body of the department on civil defence and emergency situation affairs, arrived to the place of accident[20].

3.3.1.2. Elimination of accident consequences by employees of the transport organisation, officers of the authorities of interior affairs and (or) rescue units of the territorial management body on civil defence and emergency situation affairs arrived to the place of accident, in accordance with the requirements of emergency card[21], taking into account information contained in the labels and signs of radiation danger on RM cargo and transport vehicles (in case of loss of capability by the personnel escorting RM cargo, or in case of absence thereof). Call for a representative of the consignor to the accident place (of the consignee, if the latter transports RM cargo) to define a possibility for further conveyance of RM cargo.

3.3.1.3. Making decision on a possibility for further conveyance of RM cargo by a person escorting RN cargo, and in the case of his/her absence or incapacity – by the consignor's representative (consignee's one, if the latter transports RM cargo) jointly with employees of the transport organisation, after the transport vehicle and RM cargo are put in good order, and a protocol of the accident is drawn up.

3.3.2. In case of the accident of categories II and III:

3.3.2.1. In the "Initial phase" (phase 1) – actions performed by a person escorting RM cargo[22], and in case of his/her absence or incapability – by employees of the transport organisation[23]:

3.3.2.1.1. Immediate notification of the consignor, consignee, organisation-carrier, authorities of interior affairs, territorial management body on civil defence and emergency situation, authority of local government, authority of the state safety regulation during the use of atomic energy, authority of management of atomic energy use, about the fact and place of the accident, time and category thereof.

3.3.2.1.2. Taking necessary and available measures on rendering the first medical (before-doctor examination) aid in case of the incidents, threat to life or overexposure of people.

3.3.2.1.3. Prevention or extinguishing of fire.

3.3.2.1.4. Primary definition of an accident radiation hazard and transmission of information about radiation state at the place of the accident.

3.3.2.1.5. Taking out the people from the accident zone according to the requirements of emergency card and instructions of person escorting RM cargo; in case of absence of the emergency card and person escorting RM cargo – taking the people to the windward side at the

[20] Actions of personnel escorting RM cargo, regarding transmission of information about an accident and elimination of its consequences must be stipulated in the instruction developed on the basis of the Plan of Actions on Elimination of Accident Consequences for the personnel escorting cargo.
[21] Emergency cards shall be developed in the routine defined by the federal authority of executive power in the field of atomic energy use.
[22] Actions of personnel escorting RM cargo during an accident must be stipulated in the instruction developed on the basis of the Plan of Actions on Elimination of Accident Consequences for the personnel escorting cargo.
[23] Actions of personnel of the transport organisation being performed in case of absence or incapability of the personnel escorting RM cargo, must be indicated in the emergency card.

distance (if possible) of no less than 100 m from the accident place till the arrival of experts on radiation monitoring with the relevant instrumentation.

3.3.2.1.6. Installation of the signs of radiation danger at the boundary of radiation accident zone.

3.3.2.1.7. Arrangement of cordoning off the radiation accident zone, additional guard of RM cargo (if necessary), public order ensuring.

3.3.2.1.8. Visual examination and (if possible) radiation monitoring of RM cargo with the purpose to clarify an accident category and define the boundaries of dangerous zone (area).

3.3.2.1.9. Installation of the signs of radiation danger at the boundary of dangerous zone (area) with the text: "Dangerous zone (area)", and (if possible) guard railing of dangerous zone (area).

3.3.2.1.10. Transmission of refined information about a state at the accident place and required assistance in accordance with the established communication routine, instruction and emergency card.

3.3.2.1.11. Taking of primary immediate measures on prevention of radiation accident evolution and its consequences.

3.3.2.1.12. Registration of persons, who could be undergone to radiation impact during accident (exposure, contamination with RS), and their detention till arrival of experts on radiation monitoring with the relevant instrumentation (except for the persons, who need urgent medical aid at the hospital).

3.3.2.1.13. Establishing (if possible) of radiation monitoring at the boundary of radiation accident zone from the windward side.

3.3.2.2. In the "Phase of combating with the accident" (phase 2) actions (measures, works) being performed by the arrived forces of ERF (SET):

3.3.2.2.1. Conduction of radiation and general survey of the accident place with the purpose to clarify radiation hazard, boundaries of radiation accident zone and dangerous zones (areas), condition of RM cargo and transport vehicle, and operative transmission of the results to the manager of emergency works at the emergency control point.

3.3.2.2.2. Assessment of data about radiation and general survey of the accident place and transport vehicle by the manager of emergency works for making decision about recovery of control over radiation source (RM cargo), elimination of radiation consequences of the accident and measures on radiation protection of the staff (personnel) and population.

3.3.2.2.3. Informing the head of the local government authority and the head of the territorial (regional) management body on civil defence and emergency situation about the results of radiation survey of the accident place for making a decision on a necessity of urgent intervention (protection measures), including evacuation (temporary resettlement) of the population from the radiation accident zone in case of excess of the exposure levels established by the radiation safety norms, when urgent intervention is required.

3.3.2.2.4. As per the results of radiation and general survey of the accident place – arrangement of restricted zones: zone of radiation accident with the dangerous zones (areas) therein and zone for surveillance of the radiation accident place. Installation of the signs of radiation danger at the boundaries of the zones with indication thereof.

3.3.2.2.5. Fencing of the radiation accident zone and exclusion, jointly with the authorities of local government and interior affairs, of free access of people to the radiation accident zone.

3.3.2.2.6. Arrangement of entry to and exit from the radiation accident zone through RMP equipped at the boundary of radiation accident zone from the windward side.

3.3.2.2.7. Arrangement of continuous radiation monitoring in the radiation accident zone and periodical monitoring of radiation state in the zone for surveillance of the radiation accident place.

3.3.2.2.8. Equipping of the places at RMP for decontamination of transport vehicles, IPM, places for sanitisation of staff (personnel), places for collection and temporary storage of IPM and equipment contaminated with RS.

3.3.2.2.9. Organisation of works on recovery of control over ionising radiation source (RM cargo) and elimination of radiation accident consequences in the dangerous zones (areas), which envisages as follows:

- Fencing of dangerous zones (areas) along with installation of signs of radiation danger at the boundaries of dangerous zones (areas) with the text: "Dangerous zone (area)";
- Equipping of temporary RMP (for the period of staff (personnel) stay in the dangerous zone and performance of works therein) at the entrance to the dangerous zone (area) and exit from the dangerous zone (area) for the following purposes:
    - Access of staff (personnel) to the dangerous zone (area) only in accordance with the job-permit signed by the manager of emergency works, with an individual dosimeter, in special overalls and with required IPM;
    - Constant monitoring of radiation state changes (of all the radiation factors, which impact is likely during the works with the given RM) at the place of work performance;
    - Control of fixed time for work performance;
    - Conduction of an obligatory (forced) radiometric examination of the staff (personnel)) at their exit from the dangerous zone (area);
    - Measurement and registration of individual exposure doses of the staff (personnel) obtained during their work, and immediate informing the manager of emergency works about persons with the individual exposure dose of more than 0.2 Sv;
    - Decontamination of equipment and IPM contaminated with RS or their removal for the next decontamination or burial;
    - Implementation of partial sanitisation with radiometric examination of its completeness and informing the manager of emergency works about persons with the fixed contamination of derma with RS and (or) ingress of RS inside the body;
    - collection, registration and temporary storage of removed equipment, IPM and overalls, contaminated RS.

3.3.2.2.10. Medical support of measures (works) on elimination of radiation accident consequences, which envisages as follows:

- preparation of places for rendering medical (primary) aid to victims;
- storing of medical means, medications and property, including individual counter-radiation first-aid sets, control over their storage;
- rendering medical (primary) aid to victims;
- taking counter-radiation medical medications;
- evacuation of victims from the radiation accident zone to the hospitals for rendering specialised aid;
- urgent hospitalisation of victims with the individual exposure dose over 1 Sv;
- appointing the persons with the individual exposure dose exceeding the dose limit established by the radiation safety norms in 5 time, for medical examination.

3.3.2.2.11. Organisation of physical protection of RM cargo.

3.3.2.2.12. Organisation of protection of public order in the radiation accident zone, which envisages as follows:

- stopping of movement of people and all the types of transport vehicles, except for those involving in accident consequences elimination, in the radiation accident zone;
- blocking of the radiation accident zone by the officers of interior authorities;
- patrolling of the territory round the radiation accident zone by the officers of interior authorities;
- handling of traffic at the evacuation routes by the officers of interior authorities.

3.3.2.2.13. Providing the ERF (SET) with required logistics, foodstuffs, water, fuel and lubricating materials, transport vehicles.

3.3.2.3. Definition of the following conditions, under which the works on elimination of radiation consequences of the accident (phase 2) are considered as completed ones:

3.3.2.3.1. Control over ionising radiation source (RM cargo) has been recovered. (Condition of?) TPS, containers, packages with RM shall allow to carry out further RM conveyance in accordance with the requirements of the Rules of Safety during Transportation of Radioactive Materials.

3.3.2.3.2. Decontamination of the transport vehicle has been fulfilled; a sanitary-epidemiological protocol issued by the authority of state sanitary-epidemiological supervision about correspondence of conditions and methods of transportation of radioactive substances, nuclear materials, equipment and facilities with radiation sources and radioactive waste to the sanitary rules, is available.

3.3.2.3.3. Traffic safety for the transport vehicle with RM cargo is provided and confirmed by a document of the transport organisation; and traffic on the route of conveyance has been recommenced.

3.3.2.3.4. Decontamination of the territory and objects of the radiation accident zone has been fulfilled and its sufficiency has been confirmed by radiometric control.

3.3.2.4. Actions (measures, works) in the "Post-accident phase" (phase 3):

3.3.2.4.1. Commission draws up an act on elimination of radiation consequences of the accident. The following is enclosed to the act:

- radiation-hygienic protocol of the authority of state sanitary-epidemiological supervision on completion of elimination of radioactive contamination;
- document of the transport organisation confirming safety of conveyance of RM cargo by the indicated transport vehicle RM cargo in accordance with the rules of conveyance of hazardous cargos for the given type of transport vehicle;
- protocol (map) of radiometric control of the territory and objects of the radiation accident zone undergone to contamination with RS.

3.3.2.4.2. Decision making by the consignor or consignee (when they transport RM cargo) – the manger of emergency works about a possibility for further conveyance of damaged RM cargo provided that the safety level meets the Rules of Safety during Transportation of Radioactive Materials. Conditions for further conveyance must be agreed with the authority of management of atomic energy use, as well as (in case of conveyance by railway) – by the federal authority of executive power in the field of railway transport.

3.3.2.4.3. Informing of the authorities of local government about the results of elimination of radiation accident and a lack of radiation hazard for the population.

3.3.2.4.4. Submission of the lists of civil persons undergone, as a result of radiation accident, to radiation impact over the dose limits established by the radiation safety norms for the above category of exposed persons (for appointing thereof to special medical examination) to the authorities of local government.

3.3.2.4.5. Submission of the lists of persons undergone to radiation impact over the dose limits established by the radiation safety norms for the above category of exposed persons (for appointing thereof to special medical examination) to the heads of organisations and agencies, whose employees participated in conveyance of RM cargo and (or) elimination of radiation consequences of the accident.

3.3.2.4.6. Appointing of the personnel undergone, as a result of the accident, to radiation impact over the dose limits established by the radiation safety norms for the above category of exposed persons to special medical examination.

3.4. Actions of the person escorting RM cargo and concerning methodological management of the rescue forces of transport organisations arrived to the accident place, the transport vehicle with RM cargo, RM cargo handling during performance of rescue and (or) emergency recovery works must be stipulated in the instruction for escort-personnel developed on the basis of the Plan of Actions on Elimination of Accident Consequences[24].

3.5. In case of conveyance of RM cargo by water the following additional requirements for planning the measures on elimination of radiation accident must be fulfilled:

3.5.1**.** Prior to conveyance of RM cargo the shipmaster and executive representative of the port must get familiarised with the relevant parts of the emergency card for the given cargo and with the Consignor's (Consignee's, when the latter transports RM cargo) Plan of Actions on Elimination of Accident Consequences.

3.5.2. Ship regulations must define the actions of the ship crew at radiation accident during conveyance of RM cargo. Persons on board the ship must be trained for performance of works in case of radiation accident with RM cargo.

3.5.3. Emergency works at the radiation accident on board the ship must be carried out under the supervision of the shipmaster or a person specially appointed by the shipmaster for the above purposes in accordance with the instruction for the carrier and the emergency card requirements.

3.5.4. Works on elimination of radiation consequences of the accident during anchorage of the ship in the port or mooring of the ship in the port after the radiation accident shall be performed with involvement of ERF.

4. Requirements for Ensuring the Preparedness tor Elimination of Accident Consequences During Transportation of Radioactive Material Cargos

Measures on and responsibility for ensuring the preparedness for elimination of consequences of possible accidents during transportation of RM cargo must be defined by the Plan of Actions on Elimination of Accident Consequences and documents of the operating organisation, which are developed in accordance with the above Plan, and must comprise as follows:

4.1. Preparation of RM cargo for transportation, envisaging:

[24] The emergency cards developed for the transport organisations must stipulate as follows: 1) rescue and (or) emergency-recovery works being performed by the rescue forces of transport organisations must be carried out taking due account of the instructions of the person escorting RM cargo, 2) as well as the order of actions on RM cargo handling in case of absence of the person escorting RM cargo must be set therein, but for all that, the works dealt with handling of packages of B, C type and with fissionable NM must be carried out only as per instructions of the person escorting RM cargo, representative of the management authority for the use of atomic energy or head of ERF upon their arrival to the place of the accident.

4.1.1. Definition of a structural unit (division, shop, service) and (or) an official responsible for preparation of RM cargo for transportation.

4.1.2. Fulfillment of a complex of measures for preparation of RM cargo for transportation, including:

- verification of availability of certificate-permits on design and conveyance of the corresponding types of RM cargos;
- verification of implementation of conditions for conveyance, stipulated in the above certificate-permits, including provisions of emergency response;
- testing (verification) for correspondence to the safety requirements defined by the normative documents, maintenance documentation and specifications on package sets and transport vehicles;
- verification of availability of required marking, labels, signs of danger defined by the norms and rules (marking thereof in case of a lack).

4.1.3. Documenting (formalisation of an act) of the results of preparation of RM cargo for transportation.

4.2. Training of escort-personnel, envisaging:

4.2.1. Development of a programme of training, including an order of periodical verification of theoretical knowledge and co-ordination of actions in practice.

4.2.2. Training and co-ordination of actions in practice on nuclear and radiation safety aspects, measures on rendering the first medical aid (before-doctor examination) to victims, measures of fire-fighting and other measures defined by the programme of training, with verification of theoretical knowledge and co-ordination of actions in practice, including the use of emergency card, instruction for escort-personnel, instruction on handling with damaged RM cargo.

4.2.3. Appointment of an official responsible for briefing of escort-personnel, and definition of its routine.

4.2.4. Briefing of escort-personnel prior to the beginning of conveyance and verification of a complete set of emergency equipment as per the table (list) of equipping, approved by the head of the operating organisation, including communication means, availability of the emergency card, instruction for escort-personnel, instruction on handling with damaged RM.

4.2.5. Documentary formalisation and drawing up an act of the results of escort-personnel briefing and verification of a complete set of emergency equipment till the beginning of conveyance.

4.3. Training in the use of relevant emergency cards, development of instructions and training in the use thereof for escort-personnel, including the instructions on handling with damaged RM in accordance with the following basic requirements:

4.3.1. RET head, duty-dispatcher and transport services of the operating organisation[25] must have the emergency cards on all the types of shipped (received) RM cargos.

4.3.2. Prior to the beginning of conveyance the emergency cards on a certain type of shipped RM cargos must be handed over by the transport service of the operating organisation to the following officials:

[25] The order of development and approval of emergency cards, supplying therewith the transport organisations and territorial management authorities on affairs of civil defence and emergency situations and Interior Ministry of Russia shall be set by the federal authority of executive power in the field of use of atomic energy.

- person responsible for escorting RM cargo;
- person responsible for carrying out of RM cargo conveyance on the given transport vehicle;
- person responsible for guard of RM cargo during conveyance (if any).

4.3.3. Instructions for escort-personnel in case of incidents and accidents during transportation of RM cargo and on handling with damaged RM must be detailed and similar to the emergency cards and must define necessary scope of actions by escort-personnel, routine and sequence of their implementation, and must be developed talking into account the available experience of emergency response.

4.3.4. Instruction for escort-personnel must indicate an order of transmission of information about an accident during transportation of RM cargo and a list of channels (numbers) for communication in the process of conveyance.

4.4. Control over transportation of RM cargos, comprising as follows:

4.4.1. Advance notification of the consignee about forthcoming shipment of RM cargo with the packages of B, C types and (or) with fissionable materials and (or) uranium hexafluoride[26].

4.4.2. Organisation of control over conveyance of RM cargo on the route of its transportation in accordance with the list approved by the head of the operating organisation, by the manpower of DDS in interaction with the ERF DDS of the Federal Agency for Atomic Energy and carrier's DDS (if necessary).

4.4.3. Regime "Emergency Readiness" in case of non-arrival of RM cargo at the appointed place or a lack of established report (message) beyond the set terms, when the following must be envisaged:

- informing of the head of the operating organisation (chief engineer);
- informing of and call for the SET manager to the workplace;
- clarification of information about a place of location and a state of RM cargo through ERF DDS and (or) carrier's DDS;
- reduction of SET forces and means into the "Emergency Readiness" state within the established terms.

4.5. Organisation of functioning of DDS system, envisaging:

4.5.1. Performance of duties providing for communication with the head (chief engineer) and SET manager of the operating organisation, DDS of SCC and SPb EEC (ERF), DDS of the organisation-carrier and organisation-consignor (consignee)[27].

4.5.2. Regime "Accident"[28] in case of receipt of information about an accident during RM cargo transportation, when the following must be envisaged:

- informing of and permanent communication with the head (chief engineer) and SET manager of the operating organisation about the accident;
- keeping of permanent connection with the personnel escorting RM cargo and those being at the accident place;
- keeping of permanent connection with DDS of SCC and SPb EEC (ERF);

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[26] Shipment of the given RM cargo can be started only after obtaining a consignee's confirmation regarding the possibility and readiness of receipt of the above type of RM cargo.

[27] As per the established list of RM cargos the duty and communication must be provided 24 hours a day.

[28] In case of the introduction of an "Accident" regime a category of the accident shall be indicated.

- keeping of permanent connection with DDS of the organisation-carrier and organisation-consignor (consignee);
- keeping of permanent connection with SET OG and SET manager in the course of emergency response;
- keeping of permanent connection with the management authority on CD and ES affairs.

4.6. Organisation of interaction with BCES, NRSD and ERF of the Federal Agency for Atomic Energy, envisaging:

4.6.1. Establishment of the special regime of communication for transmission of information and instructions between the head and (or) chief engineer (through DDS) of the operating organisation and BCES and NRSD (through SCC) of the Federal Agency for Atomic Energy, ERF.

4.6.2. Agreement of a Provision on SET, control over emergency response system, attestation of the manager and staff of SET of the operating organisation with and by NRSD of the Federal Agency for Atomic Energy.

4.6.3. Involving of ERF in the measures on ensuring preparedness and the works on emergency response through SPb EEC.

4.7. Workup of the routes for RM cargo[29] transportation and organisation of interaction with the regional (territorial) management authorities on CD and ES affairs and IM of Russia with the purpose of operative response, envisaging:

4.7.1. Appointment of an official responsible for workup and updating of data on the routes for RM cargo conveyance.

4.7.2. Definition of a possibility and the ways of communication with escort-personnel on the routes of RM cargo conveyance.

4.7.3. Definition of a possibility and the ways of transport of SET to the accident place.

4.7.4. Clarification of the staff and means of the regional (territorial) management authorities on CD and ES affairs and their capabilities regarding elimination of consequences of the accident with RM cargo on its conveyance routes, and organisation of communication with the above staff.

4.7.5. Definition of a possibility and the ways of communication with the regional (territorial) bodies of the Interior Ministry of Russia.

4.8. Order of actions regarding emergency response, including:

4.8.1. Initiation of conduction of measures on emergency response.

4.8.2. Sequence of conduction of basic measures on emergency response (algorithm of actions).

4.9. Order and periodicity of practical training in actions as per the Plan of Actions on Elimination of Accident Consequences in the process of training, exercises or studies.

[29] Data as per the results of workup of conveyance routes for RM cargo must be included in the instructions for escort-personnel.

5. DRAFT OF A STANDARD CONTENT OF THE PLAN OF ORGANISATION OF ACTIONS ON ELIMINATION OF ACCIDENT CONSEQUENCES DURING CONVEYANCE OF RARIOACTIVE MATERIAL CARGO

5.1. Preliminary Comment

In accordance with the requirement of Art. 36 of the Law "On the Use of Atomic Energy" dated from 21.11.1995, No. 170-FZ, the duties and order of actions of the operating organisation, as well as the order of interaction thereof with the authorities of state power, authorities of local government and authorities for the use of atomic energy on performance of measures on protection of employees of the objects for the use of atomic energy and population in case of an accident, including the one during RM transportation, must be envisaged by the plans of the indicated measures; with that, the Law stipulates that the order of development and approval of the above plans shall be established by the norms and rules in the field of use of atomic energy.

This requirement of the Law is realised in the given FNR draft, in section 3 of the present report, where Art.1.1 stipulates that the Rules establish:

- requirements for planning and ensuring of preparedness for elimination of accident consequences during transportation of nuclear materials and radioactive substances;
- order of development and approval of the Plan of Organisation of Actions on Elimination of Accident Consequences during Conveyance of RM Cargo.

FNR refer to the upper level of the system of regulating ND existing in Russia. They set the requirements mandatory for implementation both by operators and regulators. According to the practice existing in Russia for further development of FNR requirements the ND of a "soft" regulation – safety guide (hereinafter referred to as SG /RB/) are developed. SG shows the operator the opinion of the Federal Environmental, Industrial and Nuclear Supervision Service regarding implementation of FNR requirements and bears a recommendation character, it means that the operator may deviate from SG recommendations, with that, the operator must soundly prove to the regulatory authority that the proposed way would not worsen safety.

Thus, after approval and putting into effect of FNR "Requirements for Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" the operating organisations, at development (correction) of their plans of emergency response, must be obliged to implement the requirements stipulated in the above FNR, but with that, the structure and content of the Plan will be defined thereof independently, whereas a lack of recommendations of the relevant SG, as, for instance, it was done in the joint document of Rosatom and OAO "RZhD" - "Statute on Organisation of Actions on Elimination of Accident Consequences during Conveyance of Nuclear Materials and Radioactive Substances by the Federal Railway Transport" (PLA-2001).

Perhaps, at development of a programme of scientific-and-technical activity for 2007 the Federal Environmental, Industrial and Nuclear Supervision Service will make a decision to include the elaboration of SG into the programme, which develops the provisions of the above mentioned FNR and defines a standard content of the plan, duties and order of actions of the operating organisation, as well as the order of interaction thereof with the authorities of state power, authorities of local government and authorities for the use of atomic energy on performance of measures on protection of employees (personnel) and population in case of an accident during RM transportation by various types of transport vehicles (by railway, motor, sea, river, air).

Below the recommendations on development of the standard content of the Plan of Organisation of Actions on Elimination of Accident Consequences during RM Cargo Conveyance are given.

During development of the standard content of the Plan of Organisation of Actions on Elimination of Accident Consequences during RM Cargo Conveyance, except for the documents listed in section 2 of the given report, the FNR "Standard Content of the Plan of Measures on Personnel Protection in Case of an Accident at the Nuclear Power Plant" (NP-015-2000), were used.

5.2. Recommendations on Development of the Standard Content of the Plan of Organisation of Actions on Elimination of Accident Consequences during RM Cargo Conveyance

The recommended structure and content of a standard Plan of Organisation of Actions on Elimination of Accident Consequences during RM Cargo Conveyance (hereinafter referred to as the Plan) are as follows:

CONTENT

I. LIST OF ACCEPTED ABBREVIATIONS

Full name of all the abbreviations used in the test should be given.

II. GENERAL PROVISONS

It should be indicated for what purposes and on the basis of which documents the Plan is developed, the scope of the Plan and who is in charge to ensure readiness for implementation thereof.

III. BASIC DATA FOR PLANNING OF MEASURES ON ELIMINATION OF ACCIDENT CONSEQUENCES

The following should be specified:

- Characteristics of the transported RM cargos taking into account their potential nuclear and radiation hazard in case of an accident during conveyance;
- System of categorisation of accidents according to the degree of their severity and potential danger as per NP-053-04;
- Design capabilities of transport vehicles regarding conveyance of RM cargos with indication of a number of staff providing the above conveyance, as well as availability and possibilities of means for radiation monitoring and fire-fighting;
- Brief description of the route of transport (length in kilometres with indication of towns (built-up areas, railway stations, ports, airports, places for transit storage and (or) transfer (trans-shipment, reloading) of RM cargo from one transport vehicle to another;
- Peculiarities of the natural environment and climatic conditions on the route of RM cargo transportation;
- Main features of an accident with radiation consequences during transportation of RM cargo;
- Criteria for regimes "Emergency Readiness" and "Accident";
- Determination of action phases at elimination of accident consequences (initial, combating with the accident and post-accident).

Annexes to the section:

1. Scheme of the route of RM transportation on a topographic map (plan).
2. Plan (scheme) of RM cargo placement on the transport vehicle.
3. Calculation – substantiation of the sizes of the zones of contamination with RS at the accident entailing RS and (or) NM release.

IV. BASIC MEASURES ON AND RESPONSIBILITY FOR EMERGENCY RESPONSE ENSURING

IV.1. Preparation of RM Cargo for Conveyance

The following should be specified:

- Who is responsible for implementation of the safety rules during preparation of RM cargos for transportation;
- What must be done during preparation of the corresponding types of RM cargos for transportation;
- Who must formalise the results of implemented inspections and in what way.

IV.2. Training of Escort-Personnel

The following should be specified:

- Order of training of escort-personnel for actions in case of an accident during RM cargo transportation;
- Persons responsible for development of a programme of training and verification of knowledge of escort-personnel, organisation of their access to independent implementation of duties on escorting the RM cargos;
- Persons responsible for briefing of escort-personnel before concrete conveyance of RM cargo and verification of their equipping with emergency property according to the approved list, including communication means, emergency cards, instructions for escort-personnel on handling with damaged RM cargo, which they must accompany;
- Who must formalise the results of the above verifications and briefing, and in what way.

IV.3. Emergency Cards and Instructions

The following should be specified:

- Order of development and approval of emergency cards on all the types of transported RM cargos;
- Agencies, organisations and officials, which and who must be provided with the emergency cards, and order of submitting the cards thereto;
- Order of development and approval of special instructions for escort-personnel on safe works with RM cargos and routine of required actions in case of an accident during transportation of RM cargos, with indication of channels (numbers) for communication with DDS and other participants of emergency response;
- Where must be (and who must have) copies of instructions for escort-personnel;
- Person responsible for timely development and review of instructions for escort-personnel.

IV.4. System of Duty-Dispatcher Service

The following should be specified:

- Purpose, targets, objects and organisation of functioning of the Duty-Dispatcher Service (hereinafter referred to as DDS);
- Actions of DDS on control over transportation of RM cargos;
- Actions of DDS in case of non-arrival of RM cargo at the destination point or a lack of the established report (message) on passing RM cargo on the route beyond the fixed terms;
- Actions of DDS on introducing the regime "Emergency Readiness";

- Actions of DDS in case of receiving information about the accident during transportation of RM cargo and introducing the regime "Accident";
- Order and organisation of communication and notification at all the regimes of DDS system functioning (day-to-day, emergency readiness, accident);
- Person responsible for DDS system functioning.

IV.5. Interaction and Co-ordination of the Actions with the Organisations and Agencies

The following should be specified:

- Organisation of interaction with the branch commission on emergency situations (hereinafter referred to as BCES) the department on nuclear and radiation safety (hereinafter referred to as NRSD) of Rosatom;
- Organisation of interaction with the transport organisation (carrier), co-ordination of actions and distribution of responsibility between the escort-personnel and carrier's specialised emergency team (hereinafter referred to as SET) arrived to the accident place, at performance of actions (measures, works) on elimination of accident consequences, as well as the order of actions by carrier's SET in case of a lack of escort-personnel or their incapability;
- Order for involving the regional emergency-rescue forces (hereinafter referred to as ERF) of Rosatom for the elimination of accident consequences;
- Organisation of interaction and co-ordination with the outside organisations, including the authorities of local government, management authorities on affairs of CD and ES, authorities of interior affairs, medical institutions on the entire route of transport.

Annexes to the section:

1. Scheme (schemes) of communication and notification at all the regimes of DDS system functioning.

V. ORDER OF DECLARATION OF THE "EMERGENCY READINESS", "ACCIDENT" REGIMES AND PUTTING INTO EFFECT OF THE PLAN OF ACTIONS ON ELIMINATION OF ACCIDENT CONSEQUENCES

The following should be specified:

- Factors (criteria) being the basis for declaration of the "Emergency Readiness" and "Accident" regimes;
- An official, who is granted the right to declare the "Emergency Readiness" and "Accident" regimes;
- List of officials, organisations and agencies, who must be informed about introducing of the "Emergency Readiness" and "Accident" regimes, order of and a person responsible for notification;
- Order of carrying out the measures on putting into effect of the Plan of Actions on Elimination of Accident Consequences;
- An official responsible for putting into effect of the Plan of Actions on Elimination of Accident Consequences and carrying out the measures on elimination of accident consequences envisaged by this Plan.

Annexes to the section:

1. Factors (criteria) for declaration of the "Emergency Readiness" and "Accident" regimes.
2. Calendar plan-schedule (time-schedule) on putting into effect of the Plan of Actions on Elimination of Accident Consequences and carrying out the measures on elimination of accident consequences envisaged by this Plan.

VI. ORDER OF ACTIONS AT THE ACCIDENT AND ELIMINATION OF ITS CONSEQUENCES

VI.1. Actions at the accidents causing no impact on RM cargo[30]

The following should be specified:

- Order of transmission of information about the accident;
- Organisation of rendering aid to victims;
- Organisation of elimination of malfunctions and breakages, with that, it is recommended to indicate that malfunctions and breakages of the transport vehicles must be eliminated at every type of transport in the established routine with the observance of the requirements for radiation safety under supervision of the person responsible for escorting the RM cargo, and (or) taking due account of information containing in the danger signs installed on the cargo and transport vehicles, as well as the requirements of sanitary rules at transport of RM;
- Order of decision-making on continuation of RM cargo conveyance after elimination of malfunctions and breakages.

VI.2. Actions of escort-personnel at the accident of category I [31]

The following should be specified:

- Order of transmission of information about the accident;
- Organisation of rendering aid to victims;
- Order of implementation of radiation monitoring and use of individual protection means (hereinafter referred to as IPM);
- Organisation of elimination of accident consequences jointly with the employees of the transport organisation, officers of the authorities of interior affairs and (or) rescue units of the territorial management authority on affairs of CD and ES, arrived at the accident place;
- Organisation of elimination of accident consequences (in case of loss of capability by the personnel escorting RM cargo, or in case of their absence) by the employees of the transport organisation, officers of the authorities of interior affairs and (or) rescue units of the territorial management authority on affairs of CD and ES, arrived to the accident place[32];
- Order of documentary formalisation of the results regarding elimination of accident consequences and decision-making on continuation of RM cargo conveyance.

VI.3. Actions of the escort-personnel at the accidents of categories II and III in the "Initial Phase of the Accident" (phase 1)[33], and in case of absence or incapability thereof – actions of the employees of the transport organisation,[34]

The following should be specified:

- Order of actions on immediate informing the consignor, consignee, carrier-organisation, authorities of interior affairs, territorial management authority on affairs of CD and ES, authority of local government, authorities of the state safety regulation during the use of

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[30] It must be reflected in the instruction for escort-personnel and carrier's emergency card.

[31] It must be reflected in the instruction for escort-personnel.

[32] It must be reflected in the emergency cards of these organisations. The emergency cards shall be developed in the routine defined by the federal authority of executive power in the field of use of atomic energy.

[33] It must be reflected in the instruction for escort-personnel.

[34] The transport organisation employees' actions being carried out in case of absence or incapability of the personnel escorting RM cargo, must be indicated in the emergency card.

atomic energy, authority of management of the atomic energy use, about the fact and place of the accident, time and category of the accident;

- Organisation of rendering aid to victims;
- Order of actions on fire prevention or extinguishing;
- Order of actions on primary definition of radiation danger of the accident and transmission of information about radiation state at the accident place;
- Necessity in evacuation of people from the accident zone to the windward side at the distance of no less than 100 m from the accident place (if possible);
- Need in installation of signs of radiation danger at the boundary of radiation accident zone;
- Organisation of cordoning off the radiation accident zone, supplementary guard of RM cargo (if necessary), ensuring of public order;
- Need in implementation of visual examination and (if possible) radiation monitoring of RM cargo with the purpose to clarify the accident category and to define the boundaries of dangerous zone (area);
- Need in installation of radiation danger signs at the boundary of dangerous zone (area) with the text: "Dangerous Zone (Area)", and (if possible) installation of a guard railing of the dangerous zone (area);
- Order of transmission of specified information about a state at the accident place and the required assistance in accordance with the established scheme of communication, instruction and emergency card;
- Organisation of taking primary urgent measures on prevention of evolution/development of the radiation accident and its consequences;
- Order of registration of persons, who could undergo to radiation impact during the accident (exposure, contamination with RS);
- Order of establishment (if possible) of control over a radiation state at the boundary of radiation accident zone from windward side.

VI.4. Actions at the accidents of categories II and III in the "Phase of combating with the accident" (phase 2)

The following should be specified:

VI.4.1. Main actions (measures, works) carrying out by ERF (SET) arrived to the accident place:

- Implementation of radiation and general survey of the accident place with the purpose to clarify radiation hazard, boundaries of the radiation accident zone and dangerous areas, condition of the RM cargo and transport vehicle, and operative transmission of the results to the manager of emergency works at the point for control over emergency actions;
- Assessment of data regarding radiation and general survey of the accident place and transport vehicle by the manager of emergency works for making decision on recovery of control over the radiation source (RM cargo), elimination of radiation consequences of the accident and measures on radiation protection of the employees (personnel) and population;
- Informing the head of the local government authority and the manager of the territorial (regional) management authority on affairs of CD and ES about the results of radiation survey of the accident place for making decision on a need in an urgent intervention (protection measures), including evacuation (temporary resettlement) of the population form the radiation accident zone in case of excess of the exposure levels established by the radiation safety norms, when an urgent intervention is required;

- Arrangement of restricted zones as per the results of radiation and general survey of the accident place: the zone of radiation accident with dangerous zones (areas) inside it and the zone for surveillance of the radiation accident place. Installation of signs of radiation danger at the boundaries of the zones with the name of the zone;
- Fencing of the radiation accident zone and exclusion of free access of people to the zone of radiation accident with the help of the local government authority and authorities of interior affairs;
- Organisation of entrance to (exit from) the radiation accident zone through RMP installed at the boundary of the radiation accident zone from the windward side;
- Organisation of permanent radiation monitoring in the radiation accident zone and periodical control of the radiation state in the zone for surveillance of the radiation accident place;
- Establishment of the places at RMP for decontamination of transport vehicles, IPM, for sanitisation of employees (personnel), for collection and temporary storage of IPM and equipment contaminated with RS;
- Organisation of works on recovery of control over the ionising radiation source (RM cargo) and elimination of consequences of the radiation accident in the dangerous zones (areas), envisaging as follows;
- Organisation of medical support of measures (works) on elimination of radiation accident consequences;
- Organisation of physical protection of RM cargo;
- Organisation of protection of public order in the radiation accident zone;
- Organisation of logistical support of ERF (SET) with required logistics, foodstuffs, water, oil and lubricating materials, transport.

VI.4.2. The works in the "Phase of combating with the accident" (phase 2) are considered as completed ones under the following conditions:

- Control over the ionising radiation source (RM cargo) has been recovered. TPS, containers, where RM is placed, shall allow for further conveyance of RM in accordance with the requirements of the Rules of Safety during Transportation of Radioactive Materials;
- Decontamination of the transport vehicle has been performed; the protocol issued by the authority of the state sanitary-epidemiological supervision on the correspondence of conditions and ways of transport of radioactive substances, nuclear materials, devices and equipment with radiation sources and radioactive waste to the sanitary rules, is available;
- Safety of traffic of the transport vehicle with RM cargo is provided and confirmed by the document of the transport organisation, and traffic on the route of conveyance has been recovered;
- Decontamination of the territory and the objects of the radiation accident zone has been performed and its sufficiency has been confirmed by radiation monitoring.

VI.4.3. Actions in the "Post-accident phase" (phase 3):

- Formalisation of an act on elimination of radiation consequences of the accident by the commission;
- Making a decision by the consignor or consignee (if the latter transports RM cargo) – by the manager of emergency works on a possibility for further conveyance of the damaged RM cargo, ensuring the safety level required by the Rules of Safety during Transportation of Radioactive Materials. Conditions of further conveyance must be agreed with the management authority for the use of atomic energy, as well as by the federal authority of executive power in the field of railway transport (in case of conveyance by railway);

- Informing of the local government authorities about the results of elimination of the radiation accident and absence of radiation hazard for the population;
- Submission of the lists of persons from the population undergone to radiation impact as a result of the radiation accident, over the dose limits established by the radiation safety norms for the above category of exposed persons (for their further special medical examination), to the local government authorities;
- Submission of the lists of persons undergone to radiation impact over the dose limits established by the radiation safety norms for the above category of exposed persons (for their further special medical examination), to the heads of the organisations and agencies involved in RM cargo conveyance and (or) elimination of radiation consequences of the accident;
- Sending of the personnel undergone, as a result of the accident, to radiation impact over the dose limits established by the radiation safety norms for the above category of exposed persons, to the special medical examination.

Annexes to the section:

1. Organisational structure for notification of an accident during transportation of RM cargos and elimination of its consequences.
2. Members and equipping of ERF (SET).

VII. ORGANISATION OF GUIDANCE AND MANAGEMENT OF ACTIONS ON ELIMINATION OF THE ACCIDENTS OF CATEGORIES II AND III, AND THEIR CONSEQUENCES

The following should be specified:

- Who is in charge of all the forces and means involved in elimination of consequences of the accidents of II and III categories, and the order of the above person appointment in accordance with the legislation of the Russian Federation;
- Who accepts and executes the powers of a manager of emergency works till his/her arrival to the accident place;
- Order of transferring the leadership from the person carrying out the functions of a manager of emergency works at the initial phase of works to the appointed manager of emergency works, arrived to the accident place;
- Rights of the manager of emergency works on management of the forces and means of ERF (SET) and other services arrived for elimination of accident consequences, and who is under his/her subordination;
- Rights of and order of decision-making by the manager of emergency works about the measures on evacuation of population from the neighboring territory; suspension of activity of the organisations being in the accident zone; use of communication means, transport vehicles and other property of the organisations being in the accident zone; involvement of ERF being not on the regular staff, as well as population, certain rescuers and other persons in the works on elimination of accident consequences.
- Order of informing of the relevant authorities of executive power and local government authorities about the accepted decisions and course of works on elimination of accident consequences.

Annexes to the section:

1. Scheme of guidance and management of the forces involved in elimination of accident consequences.

VIII. ORGANISATIONAL-AND-LEGAL DIRECTIONS FOR REALISATION OF THE PLAN OF ACTIONS ON ELIMINATION OF ACCIDENT CONSEQUENCES

The following should be specified:

- Order of familiarisation of the employees participating in transportation of RM cargos (within her/his competence) with the provisions of the Plan;
- Introducing of the requirements of the approved Plan in the statutes on structural units and duty regulations for personnel;
- Order of tryout of the requirements of the Plan in the course of training, studies, teaching-and-methodological training or exercises;
- Organisation of verification of the system for notification of personnel and organisations, the communication channels with the organisations involved in transportation of RM cargos and emergency response;
- Order of review (correction) of the Plan.

ANNEXES

1. Scheme of the route of RM transportation on a topographic map (plan).
2. Plan (scheme) of RM cargo placement on the transport vehicle.
3. Calculation – substantiation of the sizes of the zones of contamination with RS at the accident entailing RS and (or) NM release.
4. Scheme (schemes) of communication and notification at all the regimes of DDS system functioning.
5. Factors (criteria) for declaration of the "Emergency Readiness" and "Accident" regimes.
6. Calendar plan-schedule (time-schedule) on putting into effect of the Plan of Actions on Elimination of Accident Consequences and carrying out the measures on elimination of accident consequences envisaged by this Plan.
7. Organisational structure for notification of an accident during transportation of RM cargos and elimination of its consequences.
8. Members and equipping of ERF (SET).
9. Scheme of guidance and management of the forces involved in elimination of accident consequences.

5.3. Final Comment for the Section

At decision-making by the Federal Environmental, Industrial and Nuclear Supervision Service on the elaboration of a SR developing provision of FNR – the "Requirements for Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" regarding definition of the structure and content of a standard Plan of Organisation of Actions on Elimination of Accident Consequences during RM Cargo Conveyance, the recommendations specified in subsection 4.2 of the given Report may become its draft.

It should be pointed out that in accordance with the ND development procedure accepted in the Federal Environmental, Industrial and Nuclear Supervision Service the editions of developed SR will be distributed for comments to the organisations and agencies being involved in transportation of RM cargos and elimination of accident consequences during transportation of RM cargos. As per the obtained comments and results of conciliatory meetings the second and final editions of SR, which structure and content may differ from those suggested in the given Report, will be developed. For instance, there may be proposals to take due account of the peculiarities of transportation by concrete types of transport vehicles (by motor, railway, sea, air), etc., at development of the Plans.

6. CONCLUSION

1. Selection and analysis of the normative-legal acts and documents, which requirements must be taken into account at planning and ensuring of preparedness for elimination of radiation consequences of the accident during transportation of radioactive materials, have been made.

2. A draft of FNR "Requirements for Planning and Ensuring of Preparedness for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances" has been developed.

3. Recommendations on the structure and content of the standard Plan of Organisation of Actions on Elimination of Accident Consequences during RM Cargo Conveyance have been prepared.

4. It is recommended to develop a safety guide to provide more detailed guidance on developing and implementing emergency plans for elimination of accident consequences during conveyance of radioactive material cargo.

5. it is recommended, in order to benchmark the emergency arrangements against Western and international standards:

- To present for review by Western and Russian experts a “Plan of Organisation of Actions on Elimination of Accident Consequences during RM Conveyance” developed by a consignor involved in the RTG decommissioning process on the basis of the safety guide.
- To organise an emergency exercise based on a simulated accident during RTG transport, involving relevant Russian organizations and Western observers.

REFERENCES

During development of the Report and ND draft the following materials have been used:

1. Federal Law "On the Use of Atomic Energy" dated from 21.11.1995, No. 170-FZ, (with amendments and supplements dated from 10.02.1997 - No. 28-ФЗ, from 10.07.2001 - No. 94-FZ, from 28.03.2002 - No. 33-ФЗ).

2. Federal Law "On Radiation Safety of Population" dated from 9.01.1996, No. 3-FZ.

3. Federal Law "On Protection of Population and Territories in case of Natural and Man-Caused Emergency Situations " dated from 21.12.1994, No. 68-FZ.

4. Federal Law "On the Emergency Rescue Services and Status of the Rescuers" dated from 22.08.1996, No. 151-FZ.

5. Federal Law "Code of Trade Navigation of the Russian Federation" dated from 30.04.1999, No. 81-ФЗ.

6. Federal Law "On Environmental Protection" dated from 10.01.2002, No. 7-ФЗ.

7. Draft of Law "On Radioactive Waste Management" (Accepted by the State Duma on 05.12.1995).

8. Federal Law "On Combating with Terrorism" dated from 25.07.1998.

9. Federal Law "On the Sanitary-Epidemiological Well-Being of Population" dated from 30.03.1999.

10. The Russian Federation President's Order dated from 15.9.1994, No. 1923 "On the Priority Measures on Improvement of the System for Nuclear Material Accountancy and Safety".

11. The Russian Federation Government's Decree dated from 19.03.2001, No. 204 "On the State Competent Authority on Nuclear and Radiation Safety at Conveyance of Nuclear Materials, Radioactive Substances and Products Made Thereof".

12. The Russian Federation Government's Decree dated from 20.06.1997, No. 761 "On Approval of the Rules of Formation, Functioning and Financing of the Regional Emergency Forces of Operating Organisations for Elimination of Accident Consequences during Transportation of Nuclear Materials and Radioactive Substances".

13. "Statute on the Unified State System for Warning and Elimination of Emergency Situations" (approved by the Russian Federation Government's Decree dated from 30.12.2003).

14. The Russian Federation Government's Decree dated from 24.07.1995, No. 738 "On the Routine of Training of the Population in the Field of Protection against Emergency Situations".

15. Federal norms and rules "Rules of Safety during Transportation of Radioactive Materials" (NP-053-04).

16. Federal norms and rules "Standard Content of the Plan of Actions on Protection of the Population in case of an Accident at a Nuclear Power Plant" (NP-015-2000).

17. Federal norms and rules " Rules of Safety during Storage and Transport of Nuclear Fuel at the Facilities of Nuclear Power Industry" (PNAE G-14-029-91)

18. "Norms of Radiation Safety" (NRB-99).

19. "Basic Sanitary Rules of Ensuring the Radiation Safety" (OSPORB-99).

20. "Sanitary Rules of Radioactive Waste Management" (SPORO-2002).

21. "Special Sanitary Rules of Designing, Building and Operation of the Vessels for Nuclear-Process Service" (SP-SATO-2001).

22. "Rules of Ensuring the Radiation Safety during Transport of Spent Nuclear Fuel from Nuclear Power Plants by Railway Transport", (PRB-88).

23. "Rules of Sea Shipping of Hazardous Cargos" (Rules MOPOG), 1989.

24. Addendum to "Statute on Technical Operation of the Fleet. Nuclear Vessels and Vessels for Nuclear-Process Service /ATO/".

25. Addendum to "Manual on Fighting for Vitality of the Sea Vessels" (RD 31.21.18-95).

26. "Rules of Radiation Safety of Sea Trade Ports of the USSR during Call and Anchorage Therein of Nuclear Vessels", 1982.

27. "Agreement on Interactions of the Ministry of the Russian Federation for Atomic Energy and the Ministry of Transport of the Russian Federation on the Issues Regarding Safety and Elimination of Emergency Situations during Transportation of Nuclear Materials and Radioactive Substances", 2002.

28. Safety at Emergency Situations. Natural, Technogenic and Biologic & Social Emergency Situations. Classification as per Types and Scopes. GOST R 22.0.

29. "International Convention on Prevention of Pollution of the Sea from Vessels", 1973.

30. "Code of Safety of Nuclear Trade Vessels", (Code IMO), 1981.

31. "Planning of Measures and Readiness for the Case of Transport Accidents Connected with Radioactive Substances" (IAEA Safety Guide, No. 87, IAEA, 1989)

32. "International Convention on Protection of a Man Life in the Sea", 1974.

33. "Convention on Operative Alert to Nuclear Accident", 1986.

34. "Convention on Physical Protection of Nuclear Material", 1986.

35. "Convention on Rendering Assistance in Case of a Nuclear Accident or Radiation Emergency Situation", 1987.

36. "Convention on Assessment of Environment Impact within the Trans-boundary Space", 1991.

37. "Convention on Nuclear Safety", 1996.

38. "The Joint Convention on Safety of Spent Fuel and Radioactive Waste Management", 1998.

39. Safety Guide No. TS-G-1.2 (ST-3) "Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material", (IAEA Safety Guide, 2002).

Appendix E
Physical protection in RTG decommissioning (Task 5)

E-1. Physical Protection in RTG decommissioning (Deliverable D8)

"Under specific conditions RTGs represent a potential radiological hazard and require the development and functioning of the modern system of monitoring, alarm, physical protection and control of the operating RTGs, development and implementation of the transport and process scheme providing for safe RTG decommissioning and disposal of."

a) Analysis of distribution of duties and responsibility among bodies for control of the use of atomic energy, organisations operating RTGs (as regards physical protection) at the stages of RTG operation, decommissioning, transportation, temporary storage and disposal

More than 700 Radioisotope Thermoelectric Generators (RTGs) which belong to the federal executive authorities are in operation in the Russian Federation. The service life of most of the RTGs has been already expired and now decommissioning works should be carried out.

By the present time more than 200 RTGs have been decommissioned and disposed at FSUE "PA "Mayak", including those decommissioned and disposed with the international financial assistance.

RTGs in operation belong to two different authorities – Transport Ministry of Russia represented by Rosmorrechflot (Federal Sea and Inland Water Transport Agency) and Defence Ministry of Russian represented by Hydrographic Service of the North Fleet.

Maintenance (technical support) related to RTG operation is implemented by one more authority – Rosatom as a RTG developer.

Seven organisations which belong to different authorities are involved in RTG decommissioning works in the North-Western Region:

1. Federal State Unitary Enterprise "All-Russia Scientific and Research Institute for Technical Physics and Automation" of the Federal Atomic Energy Agency (FSUE "VNIITFA").
2. Federal State Unitary Enterprise "Production Association "Mayak" of the Federal Atomic Energy Agency (FSUE "PA"Mayak").
3. Federal State Unitary Enterprise All-Regional Association "Isotope" of the Federal Atomic Energy Agency (FSUE VO "Isotope").
4. Federal State Unitary Enterprise "Base for Special Shipment" of the Federal Atomic Energy Agency (FSUE "Base for Special Shipment").
5. Federal State Unitary Enterprise of Atomic Fleet of the Transport Ministry of Russia (FSUE "Atomflot"),
6. Federal State Unitary Engineering Works Enterprise "Zvezdochka" (FSUE EWE "Zvezdochka").
7. Hydrographic Service of the North Fleet of the Defence Ministry (HS NF).
8. RHBZ Depot of the North Fleet of the Defence Ministry.
9. Murmansk Aviation Company.

It's obvious that RTG decommissioning activity requires rather efficient interdepartmental coordination.

Now Rosatom is in charge of the interdepartmental coordination of works.

In organisation of RTG decommissioning activities **Rosatom** is responsible for (as regards physical protection):

- interdepartmental coordination of activities related to RTG monitoring, physical protection, decommissioning, disposal of, establishment of the infrastructure for the safe temporary storage;
- establishment of the infrastructure for the safe temporary storage and transportation of RTGs;
- dismantling and disposal of decommissioned RTGs.

In accordance with the Federal Law "On the Use of Atomic Energy" the state control of the use of atomic energy is implemented by:

Federal executive authorities implementing **control of the use** of atomic energy, Article 20 (for example, Rosatom). At that their competence includes (among others) **state monitoring** of the radiation situation, state control of technical safety of ships and other floating facilities with nuclear installations and radiation sources etc.;

Federal executive authorities implementing state safety regulation in the use of atomic energy, Article 24 (Rostechnadzor, Rospotrebnadzor, Ministry of Emergency of the Russian Federation, Federal Medical and Biological Agency – Decree of the Russian federation Government of 03.07.2006 N 412). At that, their competence includes (among others) supervision of nuclear, radiation, technical and fire safety, supervision of physical protection etc.

Bodies for control (**the Defence Ministry and Transport Ministry**) that include organisations operating RTGs are responsible for:

- feasibility study, development of the design and plan to equip RTGs with monitoring and physical protection means;
- equipping RTGs with monitoring means and construction (improvement) of RTG physical protection system;
- providing for the functioning of the monitoring, security alarm, physical protection and control systems for the operating RTGs;
- RTG decommissioning and delivery to the place of their temporary storage and transshipment;
- providing for the temporary storage of decommissioned RTGs at subordinate enterprises.

The term "physical protection" means a set of organisational measures, engineering means and actions taken by security divisions to prevent sabotages or theft of the nuclear materials and radioactive substances.

Rostechnadzor is a body for state safety regulation in the use of atomic energy. Its authorities include, among others, supervision of physical protection of nuclear installations, radiation sources, storage facilities for nuclear materials and radioactive substances, supervision of the unified state accounting and control systems for nuclear materials, radioactive substances, radioactive waste.

So, Rostechnadzor implements, among others, supervision of security of nuclear materials and radioactive substances.

Rostechnadzor is responsible for regulatory control of safe RTG handling. Safety regulation in RTG decommissioning includes the following aspects:

- development of radiation safety requirements for RTG decommissioning and disposal of;
- development of requirements to the package and contents of documents related to RTG operation and decommissioning, and licensing of the mentioned activity;
- supervision of safety in RTG operation and disposal of.

According to the approved transport diagrams for RTG decommissioning works most of RTGs are transported by sea and road to the territory of RHBZ Depot of the North Fleet (Ministry of Defence, Roslyakovo of the Murmansk region). Some RTGs are emplaced on the territory of Kandalaksha commercial port.

After the RTG batches have been formed they are transported by railway to FSUE VO “Isotope” (Kupavna of the Moscow region) followed by road transportation to FSUE “VNIITFA” for dismantling (disassembling). RHSs removed from RTGs are transported to FSUE VO “Isotope” to be loaded and shipped by railway to PA “Mayak” for long-term storage.

For information:

39 RTGs were decommissioned in 2005. The decommissioning was implemented in accordance with the contractual agreements between FSUE “VNIITFA” and Department of economic development of Murmansk region.

Another 30 RTGs are planned to be decommissioned and transported to FSUE “VNIITFA” in 2006.

Responsibility for physical protection at different RTG decommissioning stages is distributed in the following way.

At the stages of operation and decommissioning RTGs are under the jurisdiction of **Rosmorrechflot and Ministry of Defence of the Russian Federation**, whose competence covers the physical protection of radiation sources, storage facilities and radioactive substances.

In accordance with **Article 35** of the Federal Law “On the Use of Atomic Energy” an operating organisation bears full responsibility for safety of radiation source and storage facility as well as for appropriate use of radioactive substances. If the operating organisation is not capable of ensuring safety of these facilities an appropriate body for control of the use of atomic energy bears the responsibility for safety and appropriate handling.

Article 34 states that the operating organisation shall mean an organisation established in accordance with the Russian Federation legislation and recognised by an appropriate body for control of the use of atomic energy as an organisation capable of operating the radiation source or storage facility and implementing the activity related to sitting, design, construction, operation and decommissioning of the radiation source and storage facility, as well as activity on radioactive substances handling with its own forces or involving other organisations.

According to the Statue of the Federal Sea and Inland Water Transport Agency (**Rosmorrechflot**):

- Rosmorrechflot is a federal executive authority implementing the functions on rendering state services and managing the state property in the field of sea and inland water transport;
- Rosmorrechflot is a competent authority in the field of sea and inland water transport to implement the commitments under the international treaties of the Russian Federation as regards rendering state services and managing the state property;
- Rosmorrechflot is subordinate to the Transport Ministry of the Russian Federation.

It should be noted that Rosmorrechflot is not a body for state safety regulation.

The state-of-the-art of the RTG physical protection in most of the operating locations is considered by Rostechnadzor as being in non-compliance with the current requirements (see a picture below). As a rule, the RTG operating locations are equipped only with disciplinary barriers (fences with “radiation hazard” signs). Such requirements are provided for by documents published earlier in seventies. It’s an urgent task to bring the physical protection system in compliance with the requirements of NP-034-01.

At the stage of transportation a carrier (consignor and consignee) is responsible for physical protection.

During the temporary storage and preparation for RTGs disposal implemented in FSUE "VNIITFA" the administration of this organisation is responsible for the physical protection.

Administration of FSUE PA "Mayak" is responsible for the physical protection during RTGs storage and disposal of in FSUE PA "Mayak".

b) Analysis of the Russian regulatory basis that establishes physical protection requirements and a possibility to apply this basis to RTG decommissioning and disposal

Requirements for RTG physical protection established in the existing Russian regulatory documents do not differ from requirements imposed on other radiation sources of the same radiation hazard category.

Laws, legal acts and regulations of the President and the Government of the Russian Federation, subjects of the Russian Federation; federal norms and rules in the field of the use of atomic energy, guidelines of the state safety regulatory authorities; standards and rules of bodies for control of the use of atomic energy comprise the system of the legal acts and regulatory documents of the Russian Federation.

Structure of the system of legal acts and regulatory documents used to regulate the activity in the field of use of atomic energy is shown in Figure 1

Fig.1

Laws
Presidential Acts and Governmental Decrees of the Russian Federation
Federal standards and rules in the field Of use of atomic energy
Guiding documents of the state safety regulatory authorities
Standards and rules of the state bodies for control of the use of atomic energy

As regards the physical protection of radiation sources and radioactive substances the following laws can be mentioned:

- Federal Law "On the Use of Atomic Energy" - 1995;
- Federal Law "On Radiation Safety of Population" - 1995;
- Federal Law "On Environmental Protection" – 1991;
- Federal Law "On Combating Terrorism" - 1998;
- Federal Law "On the Internal Troops of the Interior Ministry of Russia" - 1997;
- Federal Law "On Weapons" - 1996;
- Federal Law "On Departmental Security" - 1999;
- Code of the Russian Federation on the Administrative Violations– 2001.

The Federal Law "On the Use of Atomic Energy" is the basic document. It does not include any detailed physical protection requirements but determines general areas to be covered by the physical protection system. The rest of the above mentioned documents detail the provisions of this Federal Law.

The Law (**Article 35**) defines that the physical protection shall be ensured by operating organisations fully responsible for its ensurance.

According to **Article 49** the areas to be covered by the physical protection system are the following:

- prevention of unauthorised access to the territory of a nuclear facility, nuclear materials and radioactive substances, prevention of their theft and damage;
- detection and suppression of infringements of integrity and security of nuclear materials and radioactive substances; detection and suppression of acts of sabotage and terrorism;
- finding and returning of missing or stolen nuclear materials and radioactive substances;
- physical protection shall be ensured at all the stages of design, construction and operation of nuclear facilities, including the transportation of nuclear materials and radioactive sources.

As regards radiation sources (RS) **Article 39** of the Federal Law establishes that the physical protection of RS is ensured by the operating organisations and appropriate federal executive authorities within their competence.

Bodies for the state safety regulation are responsible for supervision of the physical protection of RS.

Article 50 (physical protection requirements for nuclear installations, RS, storage facilities, nuclear materials and radioactive substances) determines that the physical protection requirements for RS are established by standards and rules in the field of use of atomic energy.

And: it is forbidden to operate RS and also to carry out any works related to the use of radioactive substances present in any form and at any stage of production, use, processing, transportation or storage, if measures have not been taken to meet the physical protection requirements for the mentioned nuclear facilities.

The Law also regulates some other issues related to the physical protection:

- limitation of the persons' rights related to the work or visit to the site of radiation-hazardous facilities (in terms of the persons' entrance check including the check using special tools) – Article 51;
- check of reliability, qualification requirements and absence of medical contra-indications – Article 52;
- liability for violation of the Russian legislation in the field of use of atomic energy (Article 61). As per the Law such violations in the field of the physical protection include non-compliances with the conditions of the permit to carry out work, non-compliances with RS and RadS physical protection requirements.

Operating organisations in the field of use of atomic energy and organisations rendering services to them in this field carry out their activities on the basis of permits and licenses issued by the state safety regulatory authorities.

List of activities in the field of use of atomic energy, which are subjected to licensing, is established by the "Provisions for Licensing in the Field of Use of Atomic Energy".

As for the present moment, Rostechnadzor performs functions of the state regulation in the field of physical protection by including appropriate physical protection requirements into the license conditions of licenses issued to supervised facilities for carrying out activities. An individual license to carry out physical protection activities is not issued to the operating organisations.

Presidential Acts and Governmental Decrees of the Russian Federation

These documents are:

- Statute of Rostechnadzor, approved by Decree of the Government of the Russian Federation № 401 dated the 30th of July 2004, which defines tasks, functions and rights of Rostechnadzor as the federal executive authority;

- Provisions for licensing of activities in the field of use of atomic energy, approved by Decree of the Government of the Russian Federation №865 dated the 14th of July 1997;
- Provisions for visits to nuclear facilities by the citizens of the Russian Federation, approved by Decree of the Government of the Russian Federation №1516 dated the 18th of December of 1996, which defines the procedure for visiting the nuclear facilities by the citizens of the Russian Federation for familiarisation purposes;
- List of positions of personnel working for nuclear facilities who shall obtain permits to work in the field of use of atomic energy issued by the Federal Nuclear and Radiation safety Authority of Russia approved by Decree of the Government of the Russian Federation of 03.03.1997 N 240. This list includes a managerial staff of facilities responsible for physical protection: Deputy Head of a facility for physical protection, Division Head for physical protection (Security Service Head);
- Statute of extra-departmental (external) security service under Interior Bodies of the Russian Federation, approved by Decree of the Government of the Russian Federation №589 dated the 14th of August 1992**;**

Federal standards and rules in the field of use of atomic energy

Federal standards and rules are developed in accordance with the Provisions for development and approval of the federal standards and rules in the field of use of atomic energy, approved by Decree of the Government of the Russian Federation № 1511 dated the 1st of December 1997, and included in the special List.

Federal standards and rules are approved by the federal executive authorities carrying out state regulation of safety in the use of atomic energy and establish requirements for radiation, technical and fire safety, physical protection, accounting and control of radiation sources and radioactive wastes.

Federal standards and rules are developed in the form of general provisions, standards and rules.

Standards regulate the maximum (critical) permissible values of parameters and conditions under which these parameters are met, as well as establish equations, ratio and computation methods to determine these values.

Rules establish safety (physical protection) requirements for activities in the field of use of atomic energy or requirements for operation of systems and elements being the part of the nuclear facility.

While regulating nuclear and radiation safety Rostechnadzor also uses federal standards and rules developed by the other regulatory authorities.

Physical Protection Rules for Radiation Sources, Storage Facilities, Radioactive Substances (NP-034-01) effective since the 1st of June 2002, can be, first of all, attributed to this level of the documents as regards NM, RS and RadS.

These Rules are the first regulatory document of the federal level establishing the uniformed physical protection requirements for radiation sources and radioactive substances on the whole territory of the Russian Federation, which are mandatory for all legal entities carrying out nuclear activities.

Physical Protection Rules for Radiation Sources, Storage Facilities, Radioactive Substances (NP-034-01) do not apply to physical protection of nuclear materials and radioactive substances during their transportation.

RS and RadS physical protection rules determine:

- objectives of physical protection;
- physical protection requirements for radiation sources, radioactive substances and storage facilities;

- procedure to set up requirements for RS and RadS physical protection system;
- categorisation of radiation hazardous facilities in terms of their potential hazard;
- notification procedure in case of unauthorised actions involving radiation sources and radioactive substances;

Rules establish a set of requirements to the physical protection system of radiation hazardous facilities (RHF) taking account of its category in terms of the potential radiation hazard.

As per the Rules the operating organisation shall determine the RHF category in terms of its potential hazard in accordance with the established categorisation and define the requirements to the physical protection system of the given RHF on the basis of these Rules.

The Guidelines for Inspections being developed under Contract N M8-05/11 (Task 3, Deliverable D5) provides for the check of compliance with requirements to maintenance of physical protection system functioning in accordance with NP-034-01 requirements.

The following documents are also attributed to the federal standards and rules:

- Basic Sanitary Rules for Radiation Safety, OSPORB-99;
- Sanitary Rules for Radioactive Waste Management, SPORO-85;
- Radiation Safety Standards, NRB-99.
- Collection, Reprocessing, Storage and Conditioning of Liquid Radioactive Waste. Safety Requirements. NP-020-2000;
- Collection, Reprocessing, Storage and Conditioning of Solid Radioactive Waste. Safety Requirements. NP-024-2000;
- Rules for Investigation and Recording of Violations in Management of Radiation Sources and Radioactive Substances Applied in the National Economy, NP-014-2000.
- General Safety Provisions for Radiation Sources, NP-038-02.
- Requirements to Contents of Safety Analysis Report for Radiation Sources, NP-039-02.
- Safety Rules for Transportation of Radioactive Materials, NP-053-04;
- Physical Protection Rules for Radioactive Substances and Radiation Sources during their Transportation, NP-xxx-06 (draft).

The last four documents from the mentioned standards and rules should be addressed in more detail.

NP-038-02. Section 3 "Safety requirements to siting, design, manufacturing and construction of RS" outlines that RS design shall define and justify physical protection systems of RS in accordance with the RS radiation hazard category and existing rules for RS protection.

NP-039-02. Section 6 (RS Physical Protection) outlines that independently from the RS radiation hazard category there shall be main organisational and technical measures to prevent unauthorised actions taken by the personnel or other persons as regards RS or systems important for RS safety that may directly or indirectly cause radiation accidents, as well as measures to prevent and suppress acts of sabotage and terrorism at RS. Sub-section "Physical Protection Constituents and Requirements" shall list and briefly describe engineering sub-systems: security alarm, access control, operative communication, engineering security means, auxiliary systems and means providing for functioning of physical protection system. Description of organisational measures shall include description of RS security arrangements including training of security personnel, as well as organisation of personnel access and presence at RS. The Section shall describe the provided procedure of interaction with local interior authorities in routine and emergency situations.

NP-053-04. To ensure physical protection during transportation of radioactive substances it is required to:

- limit, as much as possible, total time when radiation materials are on route;
- minimise a number of reloading operations from one conveyance to another, and storage time expecting a conveyance to arrive;
- inform a consignee about shipment and consigner about receipt;
- choose a transport route that will not go through the regions of emergency situation, natural disaster, other extreme situations etc;
- limit, as much as possible, a circle of officials being aware of the route and dates of shipments of radioactive substances;
- grant a permit to implement transportation, escort and security of radioactive substances to individuals from those persons who passed the preliminary exams.

NP-xxx-06 (draft). It is at a final development stage. Its approval is planned for the 4-th Quarter of 2006. While developing the regulatory document federal laws "On the Use of Atomic Energy", "On Radiation Safety of Population", Basic Sanitary Rules for Radiation Safety SP 2.6.1.799-99, Physical Protection Rules for Nuclear Materials, Nuclear Installations and Storage Facilities for Nuclear Materials, Physical Protection Rules for Radiation Sources, Storage Facilities, radioactive Substances, IAEA recommendations "Physical Protection of Radioactive Sources"-TECDOC-1355, "Categorization of Radioactive Sources" IAEA-TECDOC-1344 and "Method for Developing Arrangements for Response to a Nuclear or Radiological Emergency" IAEA-TECDOC-953 were used.

The regulatory document is issued for the first time.

c) Assessment for possible improvement of the regulatory basis for RTGs (as regards physical protection) mainly during their transportation and emplacement on special accumulation sites and in temporary storage facilities taking account of IAEA recommendations and European experience.

To improve the Russian regulatory basis it is reasonable to:

- finalise (revise) the "Physical Protection Rules for Radiation Sources, Storage Facilities, Radioactive Substances" (NP-034-01) to put the categorisation of radiation sources in terms of their radiation hazard in consistency with the IAEA recommendations (in particular, the IAEA-TECDOC-1344 – "Categorization of Radioactive Sources").
- put into effect the above mentioned Physical Protection Rules for Radioactive Substances and Radiation Sources during their Transportation in the 4-th Quarter of 2006;
- complete the development and put into effect the regulatory document "Requirements to Planning of Measures to Provide for Preparedness to Eliminate Radiation Consequences of Accidents during Transportation of Nuclear Materials and Radioactive Substances" in the 4th Quarter of 2006.

Finalisation of the "Physical Protection Rules for Radioactive Substances and Radiation Sources during their Transportation" and "Requirements to Planning of Measures to Provide for Preparedness to Eliminate Radiation Consequences of Accidents during Transportation of Nuclear Materials and Radioactive Substances" in underway according to the established procedure. It is planned to put then into effect at the end of 2006.

Regarding the Issue of "Safety" and "Security/Physical protection" addressed in the comments on the first draft deliverable D8

Historically it was so that as regards radionuclide sources (both open and sealed) their radiation **safety** was in the **first** place. Responsibility of persons in charge of radiation protection was ***to guarantee*** that radionuclide sources were ***used*** for the good purposes with ***no harm to a human being***.

Measures to ensure ***security*** were an integral, but at the same time a small ***part of safe*** use of sources which was used to prevent inadvertent (accidental) exposure of people either if they had a direct access to the sources or if radioactive material came to their hands somehow.

The article "Safety and security of radioactive sources: conflicts, commonalities and control" by Brian Dodd states that at one of the conferences one of the participants described **safety-security interrelations** in the following way: "***Safety keeps sources away from people, whereas security keeps people away from sources".***

If it's borne in mind that people are different in each case (ordinary public - in the first case, people with criminal intentions – in the second case), this resume is rather short and memorable.

There are four possible models of safety-security interface that were tabled to experts in these fields for discussion (Fig.1).

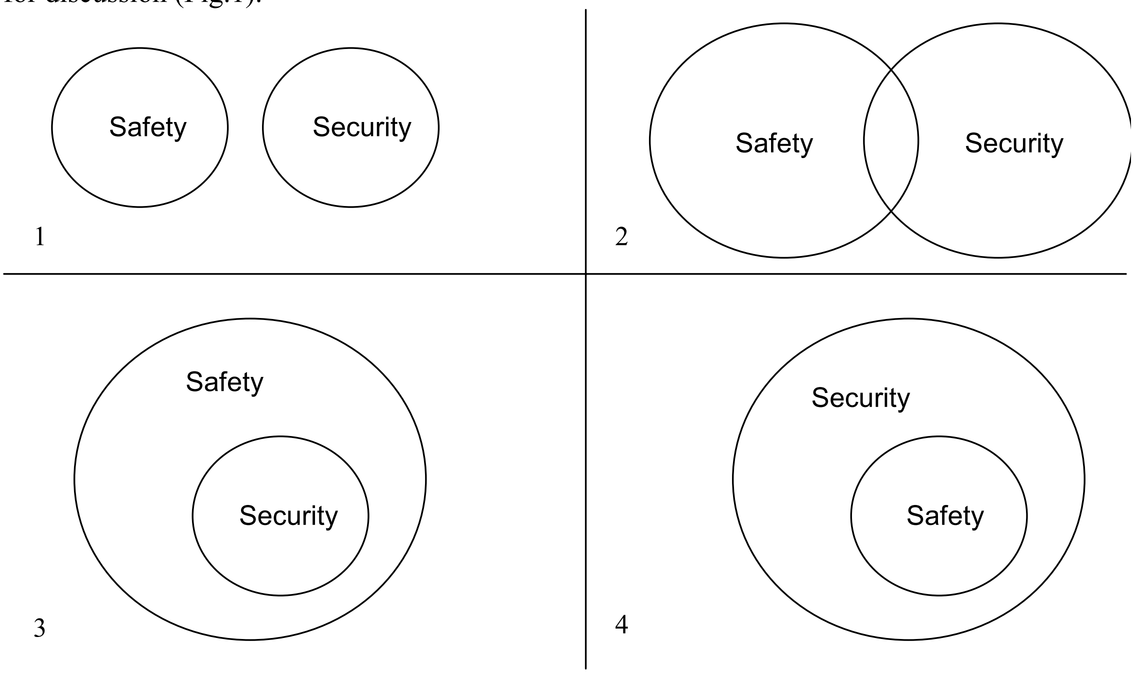

Fig. 1. Possible models of safety - security interface

Most of experts agreed that the first model is wrong. Safety and security are not independent and isolated, but shall be interconnected somehow.

Many experts also considered models 3 and 4 to be not quite correct.

So, the **most correct model is model 2**. One of the arguments for this model is that as regards radionuclide sources there are such safety aspects that do not have any relation to security as, for example, individual dosimetry, and also such security aspects that do not have any relation to safety as, for example, threat assessment. However, there are such areas as, for example, access control (especially, in the form of physical barriers), where obvious overlapping can be observed. It is evident that **emplacement of a high-level radiation source within a lock-up shielded container located in a lock-up room with thick concrete walls relates both to safety and security.**

Appendix F
Environmental impact assessment review for RTG dismantling, transportation, temporary storage and disposal (Task 6)

F-1. Environmental review for RTG dismantling, transportation, temporary storage and disposal (Deliverable D9)

1. Introduction and objectives

At present, about 700 Radioisotope Thermoelectric Generators (RTG) are in use in the Russian Federation, but service lifetime of 30 % from this number has been already expired.

RTGs themselves represent a high potential radiological hazard. Sealed ionising radiation sources with the activity level amounting to tens of thousands of Curies (possibly up to 15,000 TBq) are used as a part of an electrical equipment. Thus, as per IAEA requirements they shall be classified as “first category” radioactive sources, i.e. sources that could cause exposures at levels that might lead to death within a relatively short period of time. In conjunction with that, a decision was made in the Russian Federation that obliges organisations, which own or control the use of RTGs, to make up a full RTG inventory, perform technical examination, take measures to improve physical protection and carry out all activities required for subsequent RTG decommissioning and disposal.

This problem became particularly urgent after several cases occurred when a responsible organisation lost separate RTGs followed by possible attempts of their unauthorised use. The most outstanding case is an emergency flooding of installations happened in different years during RTGs transportation by air to the Eastern coast of the Island of Sakhalin.

As the first step of activities related to decommissioning and disposal of RTGs located on the costs of the White and Barents seas, the Norwegian Radiation Safety Authority provided financial support of the industrial project targeted to develop the basis for the safe RTGs decommissioning and disposal from the environmental and radiological point of view.

Rostechnadzor reviewed the results of this project and revealed some weak points within some very important areas, for example, assessment of radiological risks in case of possible emergency situations at all operation stages including violations of the processes, accidents during transportation and non-compliances with the established procedures.

Also a conclusion was made to improve the regulatory framework for the safe RTGs decommissioning and disposal taking into account the scope of the task and high risk of future activities related to their decommissioning and disposal, as well as lack of experience in this field.

Review of the environmental impact assessment for RTGs dismantling, transportation, temporary storage and disposal is one of the important areas of these activities and an effective instrument to prevent and minimise possible radiological consequences.

Documentation related to RTGs dismantling, transportation, temporary storage and disposal should include the environmental feasibility study as regards safety to assess environmental risk that may be caused by planned activities, provide for timely accounting of ecological, social and economical consequences of the environmental impact of the mentioned activities and prevention of their negative impact on the environment.

At that, the suggested solutions shall guarantee the ecological safety of the population, minimum damage to the natural environment and population, favourable ecological conditions for habitation of population, conservation of biological variety, air purity, water supply sources and other natural objects, historical heritage of the nation.

Environmental feasibility study for the economical or other activity addressed in the documentation shall be made in accordance with the requirements of the Russian legislation in the field of the environmental protection and environmental review and is an integral part of the international projects on the rehabilitation of radiation-hazardous facilities on the territory of the Russian Federation.

While developing this report the authors took into account the fact that the information presented in the report should be of interest to specialists involved in the project activities related to RTGs dismantling, transportation, temporary storage and disposal in terms of quality assurance to provide for effective implementation of the projects and exclude possible delays in review of the licensing documentation.

2. Terms and definitions

National procedure for the potential environmental impact assessment of the planned economical and other activity shall mean environmental impact assessment of the national and other activity and environmental review related to the documentation justifying the planned economical and other activity.

Environmental impact assessment of the planned economical and other activity (hereinafter referred to as the "environmental impact assessment") shall mean a process implemented by a customer (initiator) of the economical or other activity, that facilitates the decision-making of a managerial level from the point of the environment, which relates to the implementation of the planned economical and other activity by determining potential unfavourable impacts, assessing ecological consequences, taking account of the public opinion, developing measures to reduce and to prevent the impacts.

Environmental review shall mean determination by a body for state safety regulation whether the planned economical or other activity meets ecological requirements and whether the activity subjected to the environmental review is acceptable in terms of prevention of the possible unfavourable environmental impacts of this activity and associated social, economical and other consequences of this activity.

Studies for the environmental impact assessment shall mean analysis and documenting of information for the purposes of the environmental impact assessment.

Planned economical and other activity shall mean an activity capable of producing the impact on the natural environment and being subjected to the environmental impact assessment.

Customer shall mean a legal entity or physical person responsible for preparing the documentation related to the planned activity in accordance with the regulatory requirements imposed on the given type of the activity and submitting the documentation related to the planned activity for the environmental review.

Executor of works related to the environmental impact assessment shall mean a legal entity or physical person who performs the environmental impact assessment (a customer or physical (legal) person entitled by the customer to carry out work related to the environmental impact assessment).

Materials related to the environmental impact assessment shall mean a set of documentation developed during the environmental impact assessment of the planned activity. This set of documentation is an integral part of the documents submitted for the environmental review.

Public discussions shall mean a complex of activities implemented within the frames of the environmental impact assessment which are targeted to provide the public with the as full as possible information about the planned economical and other activity and its possible impact on the environment with the purpose to identify public preferences and proposals and take them into account during the decision-making as regards the planned economical or other activity.

Environment shall mean a combination of components of the natural environment, natural, natural and anthropogenic objects, and also anthropogenic objects.

Components of the natural environment shall include the population, ground, soils, interiors of the Earth, surface and underground water, ambient air, flora, fauna and other organisms as well as ozone layer of the atmosphere and near-Earth space environment that being in combination provide the favourable conditions for life on the Earth.

Anthropogenic object shall mean a man-made object to meet human social needs which does not have properties specific for natural objects.

Natural ecological system shall mean an impartially existing part of the natural environment which has space and territorial boundaries and within which its living (plants, animals, other organisms) and dead components interact as a single functional whole and are connected between each other by the energy and matter exchange.

Environmental protection shall mean an activity implemented by the governmental authorities of the Russian Federation, governmental authorities of the subjects of the Russian Federation, local authorities, public and other non-commercial associations, legal entities and physical persons which is aimed at conservation and rehabilitation of the natural environment, rational use and reproduction of the natural resources, prevention of the negative environmental impact of the economical and other activity and elimination of the activity's consequences (hereinafter referred to also as the "environmental activity").

Environmental quality shall mean a state of the environment which is characterised by physical, chemical, biological and other properties and (or) their combination.

Environmental impact shall mean consequences for the environment and population caused by the implemented economical and other activity.

Negative environmental impact shall mean the consequences for the environment and population that are considered or defined as negative and unfavourable change of the environment by politicians, authorities, decision-makers, individuals or the public (changes and effects on sustainability, variety, reproducibility, natural resources, health, economy, well-being, etc.) or shall mean such situations when probability of reaching or exceeding such changes and effects are considerable.

Environmental pollution shall mean release of the matter (substance) and (or) energy into the environment, whose location or amount causes a negative environmental impact.

Pollutant shall mean a substance or mixture of substances whose amount and (or) concentration exceeds standards established for the chemical substances including radioactive and other substances and microorganisms and causes a negative environmental impact.

Standards in the field of environmental protection shall mean established standards for the environmental quality and standards for permissible environmental impact. Should these standards be complied with, steady functioning of the natural ecological systems is ensured and biological variety is conserved.

Standards for the environmental quality shall mean standards established in accordance with the physical, chemical, biological and other properties to assess the state of the environment. Should these standards be complied with, favourable environment is ensured.

Standards for the maximum permissible concentrations of chemical substances including radioactive and other substances and microorganisms (hereinafter referred to also as the

“standards for the maximum permissible concentrations”) shall mean standards established in accordance with the values of the maximum permissible content of chemical substances including radioactive and other substances and microorganisms in the environment. Non-compliances with these standards may cause the environmental pollution, degradation of the natural ecological systems.

Environmental monitoring shall mean an integrated system for the surveillance of the state of the environment, assessment and forecast of changes to the state of the environment caused by the impact of the natural and anthropogenic factors.

Requirements in the field of the environmental protection (hereinafter referred to as the “environmental requirements”) shall mean mandatory conditions, limitations or their combination placed on the economical and other activity which are established in accordance with laws, other legal acts and regulatory documents, environmental standards, state standards and other regulatory documents in the field of the environmental protection.

Damage to the environment shall mean negative change to the environment caused by its pollution and followed by the degradation of the natural ecological systems and depletion of natural resources.

Environmental risk shall mean a probability of the event which has unfavourable consequences for the natural environment and is caused by the negative impact of the economical and other activity, natural and man-induced emergency situations.

Environmental safety shall mean a state of protection of the natural environment and life-important human interests against a possible negative impact of the economical and other activity, natural and man-induced emergency situations, their consequences.

3. Significance of the environmental impact assessment

The objective of the environmental impact assessment is to prevent or mitigate the environmental impact of the activity and associated social, economical and other consequences. At that, the environmental impact assessment is carried out as regards the planned economical and other activity. Justifying documents related to this activity are subject to the environmental review (as per the Federal Law of 23.11.95 N 174-FZ “On Environmental Review”).

The sequence and scope of works, package of documentation related to the environmental impact assessment are defined by the existing Russian legislation in accordance with the types and (or) specific characteristics of the planned activity as per the established procedure.

An emphasis on the rigid administrative function assigned to EIA in the Russian Federation is not incidental. During the whole modern history of the Russian industrial development the environmental issues occupied the last place among the priorities taken into account in selection and implementation of the huge economical projects. And, moreover, the environmental problems were not the urgent ones while selecting the design solutions. As a rule, design and commissioning activities for the environmental equipment were funded under the leftover principle.

Results of such relation to the environmental problems are well known and rather sad. Russia is a leader for the releases into the atmosphere, discharges into the water bodies and accumulation of waste per a unit of the output, as well as for a number of settlements where the maximum permissible levels of the atmospheric pollution, water bodies, soil, flora etc. are permanently exceeded.

That is why, the adoption of a set of legal acts in the field of the environmental protection (and this is the protection of the atmospheric air, water bodies, interiors of the Earth, woods, flora and fauna) and protection of the population health enabled the environmental authorities to prevent the decision-making that might cause irreversible negative environmental impact to the environmental objects.

Taking into account these principles it's obvious that the process of environmental review shall be organised so that before a decision related to this or that economical activity or project is made, all available information about potential negative impacts of this activity or project on the environment shall be collected, systematised and analysed. Such information is required, first of all, to establish possible conditions targeted to exclude or mitigate negative impacts. Thus, it can be stated that EIA is not only of administrative importance but is one of the planning elements.

But, besides, it should not be forgotten that EIA is one of the elements of the support system for the decision-making. And these decisions, as a rule, are made during the licensing process and while making financial and investment decisions, as well as decisions related to safety and pursuance of the strategic interests of the state.

Thus, EIA is a function of the state regulation and, first of all, state regulation in the field of the environmental protection.

4. Comparison of IEA systems in the Russian Federation and other states

EIA in Russia

Legal and regulatory EIA basis in the Russian Federation is grounded on Federal Laws "On Environmental Protection" (2002) and "On Environmental Review" including decrees and resolutions of the Russian Federation Government subjected to a state registration according to the established procedure.

Main legal acts and regulatory documents related to EIA in Russia are:

- Order of the State Committee for the Environmental Protection of the Russian Federation of 16 May 2000 N 372 "On Approval of Provisions for Environmental Impact Assessment of the Planned Economical and Other Activity in the Russian Federation";
- Order of the Ministry for the Environment and Natural Resources of the Russian Federation of 29 December 1995 N 539 "On Approval of the Guide for Environmental Feasibility Study of Economical and Other Activity";
- Decree of the Russian Federation Government of 11 June 1996 N 698 "On Approval of Provisions for State Environmental Review Procedure".

In accordance with the mentioned legal acts for the environmental impact assessment, mandatory requirements to the arrangements for the EIA process itself are established.

From the conceptual point of view it's reasonable to list basic principles which serve as a basis of the environmental review in the Russian Federation:

- presumption of the potential environmental hazard of any planned economical and other activity;
- mandatory performance of the state environmental review before a decision related to the implementation of the activity subjected to the environmental impact assessment has been made;
- complexity of the environmental impact assessment for the economical and other activity and its consequences;
- mandatory compliance with the environmental safety requirements for the environmental review
- reliability and completeness of information submitted for the environmental review;
- independency of the environmental review experts in implementing their authorities in the field of the environmental review;

- scientific foundation, objectivity and legacy of the environmental review statement;
- openness, participation of public organisations (associations), taking account of the public opinion;
- responsibilities for the organisation, implementation, quality of the environmental review assigned to the environmental review participants and persons concerned.

Comprehensive implementation of these principles by all participants of the process- politicians, executives, decision-makers, individuals or public – shall guarantee the most environmentally justified solutions.

Implementation of the presumption principle of the potential environmental hazard of any planned economical and other activity excludes any alternatives for the Customer in its age-long desire to reduce its costs (time and money). The conditions have been already created under which implementation of legal procedures is more beneficial that neglect of these procedures.

The environmental impact assessment is mandatory at all stages of the development of the documents justifying the economical and other activity before they are submitted for the state environmental review (the principle of the mandatory performance of the state environmental review). At that, the documents submitted for review include the documentation related to the environmental impact assessment of the planned and other activity subjected to the environmental review.

It is required to provide for the prevention of potential unfavourable impacts on the environment and associated social, economical and other consequences caused by the planned economical and other activity. And, as a matter of fact, it's one of the main tasks in planning of this or that project. At that, accounting of all consequences enables to make an objective estimation whether the planned activity is acceptable.

During the environmental impact assessment a customer (executor) shall consider alternative options to reach the objective of the planned economical and other activity. It is provided for, that the customer (executor) should detect, analyse and take into account the environmental and associated consequences of all considered alternative options to reach the objective of the planned economical and other activity including the "zero" option (refusal from the activity).

It is required to provide for participation of the public in the development and discussion of the documents related to the environmental impact assessment of the planned and other activity subjected to the environmental review as an integral part of the environmental impact assessment (the principle of openness, participation of the public organisations (associations), taking account of the public opinion during the environmental review). At that, it is determined that the participation of the public including provision of the public with the information about the planned economical and other activities and its involvement in the environmental impact assessment should be carried out by the customer at all stages of this process starting from the development of the terms of reference for the environmental impact assessment. The customer jointly with the local authorities shall arrange for the public discussions of the review subject including the documents related to the environmental impact assessment of the planned economical and other activity in accordance with the Russian legislation.

The documents related to the environmental impact assessment shall be justified from the scientific point of view, reliable and reflect results of studies carried out taking into account the interface of different environmental, and social and economical factors (the principle of scientific foundation, objectivity and legacy of the environmental review statement).

The customer shall give all the participants of the environmental review a possibility to receive complete and reliable information in due time (the principle of reliability and completeness of information submitted for the environmental review).

The results of the environmental impact assessment serve as a basis for the monitoring, post-project analysis and environmental monitoring of the planned economical and other activity.

If the planned economical and other activity can cause transboundary impact, studies and development of documents related to the environmental impact assessment shall be carried out taking into account the provisions of the UNO Convention on Environment Impact Assessment in a Transboundary Context.

The EIA structure itself, as well as the requirements of the Russian legislation for the determination and ranking of the activities subjected to the environmental review, its procedure, responsibilities of the participants are not significantly changed after the Report ISBN 82-995962-0-3 "The Russian System of the Environmental Impact Assessment for the Radiation-Hazardous Facilities. Comparison with the Norwegian and other Western Systems", May 2001 has been published. Appendix 1 presents exemplary contents of the EIA report.

At the same time during the recent period significant changes occurred to the system of the executive authorities of the Russian Federation, distribution of their functions and responsibilities.

Now the main functions of the state regulation in the area of prevention of the negative anthropogenic impact on the environment, including administrator's functions to organise the state environmental review are assigned to the Federal Environmental, Industrial and Nuclear Supervision Service (Rostechnadzor).

Rostechnadzor organises and carries out the state environmental review in accordance with the procedure established by the Russian Federation legislation. The state environmental review applies to:

- draft legal acts, international agreements of the Russian Federation that may lead to negative environmental impact, regulatory, technical and methodological documents regulating economical and other activities that may affect the environment (excepting the review of facilities in the sphere of nature management) to be approved by the governmental authorities of the Russian Federation;
- draft intergovernmental investment programs involving the Russian Federation , and federal investment programs;
- feasibility study reports and projects of construction, reconstruction, expansion, backfitting, closure or liquidation of organisations and other facilities of economical activity of the Russian Federation which may produce an impact on the environment, including the environment of the contiguous states;
- documents justifying safety of the activities subject to licensing capable of producing a man-induced environmental impact;
- draft technical documentation for new technologies or equipment;
- other types of documentation regarding economical and other activities capable of producing direct or indirect negative impact on the environment (excepting review of facilities in the sphere of nature management).

EIA in other states

All states of the European Union or state-participants of the European Agreement on the Environmental Protection shall follow the Council Directive 85/337/EEC of 27.06.1985 (as amended by the Council Directive 97/11/EC of 03.03.1997 and 2004/35/EC of 21.04.2004) on the environmental impact assessment of the state and private projects.

At that, the mentioned Directives establish that the EIA procedure is common for all states-participants. Each state shall undertake all measures to provide for EIA before a permit to implement projects that may cause considerable environmental impact due to their specifics, scales or place of implementation is issued. These projects include construction of such installations as heat power electric stations and other heat installations with heat production of 300 MW and higher, nuclear power plants and nuclear reactors (excluding research installations for production and conversion of fissile and combustible materials with maximum heat power of not more than 1 kW); installations designed for permanent storage and disposal of radioactive waste.

If the states-participants deem it necessary, EIA may be performed as regards installations designed for production and enrichment of nuclear materials, processing of irradiated fuel assemblies of nuclear reactors, collection and reprocessing of radioactive waste.

Common provisions for EIA consist in the fact that all direct and indirect impacts of the project shall be detected, described and analysed in each specific case. These are impacts on:

- people, flora and fauna;
- soil, atmospheric air, water bodies, climate and landscapes;
- interaction between the objects and existing factors presented in the first and second paragraphs;
- material resources and cultural heritage.

Of course, it should be noted that guides regulating EIA for specific types of radiation-hazardous installations are not available both in most of the EU states and the Russian Federation. Consequently, EIA for such installations is carried out similar to EIA for other types of the activity.

Taking into account that EIA shall be an integrated assessment of the impact of the planned facility or activity on the environment, health of the population and natural resources and other significant aspects, the most important is availability of the adequate criteria and regulatory basis providing for the objective consideration of the role of all factors of the potential or actual environmental impact during EIA for the radiation-hazardous installations.

At that, the foreign experience in this field is worth mentioning.

A Law on radiation safety and use of ionising radiation (SHD 2000) is adopted in **Norway.** The objective of this Law is to ensure radiation safety of personnel and population and the environmental protection against possible harmful impacts conditioned by the ionising radiation effect. Now international studies on the development of the environmental protection principles are underway.

A Law on protection against radiation covering both issues of radiation safety of a person and issues of the environrmental protection is adopted in **Sweden** in 1988. However, some EIA documents for the radiation-hazardous installations have not been approved yet, since the required practical experience is being gained.

The similar situation is observed in the Russian practice of the development of regulations and implementation of project works. It should be noted that works related to different aspects of radiation-hazardous activities have been intensified during the last years.

5. Analysis of the compliance with EIA requirements for RTG decommissioning and disposal stages in the Russian Federation

The Russian experience in EIA for the potentially radiation-hazardous installations relates to dozens of projects. These are the projects for construction of new NPP units (Volgodonsk NPP Unit 1 and Kalinin NPP Unit 3 are commissioned); nuclear material storage facility at FSUE “Mayak”, SNF storage facility at Smolensk NPP, low- and medium-level radioactive waste storage facility at Novaya Zemlya Archipelago, a complex of surface storage facilities for radioactive waste at Radon; projects for decommissioning of some nuclear submarines; radioactive waste reprocessing complexes at FSUE “Zvezdochka”, FSUE “Zvezda”, Smolenskaya NPP and many others less recourse-intensive projects.

Analysis of the main trends in EIA for the radiation-hazardous installations allows to describe briefly approaches used.

Pre-design / design documents for the potentially radiation-hazardous installations submitted for the state environmental review address a complex of possible radiation and non-radiation impacts. Along with the common analysis of characteristics of the installation's location region and installation itself which are important for setting restrictions to the nature management and assessing acceptability of the forecasted impact of the installation on the environment and health of population, vast majority of projects covers a detailed analysis of radiation hazard sources related to its operation.

Usually design documents include the following additional sections:

Radiation monitoring. This section presents information about arrangements for the radiation monitoring, including:

- objectives and tasks of the radiation monitoring taking into account the radiation hazard level of the planned types of the activity under normal operation conditions and in case of accidents;
- description of functions performed by the radiation situation monitoring system and the scope of the radiation monitoring with separate description of information on radiation process monitoring systems, radiation monitoring of the occupational exposure level, radioactive contamination monitoring of the environmental objects, monitoring of releases and discharges of radioactive substances into the environment;
- list of engineering means and organisational measures to monitor the radiation situation related to the operation of the radiation-hazardous installation in question.

Radiation protection. This section includes information specific for on-site radiation protection systems designed to minimise the level of radiation impact on personnel, population and the environment, including:

- characteristics of the ionising radiation sources that may cause external and internal exposure (through pollution of air and other media);
- requirements to the radiation protection of personnel with indication of regulated level of occupational exposure, requirements to radiation protection of processes, limitations for radioactive contamination, classification of the radioactive waste generated and radiation protection measures for radioactive waste;
- project of protection against ionising radiation with general principles of arrangements for radiation protection during the installation operation including protection during transport and process operations, air protection inside the premises against radioactive pollution etc. and documents justifying the efficiency of protection.

Radiation safety. This section includes:

- requirements related to the protection of the population and environment against the radiation impact during operation of radiation-hazardous installation under a nominal mode and in case of the design basis and beyond design basis accidents;
- limitations for releases and discharges of the radioactive substances into the environment during normal operation and accidents;
- radioactive waste management system and justification of its safety.

Sections which contain justifications of design solutions for radiation situation monitoring, radiation protection and radiation safety shall include comprehensive information on radiation impact of the radiation-hazardous installations on the environment, personnel and population during the construction, operation under nominal and emergency modes and decommissioning of the installation, as well as information justifying the proposed selection of the environmental activities.

Additionally, the justifying documents shall present the program for the local radiation and environmental monitoring which provides for the timely detection of possible negative consequences caused by the operation of the radiation-hazardous installation on the environment, personnel and population.

It is planned to use these approaches in developing documentation related to the environmental impact assessment for operation and subsequent decommissioning and disposal of radiation installations and sources, including RTG.

For the purposes of this work, it should be taken into account that the RTG decommissioning activity itself has been being implemented during several decades, and, consequently, justifying documents for this activity are not the subject of the state environmental review, development of a separate document, which use would be accompanied by implementation of the legal procedures, is not required.

6. Conclusion and follow-up work

Environmental impact assessment principles and methods in Norway, Sweden and European Union countries and in Russia have much in common. The environmental impact assessment procedures are based everywhere on the principles generally recognised at the international level (for example, prevention, openness, mandatory environmental impact assessment for all projects that are capable of causing considerable environmental impact).

Existing differences relate mainly to the level and forms in which these principles are implemented and are conditioned to a great extent by differences in the state structure and institutional specifics of each country.

Nevertheless, certain reserves for convergence and unification of the regulatory basis, environmental impact assessment procedures and criteria used in Scandinavian and EU countries, and the Russian Federation exist. Further work in this area is required, especially, as regards installations and types of activity that may cause considerable radiation impact on the environment and population. It is connected with the broad planned international co-operation targeted to solve the most acute problems related to radiation and environmental safety in the North-West of Russia, and also with possible transboundary impacts caused by accidents at potentially radiation-hazardous installations. This is also important for implementation of such activities as RTG dismantling and disposal.

It’s very important to ensure that criteria include criteria for protection of the ecological systems and objects of flora and fauna themselves and not only in relation to a human protection against the ionising radiation, as it is practiced in the legislation of practically all countries up to now. In particular, it is considered to be necessary to develop reference radionuclide concentrations in different media, marine environment, soil and some indicator species of marine and ground flora and fauna. The reference concentrations could be used to assess the actual environmental conditions of the territories in question, consequences of the projects’ implementation and operation of radiation-hazardous installations.

Application of the methodology for health and environmental risk assessment in development of the emergency scenario for different works involving RTG gives a real possibility to make an objective assessment of hypothetical consequences and to adjust processes and minimise a probability of negative consequences in advance. It is planned that this methodology will be a mandatory instrument of the EIA methodology.

It’s very important to provide for the close interaction between developers of the projects, especially, those that are devoted to rehabilitation of the radiation-hazardous installations and state regulatory bodies responsible for the health protection, environmental protection, nuclear and radiation safety at the design stage of the potentially radiation-hazardous operations. Also it’s important that all EIA participants have been familiar with the necessary information and authorisation system as regards the planned activity. Only in such a way the achievement of the main EIA objective can be ensured, i.e:

optimal selection of the site, application of this or that technology, implementation of the project related to the economical activity in terms of the environmental and human health protection can be guaranteed.

Appendix 1 Exemplary contents of EIA report

Taking into account the common approaches to the environmental assessment for RTG handling at all life cycle stages it would be reasonable to specify requirements to EIA documents for other types of the activity, which can be applied to RTG at different work stages.

Requirements to the contents of the EIA report as a part of pre-design and design documentation for construction of a facility of the economical and other activity

1. Justifying documents related to siting of a facility shall be developed on the alternative basis and based on the detailed analysis of the input information about the impact sources, natural features of the territory, its historical and cultural heritage, and the state of ecosystems within the area of the facility's impact as regards each location site.

2. For justification of the facility location site, sources of the input information may be published documents of specially authorised state authorities in the filed of the environmental protection and their territorial offices and library materials of scientific organisations and institutions, statistical reporting and environmental monitoring data, engineering survey and environmental data as regards the facilities – prototypes, calculations and prediction models. Also the following should be used as the input information:

- cadastral map of natural resources, maps and maps-diagrams of the components of the natural environment (soil, geobotanical, fauna, etc.), underground water protection map, etc.);
- database for production and consumption waste.

3. The package of the justifying documents for the facility site shall include:

- data on the facility site, location of the site to be allotted for the temporary or permanent use;
- description of natural conditions of the territory within the facility site region, assessment of the added value of economical activity on this territory;
- brief information on the current and perspective use of the territory (in accordance with the development diagrams and programs) including information on the use of natural resources while implementing the planned activity;
- limitations in nature management;
- information on the natural and historical features of the territory within the area of the possible facility's impact, state of components of the natural environment;
- description of the planned activity;
- information about the impact sources – planning and other construction violations, releases, discharges, production waste (indicating toxicity of contaminations ingressed into the environment), physical and other impacts;
- preliminary assessment of the environmental impact caused by the planned activity, including the impact on specially secured facilities;
- recommended set of the environment measures which is determined on the basis of optimal (optimised) values of the permissible releases and discharges;
- preliminary environmental risk assessment of the facility siting.

4. Preliminary environmental impact assessment during the facility siting includes:

- assessment of the level of study of the territory and adequacy of the input information on the natural and historical features of the territory, state of the components of the natural environment;

- assessment of the possible nature management on the basis of the environmental potential of the territory (in accordance with the facility needs) and state of the ecosystems;
- assessment of the impact scale and level under the normal operating mode of the facility and in case of the emergency situations;
- predictive estimation of changes in the natural environment – state of the components of the natural environment, activity of natural processes, and consequences of these changes for a human being.

5. Environmental measures shall be determined in terms of each component of the natural environment and include proposals on efficient use of natural resources, prevention of their exhaustion and pollution of the ecosystems.

6. An option which provides for a minimum predictive environmental risk of the planned activity shall be a priority one in selecting the facility location site.

7. In addition to the justifying documents related to the facility siting it is required to present:

- recommendations on the development of the environmental feasibility study report in the design documentation;
- proposals on the study of the natural features of the territory at the subsequent design stages (if the input information is not adequate);
- proposals on the organisation of the local (production) environmental monitoring.

8. As regards the development of the technical, process and other design solutions the justifying documents shall be developed for the one (single) location site approved by the authorities (if necessary, they can be developed also for other possible options of the location site).

9. Documents justifying the design solutions shall contain the comprehensive information about the environmental impact caused by the facility during construction and normal operating mode (maximum load of the equipment) and in case of possible burst and emergency releases (discharges), as well as argumentation for the selection of the environmental measures.

The documents shall include:

- description of ecosystems in the area of the facility impact, assessment of the state of the components of the natural environment, resistance of the ecosystems against the impact and restoration capability;
- information about objects of the historical and cultural heritage;
- estimation of changes in the ecosystems caused by replanning of the territory and implementation of construction operations;
- assessment of the process and technical solutions related to the efficient use of the natural resources, mitigation of the environmental impact caused by the facility (treatment facilities, production and consumption waste neutralisation facilities, etc.);
- list of waste, information about waste amount, environmental hazard, emplacement (storing) and use;
- prediction of changes to the natural environment (as regards each of its components) during construction and operation of the facility;
- justification of the environmental measures related to the environmental restoration and sanitation, conservation of biological diversity;
- integrated assessment of the environmental impact caused by the planned activity – consequences of the possible impact (taking into account the planned environmental measures);

- justification of capital investments in the environmental measures (by the types);
- charge for the nature management.

10. Additionally to the justifying documents it is required to submit a program for organisation of the local environmental monitoring and relevant funding plan.

11. As regards the facility decommissioning (abandonment, conversion), additionally the following should be included:

- justification of the necessity in abandonment (conversion) of the facility;
- assessment of changes to the natural environment caused by the facility operation;
- assessment of the consequences caused by the environmental degradation within the area of the facility location to the population health;
- justification of the set of measures targeted to restore the natural environment and create favorable conditions for the life of the population.

Requirements to the environmental justification of the technique, technology, materials

1. Justification of the process solution requires to specify:

- resource consumption and resource-saving features of the technologies;
- technical indicators characterising the environmental impact level of the products, used materials, i.e.: data on the material and energy balance of the process (consumption – waste) indicating the waste types (gaseous, liquid, solid), waste amount (volume);
- principles and diagrams of the processes, treatment facilities for releases and discharges, calculated and experimental characteristics of release and discharge sources (volumes, concentrations, temperatures, flow rates of the mixtures, etc.), characteristics of the specific releases and discharges (comparing the mentioned characteristics with similar technologies used at other facilities);
- information whether the technologies meet the requirements related to low-waste level and wastelessness of concrete processes;
- data on accident rate of the process diagrams and specific productions in using concrete types of resources (energy, natural) and materials, accident probabilities (including characteristics of the forecasted releases and discharges under different accident propagation scenario);
- efficiency assessment of measures targeted to prevent emergency situations under specific natural conditions during the use of the recommended technologies;
- environmental safety assessment for elimination of the technique and proposed technologies (if necessary);
- characteristics of noise, oscillation, electromagnetic and ionising radiation levels, their compliance with maximum permissible levels;
- specific factors of natural resources consumption per a unit of the output;
- justified conclusions on disposal and elimination methods for the products after the treatment;
- justified conclusions on the environmental impact assessment caused by the used engineering means and technologies, as well as used materials and produced items;
- monitoring means and methods to assess the environmental impact of the technologies planned to be applied.

2. Environmental hazard (risk) assessment documents related to the used and manufactured products shall include information on the actual and potential hazard caused by the use of the products including:

- toxicological hazard caused by impurities generated in the process of manufacturing of new products and hazard caused by by-products generated during operation of the products, their transformation, decomposition or interaction with the environment;
- conditions of distribution and proliferation of toxic impurities and by-products within the regions where the products are used – mobility, migration, resistance, stability, lifetime;
- conditions of transformation, decay (decomposition) of the by-products in the environment, duration of their transformation;
- monitoring of proliferation and detection of toxic impurities in the products and by-products (assessment of the current level and proposed measures);
- negative environmental consequences caused by ingress of the toxic impurities and by-products into the environment, food, habitation, process premises.

Appendix G:

List of Acronyms and Abbreviations

BCES	Branch commission on emergency situations
CD	Civil defence
DalRAO	Far Eastern Federal Enterprise for the Management of Radioactive Waste
DDS	Duty dispatch service
DU	Depleted uranium
EIA	Environmental impact assessment
ERF	Emergency rescue forces
ES	Emergency situation
FGUP	See FSUE
FNR	Federal norms and rules
FSUE	Federal State Unitary Enterprise (Russian FGUP)
HLW	High level waste
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IPM	Individual protection means
IRSN	Institut de radioprotection et de sûreté nucléaire. France
JSC "RZhD"	Joint Stock Company "Russian Railways"
Mintrans	Ministry of Transport
MChS	Ministry of affairs on civil defence, emergency situations and elimination of consequences of natural disasters
ND	Normative document
NM	Nuclear material
NRB-99	Russian Federation Norms of Radiation Safety
NRPA	Norwegian Radiation Protection Authority
NRSD	Nuclear and Radiation Safety Department
NRS SEC	Scientific & Engineering Centre for Nuclear and Radiation Safety
OG	Operative group
OSPORB-99	Russian Federation Basic Sanitary Rules of Radiation Safety
RadS	Radioactive substance
RHS	Radioisotope heat source
RM	Radioactive material
RMP	Radiation monitoring point
Rosatom	Federal Agency for Nuclear Energy
Rosgidromet	Federal Service for Hydrometeorology and Environmental Monitoring
Rosmorrechflot	Federal Agency for Sea and River Transport

Rospotrebnadzor	Federal Service for Supervision in the Area of Consumer Rights and Welfare Protection
Rostechnadzor	Federal Environmental, Industrial and Nuclear Supervision Service
RS	Radiation source
RTG	Radioisotope thermoelectric generator
SCC	Situation-Crisis Centre
SET	Specialised emergency team
SevRAO	Northern Federal Enterprise for the Management of Radioactive Waste
SG	Safety Guide
SNF	Spent nuclear fuel
SPb EEC	Emergency-Engineering Centre of the Federal Agency for Atomic Energy
SPORO-2002	Russian Federation Sanitary Rules for Radioactive Waste Management
Sr-90	Strontium-90
SSI	Statens strålskyddsinstitut (Swedish Radiation Protection Authority)
TPS	Transport packing set
VNIITFA	All-Russia Scientific and Research Institute for Technical Physics and Automation

Appendix H Photos

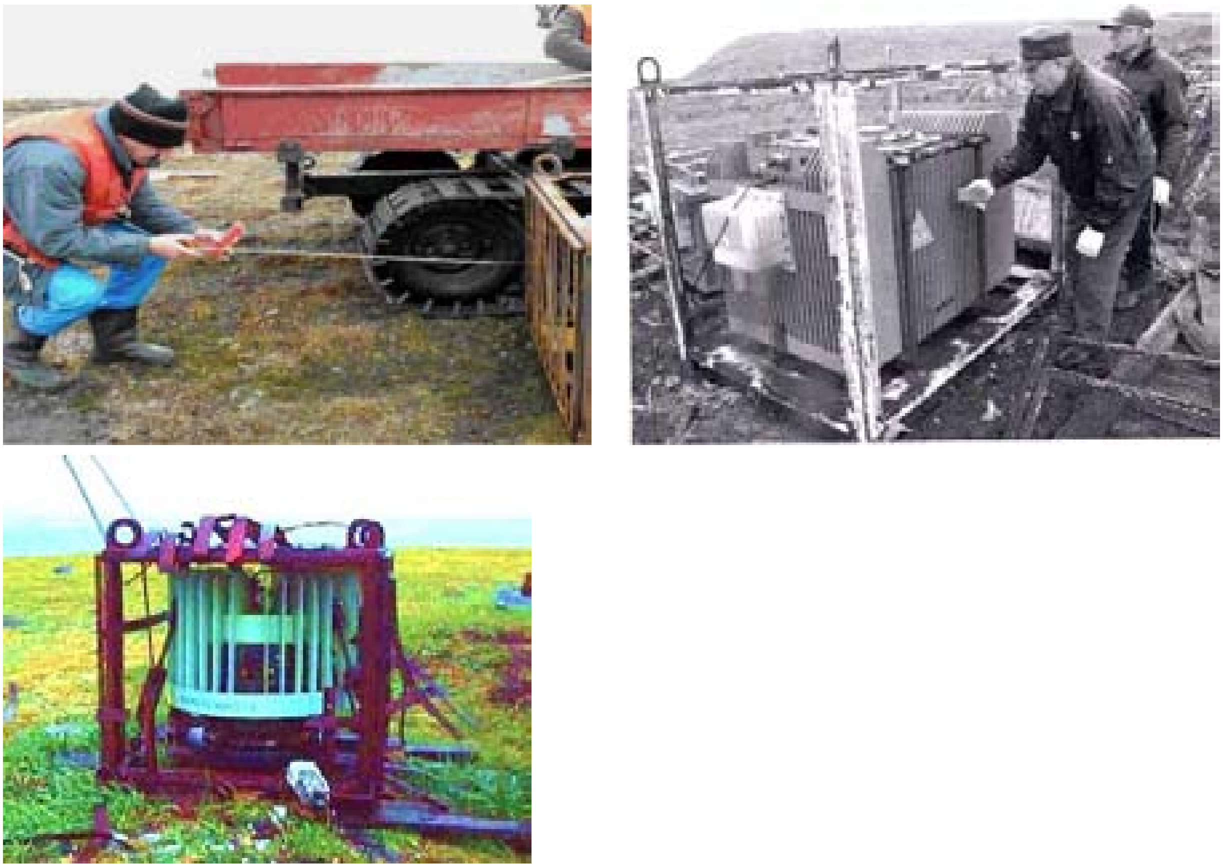

Fig.1. *Examination of RTG in the place of its operation (presence) to identify whether it is possible to transport it (Monitoring of gamma radiation dose rate on the RTG surface and at 1 m from the RTG surface and monitoring of shielding containers condition).*

Fig.2. *Preparation of RTG to dismantling. These operations are carried out by trained personnel of the operating organisation. A work permit is to be issued to execute this work.*

Fig. 3. *RTG dismantling and its placing on a vehicle to deliver to the place where it is put on a pontoon. Each RTG dismantling shall be formalised in a deed signed by personnel involved in dismantling operations and approved by Head of operating organisation.*

Fig.5. *The decommissioned RTG package is placed on pontoon (for delivery to ship). The pontoon personnel should be minimal.*

Fig. 6. *The anchored ship for transportation of dismantled RTGs.*

Fig. 7. *The RTG packages are unloaded from the pontoon by the ship's crane. RTG packages are placed and fixed in the ship's hold or on deck in locations that are the most distant from the ship's crew temporary or permanent attendance of the personnel.*

Fig. 8. *The transportation of the dismantled RTGs from their installation locations to the coastline where it is possible to place them on a pontoon.*

Fig. 9. *Unloading of the ship with delivered RTG packages and their putting on the extension platform of a special railcar at FSUE Atomflot.*

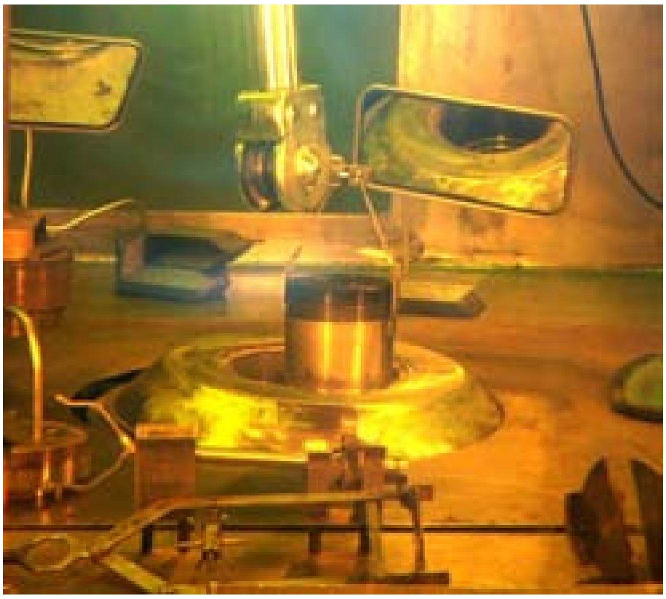

Fig. 10. *Reloading of RHS from RTG to transportation containers in "hot" cell at VNIITFA.*

Fig. 11. *External view of RHS of different types (RHS mock-ups)*

Fig12 *The Radioactive Isotope Plant of FSUE PA Mayak. It receives RHS transportation packages coming from FSUE VNIITFA.*

Picture 12. *RHS are stored for a long term in these cells*

Fig. 13. *Photo of the two dropped RTGs of the type Efir-MA, Tiksi hydroraphic base.*

Photos: Rostechnadzor, NRPA and County Govenor of Finnmark.

Statens strålevern
Norwegian Radiation Protection Authority

StrålevernRapport 2007:1
Virksomhetsplan 2007

StrålevernRapport 2007:2
Representative doser i Helse Øst. Representative doser for røntgendiagnostikk rapportert fra virksomheter i Helse Øst høsten 2006

StrålevernRapport 2007:3
Radioecological consequences of a potential accident during transport of radioactive materials along the Norwegian coastline

StrålevernRapport 2007:4
Measuring radon levels at high exposures with alpha-track detectors. Calibration and analysis

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