SOLUTIONS FOR THE SAFE HANDLING OF RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL FROM RUSSIAN NUCLEAR SUBMARINES

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ABSTRACT

The paper contains a review of the activities performed in 1999-2003 in the framework of the Cooperative Threat Reduction Program aimed at the creation of an infrastructure for solid and liquid radioactive waste processing in the RF and safe temporary storage of spent nuclear fuel originated from the dismantlement of Russian nuclear-powered submarines.

The main parameters and a comparative analysis of the installations for solid and liquid radioactive waste processing at two Russian shipyards (SUE Zvezdochka and FEF Zvezda (Low Level Radioactive Wastes (LLRW) Project implemented in 1999-2001)) are considered.

The paper includes a consideration of the options for safe handling of irradiated nuclear fuel in the process of its reloading and storage at accumulative sites and justification of the construction expediency for a container-type temporary dry storage facility at PO Mayak.

The paper analyzes the environmental aspects of safe interim storage of irradiated nuclear fuel at regional dry facilities.

The paper comes to a conclusion about the expediency to use the experience gained during development of complex science-intensive projects within the CTR Program framework for similar international activities envisioned within the framework of the "global partnership" program.

INTRODUCTION

The issues related to safe management of spent nuclear fuel (SNF) and radioactive waste generated from the dismantlement of the nuclear submarines (SSBN) has always been of the highest priority to the specialists and management of Minatom (Ministry of Atomic Energy) of the Russian Federation. It includes both technical aspects of the problem, which alone are complicated and expensive, and ecological aspects. All SSBN bases and the corresponding infrastructure for radioactive waste (RW) and SNF management have been located in the inshore waters of the Russian Federation close to the state border, and, therefore, a principle of

environmental safety is and always will be of the utmost importance for resolving issues related to RW and SNF management.

After the Government of the Russian Federation, in 1998, both accepted the "Concept for Integrated Dismantlement of SSBN and Surface Ships with Nuclear Power Reactor Facilities" and transferred the functions of public administration and coordination of these activities to RF Minatom, the situation with resolution of these issues has considerably improved. A number of the departmental documents regulating the work performance procedure in this field have been developed by Minatom, and the leading organizations of RF Minatom have been mobilized for development of conceptual engineering solutions to the entire complex of problems connected with SNF and RW management. The developed programs were based on the principles of environmental safety and cost minimization for implementation of the entire scope of work. At the first phase, it was decided to develop an infrastructure complex for RW and SNF management at the main SSBN dismantling facilities (SRZ "Nerpa" and GMP "Zvezdochka" shipyards located in Murmansk and Arkhangelsk regions and DVZ "Zvezda" shipyard located in Primorski Krai).

After negotiations with the representatives of the US Department of Defense and signing the corresponding protocols, the Defense Threat Reduction Agency (DTRA) of the US Department of Defense has actively joined the efforts on resolution of these problems. In 1994, the delivery of special equipment for cutting SSBN bodies to shipbuilding facilities began, and, in 1997, a complex of activities was initiated on management of RW and SNF generated from SSBNs being dismantled. In Fig. 1, major projects related to SSBN dismantling and funded by DTRA within the framework of CTR program are shown, and, in Table 1, a general situation with SSBN dismantling activities is outlined as of December 2003. Within the last years, an annual pace of SSBN dismantling has reached the level of 15 to 18 submarines. International collaboration programs contributed in many aspects to this success.

Figure 1 provides a list of the main projects in this direction financed via DTRA.

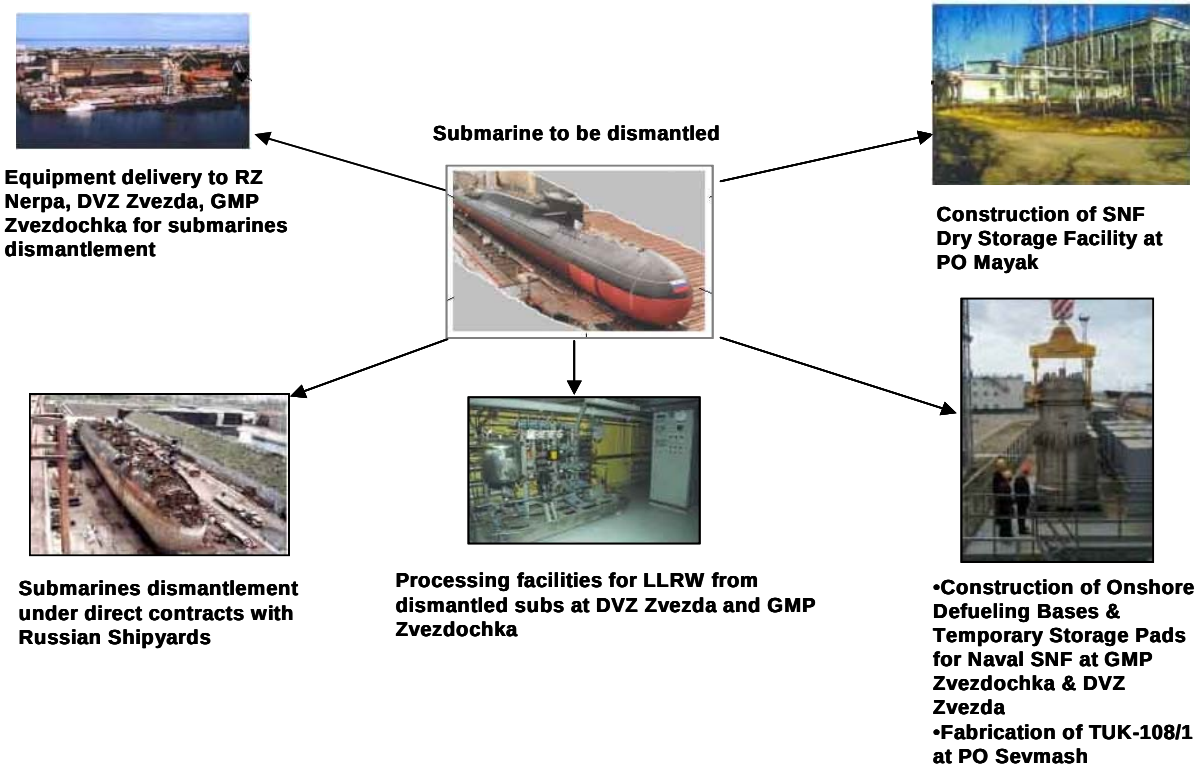

Fig. 1 Submarines dismantlement efforts financed within the framework of CTR program

Table I Pace of dismantling RF Navy SSBN decommissioned from operation

No.	Year	SSBN		
		Decommissioned	SNF Unloaded	Dismantled
1	1989 – 1998	177	53	39
2	1998 – 2003	193*	115	89**

Notes:

* Including 140 multi-purpose submarines.

** Including 23 SSBNs utilized under the Nunn-Lugar Program

Indeed, the increase in the annual pace of dismantling SSBN over 12 and more submarines has become possible due to existence of the international collaboration programs (such as Nunn-Lugar Program and AMEC Progam). Major projects that have contributed to the intensification of the SSBN dismantlement efforts are summarized below.

Low Level Waste Program Experience

In 1998-2001, the LLRW project on integrated processing of low-level radioactive waste generated during SSBN dismantlement was implemented.

This project was unique within the framework of the CTR program, because it became the first example of actual international cooperation in successful implementation of complicated

science-intensive work. The international consortium of the Russian, American, French and British companies supervised by the US integrating contractor has created the most perfect instrumentation-process system for processing LRW and SRW generated during SSBN dismantlement. All the facilities were constructed based on a modular concept and allowed separate processing of various types of LRW and SRW. The entire scope of work, starting with the design stage and including facilities construction and commissioning to the shipyard user, was completed within very tight schedule - less than three years.

The main scope of work on creation of process and instrumentation system for LRW processing, on development of design documentation and on fabrication of non-standard equipment was completed by the Russian specialists.

The system for processing low-level LRW at GMP Zvezdochka includes major units supporting the following processes:

- selective sorption of radioactive cesium nuclides by NZhS non-organic ferrocianyde sorbent;
- sodium/phosphate softening;
- purification at microfilters and consecutive single-stage reverse-osmosis desalination; and
- polishing purification from radioactive nuclides through sorption on TsMP-A sorbent.

Salts have been concentrated via the following stages:

- single-stage reverse-osmosis concentration;
- further evaporation of the produced brine in a centrifugal evaporator; and
- salt drying in Ohmtemp LRW driers.

In order to provide an additional protective barrier, a provision was made for the system to include a stage of polishing by using mix-bed ion-exchange polisher (FSD). However, purification parameters that have been achieved even without use of the FSD filter have been in compliance with the design criteria, and this filter has not been necessary thus far.

A subsystem for concentrating and salt drying has also complied with the design criteria for concentration of secondary SRW.

Major characteristics and comparative analysis of systems for SRW processing that have been ever operated in Russia are shown in Table 2.

Table II Major parameters of various diagrams for processing low-level LRW generated by nuclear fleet

Design Parameters	Sorption System at FGUP Atomflot (1989 – 1996)	PZO Landysh (DVZ Zvezda)	Membrane/Sorption System at GMP Zvezdochka
Secondary SRW quantity, m3 per 1 m3 of the original LRW	0.001	0.07	0.02
Type of buried waste	Sorbents only	Sorbents, sludges and brines in the form of cement matrix	Sorbents, sludges and dry salts in double-protection containers
Cost of processing per 1 м3 of SRW, USD	$100	$380	$180

Note:
The process diagram that have been used at FGUP Atomflot is characterized by the lowest levels of major parameters, since it makes a provision for LRW purification from radioactive nuclides by sorption only, while the other two systems are based on integrated process diagrams and ensure complete purification from all harmful contaminants. In addition, the process based on sorption only has limited use in terms of the chemical composition of LRW being processed, since it could be used for processing LRW with a salt content of no more than 3 to 5 g/l only.

Spent Nuclear Fuel (SNF) Management

In 1998 – 2002, a complex of activities was conducted under the direct contracts with DTRA at two shipbuilding facilities, GMP Zvezdochka and DVZ Zvezda, on construction of onshore reloading bases for unloading spent nuclear fuel (SNF) from SSBN being dismantled. These bases included accumulation sites for temporary storage of SNF in TUK-108/1 concrete-filled metal containers specifically designed for this purpose.

These activities conducted by Russian specialists in compliance with the Russian standards and regulations on handling RW and SNF have been successfully completed. Direct dismantlement of SSBN was conducted in parallel at GMP Zvezdochka, SRZ Nerpa and DVZ Zvezda under the direct contracts with DTRA.

However, a transport/process diagram for handling SNF at the shipbuilding facilities has not made provisions for long-term (more than 6 months) storage of TUK containers at the accumulation sites. Therefore, the spent fuel assemblies (SFA) located in special stainless-steel casks loaded into TUK containers have not been appropriately prepared (residual moisture has not been eliminated and the internal spaces of TUK containers and casks have not been filled with inert gas).

Therefore, a decision has been made to design and construct an interim dry storage facility of container type at PO Mayak in order to ensure, in compliance with the strict requirements of nuclear and radiation safety, interim storage (for up to 5 years) of SNF in TUK containers until

their re-processing at PO Mayak. This decision has been completely justified by the issues related to both a safe storage of SNF at a specifically designed facility equipped with all systems needed to prevent emergencies and a physical security. Specialists in this field are well aware that, undoubtedly, threat of non-authorized access to highly toxic SNF at the PO Mayak storage facility is dramatically lower than at the shipbuilding facilities located at the seashore borders.

Significant aspects of environmental protection through safe interim storage of SNF in dual-use transportation protection containers is also achieved. In the Russian practice, there have been no actual precedents of long-term (more than 1 year) storage of SNF in TUK-108/1 containers, and, therefore, any hypothetical emergency with TUK containers at the shipbuilding facilities could result in an extremely adverse environmental impact that would be averted at PO Mayak

At this time these works have been successfully accomplished and the project has completely passed all the indispensable stages of the State coordination and approval process.

The flowchart for coordination and approval of the design documentation is given on the Fig. 2.

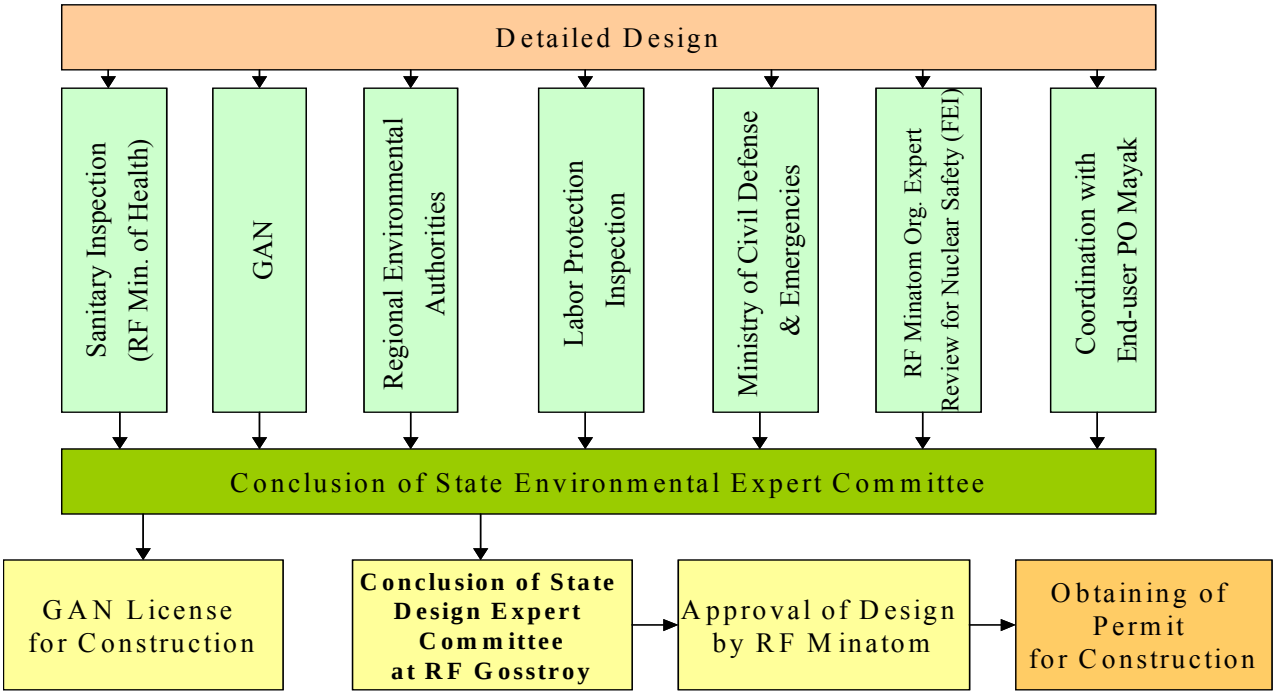

Fig. 2 Procedure for approval and expert review of detailed design for spent nuclear fuel storage facility at PO Mayak

Based on the aforementioned considerations, the RF Minatom management intends to complete the project up to the logical end, i.e., to construct a container-type storage facility for SSBN SNF at the PO Mayak site.

General Approach to Submarine Dismantlement Projects

From the above experience, such approaches can result in successful implementation of complicated science-intensive projects. In all the cases, when the US integrator attempts to declaratively implement a practice for design and construction works adopted in USA on the "Russian ground", there are considerable disruptions to the program schedule and, sometimes, total failure of the program.

The analysis of successfully implemented projects related to SSBN dismantlement has shown that their organizational structure included the following basic elements:

- The project work is led by an integrating foreign (US) company simultaneously performing functions of a financial intermediary between the country - investor and the Russian contractors;
- From the Russian side the design works are managed by a company having required scientific, technical and management proficiency and playing the role of a coordinating Russian contractor at the same time supervising coordination and approval of project documentation with the federal and local authorities,
- Russian managing company, as rule, is selected by the US integrating contractor at the stage of preparation of the tender proposals with allowance for analysis of actual capabilities of the potential Russian partner;
- The managing Russian company should have the staff of specially trained highly qualified specialists in the field of management (technical, contract and financial managers);
- During the work implementation, the professional cooperation of the Russian and foreign subcontractors shall be organized when completing certain parts of design activities and their interface;
- In the course of work it is necessary to make a beforehand analysis of the market condition and to arrange competitive selection of potential subcontractors for the works not involving special requirements for delivery of the standard equipment and components;
- There shall be an organizational structure for the works requiring special licenses and permits;
- There shall be developed an optimal organizational structure for of all the work to be performed by the Russian subcontractors of the lower tier;
- The subcontracts relating to the technical assistance programs engaging Russian subcontractors shall be documented and supervised technically competently and legally correctly at all the stages in order to realistically exempt them from VAT;
- When placing subcontracts it is necessary to observe the Russian legislation in the field of contractual works (audit the financial status of potential subcontractors, concluding contracts only with legal entities, check licenses for certain activities);
- It is necessary to ensure observance of the Russian legislation concerning protection of intellectual property for up-to-date engineering solutions and "know-how" used in the implementation of the work.

CONCLUSION

A decision made by the international community on establishing the Global Partnership opens new opportunities for implementation of complex and expensive projects related to integrated dismantlement of submarines, such as:

- develop onshore regional storage facilities of nuclear compartments (in North and East regions);
- develop infrastructure for processing SRW and LRW accumulated at the former naval technical facilities;
- take integrated measures on rehabilitation of these facilities;
- increase pace of dismantlement for those decommissioned multi-purpose nuclear submarines that are currently kept idle;
- conduct environmental-protection activities on liquidation of consequences of emergencies that have occurred at the two nuclear submarines currently located in the East region.

These types of projects can form the basis for increased international collaboration between scientists and specialists of Russia and G8 countries in coming years.