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# Threat Assessment of Radioisotope Thermoelectric Generators (RTG) Management Radiation Protection and Safety Regulations

Statens strålevern

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*Key words:*
Threat Assessment. Radioisotope Thermoelectric Generators (RTG) in NW Russia. Radiation Protection and Safety Regulation. Decommissioning and Disposal of RTG. Supervision and control.

*Abstract:*
The purpose of this threat assessment is to obtain a view from the regulatory perspective of Rostechnadzor of the most important issues which require supervision and regulatory development, regarding activities connected to RTG decommissioning and disposal. The main radiological threats have been identified and actions to reduce them have been proposed.

*Referanse:*
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*Emneord:*
Trusselvurdering. Radioisotope Thermoelectric Generators (RTG) i Nordvest Russland. Regulerende strålevern og sikkerhet. Dekommisjonering og sluttdeponering av RTG. Oppsyn og kontroll.

*Resymé:*
Formålet med denne trusselvurderingsrapporten er å gi regulerende myndigheters (Rostechnadzor) syn på de viktigste områder som krever overvåking og regulativ utvikling når det gjelder aktiviteter koblet til RTG dekommisjonering og sluttdeponering. De største radiologiske truslene har blitt identifisert og tiltak for å redusere dem har blitt foreslått.

Head of project: Malgorzata K. Sneve.
*Approved:*

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

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# Threat Assessment of Radioisotope Thermoelectric Generators (RTG) Management Radiation Protection and Safety Regulations

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# Executive Summary

The Norwegian Government, through a Plan of Action implemented by the Ministry of Foreign Affairs (MFA), is promoting improvements in radiation protection and nuclear safety in North-West Russia.

As part of this programme, the Norwegian Radiation Protection Authority is carrying out work directed towards regulatory support for the safe decommissioning of radioisotope thermoelectric generators (RTGs) which are mainly used as electric power sources in remote navigation facilities (lighthouses).

As part of that regulatory support, implemented with the Russian Federation Nuclear Industrial and Environmental Regulatory Authority, this report describes a threat assessment which identifies:

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

The output from this report is being used in continues process of accessing regulatory requirements to improve the safety and procedures in RTG management.

*Transport of RTGs by helicopter.* *Photo: County Governor of Finnmark*

# Contents

# 1 Introduction, Scope and Objectives

The Norwegian Government, through a Plan of Action implemented by the Ministry of Foreign Affairs (MFA), 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 [2005], 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.

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, the Norwegian Ministry of Foreign Affairs 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 Nuclear, Industrial and Environmental Regulatory Authority 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.

*RTG awaiting transportation Photo: County Governor of Finnmark*

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. The regulatory project is intended to highlight and address the regulatory issues most important to ensuring safety and environmental protection in the successful completion of the industrial project. The overall objective of the collaborative project is 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.

The collaborative project has six tasks, based on these areas.

Taking all of the above into account, an early step in the regulatory project is to assess the radiological threats currently existing and presented by the work which will have to be carried out to safely decommission the RTGs. The purpose of this threat assessment[1] is to obtain a view, from the regulatory perspective of Rostechnadzor, of the most important issues which require supervision and regulatory development in order to support the safe development of the industrial project.

It is noted that the basic laws of the Russian Federation on use of radioactive materials and radiation protection provide a full basis for operation. However, given the special situation of the RTGs, this assessment is intended to:

*RTGs measured on the beach. Photo: County Governor of Finnmark*

- 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.

Accordingly, Section 2 sets out the issues identified and Section 3 develops the common conclusions. References are provided in Section 4. The main steps in the RTG decommissioning process are described in Appendix A, the main regulatory issues are discussed in detail in Appendix B, relevant legal and regulatory documents of the Russian Federation are listed in Appendix C and a list of acronyms and abbreviations is given at Appendix D.

It is recognised that the findings in this report are of a preliminary nature and should provide a basis for further development of the collaborative project. Furthermore, these initial findings can already offer some useful input to prioritising and providing regulatory basis for activities in the industrial project.

[1] The term threat assessment is used to avoid confusion with the rather precise terminology associated with the term "risk assessment". This threat assessment is a preliminary, qualitative review of hazards and associated risks, providing outline details to enable additional effort and resources to be focussed on those areas that most require the attention. It is an assessment of the risks to efficient and effective regulation. It is not an assessment of risks to human health and environment (which is addressed through other documentation, such as the Safety Assessment Report), nor a "threat assessment" in the sense that the term is sometimes used in the context of physical protection or security issues.

# 2 Threat Assessment

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.

This section aims to identify and prioritise, at a general, qualitative level:

- The risks associated with the different parts of the decommissioning process and the technical measures used in the industrial project to control them; and
- The regulatory measures already in place and areas in which further regulatory developments may be needed to ensure that the risks are adequately controlled throughout the process.

## 2.1. Characteristics of RTGs

RTGs are self-contained power supply sources with a DC voltage from 7 to 30 volts, used for different autonomous apparatus with a capacity from several watts up to 80 W. RTGs are commonly used as a power supply source for navigational lighthouses and light signs, as well as for radio beacons and weather stations.

RTGs of the types relevant to this project contain 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 use strontium in the form of strontium borosilicate glass. The surface temperature is 300–400°C, and dose rates close to the RHS surface are thousands or tens of thousands of R/h (tens or hundreds of Gy/h). The capsule is protected against external impacts by a thick RTG cladding made from stainless steel, aluminum and lead. Biological shield is fabricated so that the radiation dose on the apparatus surface does not exceed 200 mR/h (2 mGy/h), and the radiation dose at the distance of 1m from the apparatus does not exceed 10 mR/h (0.1 mGy/h).

*Radioisotope Thermoelectric Generators (RTG) Photo: NRPA*

The half-life of Sr-90 is 29 years. When RHS-90 is fabricated it contains from 30 to 180 kCi (1 to 5 PBq) of Sr-90. The strontium decay produces a daughter isotope: a 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 (4–8 Gy/h) at a distance of 0.5 m and 100–200 R/h at 1 m from RHS-90. Because of the very high initial activity, RHS-90 becomes safe in terms of the activity only in 900-1000 years (i.e. more than 30 half-lives).

RTGs vary in parameters for the output electric voltage, output electric power, mass, dimensions etc. The most commonly used RTG type is "Beta-M" – one of the first developed RTG design.

**Technical characteristics of the most commonly used RTG types**

| Parameters | RTG Type | | | |
|---|---|---|---|---|
| | IEU-1 | IEU -2 | Beta-M | Gorn |
| Electric power, W | 80 | 11 | 9 | 60 |
| Range of operating temperatures, °C | -50 to +40 | -40 to +35 | -60 to +55 | -60 to +55 |
| Dimensions:<br>diameter, mm<br>height, mm | excl packaging:<br>760<br>1510 | <br>975<br>1675 | <br>600<br>655 | excl packaging<br>850<br>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 pc.) |
| Nominal activity as for the date of production, kCi (PBq) | 340 (12.6) | 90 (3.3) | 35 (1.3) | 170 (6.3) |
| Equivalent radiation dose rate produced by RTG, μSv/s (mRem/h) not higher than:<br>- on the RTG surface,<br>- at 1 m from the RTG surface | <br>0,56 (200)<br>0,028 (10) | <br>0,56 (200)<br>0,028 (10) | <br>0,56 (200)<br>0,028 (10) | <br>0,56 (200)<br>0,028 (10) |

According to the designers of the RTGs, the design of the RHS completely excludes any radionuclide release into the environment within the whole period of its radioactive decay. It is provided with a range of 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:

- 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. This is made from one of a variety of heavy metals, primarily lead, and tungsten or depleted uranium (DU). The DU material is subject to corrosion, which may cause problems in decommissioning which are not found with tungsten[2].

However, there are reported cases of radioactive 'leaks' from RTGs.

For example, in 1998 activity contaminated an area around a damaged RTG at Cape Navarin in the Chukotka Autonomous Region of north-east

[2] Mentioned during visit to FSUE Izotop in February 2006.

Russia following an incident of unauthorised tempering and the subsequent measures to remedy the situation. The RHS appears to have been damaged by extreme physical force, e.g. being run over by a vehicle. Appropriate measures are now being carried out to improve the situation. Severe mechanical effects on gas supply nozzles or electrical seals, combined with welding defects and metal fatigue in the areas around the welds, have been found to cause depressurisation of the DU cladding in older RTGs (greater than 25 years' operation). The resulting loss of the RHS's inert atmosphere can lead in time to a gradual degradation of the RHS.

*Reloading RTGs from boat on to ship for further transport. Photo: County Governor of Finnmark*

There are also reported instances in which the depleted uranium (DU) shielding in the RTG has oxidised and peeled away or crumbled, causing two effects: firstly the DU oxides can be dispersed, causing detectable radioactive contamination around the RTG; and secondly, the loss of shielding around the RHS leads to significantly elevated external dose rates outside the RTG. It is not believed that this process results in any release of activity from the RHS – the inert atmosphere around the RHS is maintained but the combination of the two effects may be mistaken at first sight for a leak of strontium. This phenomenon may also cause problems during decommissioning, particularly if the RTG does not have a tungsten outer shield This phenomenon has been observed, for example, in an IEU-2 type RTG at Rybachiy Peninsula (south of Novaya Zemlya).

*Loading RTGs on to boat. Photo: County Governor of Finnmark*

It is also accepted that activity from RHSs accidentally dropped into the sea and not recovered might be expected to be released in the long term due to gradual corrosion processes.

The other characteristic of RTGs that affects safety during decommissioning is heat generation. This heat needs to be dissipated to prevent the possibility of overheating that could potentially result in damage to the RHS and/or shielding. The RTG is designed to ensure adequate dissipation of the heat under all normal circumstances, but there could be unusual circumstances (e.g. burial under soil or sand) where heat conduction away from the RTG might be inadequate. There would also a possibility of damage due to thermal shock if an RHS were to be suddenly exposed to cold air or water. Clearly such circumstances need to be avoided through safety measures.

More than 1000 RTGs were produced in the USSR. Some of these (about 250) have already been disposed of after their operational period had expired. At present, more than 700 RTGs are in operation or waiting to be decommissioned in the Russian Federation. The design or extended service lifetime of all RTGs will expire in the next 10–15 years. About 450 RTGs to be decommissioned in 2006 or later that fall within the scope of the industrial project are in four groups:

- The majority (273) are owned by the Federal Agency for Sea and River Transport (Rosmorrechflot, subordinate to the

Ministry of Transport) and are operated at hydrographic stations by the FSUE Hydrographic Enterprise of the Ministry of Transport along the Northern Marine Route, i.e. on the north coast of the Russian Federation, and primarily east of Novaya Zemlya. These are referred to in this report as RTGs from the **Northern area**, and are of "Beta-M", "Efir-MA", "Gorn" and "Gong" types;

- 84 are owned by the Hydrographic Service of the Northern Fleet, part of the Russian Ministry of Defence, and are primarily located along the north coast of the Russian Federation and west of Novaya Zemlya (the **North-West area**);
- 25 are owned by the Hydrographic Service of the Pacific Fleet (also part of the Russian Ministry of Defence), and are primarily located around the coasts of the Sea of Okhotsk (the **Far East area**); and
- A further 95 are owned by the Hydrographic Service of the Baltic Fleet (again, part of the Russian Ministry of Defence), and are located in the **Baltic area**.

(In total, the Ministry of Defence owns about 330 RTGs of different types, including IEU-1, IEU-1M, IEU-2, IEU-2M, "Gong", "Beta-M", "Efir", "Grab" and "Gorn" types.)

The primary focus for this project is on the RTGs in the North-West area, which are being decommissioned in the framework of Russian–Norwegian cooperation, and some RTGs in the Northern Area, which will be decommissioned with international assistance. The project should also have some relevance to the decommissioning of the RTGs in the Northern, Far East and Baltic areas, which are being decommissioned through Russian–US and Russian–German cooperation respectively. The Guide for inspections being developed under the project takes into account the features of all the mentioned areas and is designed for the use by inspectors of the Territorial Offices responsible for the supervision in each of the areas.

## 2.2. Steps in RTG Decommissioning

For the threat assessment, we consider nine steps in the decommissioning process identified in (Rostechnadzor, 2006), namely:

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.

It appears that not all steps necessarily apply for all RTGs. For example, steps 5–8 appear to apply only to RTGs from the North-West area and western parts of the Northern area. RTGs from the rest of the Northern area and the Far East and Baltic areas are sent directly to Mayak and the RHSs are removed there. This illustrates that regulatory issues may differ, even among RTGs of the same type.

The nine stages of the decommissioning process are shown in the Figure and are described in more detail in Appendix A.

It should be noted that a number of the stages listed above include temporary storage of RTGs or RHSs at various places. Storage is not identified as a specific regulatory issue –

because there are no regulations specifically for temporary storage – but the possible risks associated with storage of RTGs or RHSs at different places need to be considered as part of the relevant step. In particular, it should be taken into account that some of these periods of storage are intended to allow the accumulation of a number of RTGs (or RHSs) sufficient to make up a 'shipment' to be sent together on the next stage.

The risks associated with the nine steps listed above must be addressed for each RTG through:

- The decommissioning plan (programme and project specification);
- A safety analysis report; and
- The environmental impact assessment (EIA).

Each of these should be developed for each batch of RTGs before work starts to decommission them. There will be manycommon features in the programmes and safety assessments between different RTGs, but they should be tailored to take account of the specific characteristics of each batch or each RTG (location, history, operating conditions, etc.) and the specifics of the decommissioning process for that batch or RTG (working plan-schedule, planned process and transport, dismantling schemes, expected physical condition and radiation situation, etc.).

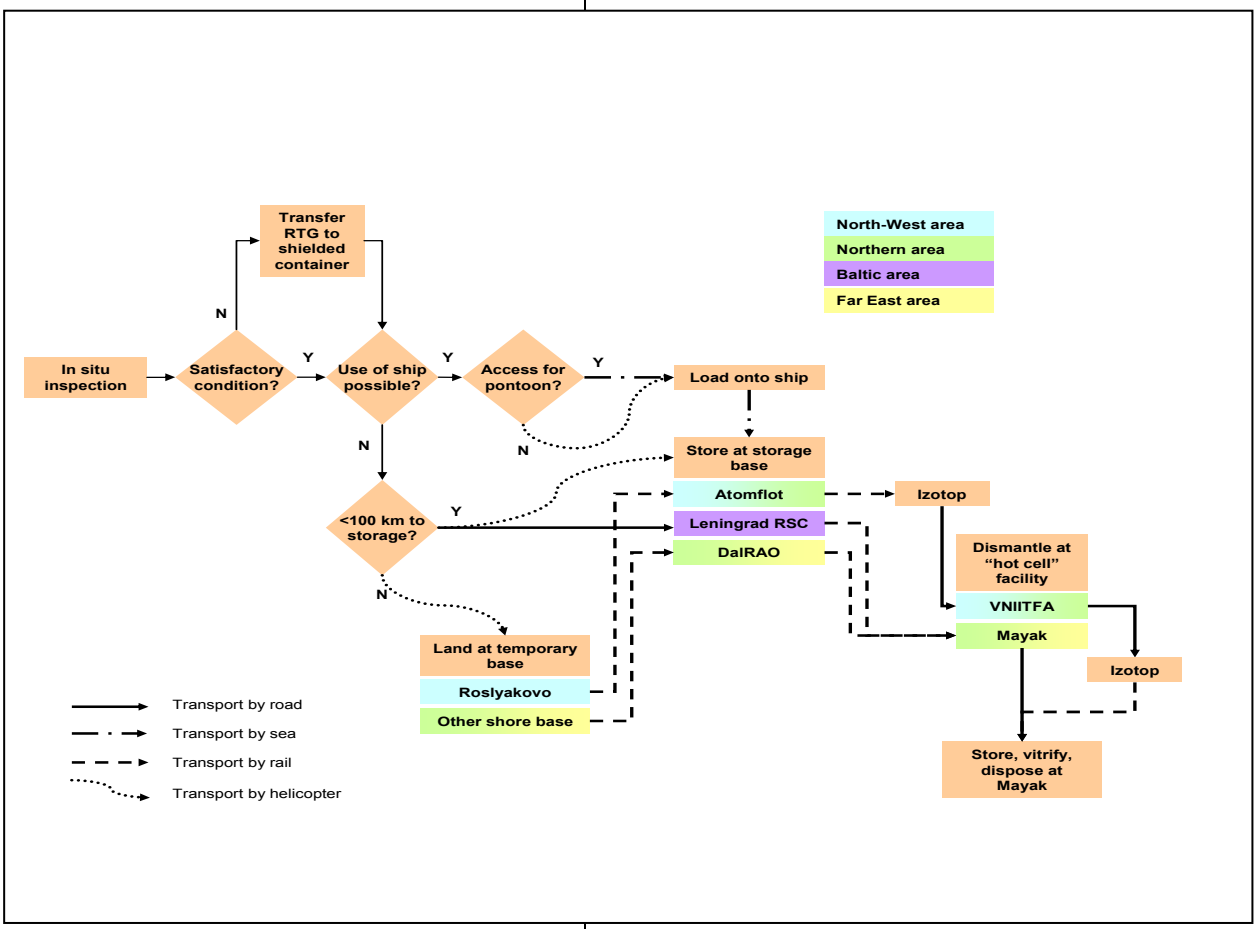


*Figure 2 Flow diagram of RTG decommissioning*

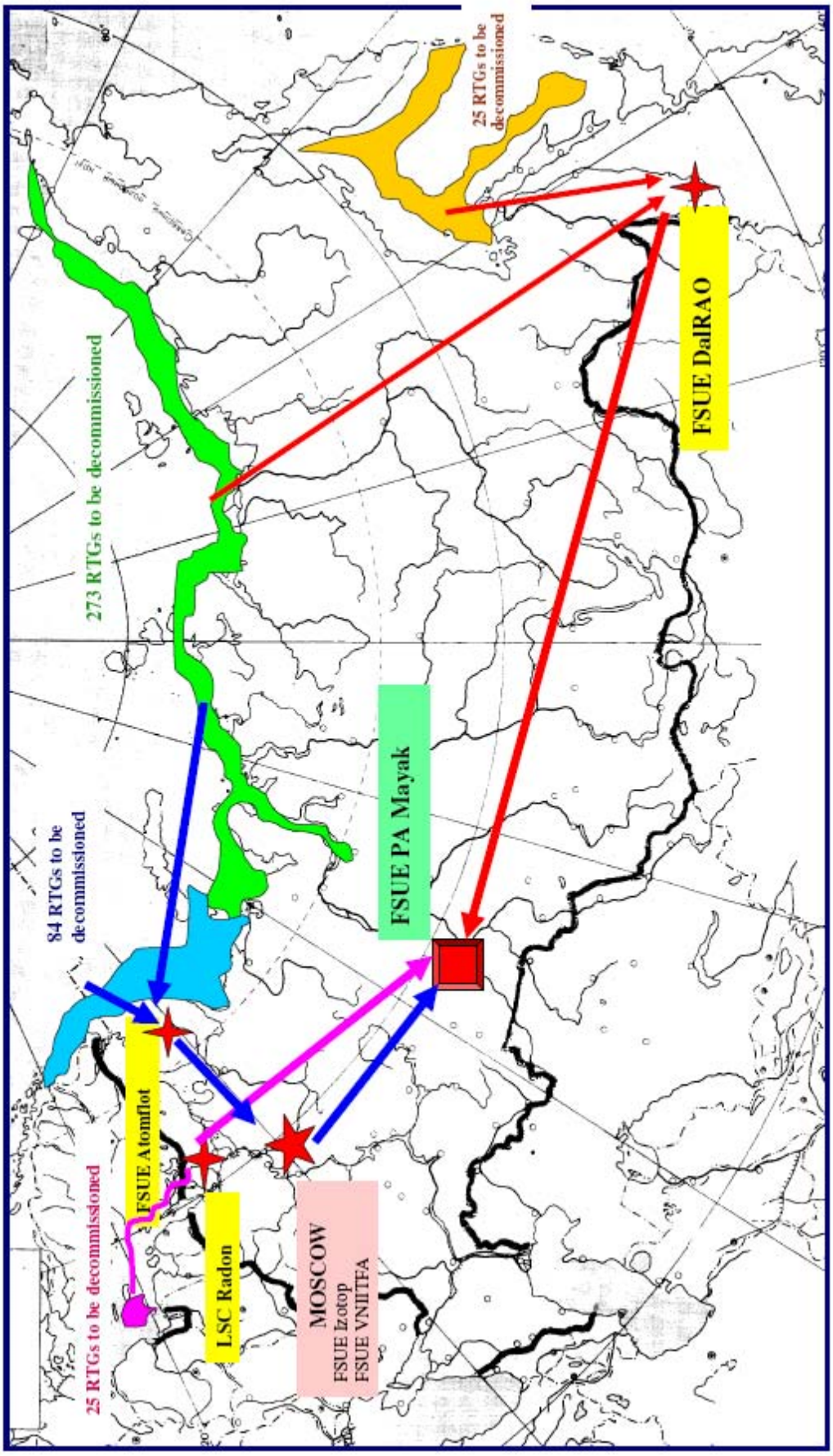


*Figure 1 Map of RTG decommissioning routes*

## 2.3. Regulatory Issues

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 and ultimately for disposal.

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 whether surface radioactive contamination of a product and within the area around it is available, and its magnitude.

Based on the engineering examination and radiation survey the operating organisation shall develop a RTG decommissioning programme 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 need for inter-departmental coordination of RTG decommissioning activities. The following organisations are involved in RTG decommissioning activities:

- FSUE "All-Russia Scientific and Research Institute for Technical Physics and Automation" of Rosatom (VNIITFA);
- FSUE "Production Association "Mayak" of Rosatom (PA Mayak);
- FSUE All-Regional Association "Izotop" of Rosatom (Izotop);
- FSUE "Base for Special Shipment" of Rosatom ("Base for Special Shipment");
- FSUE of atomic fleet of the Transport Ministry of Russia (Atomflot);
- FSUE Engineering Works "Zvezdochka" (Zvezdochka);
- Hydrographic Service of the Northern Fleet of the Defence Ministry (HS NF);
- RHBZ Depot of the Northern Fleet of the Defence Ministry;
- Murmansk Aviation Company Ltd.

Now this coordination is being carried out by the Federal Atomic Energy Agency (Rosatom), to which such subordinate organisations as VNIITFA, Izotop, PA Mayak, and the "Base for Special Shipments" belong.

*Tranportation by boat. Photo: County Governor of Finnmark*

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, programmes, contracts and projects;
- establishment of the infrastructure for the safe temporary storage and transhipment 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 (Ministry of Defence, 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, alarm, physical protection and control systems for the operating RTGs;
- RTG decommissioning and delivery to the place of their temporary storage and shipment;
- RTG replacement by alternative electric power supply sources (if necessary);
- providing for the temporary storage of decommissioned RTGs at subordinate enterprises.

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;
- supervision of safety in RTG operation and disposal.

A draft progress report (Rostechnadzor, 2006) on Task 3 of the project (on regulatory supervision/inspection) identifies nine key regulatory issues:

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

These nine regulatory issues are described in more detail in Appendix B.

The nine regulatory issues listed above are addressed in the first instance through regulatory review of the three reports listed in the previous section: the decommissioning programme and project specification; the SAR and the EIA. This a priori review is then supported by inspection and review activities throughout the course of the decommissioning operations.

*Gathering RTGs and preparing for transport by boat. Photo: County Governor of Finnmark*

## 2.4. Analysis of regulatory issues and decommissioning steps

The steps in decommissioning and key regulatory issues are defined on the basis of initial project reports [Rostechnadzor, 2006]. Cross-checking of these issues is carried out through the following four types of inspection:

- Inspection of preparedness;
- Inspection of safety;
- Inspection of compliance; and
- Inspection of storage conditions.

Inspections of preparedness are intended to verify that the administrative and technical (preliminary) stage of the work on RTG decommissioning activities has been carried out satisfactorily.

The inspections of preparedness of operating organisations, as a rule, 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.

The inspections of transport organisations, as a rule, 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).

The inspections of preparedness of organisations exercising temporary storage of RTG 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.

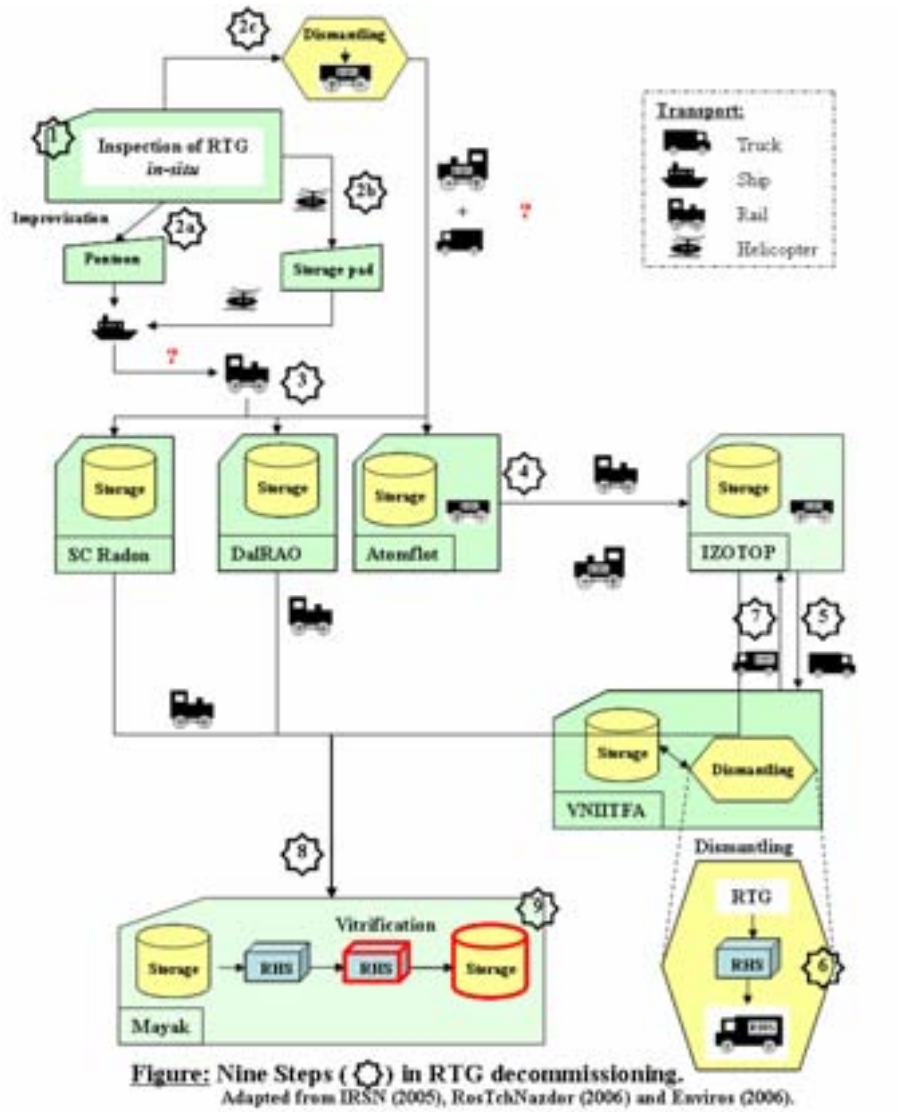


**Figure:** Nine Steps (⬡) in RTG decommissioning.
Adapted from IRSN (2005), RosTchNazdor (2006) and Enviros (2006).

Inspections of safety are conducted during field 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 and 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.

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

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.

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

- inspection and dismantling reports for the RTGs decommissioned in the course of inspected stage of the work;
- final documents drafted based on the results of inspections of preparedness and safety;
- reports on investigation of the violations in the course of the decommissioning work;
- other information about the achieved level of safety in the course of the completed stage of the work on decommissioning.

Prescriptions requiring the operating organisation to revise the work process for decommissioning or to introduce changes in the administrative and regulatory documents shall be given in the case of discrepancies in the documents, violations of radiation safety principles or any reasons for the above, weak points in quality assurance and radiation protection programmes, or in other documents for radiation safety assurance.

The inspections of storage conditions shall be planned, organised and conducted by the Rostechnadzor territorial offices that have specialised centres for temporary storage of decommissioned RTGs (RHSs) in the territory under their supervision.

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

Using the two lists – steps in the decommissioning process and regulatory issues – a matrix can be developed to provide a checklist of potential issues for each step of the decommissioning process. On the basis of experience gained to date through the types of inspection described above, each combination of a regulatory issue and a step in the decommissioning process can then be put into one of the following categories:

- The issue is not important for that step of the process (-);
- The issue is important for that step of the process, and so is subject to regulatory inspection, but is already adequately addressed by existing regulatory processes (✓);
- The issue is important for that step of the process, and further regulatory development is necessary to address it adequately (★).

In this context, a regulatory issue is important if failure of the regulator to address the issue adequately could significantly affect the radiological risks to workers or the public or significantly hinder the progress of the RTG decommissioning programme.

A major aim of this threat assessment is therefore to identify combinations of issues and stages that are of the third type (★).

| 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 adequately by existing processes; ★ indicates a priority issue where further regulatory development is needed.

# 3 Conclusions

This section summarises the priority radiological threats and the technological and regulatory actions in place or needed to reduce the risk associated with those threats, as identified in section 2, and proposes a provisional set of priority regulatory activities aimed at ensuring that adequate regulatory control is maintained over the whole RTG decommissioning process.

## 3.1. Radiological threats

RTGs represent a large hazard in terms of potential local effects on individuals, but a small hazard in terms of potential wider impacts on the general population or contamination of the environment. This can sometimes cause differences, in categorising them on the basis of hazard, between systems that focus on potential harm to an individual and those that focus on the potential extent of harm.

The physical form of the RHSs is intended to make it very unlikely that significant dispersion or leaking of activity could occur except under extreme conditions such as:

- Very severe impact or crushing;
- Very intense and/or prolonged fire;
- Long term immersion in water (e.g. in the sea); or
- Explosion (presumably a deliberate act).

Some observations of damaged RTGs have been suggested as indicating some form of 'leaking' of Sr-90 in other circumstances due to unknown physical or chemical processes. The evidence for this is inconclusive, but should be investigated further.

In the absence of plausible dispersion mechanisms, there is in most cases little potential for significant radiological impact due to intake of Sr-90. [For the unlikely cases of dispersed Sr-90 from RHSs, it may be noted that, in the form of $SrTiO_3$, Sr-90 is a significantly greater hazard via inhalation – 0.16 μSv/Bq – than ingestion – 5.4 nSv/Bq.]

The primary threat is direct exposure to radiation from the source – whole body exposure to gamma radiation (Bremsstrahlung) and skin exposure to beta radiation. Since the source is of very high activity, the potential dose rates are extremely high. With proper shielding in place – i.e. with the RTG casing intact or in an approved transport package – the dose rates should be sufficiently low to allow safe handling. High dose rates can only occur in the event of damage to the RTG or to RHS packaging, or during transfer of an RHS from the RTG to a transport package. (see Section 3.2).

## 3.2. Actions to reduce the threats

Proper control of RTGs to reduce these threats requires correct actions by the operator, who is primarily responsible for safety and security, complying with laws, regulations and regulatory guidance, but also using the 'ALARA' approach, and effective supervision of these actions by regulators.

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
- 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:

- Clear allocation and understanding of responsibilities: between operating organisations involved in different stages of

the process with different RTGs; between operators and regulators; and between different regulatory and supervisory authorities.

- 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)
- Regulatory supervision and inspection to ensure this is all done

The key operator actions to reduce the threats are therefore:

- Manage the handling of intact RTGs and packaged RHSs such that doses to workers are kept low;
- Develop and apply effective procedures for managing RTGs found to be damaged or defective, to make them safe while minimising the doses and risks to personnel;
- Apply technical and administrative safety measures to prevent (as far as possible) accidents or incidents that could damage RTGs or RHS packages at all stages of the decommissioning process,
- Apply technical and administrative security measures to prevent (as far as possible) unauthorised access to RTGs or RHSs (whether with malicious or misguided intent) at all stages of the decommissioning process,
- Develop, and apply if necessary, emergency measures to mitigate the consequences of any accidents or incidents, or breaches of security, that may occur.

Preparation for transportation of RTGs (according to 2004-2005 work practice) is carried out, as a rule, by an expert team of six persons. The team members arrive at the RTG location and dismount the RTG using special tooling; after which they prepare for transportation (attach the product onto the helicopter as an external load, deliver it to the coast by towing, load onto pontoon, etc., as appropriate). The duration of the work is about 3 hours.

For an RTG in satisfactory condition the external dose rate at 1 m form the 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 dose received by each individual during preparation for transportation of each RTG will be 0.3 mSv, and the collective dose will be 1.8 $10^{-3}$ man Sv.

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 be 0.038 man Sv.

For RTGs in "emergency condition" (i.e. damaged), the first step is to analyse the dose rate. This will depend on the nature and cause of the damage.

For example, an RTG dropped, during transport by helicopter, from a height of 100 metres onto rocks will experience stresses close to the mechanical action stated in specifications for RTG as a special type of radioactive material. (If dropped from 40–80 m onto 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.)

As a result of a real accident in September 2004, where two RTGs with RHS-90 (radioactivity ~ $4.3\times10^{15}$ Bq) were dropped onto rocks from the altitude 100 m after emergency release from helicopter external

load, the level of gamma radiation from a damaged RTG was approximately 0,8 mSv/hour at 2 m, and 52–55 μSv/hour at 5 m. No radioactive strontium-90 release from the RTG was registered.

The calculated dose rate at 1m was 3.2 mSv/hour, i.e. approximately 30 times higher than the value established by GOST 18696-90 and NRB-99. This value is taken for calculation of the emergency dose to which personnel would be exposed during operations with emergency RTGs. In such case, the repair team labour time for detection, repair, packing and preparations for transportation by helicopter will be about 6 hours (i.e. 36 man-hours for a 6-person team), and during operations at the distance of ~ 1 m from the emergency RTG the dose received by personnel will be up to 20 mSv, a collective dose of 0.12 man Sv.

Handling of the RTG accepted as emergency ones is described as regards the operations fulfilled through storage facility of the RHBZ of the Northern Fleet (at Roslyakovo, several km north of Murmansk).

The emergency RTGs are supposed to be delivered from settlement Roslyakovo 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 collective dose received by personnel in the course of repair, packing and preparation of all emergency RTGs for transportation, is calculated as above, with a correction for the activity of the RHS in the particular RTG.

So, for the RTGs with RHS -90-230, without biological shielding, the maximum dose rate is about 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 dose in such emergency situation would not exceed the emergency annual limit of 100 mSv established by NRB-99. 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.

A systematic process is needed to put these actions into place, based on a detailed decommissioning plan and safety analysis covering all steps in the process.

The regulators' responsibility is to ensure that there is an appropriate legal and regulatory framework in place to provide for these operator actions, and to ensure that operators carry out the necessary measures in a systematic manner at all times.

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 overexposure of the personnel who perform radiation hazardous works and eliminated radioactivity release to the environment.

The fundamental legal and regulatory basis exists in the Russian Federation for the safety of radiation sources, and this can be applied to RTG decommissioning, but there may be some

areas in which regulations more specific to RTGs might be helpful.

Several organisations are involved in carrying out and regulating the RTG decommissioning process. The respective roles of the organisations are generally well established in practice but the exact allocation of responsibilities is not always clearly defined. Allocation of responsibilities among different operating organisations is being addressed by Rosatom, to which several of the organisations are subordinate. However, the process also involves organisations subordinate to the Ministry of Defence.

Both the coordination of actions implemented by the multiple operating organisations and supervision of the activity implemented by divisions of the Defence Ministry during RTG decommissioning have been actual so far and requires permanent control. From 2003 this supervisory task has been assigned to Rostechnadzor. Consequently Rostechnadzor is now fully responsible for supervision of the whole RTG decommissioning process in the Russian Federation.. Consistency in this activity is needed between:

- The different regional offices of Rostechnadzor responsible for regulating RTG decommissioning in the different regions; and
- Military and civil operators.

*Lighthouse operated by solar cell batteries. Photo: County Governor of Finnmark*

Safety assessments have been carried out for the RTG decommissioning process, but decommissioning plans for RTGs need to be developed not later than one year before the end of the design service life of the source.

Regulatory inspections have been carried out of various aspects of RTG decommissioning, but these have not been based on systematic inspection procedures or schedules.

Assessments have been conducted of potential accidents and incidents during RTG decommissioning. The assessments do not appear to be fully comprehensive in terms of the whole RTG decommissioning process, and some issues appear unclear or contradictory. The worst case of the assessed accidents – in terms of the radiological consequence if it occurs – appears to be dropping an RTG with depleted uranium shielding from a helicopter onto land. However, the range of accidents considered in reaching this conclusion does not appear to consider all types of potential accident during all stages of decommissioning. Accidents during transport of RTGs or RHSs by rail and road, for example, do not appear to have been considered in reaching the above conclusion.

Actions to mitigate the effects of possible accidents are also defined, but are not currently fully comprehensive.

The legal and regulatory basis for physical protection of radiation sources in the Russian Federation is established, but does not specifically address issues associated with very high hazard sources such as RHSs.

As for safety, the general allocation of responsibilities for physical protection is reasonably clear, but there are areas of ambiguity due to the number of organisations involved and the military-civilian transition in RTG decommissioning.

An established system is in place for environmental impact assessment (EIA) of radiation hazardous activities in the Russian Federation. The Russian system differs in some ways from EIA systems in other countries. Guidance is also needed on how to apply the

system to the decommissioning of RTGs. (For example, the established system is based on assessing operations at a single site, and requires adaptation to be applied to a co-ordinated set of activities at different sites such as RTG decommissioning.)

## 3.3. Provisional regulatory activities

The threat assessment indicates a number of areas in which priority activities might be focused to further improve the effectiveness of regulation of safety of RTG decommissioning, as follows

1. Explicit agreement on the detailed allocation of operator and regulatory responsibilities for safety and physical protection throughout each step of the decommissioning process for each RTG;
2. Systematic and timely definition of decommissioning plans and specification of decommissioning projects, and regulatory approval of these
3. Thorough inspection prior to starting decommissioning operations
4. Preventing and responding to accidents during transport
5. Preventing accidents during transfer of RHSs from RTGs to transport packages
6. Physical protection of RTGs during transport
7. Long term management of RHSs at Mayak
8. Safety and security of collections of RTGs at temporary storage locations

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 1st and 2nd categories of potential radiation hazard – for the operating organisation to develop radioactive source (RS) decommissioning programme *not later than one year before the end of the design service life of the source*
- 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 programme 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 Programmes 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.

In the programmes 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 N 794 and of May 27, 2005 N 335. It is expedient to envisage "Emergency response" section in the programmes in accordance with the established requirements or to make a reference to a specific document (if available) which provide this information.

Assessments of potential accidents during the various stages of decommissioning RTGs focus on potential accidents during transport. It is stated that these represent the greatest risk in the RTG decommissioning process. This may be true, but is not demonstrated to be so.

In particular, possible accidents during the dismantling of RTGs at VNIITFA or Mayak do not appear to have been assessed because they are not considered credible. However, at least for undamaged RTGs, the removal of an RHS from the RTG and placement of the RHS in a transport package is the only time at which the RHS is not inside shielding, and so any accident during this operation would potentially have severe consequences, even if only locally.

Such accidents may be unlikely, but they are not inconceivable – engineered systems and human procedures are never 100% reliable – and some assessment of possible accident scenarios should be carried out.

Such scenarios would not involve significant release of radioactive strontium to the environment, but could result in substantial overexposure of operators and possible local contamination.

*FSUE Mayak's storage hall with RTGs and other radioactive sources.* *Photo: County Governor of Finnmark*

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# Appendix A: Steps in RTG Decommissioning

The main stages of the works for decommissioning of RTGs, the tasks to be performed in each stage and their sequence, and responsibilities for carrying out the tasks are determined mainly by the Federal regulatory document "General Safety Provisions for Radiation Sources" (NP-038-02) and the interdepartmental regulatory document "Rules for operation and decommissioning of radionuclide power installations on the basis of Sr-90 radionuclide thermal sources". They are presented in the "Justification of environmental and radiation safety of RTG disposal operations" [Rosatom, 2004] and in the draft Regulatory Guide [Rostechnadzor, 2006].

The main text refers to nine basic steps in the decommissioning of RTGs. These nine steps are discussed in more detail in this Appendix.

It should be noted, however, that these nine steps in decommissioning do not explicitly include:

- Review of the decommissioning programme and project specification, safety analysis report and EIA (inspection of preparedness);
- Operator's review of the inspection results, safety data, and final documents on safety inspection (inspection of compliance); and
- Inspection of RTG/RHS storage at temporary storage facilities (inspection of storage conditions).

Although these are not explicitly steps in the decommissioning process, they are very important tasks, and are addressed by special inspections (see Section 2.4 of the main text).

**1. Operator's inspection of RTGs in their place of operation**

The RTG is examined in the place of its operation to identify whether it is possible to transport it in accordance with the existing regulatory and technical documents and transportation rules.

This work is carried out by a Working Group of Rosatom's Central Commission, including the operator. A report produced by the Working Group 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.

There are currently no special procedures for these examinations. At the same time, the draft Regulatory Guide under development [Rostechnadzor, 2006] includes the list of issues designed for a regulator to inspect for each topic, and this may also be useful as a guide for operator inspections.

**2. Recovery of RTGs from their operational locations and loading onto a ship**

The following transportation schemes (combinations) have been used for transfer of RTGs from their operational locations to ships:

**First scheme**

- Relocation of an RTG from the site of operation to the shore line by improvised means (e.g. dragging by helicopter);
- Loading onto pontoon and fixing buoy to the RTG for the case of 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; and
- Transportation of all RTGs to Atomflot (or Kandlaksha Commercial Port) for subsequent loading to railcars.

**Second scheme (for cases of restricted access to operational location)**

The second scheme is used in cases where the local conditions prevent the pontoon and/or ship getting near enough to the operating location of the RTG, and is as follows.

- Organising an RTG interim storage pad on the shore;
- Transportation of the dismantled RTGs with fixed buoys by helicopters as an external load to the interim storage pad. Before fixing an RTG 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.
- After 10–12 RTGs are accumulated on the pad – loading to the vessel using a pontoon, and transportation to Atomflot.

The first and second schemes are carried out by the Chemical and Radiation Protection Service of the Northern Fleet (under the Ministry of Defence) and VNIITFA, with the assistance of the Murmansk Air Company where use of helicopters is necessary.

**Third scheme (for damaged RTGs)**

A third scheme is used if the RTG is found to be damaged to the extent that the RTG structure is not adequate to serve as 'packaging' for transport. In this case, VNIITFA performs a special operation: packing of the damaged RTG into a special shielded transport container with an overpack produced by VNIITFA. The damaged RTG is shipped in this transport package.

The third scheme in full is therefore:

- Delivery to the location of the damaged RTG (by road, boat or helicopter) of the specially manufactured shielded container and overpack, required equipment and process tooling;
- Re-packing of the damaged RTG into the shielded transport container and overpack provided by VNIITFA according to the developed and approved regulations;
- Putting the transport package in transportation conditions; determination of the transport category (it shall be not higher than Category III) and surface contamination of the shielded container by radioactive substances ("removable" radioactive contamination by radioactive substances is not allowed); delivery by the road vehicle (or by helicopter as an external load) to the interim RTG storage pad, and then – to the RHBZ SF Depot at Roslyakovo to be loaded onto a special railcar;
- Transportation by the special railcar to Atomflot and loading along with other dismantled RTGs to be transported to FSUE Izotop.

**3. Transportation of RTGs to a temporary storage facility, short-term storage and transfer to train**

Transportation to the temporary storage facilities (Atomflot or Kandalaksha Port) is provided, as a rule, by ships of the Hydrographic Service of the Northern Fleet (similarly, transport to DalRAO is provided by hydrographic ships of the Pacific Fleet). In the Baltic area it is planned that the decommissioned RTGs will be transported mainly by road to the Leningrad "Radon" facility designated as a temporary storage facility.

In some cases, where ships cannot gain access, use of helicopters for these purposes may be necessary.

**4. Transportation of RTGs by rail to facility for dismantling**

At present, the only permanent "hot cell" suitable for removing RHSs from RTGs is at VNIITFA in Moscow Region, and this is used only for RTGs from the North-West area and part of the Northern area. A new hot cell will be constructed at Mayak for RTGs from the rest of the Northern area and from the Far East and Baltic areas. Therefore:

- RTGs from the North-West area are transported by rail to Izotop for onward transfer to VNIITFA;
- RTGs from the Northern and Far East areas are transported by rail to DalRAO near Vladivostok, and from there by rail to Mayak; and
- RTGs from the Baltic area are transported by rail from Leningrad SC Radon to Mayak.

RTGs are transported by the Ministry of Transport, using mainly special railcars supplied by the "Atomspeztrans" enterprise of Rosatom or by PA Mayak. The shipment is accompanied and supervised by VNIITFA.

**5. Loading onto trucks and transportation by road to VNIITFA**

RTGs to be dismantled at VNIITFA are unloaded from the train at Izotop and transported by road to VNIITFA.

This is carried out by staff of Izotop, with supervision of VNIITFA.

**6. Removal of RHSs at VNIITFA and loading of RHS packages onto trucks**

RHS removal is carried out in a hot cell at VNIITFA.

The RHSs are transferred into transport containers and loaded back onto trucks for transport back to the rail terminal at Izotop. This work is carried out by VNIITFA.

RHSs can be temporarily stored in VNIITFA in case of the delay in supplying the train.

After removal of the RHSs, the depleted uranium RTG cases are stored in VNIITFA and used by it to manufacture radiation shielding and shielded containers for other types of radiation equipment, or will be transferred to specialised enterprises for disposal.

**7. Transportation of packaged RHSs by road back from VNIITFA to Izotop and loading onto trains**

This is identical to step 5, except that the RHS is in a package instead of inside the RTG.

**8. Transportation of packaged RHSs by rail to Mayak**

RHSs are transported by the Ministry of Transport, using special carriages provided by PA Mayak, and shipments are accompanied and supervised by PA Mayak.

**9. Processing of RTGs and RHSs at Mayak**

It is planned to construct a "hot" cell at Mayak for dismantling RTGs transported from Leningrad "Radon" facility and DalRAO. At present, Mayak is dealing with arrangements for the long-term storage of RHS delivered from VNIITFA. RHSs from dismantled RTGs are managed at Mayak as follows.

The RHS containers having arrived to Mayak are unloaded. The RHSs are removed from the containers, examined and their compliance with the accompanying documentation (the disposal certificate of a batch of radioactive waste issued by VNIITFA) is established. After the compliance is established the received RHSs are categorised as high-level radioactive waste (HLW). It is disposed of similarly to the disposal of other high-level waste generated at Mayak, particularly vitrified HLW from the vitrification plant at Mayak.

The RHSs, along with vitrified HLW, are sent for a long-term storage in the specially 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 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 90°C) is collected in the upper channels running above the stands and, after filtering is released into the atmosphere. During the first year of operation of a storage cell 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 period in the above-ground storage facility the RHSs and vitrified waste are 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.

According to conditions of disposal of the vitrified waste in deep geological formations, the activity in any canister must be such that before the canister 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).

# Appendix B: Regulation of RTG Decommissioning

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.

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:

- The legal and regulatory framework within which practical activity related to safety in the use of atomic energy is implemented;
- 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.

The legal and regulatory framework in the field of use of atomic energy comprises (in order of precedence:

- Federal Laws;
- Presidential Acts and Governmental Decrees of the Russian Federation;
- Federal standards and rules;
- Guiding documents of state safety regulatory authorities (such as Rostechnadzor); and
- Standards and rules of the state bodies for control of the use of atomic energy.

In particular, the Federal Laws existing in the field of use of atomic energy include:

- "On the Use of Atomic Energy";
- "On Radiation Safety of Population";
- "On Environmental Protection";
- "On Protection of Population and Territories against Natural and Man-induced Emergency Situations";
- "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 sources (RSs)[3] 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 exceeding 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 a source of radiation contamination.

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 Uniform 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).

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 siting, construction, operation and decommissioning of radiation sources including RTGs.

The next set of requirements for handling, operation and decommissioning of radiation 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);

3 The abbreviation RS is used to refer to the regulatory term radiation source meaning a regulated entity that causes radiation exposure, to distinguish it from the use of the term source meaning a single piece of radioactive material, such as an RHS. An RS may be a facility or installation, and so may include several sources. In the context of this report, the RTGs present in a single navigation aid constitute a single RS, although they contain several sources (RHSs).

- 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.

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.

**Prior assessment of safety**

As discussed in Appendix A, one of the issues for regulators is review of relevant plans and assessments prior to RTG decommissioning. This includes regulatory review of the decommissioning programme and project specification, a safety analysis and environmental impact assessment (EIA).

The federal standards Requirements to the Contents of the Safety Analysis Report for Radiation Sources (NP-039-02) 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.

The SAR RS shall include the following sections:

- Introduction
- Description of the location region of the radiation source
- Basic information about the radiation source
- Safety concept for the radiation source
- Organisation of the radiation safety service unit
- Safety justification for commissioning and operation of the radiation source
- Physical protection of the radiation source
- Analysis of possible radiation accidents and emergency planning
- Radiation source decommissioning
- Quality assurance

As can be seen from this list, one of the Sections that must be in the SAR RS is "RS Decommissioning" which should present:

- Results of the engineering examination and radiation 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 are provided for at 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 ensuring security of radioactive waste, contaminated equipment, instrumentations, fragments of biological shield etc. generated during the decommissioning);
- Generation of minimum volume of radioactive waste during the RS decommissioning, 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.

The justification of ecological and radiological safety of works for the decommissioning of RTGs in the Russian Federation is contained in the "Ecological assessment of the impact on the environment and human being" which is submitted as part of the Justification of Ecological and Radiological Safety of the Works in Decommissioning of RTGs [Rosatom, 2004] by the following organisations which participate in performing the works: VNIITFA; PA Mayak; Atomflot; and the Department of Natural Resources and Environment Protection of the Ministry of Natural Resources 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.

**Regulatory issues**

The main text refers to nine fundamental regulatory issues identified as being relevant to the decommissioning of RTGs. These nine issues are discussed in more detail in this Appendix.

**a. Compliance with terms and conditions of licences, permissions and implementation of previous orders**

The following shall be inspected:

- Compliance, in the course of RTG decommissioning, with the safety requirements preset in Rostechnadzor licence conditions.
- Availability of Rostechnadzor permissions for the right to perform the work in the

FSUE by corresponding personnel of the organisation.

- Fulfilment of the Rostechnadzor permission conditions by the personnel of the organisation.
- Conformity with the restricting conditions specified in:
  - the Rostechnadzor and Rosatom decision "On transportation of RTG packages (RHS-90, RHSu -90) by helicopter on external load";
  - permit-certificates for transport packages design and transportation;
  - sanitary and epidemiological findings on compliance of the performed work with the state sanitary and epidemiological rules and standards.
- Conformity with the limitations established to ensure safety during transportation of hazardous freight class 7 (radioactive substances).
- Character of the detected violations of safety requirements, timeliness and completeness of implementation of the prescriptions.
- The level of radiation safety achieved and registered in radiation and hygienic certificates for the previous two years.

### b. Operator's personnel selection and training

The following shall be inspected:

- Availability at the working stations of permission copies issued by the Service and certified by the organisation Head to carry out the activities at nuclear facilities (NF). Organisation of control on compliance with the standards and rules at NF and with permit conditions.
- Inspection of administrative orders on:
  - 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;
  - assignment of radiation safety unit or the person responsible for radiation safety control (radiation safety duty);
  - 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);
  - determining the list of individuals referred to personnel of Group A and B;
  - work permission for the personnel dealing with radiation sources (approved list of the individuals having permission to work with radiation source);
  - 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);
  - forming a commission for inspection of RTG radiation and engineering condition in the location of operation, and appointment of the commission chairman;
  - assignment of a person responsible for transfer of information about the violations taking place in the course of decommissioning work;
  - availability of the programmes for personnel training and initial briefing or re-briefing on the occupational safety and health agreed by the relevant state supervision bodies.
- Conformity with the preset periodicity of knowledge testing and availability of the relevant protocols.
- Inspection of logbooks (cards) of briefings, conformity with the preset periodicity of briefings on radiation safety measures during the work
- Documents confirming special training of the person responsible for radiation safety.

- 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:
  - safe methods in conducting engineering process operations in the course of the work;
  - requirements to the use of individual protection and sanitation means in the course of process operations;
  - procedure of work with individual dosimeters;
  - engineering and radiation characteristics of the RTG, its systems;
  - requirements to the RTG as a radiation source;
  - peculiarities of the RTG location at the sites of operation, including the approaches to above;
  - procedure of operations on replacement of shielding containers for different RTG types;
  - safety requirements at planned stages of decommissioning activity.
- The operating organisation personnel involved in the work on fastening (unfastening) the radiation packages on the external load of helicopter, should pass special programme of theoretical and practical training and be provided with permits for operations with external load.

### c. Regulatory inspection of RTGs prior to decommissioning

The inspection commission conducting the RTG survey in the locations of operation shall include representatives of the operating organisation, executive authorities for the use of nuclear energy (Rosatom), the RTG designers (VNIITFA), state bodies for safety control during the use of nuclear energy (Rostechnadzor), and bodies of state authorities of the region of the Russian Federation where the RTGs are located (upon agreement).

Inspection efforts are focused on the organisation and technical support of RTG survey in the locations of operation:

- Availability of the 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.
- Verification of the inspection programme. Availability in the programme of the procedure to verify correspondence of radiation parameters for the case when the surveyed facility incorporates an RTG group.
- If there is sufficient retrospective information gathered in the course of RTG operation, the RTG inspection programme in the location of operation can be shortened by the decision of the operating organisation. Such decision shall be agreed with the RTG design experts.
- It is recommended to take, during the survey, photos of the RTG at the 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.

Organisation and technical support of radiation monitoring in the course of the work on decommissioning:

- List and technical characteristics of radiation monitoring facilities:
  - conformity of technical characteristics of the applied measuring instruments with the range of monitored parameters;
  - type of devices or facilities, year of manufacture;

- availability of sufficient individual dosimeters for the personnel of group A;
- technical condition of the measurement aids, availability of valid certificates on state metrological calibration test.

- Organisation of radiation monitoring in the zones determined in accordance with the category of potential radiation hazard and class of operations.
- Organisation of individual radiation monitoring of the personnel.
- 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.
- 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.
- In the course of inspections of safety (type 2) one should focus on:
  - conformity of the measured exposure rate with the limits established for the radiation packages of transport category «III-YELLOW» on exclusive use terms.
  - lack of mechanical damage to 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.
  - 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.
  - 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).
- Radiation parameters are:
  - presence or lack of removable radioactive contamination on the RTG elements;
  - 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;
- Engineering parameters are:
  - availability, completeness and oxidation level of shielding containers;
  - technical condition of load-bearing elements, sling units and RTG shielding containers;
  - condition of RTG fixing elements and units of the transportation package (shielding containers);
  - technical condition of external elements of RTG structure;
  - presence of any defects in RTG casing and the level of their impact on safety during dismantling and transportation of the given products;
  - condition of the welded joints in the structure of the product and shielding containers;
  - condition of the mechanical and lock joints in RTG casing.

By the results of inspection of each RTG in the location of operation, the commission drafts a Report which should contain unambiguous assessments, separately for the findings with regard to radiation inspection and with regard to engineering inspection of the RTG. Based 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.

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 programme of decommissioning.

If specified parameters do not comply with the preset criteria, the commission makes a decision whether RTG removal and transportation can proceed as planned. If they decide it cannot, the inspection report provides recommendations on the dates and most safe method of removal of the given RTG. Decommissioning of the given RTG is carried out later, based on a permit-certificate for transportation under special conditions. A request for such a permit-certificate shall be made by the operating organisation on the basis of the inspection report, recommendations of the commission and RTG designer.

If the commission states, in the course of inspection, that the removal and evacuation process flow sheet does not take sufficient account of the impact from hazardous natural and/or technogenic factors, the RTG removal and transportation should not be carried out. Considering the recommendations of the commission with regard to the above factors the operating organisation shall redraft the RTG decommissioning project specification and agree upon supplements to the project with authorised bodies, according to the established procedure.

After dismounting the RTG from the navigational aid, a record is made in the RTG card and a report is formalised and signed by the individuals conducting the dismounting. After that it is approved by the operating organisation leader. The Deeds of inspection and dismounting are sent to the RTG designer, the territorial authority of Rostechnadzor, TU Rospotrebnadzor, Ministry of Interior, Rosatom and the departments operating with RTG (Ministry of Defence of Russia, Federal Agency of Sea and River Transport).

### d. Measures to prevent accidents and incidents and preparedness to respond effectively to any accidents or incidents that do occur

**Potential accidents**

Possible impacts of an RTG or RHS on the population and the environment are determined by its design and nature of impacts by which it can be affected the course of routine and anticipated accident conditions at their decommissioning work stages.

From the manufacturing through certification, storage, transportation, loading of RHS in RTG, testing, operation, return transportation until the disposal of the RHS, RTGs and their components can be affected by 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 on their origin.

In terms of environmental safety the highest hazard is posed by accidents where RTGs or RHSs can be affected by a combined adverse effect of a number of factors, including those that can last for long periods of time. For these conditions the ecological safety basis of RTGs 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 is securely confined under all plausible circumstances.

It is necessary to anticipate the following emergency impacts on RTG and RHS components, which would be certainly more extreme than impacts of the standard operation conditions:

- Heat impacts of fire at all RTG and RHS life stages;
- Heat shock in the event of an RHS being exposed to snow, ice or water as a result of accidental destruction of the RTG;
- Overheating in the event of an RTG or RHS being exposed to a low heat conductance environment (e.g. buried in sand or clay) due to a vehicle accident;
- Shock impacts during accidents with vehicles (collision, explosion, drop from the helicopter, etc.) where destruction or damage to the RTG casing or integrity of its radiation shielding is possible;
- External hydrostatic pressure following planned or emergency sinking of an RTG.

The potential impacts on RTGs or RHSs of possible natural cataclysms (landslides, earthfalls, floods, earthquakes, tsunami etc.) in the RTG locations are not expected to exceed the above impacts of man-made accidents.

Therefore, the highest potential hazard events for RTGs and RHSs are fires, drops from a height and sinking in the sea water, particular at great depths.

"The list of possible accidents during decommissioning of RTGs based on RHS-90" (Annex 7 of [Rosatom, 2004]] reviews all possible emergency situations during technological operations in RTG decommissioning. The assessment of 32 technological operations is performed which has revealed 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 the RHS is retained and Sr-90 release into the environment is prevented. Radiation shielding disintegration is possible, as well as radiation "shooting" from RHS, 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.

**Emergency preparedness**

The requirements to the personnel activities in case of radiation accidents and incidents are given by the "Programme of RTG decommissioning from the facilities of hydrographic service of the Northern Fleet" issued in 2005.

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 1st 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.

In accidents of the 2nd and 3rd 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 sequence: consignor; consignee; carrier organisation; police authorities; civil defence and emergency response authorities; nuclear safety regulatory authority; and nuclear energy authorities.

The Programme presents the routine of emergency works in mitigation of a radiation

incident in the region of the city of Kandalaksha or in Kola Bay; it names the organisations which participate in mitigation of the radiological consequences, namely:

- Three services 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 or Murmansk;
- State Sanitary and Epidemiological Service;
- Administration of the city of Kandalaksha or Murmansk;
- Administration of Murmansk region.

VNIITFA's radiation protection programme does not determine activities in an emergency, and 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:
- the prompt report has to be transmitted within 1 hour after the violation was revealed;
- the content of the prompt report;
- who is the addressee of the prompt report in accordance with class A;
- the preliminary report is transmitted within 24 hrs after the violation is revealed;
- 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.p. 3.1.8 and 3.1.9.

**Issues for regulatory inspection**

The following shall be inspected:

- Conformity of radiation facility location and zoning with the project specification (sanitary and epidemiological findings);
- Availability of the procedure of transfer of information on radiation accidents and incidents contained in the administrative and regulatory documents;
- The resolution of the organisation on the assignment of the individual responsible for real-rime information exchange on radiation accidents and incidents during decommissioning activities ;
- Instruction on accident prevention and elimination during RTG handling in the course of decommissioning activities;
- List of possible violations in the course of decommissioning activities;
- Prognosis of possible radiation accidents (depending on the distance between the facility and populated areas);
- 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;
- Instructions on personnel actions in case of emergencies;
- The programme for training and methodologies for emergency response training of personnel to perfect the action under radiation accident;
- The emergency response training schedule for personnel in the current year;

- The deeds and other documents on personnel emergency response training results in the current year;
- The resolution on establishing special emergency response team for ensuring the decommissioning activities;
- The technical and engineered devices for radiation accident localisation and consequence elimination;
- 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.
- Verification of the efficient operation of personnel alert system in warning the personnel, population and state authorities in case of radiation accident.
- Availability and completeness of:
  - emergency sets of personal protective equipment at the aircraft and special vehicle to carry out personnel and population protection measures;
  - emergency sets of engineered devices, first aid kits containing also spare sets for sanitary treatment of radioactive contamination zones;
  - Measuring instruments with expanded range of measurements allowing to measure the ionising radiation dose rate under conditions of design basis accidents;
  - communication means ensuring the required communication distance range.
- Procedure for informing about radiation and non-radiation incidents and compliance with the established requirements.
- 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.
- Level of awareness of the organisation personnel (officials) of:
  - list of possible emergencies and related action plan for liquidation of design basis accidents consequences;
  - procedure for investigation and accounting of violations during operations in the FUAE.
- Availability, staffing and preparedness of special unit (emergency team) to the actions during radiation accidents and consequence elimination.
- Completeness and timely investigation of radiation accidents and incidents, implementation of measures to eliminate the causes.
- Compliance of actual periodicity of emergency preparedness training (exercises) with the methodology of their organisation and performance.

### e. Transportation of RTGs and RHSs

Regulations for transportation include a combination of basic requirements that depend on the material to be transported but not the mode of transport, particularly in relation to packaging, and more detailed mode-dependent regulations reflecting the specific characteristics of transport by air, sea, inland waterways, rail and road.

The **Safety Rules for Transportation of Radioactive Materials (NP-53-04)** establish safety requirement for transportation of radioactive materials including requirements to 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).

The Safety Rules include sections on "Measures to be taken in case of accidents during transportation of radioactive materials" and on "Physical protection requirements for radioactive materials".

For radioactive material shipments, including RTG shipments, certificates-permits can be issued in the Russian Federation:

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

Transportation of RTGs and RHSs in satisfactory condition requires type B(U) or type B(M) packages: the structure of an undamaged RTG itself meets the requirements of a type B package without any further packaging, but RHSs are transported in separate packages. For damaged RTGs, transportation under special arrangement is necessary.

The following types of transportation are used for particular steps in the RTG decommissioning process:

- Improvised methods to drag or lift RTGs from their operational location in a navigation aid to the loading point for transportation. This may be done by helicopter, winching equipment or manually, depending on local circumstances;
- Transport of RTGs by **air**. For RTGs in locations where a ship cannot berth securely nearby, helicopters are used to transfer the RTGs to the ship. Although the distances travelled are usually relatively short, the RTGs typically have to be attached to an airborne helicopter and carried suspended from the helicopter in slings, rather than inside the helicopter.
- **Towing** of RTGs at sea. Some RTGs are towed, with the assistance of pontoons, from their operational locations to the ship.
- Transport of RTGs by **sea**. RTGs are carried by ship to ports having railheads, from which they can be transported by rail.
- Transport of RTGs and RHSs by **rail**;
- Transport of RTGs and RHSs by **road**. This appears to be used only for the relatively short distance between FSUE Izotop and VNIITFA. RTGs are taken to VNIITFA, where the RHSs are removed in a hot cell, and the RHSs are then put into packages and returned to Izotop for further storage and onward transfer to Mayak.

The safety requirements established by the existing certificates-permits and interdepartmental regulatory documents are summarised below for each mode of transport.

Rostechnadzor officials recommend that incorporation of the necessary safety requirements mentioned below into the administrative documents (procedures, instructions) of the transport organisations should be checked while concurring safety procedures for transportation.

***RTG Transportation to Fixing Site by Towing by Helicopter***

RTG transportation by towing is carried out in the cases when the product is located either in the immediate vicinity (up to 15 m) of the navigational aid from which the RTG is evacuated, or within its land surface projection area.

The helicopter should be equipped with lengthened cables and a "spider" for external load, subject to their total length exceeding the height of the navigational aid by no less than 10 m. The helicopter shall hover over the RTG, and the radiation package shall be fixed and the

package transported on external load to a convenient place.

It is prohibited to use a helicopter for towing RTGs within 5 m of a navigational aid, and the hovering height must exceed the height of the navigational aid by at least 10 m.

For the purpose of movement, it is allowed to use wooden or metal levers with length of at least 2.5 m. It is recommended to perform RTG movement in such a way that the workers would not approach RTG closer than 1 m.

During RTG transportation by towing for fixing to external load, measures to exclude the possibility of RTG overturning, should be envisaged.

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 as described below.

If further RTG transportation on helicopter external load to a significant distance is supposed:

- After moving the RTG a sufficient distance, the aircraft shall land at a safe distance (of 30-40 m) from the navigational aid; and
- The cable system shall be replaced for a shorter one to be applied for further transportation of RTG by air.

***RTG Transportation to Vessel Freight Area by Towing***

RTG 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.

The application of the given method of transportation in the course of RTG decommissioning is accepted if the following conditions are fulfilled:

- The commission concludes that it is impossible to apply other transportation methods;
- 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); and
- Measures are taken to prevent the RTG from overturning.

The route of supposed RTG transportation by towing shall be photographed, the photo is to be attached to the inspection deed.

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. 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.

***Safety Measures during RTG Transportation by Helicopter***

The use of helicopters for transportation of a dismounted RTG (RHS) as an external load to a sea vessel or to a shipment area is the principal method of RTG recovery applied in the course of RTG decommissioning process.

The Consignor should report to FSUE "Situation and Crisis Center of Rosatom" and FSUE "Emergency Technical Centre of St. Petersburg" on the starting time of transportation well in advance.

Before the helicopter take-off to travel to the navigational aid for participation in the field stage of the work on RTG decommissioning, it is necessary to provide:

- briefing of helicopter team and technical personnel on hazardous freight character, specifics and handling procedure;
- briefing of trained employees of the operating organisation participating in

preparation of RTG radiation packages for transportation, as well as fixing (unfixing) for helicopter external load.

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.

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:

- the name and trade mark of the manufacturer;
- the sling hoisting capacity;
- the date of next testing (month, year).

The transportation route should be agreed on with the operating organisation. It should not pass over residential areas and industrial works, and the flight time over the water surface should be minimised.

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 colour against the local background.

Visual checking of the package fixed at load carrier prior to transportation, state of package fixing during and after transportation should be provided.

Additional requirements during transportation route over the water area:

- 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.
- The aircraft should be equipped with operating GPS (Global Position System) receiver, ensuring the coordinates error of no less than ± 20 m.

Additional safety measures during transportation:

- Transportation of no more than one RTG radiation package on external load is permitted.
- Just before start of transportation operations a confirmation of favourable weather conditions on the entire route, with favourable stable weather forecast up to the end of transportation, should be received.
- 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.
- Radiation monitoring equipment should be available on board and the escorting person should be prepared to conduct operational radioactive control on board during transportation.

***Actions in Emergency during Transportation by Helicopter***

In case of an emergency threatening crew and aircraft safety the RTG package is subject to external load emergency release.

In the event of such an RTG emergency release the helicopter captain shall urgently report to the flight administrator when the situation is stabilised.

In case of emergency during transportation over the land:

- The freight should be released from minimum height on to sandy 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.
- The escorting person and crew shall immediately undertake measures to ensure safety according to emergency card requirements.

Following an emergency release, if the RTG structure does not appear to be severely damaged, the escorting person shall conduct an initial examination of the radiation situation by measuring the equivalent radiation dose rate (ERDR) approaching the RTG to a distance up to 1 m, initially from the side where the visible damage to external elements of the structure is the least:

- If, when approaching the RTG, the dose rate 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;
- If, when approaching the RTG, the measured ERDR does not exceed the $ERDR_{max}$, the escorting person shall take several measurements along a circular 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 damage;
- The maximum dose rate value obtained at a distance of 1 m is compared with $ERDR_{max}$:

Excess values ($ERDR > ERDR_{max}$) mean that the RTG physical barrier is damaged; in case of no excess, the physical barrier is supposed to have no damage.

It is prohibited to return a released RTG to helicopter external load for continued transportation until specialised studies have been held at the site where the released RTG landed for "removable" radioactive contamination of the RTG surface and radioactive contamination of the environment.

If landing near to the released RTG is impossible the helicopter should hover at a minimum but safe height above the released RTG. The escorting person and staff shall fix the coordinates using the helicopter's GPS, and visually assess the physical condition of the released RTG, take photographs, and, if necessary, hold radiation monitoring measurements at hovering height.

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.

In case of emergency release during transportation over the water area, the following measures are to be provided:

- As quickly as possible (following flying safety requirements) the helicopter shall descend and hover over the released RTG location (during 1-2 minutes there is a spot generated by the bubbles released by the product structure cavities);
- The emergency buoy should be released (if transported onboard the aircraft);
- The coordinates of helicopter hovering over the release location shall be determined by GPS. Repeated measurements should be taken to confirm the coordinates;
- The buoy shall be photographed on the water surface.

After return to the base after RTG 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.

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.

RTG radiation package emergency release should be classified as radiation accident class A. The released RTG is to be inspected by the commission in accordance with the programme 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.

***RTG Package Loading to Vessel and Transportation by Sea***

During RTG 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.

The vessel crew members involved in RTG stowage should be trained according to regulations.

The sea vessel crew members directly involved in RTG unfixing and on-deck positioning operations should:

- a) be specially briefed; and
- b) be equipped with personal protective equipment.

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.

Each RTG after loading should be reliably secured inside the hold. It is recommended not 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 radiation.

Upon completion of the vessel loading with planned quantity of RTGs the following is to be done:

- Radiation monitoring is carried out on the vessel deck and in the rooms adjacent to the hold, where RTGs are stowed;
- The vessel deck zone where ERDR exceeds 3 μSv/h, is fenced with radiation hazard signs;
- Measures are taken to limit the time of presence of crew members and escorting persons in the zone;
- Total radiation package transport index shall not exceed 200; and
- Measures are taken to prevent RTG overheating during transportation:
  - RTGs are not covered with any materials impairing the conditions of heat exchange to ambient air;
  - no other RTGs or freight is placed on the RTG upper surface;
  - a gap of not less than 200 mm is left between the RTG and the hold walls

***RTG (RHS) Package Transportation by Road***

During RTG (RHS) transportation by road, inspection should verify the availability of:

- Sanitary and epidemiological findings on the compliance with sanitary rules for carriers and transportation packages used for RTG (RHS) transportation;
- Certificates for transportation packages and equipment subject to certification in accordance with the legislation of Russian Federation;
- The programme for radiation protection of the personnel and population;

- Instructions for RTG (RHS) transportation and accident consequence elimination during transportation thereof;
- The action plan for the driver (escorting persons) in case of emergency;
- 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;
- 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.
- Condition of the transportation means and equipment used to transport RTG (RHS) and radiation packages.
- Preparedness of the escorting person (-s) responsible for radioactive freight convoy and the driver to transport RTG (RHS).
- 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.

In cases of RTG (RHS) transportation by the roads of general public use it is recommended that the shipment be accompanied by an escort car with trained personnel, instrumentation and personal protection emergency kits. By resolution of local or regional state authority bodies, the RTG (RHS) packages may be escorted by motor cars of the Road Police of the Ministry of Interior of Russia.

***RTG Transportation by Trailer for Loading Onboard Vessel***

The RTG delivery for loading to vessel should be scheduled so that pre-loading holding time would not exceed 3 hours. The parking site for RTG trailer should be remote from populated sites and from other transport facilities.

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.

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).

***RTG Package Loading (Unloading) to Special Railway Cars. Transportation by Rail***

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.

If the selected decommissioning plan suggests that RTGs are 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 motor car or trailer. Loading can be carried out either directly from external load or using hoisting machinery of appropriate power rating.

Transportation of RTG radiation packages in freight cars is allowed under conditions of exceptional use, subject to compliance with the following terms:

- The issue is agreed on with the federal executive body operating the RTG, the state sanitary and epidemiological supervision bodies and the Ministry of the Russian Federation on Civil Defense, Emergencies and Natural Disaster Consequence;

- The total transport index of transported packages does not exceed 50.

During radiation package transportation, the safety rules established for railway transportation shall be followed. Special railway cars with loaded RTG (RHS) radiation packages shall be transported by direct trains

### f. Compliance with radiation safety requirements

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

- The type of application for which the RS is used;
- The potential radiation hazard associated with the RS;
- The transportability of the RS; and
- The types of radionuclide source (sealed or unsealed) used in the RS.

RTGs are classified as stationary products containing sealed radioactive sources. Although they represent a large hazard to an individual who might come into contact with them, the hazard is very localised. They are therefore normally assigned to hazard category 4 – such RS where an accident causes the radiation impact limited by the premise where it is located – but the most hazardous RTGs are category 3 – such RS where an accident causes the radiation impact limited by the territory of the site or building where it is located.

The federal standards and rules provide for that the operating organisation shall develop Action Plans to protect personnel and population in case of accidents and eliminate their consequences taking into account source 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 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 programme 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 3 and 4 RSs in terms of the potential radiation hazard RS the decommissioning programme 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 possible. The radiation 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 radiation contamination level and monitoring of the surface contamination level of the site.

On the basis of the engineering examination and radiation survey the operating organisation shall develop the RTG decommissioning programme 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 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.

### g. Physical protection of RTGs and RHSs

***Distribution of duties and responsibility***

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 the 35 of the Federal Law "On the Use of Atomic Energy" an operating organisation bears full responsibility for safety 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.
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 RTGs in FSUE PA "Mayak".

***Analysis of the Russian regulatory basis***

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.

As regards the physical protection of radiation sources and radioactive substances the following **Federal 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 use of Atomic Energy" (Article 35) defines that the physical protection shall be ensured by operating organisations.

The Law does not include any detailed requirements related to the physical protection measures and determines only general areas that the physical protection system shall cover. According to Article 49 these are the following areas:

- 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.

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);

- Check of reliability, qualification requirements and absence of medical contra-indications;
- Liability for violation of the Russian legislation in the field of use of atomic energy. 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 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.

The following **Presidential Acts and Governmental Decrees** of the Russian Federation are relevant to physical protection:

- 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** 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.

As regards nuclear materials, nuclear installations, radiation sources and radioactive substances physical protection the following document may be attributed to this level of documents:

- Physical Protection Rules for Radiation Sources, Storage Facilities, Radioactive Substances (NP-034-01) effective since the 1st of June 2002.

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 determine:

- objectives of physical protection;
- physical protection requirements for radiation sources, radioactive substances and storage facilities;
- procedure to set up requirements for 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 following documents are also attributed to the federal standards and rules:

- Safety Rules for Transportation of Radioactive Materials, NP-053-04, 2004;
- 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.

Development of the draft document "Physical Protection Rules for Transportation of Radioactive Substances" is being finalised.

***Assessment for possible improvement of the regulatory basis for RTGs***

To improve the Russian regulatory basis it is reasonable to 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 N1344 – "Categorization of Radioactive Sources").

**h. Accounting and control of RTGs and RHSs**

The **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.

**i. Investigation of any accidents or incidents.**

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 PA Mayak.

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 were 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:

- To review and to assess alternative approaches to the objective and to chose optimal variant in each particular case;
- To determine and to analyze 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.

# Appendix C: List of Regulatory Documents

| | No. | Year | Description |
|---|---|---|---|
| **Federal Laws** | | | |
| On the Use of Atomic Energy | | 1995 | |
| On Radiation Safety of Population | | 1995 | |
| On Protection of Population and Territories against Natural and Man-induced Emergency Situations | | | |
| On Environmental Protection | | 1991 | |
| On Funding of Particularly Radiation- and Nuclear-Hazardous Productions and Facilities | | | |
| On Combating Terrorism | | 1998 | |
| On the Internal Troops of the Interior Ministry of Russia | | 1997 | |
| On Weapons | | 1996 | |
| On Departmental Security | | 1999 | |
| Code of the Russian Federation on the Administrative Violations | | 2001 | |
| **Presidential Acts and Governmental Decrees of the Russian Federation** | | | |
| Rules for Organisation of the State Radioactive Substances and Radioactive Waste Accounting System | | 1997 | |
| Procedure for Establishment of the Uniform State System for Monitoring and Recording of Individual Exposure Doses of Citizens | | 1997 | |
| Provisions for Development and Approval of Federal Standards and Rules in the Field of Use of Atomic Energy (approved by Decree of the Government of the Russian Federation dated 1 December 1997) | 1997 #1511 | 1997 | |
| Provisions for Licensing of Activity in the Field of Use of Atomic Energy (approved by Decree of the Government of the Russian Federation dated 14 July 1997) | 1997 #865 | 1997 | |
| Statute of Integrated State system of notification and mitigation of emergencies (approved by the Decrees of the Government of the Russian Federation on 30 December 2003 and on 27 May 2005) | 2003 #794, 2005 #335 | 2003 | |
| Statute of Rostechnadzor (approved by Decree of the Government of the Russian Federation dated 30 July 2004) | 2004 #401 | 2004 | defines tasks, functions and rights of Rostechnadzor as the federal executive authority |

| | No. | Year | Description |
|---|---|---|---|
| Provisions for visits to nuclear facilities by the citizens of the Russian Federation (approved by Decree of the Government of the Russian Federation dated 18 December 1996) | 1996 #1516 | 1996 | 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 Rostechnadzor (approved by Decree of the Government of the Russian Federation of 03.03.1997) | 1997 #240 | 1997 | 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 14 August 1992) | | 1992 | |
| **Federal standards and rules** | | | |
| General Safety Provisions for Radiation Sources | NP-038-02 | 2002 | |
| Requirements to the Contents of Safety Analysis Report for Radiation Sources | NP-039-02 | 2002 | |
| Physical Protection Rules for Radiation Sources, Storage Facilities, Radioactive Substances | NP-034-01 | 2001 | |
| Rules of Investigation and Recording of Violations in Management of Radioactive Sources and Radioactive Substances used in the National Economy | NP-014-2000 | 2000 | |
| Radiation Safety Standards | NRB-99 | 1999 | Regulate basic dose limits for radioactive substance handling |
| Basic Sanitary Rules for Radiation Safety | OSPORB-99 | 1999 | 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 | 2002 | Establish requirements for radiation safety of personnel and population for all types of radioactive waste management |
| Collection, Reprocessing, Storage and Conditioning of Liquid Radioactive Waste. Safety Requirements | NP-020-2000 | 2000 | |
| Collection, Reprocessing, Storage and Conditioning of Solid Radioactive Waste. Safety Requirements | NP-024-2000 | 2000 | |
| Sanitary Rules for Radiation Safety of Personnel and Population during Transportation of Radioactive Substances | SanPin 2.6.1.1281-03 | 2003 | Establish hygienic requirements for radiation safety of population for all types of radioactive substance handling during transportation starting from shipment by a consignor up to receipt by a consignee |
| Safety Rules for Transportation of Radioactive Substances | NP-53-04 | 2004 | Establish safety requirements for transportation of radioactive substances |
| Physical Protection Rules for Transportation of Radioactive Substances | Being finalised | 2006? | |
| **Standards and rules of the state bodies for control of the use of atomic energy** | | | |
| Minatom, Rules of operation and decommissioning of radionuclide power installations on the basis of radionuclide thermal sources using Sr-90 | | 1999 | |

# 3 Appendix D: List of Acronyms and Abbreviations

| | |
|---|---|
| **DalRAO** | Far Eastern Federal Enterprise for the Management of Radioactive Waste |
| **DU** | Depleted uranium |
| **FGUP** | See FSUE |
| **FSUE** | Federal State Unitary Enterprise (Russian FGUP) |
| **NRPA** | Norwegian Radiation Protection Authority |
| **RHS** | Radioisotope heat source |
| **Rosgidromet** | Federal Service for Hydrometeorology and Environmental Monitoring |
| **Rosmorrechflot** | Federal Agency for Sea and River Transport |
| **Rostechnadzor** | Federal Service for Supervision of Environmental, Technological and Nuclear Safety |
| **RS** | Radiation source |
| **RTG** | Radioisotope thermoelectric generator |
| **SevRAO** | Northern Federal Enterprise for the Management of Radioactive Waste |
| **VNIITFA** | All-Russia Scientific and Research Institute for Technical Physics and Automation |

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